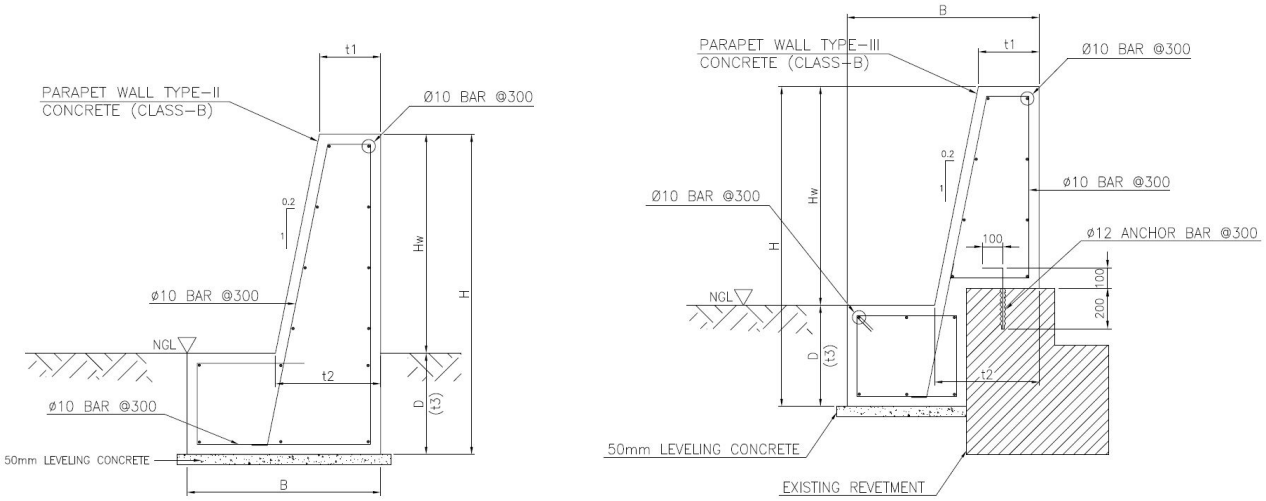
CHAPTER 3 REINFORED RIVER FLOOD WALL (PW, VW, IW AND LPW)

3.1 Parapet Wall Type-II and III

(Note: Type-I is not adapted in Phase-III.)



[Parapet Wall Type-II] [Parapet Wall Type-III]

Figure 3.1.1 Typical Cross Section of Parapet Wall Type-II, III

Table 3.1.1 Standard Dimensions of Parapet Wall Type-II, III

Hw Range (m)	H (m)	B (m)	D (m)	t1(m)	t2(m)	t3(m)
0.30	0.50	0.36	0.20	0.30	0.36	0.20
0.40	0.60	0.38	0.20	0.30	0.38	0.20
0.50	0.70	0.40	0.20	0.30	0.40	0.20
0.60	0.80	0.45	0.20	0.30	0.42	0.20
0.70	0.90	0.50	0.20	0.30	0.44	0.20
0.80	1.10	0.60	0.30	0.30	0.46	0.30
0.90	1.30	0.75	0.40	0.30	0.48	0.40
1.00	1.40	0.85	0.40	0.30	0.50	0.40
1.10	1.60	0.95	0.50	0.30	0.52	0.50
1.20	1.75	1.10	0.55	0.30	0.55	0.55
1.30	1.90	1.20	0.60	0.30	0.56	0.60
1.40	2.10	1.40	0.70	0.30	0.58	0.70
1.50	2.20	1.60	0.70	0.30	0.60	0.70
1.60	2.30	1.60	0.70	0.40	0.72	0.70
1.70	2.40	1.60	0.70	0.45	0.79	0.70

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.0~0.30

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

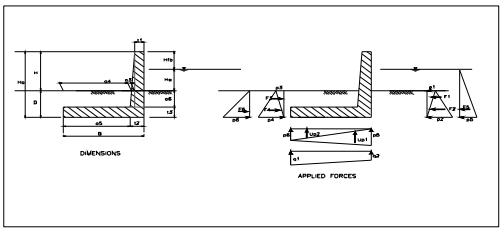
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.30	(m)
Embedment of wall	D =	0.20	(m)
Total height of wall	Ho=	0.50	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.30	(m)
Width of footing	B =	0.36	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.36 (m)	a2=	0.060 (m)
t3=	0.20 (m)	a3=	0.060 (m)
		a4=	0.000 (m)
		a5=	0.000 (m)
		a6=	0.000 (m)



(3) Stability

Sliding,

V = 4.10 (kN/m)
H = 0.72 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 3.43 > 1.5 Safe !!

Overturning,

Mr_{max} = 0.70 (kN-m/m)
Mr_{act} = 0.70 (kN-m/m)
Mo = 0.07 (kN-m/m)
SF =Mr_{max})/ M_o = 10.35 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.03 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.31 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.03 m
α = 1.0
k = 1+0.3*D/B = 1.16667
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.175

= 30 (kN/m)
Qa = 10 (kN/m) > V = 4.10 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 16.150 (kN/m2)

q2 = V/B*(1-6e/B) = 6.650 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

HT. OF WALL 0.0~0.30

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.16	0.150	0.32	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.216	0.320	0.07	
Footing	(B)(t3)γc	1.728	0.180	0.31	
Soil-1	1/2(a5)(a6)γs	0	0.360	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.360	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		4.10	0.172	0.70	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.72		0.07	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

Location = STA. 0.0~0.30
0

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.16	0.210	0.45	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.216	0.020	0.00	
Footing	(B)(t3)γc	1.728	0.180	0.31	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.360	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.320	0.00	
Sub-Total		4.10	0.187	0.77	
Uplift-1	-1/2B(D+Hw)γw	-0.88	0.240	-0.21	
Uplift-2	-1/2B(D)γw	-0.35	0.120	-0.04	
Sub-Total		-1.23		-0.25	
Total		2.87		0.51	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Active force
F2	1/2(p2)h	0.06	0.07	0.00	Active force
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.17	0.20	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		1.29		0.21	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Sliding,

V = 2.87 (kN/m)
H = 1.29 (kN/m)
HR_{max} = 1.01 (kN/m)
HR_{act} = 1.01 (kN/m)
SF =(V*f'+HR_{max})/ H = 2.13 > 1.0 Safe !!

Overturning,

Mr_{max} = 0.84 (kN-m/m)
Mr = 0.84 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 0.46 (kN-m/m)
SF = Mr_{max}/M_o = 1.81 >1.5 Safe
e = B/2 - (Mr_{max}-Mo) / V = 0.050 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.26 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.050 m
α = 1.0
k = 1+0.3*D/B = 1.16667
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.095

= 24 (kN/m)
Qa = 12.2 (kN/m) > V = 2.87 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 14.556 (kN/m2)

q2 = V/B*(1-6e/B) = 1.384 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		2.94	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	0.44	0.10	0.04	Water pressure
Total		0.44		0.04	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.00	0.00	
Soil	γsat(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Uplift	-1/2(p5)(a5)	0.00	0.00	0.00	
	-(t2p5+a5p6)(a5)/2B	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

4. Case 3 : Seismic condition

Location = STA. 0.0~0.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	2.16	0.150	0.32	0.350	0.76
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.216	0.320	0.07	0.300	0.06
Footing	(B)(t3)γc	1.728	0.180	0.31	0.100	0.17
Soil-1	1/2(a5)(a6)γs	0	0.360	0.00	0.200	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.360	0.00	0.200	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		4.10	0.172	0.70	0.242	0.99

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.20	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.20	3.85	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.22	0.13	0.03	Active force
F4	1/2(p4)h	0.38	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	0.82	0.24	0.20	Seismic force
Total of active forces		1.43		0.25	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 4.10 (kN/m)
H = 1.43 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f' + HR_{max})/ H = 1.72 > 1.2 Safe !!

Overturning,

Mr_{max} = 0.70 (kN-m/m)
Mr_{act} = 0.70 (kN-m/m)
Mo = 0.25 (kN-m/m)
d = (Mr-Mo)/V = 0.11 (m)
SF = Mr_{max}/ M_o = 2.77 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.070 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.219 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.070 m
α = 1.0
k = 1+0.3*D/B = 1.16667
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.348

= 20 (kN/m)
Qa = 10 (kN/m) > V = 4.10 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 24.955 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.43	0.15	0.06	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.04	0.10	0.00	Seismic force
Total		0.48		0.07	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-q1(3d-t2)^2/6d	-0.04	-0.01	0.00	
		0.00	0.00	0.00	
Total		-0.04		0.00	

5. Case 4 : Wind condition

Location = STA. 0.0~0.30

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	2.16	0.150	0.32
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.216	0.320	0.07
Footing	(B)(t3)γc	1.728	0.180	0.31
Soil-1	1/2(a5)(a6)γs	0	0.360	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.360	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		4.10	0.172	0.70

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	0.63	0.35	0.22	Wind force
Total of active forces		1.35		0.29	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 4.10 (kN/m)
H = 1.35 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 1.83 > 1.2 Safe !!

Overturning,

Mr_{max} = 0.70 (kN-m/m)
Mr_{act} = 0.70 (kN-m/m)
Mo = 0.29 (kN-m/m)
d = (Mr-Mo)/V = 0.10 (m)
SF =Mr_{max})/ M_o = 2.44 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.079 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.202 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.079 (m)
α = 1.0
k = 1+0.3*D/B = 1.16667
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.329 0
= 18 (kN/m)
Qa = 9 (kN/m) > V = 4.10 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 27.058 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		0.63	0.15	0.09	
Total		0.63		0.09	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	-0.14	-0.02	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-0.14		0.00	

9. Summary of stability analysis

HT. OF WALL 0.0~0.30
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	3.43	1.5	0.03	0.06	4.1	10
Flood	2.13	1	0.05	0.12	2.9	12
Seismic-2	1.72	1.2	0.07	0.12	4.1	10
Wind-2	1.83	1.2	0.08	0.12	4.1	9

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.0~0.40

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

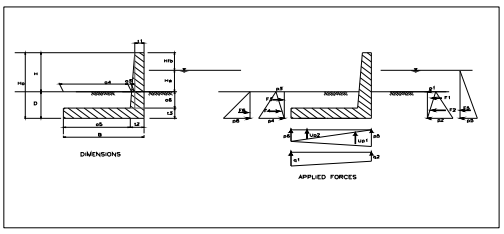
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.40	(m)
Embedment of wall	D =	0.20	(m)
Total height of wall	Ho=	0.60	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.40	(m)
Width of footing	B =	0.38	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.38 (m)	a2=	0.080 (m)
t3=	0.20 (m)	a3=	0.080 (m)
		a4=	0.000 (m)
		a5=	0.000 (m)
		a6=	0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 0.0~0.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.88	0.150	0.43	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.384	0.327	0.13	
Footing	(B)(t3)γc	1.824	0.190	0.35	
Soil-1	1/2(a5)(a6)γs	0	0.380	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.380	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		5.09	0.178	0.90	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.72		0.07	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 5.09 (kN/m)

H = 0.72 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 4.26 > 1.5 Safe !!

Overturning,

Mr_{max} = 0.90 (kN-m/m)

Mr_{act} = 0.90 (kN-m/m)

Mo = 0.07 (kN-m/m)

SF =Mr_{max})/ M_o = 13.29 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.03 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.33 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.03 m

α = 1.0

k = 1+0.3*D/B = 1.15789

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.141

= 32 (kN/m)

Qa = 11 (kN/m) > V = 5.09 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 18.823 (kN/m2)

q2 = V/B*(1-6e/B) = 7.956 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

3. Case 2 : Flood condition

Location = STA. 0.0~0.40

0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.88	0.230	0.66	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.384	0.027	0.01	
Footing	(B)(t3)γc	1.824	0.190	0.35	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.380	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.327	0.00	
Sub-Total		5.09	0.200	1.02	
Uplift-1	-1/2B(D+Hw)γw	-1.12	0.253	-0.28	
Uplift-2	-1/2B(D)γw	-0.37	0.127	-0.05	
Sub-Total		-1.49		-0.33	
Total		3.60		0.69	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Active force
F2	1/2(p2)h	0.06	0.07	0.00	Active force
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	1.76	0.20	0.35	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		1.82		0.36	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Sliding,

V = 3.60 (kN/m)

H = 1.82 (kN/m)

HR_{max} = 1.01 (kN/m)

HR_{act} = 1.01 (kN/m)

SF =(V*f +HR_{max})/ H = 1.74 > 1.0 Safe !!

Overturning,

Mr_{max} = 1.09 (kN-m/m)

Mr = 1.09 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 0.69 (kN-m/m)

SF = Mr_{max}/M_o = 1.58 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.079 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.22 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.079 m

α = 1.0

k = 1+0.3*D/B = 1.15789

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.226

= 20 (kN/m)

Qa = 10.1 (kN/m) > V = 3.60 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 21.601 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		3.92	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	0.78	0.13	0.10	Water pressure
Total		0.78		0.10	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.00	0.00	
Soil	γsat(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Uplift	-1/2(p5)(a5)	0.00	0.00	0.00	
	-(t2p5+a5p6)(a5)/2B	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

4. Case 3 : Seismic condition

(Direction of forces : Active forces are applied from land side)

Location = STA. 0.0~0.40

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	2.88	0.150	0.43	0.400	1.15
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.384	0.327	0.13	0.333	0.13
Footing	(B)(t3)γc	1.824	0.190	0.35	0.100	0.18
Soil-1	1/2(a5)(a6)γs	0	0.380	0.00	0.200	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.380	0.00	0.200	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		5.09	0.178	0.90	0.287	1.46

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.219 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.081 m

α = 1.0

k = 1+0.3*D/B = 1.15789

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.320

= 20 (kN/m)

Qa = 10 (kN/m) > V = 5.09 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 31.039 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.58	0.20	0.12	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.08	0.13	0.01	Seismic force
Total		0.65		0.13	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.20	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.20	3.85	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.22	0.13	0.03	Active force
F4	1/2(p4)h	0.38	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	1.02	0.29	0.29	Seismic force
Total of active forces		1.63		0.35	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 5.09 (kN/m)

H = 1.63 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 1.88 > 1.2 Safe !!

Overturning,

Mr_{max} = 0.90 (kN-m/m)

Mr_{act} = 0.90 (kN-m/m)

Mo = 0.35 (kN-m/m)

d = (Mr-Mo)/V = 0.11 (m)

SF =Mr_{max}/ M_o = 2.60 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.081 (m) < B/3 Safe !!

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-q1(3d-t2)^2/6d	-0.13	-0.02	0.00	
		0.00	0.00	0.00	
Total		-0.13		0.00	

5. Case 4 : Wind condition

Wind from the land side

Location = STA. 0.0~0.40

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	2.88	0.150	0.43
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.384	0.327	0.13
Footing	(B)(t3)γc	1.824	0.190	0.35
Soil-1	1/2(a5)(a6)γs	0	0.380	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.380	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		5.09	0.178	0.90

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	0.84	0.40	0.34	Wind force
Total of active forces		1.56		0.41	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 5.09 (kN/m)
H = 1.56 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 1.96 > 1.2 Safe !!

Overturning,

Mr_{max} = 0.90 (kN-m/m)
Mr_{act} = 0.90 (kN-m/m)
Mo = 0.41 (kN-m/m)
d = (Mr-Mo)/V = 0.10 (m)
SF =Mr_{max}/ M_o = 2.23 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.092 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.196 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.092 (m)
α = 1.0
k = 1+0.3*D/B = 1.15789
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.306 0
= 17 (kN/m)
Qa = 9 (kN/m) > V = 5.09 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 34.587 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		0.84	0.20	0.17	
Total		0.84		0.17	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	-0.43	-0.03	0.01	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-0.43		0.01	

9. Summary of stability analysis

HT. OF WALL 0.0~0.40
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-2	4.26	1.5	0.03	0.06	5.1	11
Flood	1.74	1	0.08	0.13	3.6	10
Seismic-2	1.88	1.2	0.08	0.13	5.1	10
Wind-2	1.96	1.2	0.09	0.13	5.1	9

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.0~0.50

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

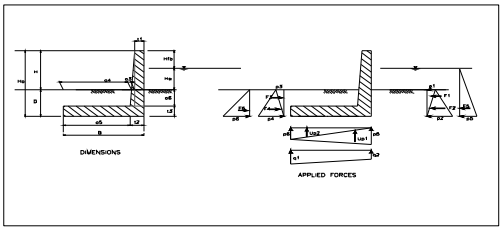
Dimensions of wall and water depth :

Height of wall	H =	0.50 (m)
Embedment of wall	D =	0.20 (m)
Total height of wall	Ho=	0.70 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.50 (m)
Width of footing	B =	0.40 (m)

Thickness of wall members :

t1= 0.30 (m)
t2= 0.40 (m)
t3= 0.20 (m)

a1= 0.000 (m)
a2= 0.100 (m)
a3= 0.100 (m)
a4= 0.000 (m)
a5= 0.000 (m)
a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 0.0~0.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.6	0.150	0.54	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.6	0.333	0.20	
Footing	(B)(t3)γc	1.92	0.200	0.38	
Soil-1	1/2(a5)(a6)γs	0	0.400	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.400	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		6.12	0.184	1.12	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.20	0.00	Passive press.
p3	Ka(γh+q)-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c$\sqrt{}$Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.72		0.07	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 6.12 (kN/m)
H = 0.72 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 5.12 > 1.5 Safe !!

Overturning,

Mr_{max} = 1.12 (kN-m/m)
Mr_{act} = 1.12 (kN-m/m)
Mo = 0.07 (kN-m/m)
SF =Mr_{max})/ M_o = 16.52 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.03 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.35 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.03 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.117

= 34 (kN/m)
Qa = 11 (kN/m) > V = 6.12 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 21.602 (kN/m2)

q2 = V/B*(1-6e/B) = 8.998 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Active force
F2	1/2(p2)h	0.06	0.07	0.00	Active force
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	2.40	0.23	0.56	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		2.46		0.56	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Sliding,

V = 4.36 (kN/m)
H = 2.46 (kN/m)
HR_{max} = 1.01 (kN/m)
HR_{act} = 1.01 (kN/m)
SF =(V*f +HR_{max})/ H = 1.47 > 1.0 Safe !!

Overturning,

Mr_{max} = 1.37 (kN-m/m)
Mr = 1.37 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 0.98 (kN-m/m)
SF = Mr_{max}/M_o = 1.40 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.111 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.18 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.111 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.333

= 16 (kN/m)
Qa = 7.8 (kN/m) > V = 4.36 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 32.514 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

3. Case 2 : Flood condition

Location = STA. 0.0~0.50
0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.6	0.250	0.90	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.6	0.033	0.02	
Footing	(B)(t3)γc	1.92	0.200	0.38	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.400	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.333	0.00	
Sub-Total		6.12	0.213	1.30	
Uplift-1	-1/2B(D+Hw)γw	-1.37	0.267	-0.37	
Uplift-2	-1/2B(D)γw	-0.39	0.133	-0.05	
Sub-Total		-1.76		-0.42	
Total		4.36		0.89	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{}$Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{}$Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{}$Kp	0.20	8.16	Passive earth press.

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		4.90	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	1.23	0.17	0.20	Water pressure
Total		1.23		0.20	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.00	0.00	
Soil	γsat(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Uplift	-1/2(p5)(a5)	0.00	0.00	0.00	
	-(t2p5+a5p6)(a5)/2B	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		0.00		0.00	

4. Case 3 : Seismic condition

Location = STA. 0.0~0.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.6	0.150	0.54	0.450	1.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.6	0.333	0.20	0.367	0.22
Footing	(B)(t3)γc	1.92	0.200	0.38	0.100	0.19
Soil-1	1/2(a5)(a6)γs	0	0.400	0.00	0.200	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.400	0.00	0.200	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		6.12	0.184	1.12	0.332	2.03

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.20	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.20	3.85	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.22	0.13	0.03	Active force
F4	1/2(p4)h	0.38	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	1.22	0.33	0.41	Seismic force
Total of active forces		1.83		0.46	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 6.12 (kN/m)
H = 1.83 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.00 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.12 (kN-m/m)
Mr_{act} = 1.12 (kN-m/m)
Mo = 0.46 (kN-m/m)
d = (Mr-Mo)/V = 0.11 (m)
SF =Mr_{max}/ M_o = 2.43 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.092 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.216 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.092 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.299

= 19 (kN/m)
Qa = 10 (kN/m) > V = 6.12 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 37.712 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.72	0.25	0.18	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.12	0.17	0.02	Seismic force
Total		0.84		0.20	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-q1(3d-t2)^2/6d	-0.33	-0.03	0.01	
		0.00	0.00	0.00	
Total		-0.33		0.01	

5. Case 4 : Wind condition

Wind from the land side

Location = STA. 0.0~0.50

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.6	0.150	0.54
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.6	0.333	0.20
Footing	(B)(t3)γc	1.92	0.200	0.38
Soil-1	1/2(a5)(a6)γs	0	0.400	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.400	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		6.12	0.184	1.12

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.05	0.45	0.47	Wind force
Total of active forces		1.77		0.54	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 6.12 (kN/m)
H = 1.77 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.07 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.12 (kN-m/m)
Mr_{act} = 1.12 (kN-m/m)
Mo = 0.54 (kN-m/m)
d = (Mr-Mo)/V = 0.10 (m)
SF =Mr_{max}/ M_o = 2.07 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.105 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.190 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.105 (m)
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.289 0

= 17 (kN/m)
Qa = 8 (kN/m) > V = 6.12 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 42.895 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
$C_eC_q\ q_s$ I H		1.05	0.25	0.26	
Total		1.05		0.26	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.00	0.00	
Footing	γc(t3)(a5)	0.00	0.00	0.00	
Reaction	-1/2(q2)(a5)	-0.99	-0.04	0.04	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-0.99		0.04	

9. Summary of stability analysis

HT. OF WALL 0.0~0.50
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	5.12	1.5	0.03	0.07	6.1	11
Flood	1.47	1	0.11	0.13	4.4	8
Seismic-2	2.00	1.2	0.09	0.13	6.1	10
Wind-2	2.07	1.2	0.10	0.13	6.1	8

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.5~0.60

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

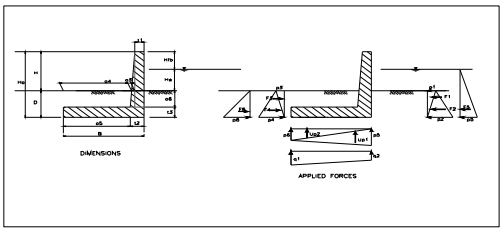
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.60	(m)
Embedment of wall	D =	0.20	(m)
Total height of wall	Ho=	0.80	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.60	(m)
Width of footing	B =	0.45	(m)

Thickness of wall members :

t1=	0.30	(m)	a1= 0.000 (m)
t2=	0.42	(m)	a2= 0.150 (m)
t3=	0.20	(m)	a3= 0.120 (m)
			a4= 0.030 (m)
			a5= 0.030 (m)
			a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 0.5~0.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.150	0.65	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.864	0.340	0.29	
Footing	(B)(t3)γc	2.16	0.225	0.49	
Soil-1	1/2(a5)(a6)γs	0	0.440	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.430	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		7.34	0.194	1.43	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.72		0.07	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 7.34 (kN/m)
H = 0.72 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.15 > 1.5 Safe !!

Overturning,

Mr_{max} = 1.43 (kN-m/m)
Mr_{act} = 1.43 (kN-m/m)
Mo = 0.07 (kN-m/m)
SF =Mr_{max})/ M_o = 20.98 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.04 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.37 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.04 m
α = 1.0
k = 1+0.3*D/B = 1.13333
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.098

= 37 (kN/m)
Qa = 12 (kN/m) > V = 7.34 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 24.992 (kN/m2)

q2 = V/B*(1-6e/B) = 7.648 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.02	0.00	
Footing	γc(t3)(a5)	0.14	0.02	0.00	
Reaction	-1/2(q2)(a5)	-0.11	0.02	0.00	
	-(t2q2+a5q1)(a5)/2B	-0.13	0.01	0.00	
Total		-0.10		0.00	

3. Case 2 : Flood condition Location = STA. 0.5~0.60

(Direction of forces : Active forces are applied from river side) 0

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.300	1.30	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.864	0.070	0.06	
Footing	(B)(t3)γc	2.16	0.225	0.49	
Soil-1	1/2(a5)(a6)γsat	0.00	0.010	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.020	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.440	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.350	0.00	
Sub-Total		7.34	0.251	1.84	
Uplift-1	-1/2B(D+Hw)γw	-1.76	0.300	-0.53	
Uplift-2	-1/2B(D)γw	-0.44	0.150	-0.07	
Sub-Total		-2.21		-0.60	
Total		5.14		1.25	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Active force
F2	1/2(p2)h	0.06	0.07	0.00	Active force
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	3.14	0.27	0.84	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		3.20		0.84	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Sliding,

V = 5.14 (kN/m)
H = 3.20 (kN/m)
HR_{max} = 1.01 (kN/m)
HR_{act} = 1.01 (kN/m)
SF =(V*f +HR_{max})/ H = 1.28 > 1.0 Safe !!

Overturning,

Mr_{max} = 1.91 (kN-m/m)
Mr = 1.91 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 1.44 (kN-m/m)
SF = Mr_{max}/M_o = 1.33 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.133 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.18 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.133 m
α = 1.0
k = 1+0.3*D/B = 1.13333
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.425

= 16 (kN/m)
Qa = 8.0 (kN/m) > V = 5.14 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 37.122 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		5.88	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	1.76	0.20	0.35	Water pressure
Total		1.76		0.35	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.02	0.00	
Soil	γsat(a6)(a5)	0.00	0.02	0.00	
Footing	γc(t3)(a5)	0.14	0.02	0.00	
Uplift	-1/2(p5)(a5)	-0.12	0.01	0.00	
	-(t2p5+a5p6)(a5)/2B	-0.11	0.02	0.00	
Reaction	-1/2(q2)(a5)	-0.50	0.01	0.00	
	-(t2q2+a5q1)(a5)/2B	-0.56	0.02	-0.01	
Total		-1.14		-0.02	

4. Case 3 : Seismic condition Location = STA. 0.5~0.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.150	0.65	0.500	2.16
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.864	0.340	0.29	0.400	0.35
Footing	(B)(t3)γc	2.16	0.225	0.49	0.100	0.22
Soil-1	1/2(a5)(a6)γs	0	0.440	0.00	0.200	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.430	0.00	0.200	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		7.34	0.194	1.43	0.371	2.72

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.20	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.20	3.85	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.22	0.13	0.03	Active force
F4	1/2(p4)h	0.38	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	1.47	0.37	0.54	Seismic force
Total of active forces		2.08		0.60	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 7.34 (kN/m)
H = 2.08 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.12 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.43 (kN-m/m)
Mr_{act} = 1.43 (kN-m/m)
Mo = 0.60 (kN-m/m)
d = (Mr-Mo)/V = 0.11 (m)
SF =Mr_{max}/ M_o = 2.38 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.112 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.225 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.112 m

α = 1.0

k = 1+0.3*D/B = 1.13333

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.283

= 20 (kN/m)

Qa = 10 (kN/m) > V = 7.34 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 43.428 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.86	0.30	0.26	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.17	0.20	0.03	Seismic force
Total		1.04		0.29	

(3) Stability

Sliding,

V = 7.34 (kN/m)

H = 1.98 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 2.22 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.43 (kN-m/m)

Mr_{act} = 1.43 (kN-m/m)

Mo = 0.70 (kN-m/m)

d = (Mr-Mo)/V = 0.10 (m)

SF =Mr_{max}/ M_o = 2.04 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.126 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.198 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.126 (m)

α = 1.0

k = 1+0.3*D/B = 1.13333

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.270 0

= 17 (kN/m)

Qa = 9 (kN/m) > V = 7.34 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 49.396 (kN/m2)

q2 = 0.000 (kN/m2)

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.02	0.00	
Footing	γc(t3)(a5)	0.14	0.02	0.00	
Reaction	-q1(3d-t2)^2/6d	-0.43	-0.03	0.01	
		0.00	0.00	0.00	
Total		-0.29		0.01	

5. Case 4 : Wind condition

Location = STA. 0.5~0.60

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.150	0.65
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.864	0.340	0.29
Footing	(B)(t3)γc	2.16	0.225	0.49
Soil-1	1/2(a5)(a6)γs	0	0.440	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.430	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		7.34	0.194	1.43

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.26	0.50	0.63	Wind force
Total of active forces		1.98		0.70	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		1.26	0.30	0.38	
Total		1.26		0.38	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.02	0.00	
Footing	γc(t3)(a5)	0.14	0.02	0.00	
Reaction	-1/2(q2)(a5)	-1.25	-0.04	0.05	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-1.11		0.05	

9. Summary of stability analysis

HT. OF WALL 0.5~0.60

0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	6.15	1.5	0.04	0.08	7.3	12
Flood	1.28	1	0.13	0.15	5.1	8
Seismic-2	2.12	1.2	0.11	0.15	7.3	10
Wind-2	2.22	1.2	0.13	0.15	7.3	9

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.6~0.70

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

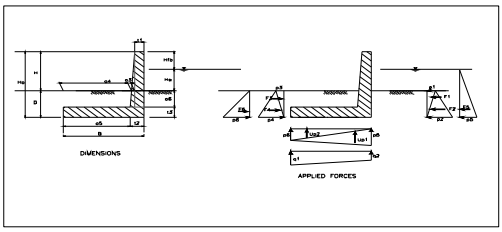
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.70	(m)
Embedment of wall	D =	0.20	(m)
Total height of wall	Ho=	0.90	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.70	(m)
Width of footing	B =	0.50	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.44 (m)	a2=	0.200 (m)
t3=	0.20 (m)	a3=	0.140 (m)
		a4=	0.060 (m)
		a5=	0.060 (m)
		a6=	0.000 (m)



(3) Stability

Sliding,

V = 8.62 (kN/m)

H = 0.72 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 7.21 > 1.5 Safe !!

Overturning,

Mr_{max} = 1.76 (kN-m/m)

Mr_{act} = 1.76 (kN-m/m)

Mo = 0.07 (kN-m/m)

SF =Mr_{max})/ M_o = 25.92 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.05 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.39 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.05 m

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.083

= 39 (kN/m)

Qa = 13 (kN/m) > V = 8.62 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 28.233 (kN/m2)

q2 = V/B*(1-6e/B) = 6.231 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

HT. OF WALL 0.6~0.70

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.04	0.150	0.76	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.176	0.347	0.41	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γs	0	0.480	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.460	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		8.62	0.205	1.76	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.72		0.07	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.03	0.00	
Footing	γc(t3)(a5)	0.29	0.03	0.01	
Reaction	-1/2(q2)(a5)	-0.19	0.04	-0.01	
	-(t2q2+a5q1)(a5)/2B	-0.27	0.02	-0.01	
Total		-0.17		0.00	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

Location = STA. 0.6~0.70

0

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.04	0.350	1.76	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.176	0.107	0.13	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γsat	0.00	0.020	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.040	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.480	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.367	0.00	
Sub-Total		8.62	0.289	2.49	
Uplift-1	-1/2B(D+Hw)γw	-2.21	0.333	-0.74	
Uplift-2	-1/2B(D)γw	-0.49	0.167	-0.08	
Sub-Total		-2.70		-0.82	
Total		5.92		1.67	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Active force
F2	1/2(p2)h	0.06	0.07	0.00	Active force
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	3.97	0.30	1.19	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		4.03		1.19	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Sliding,

V = 5.92 (kN/m)
H = 4.03 (kN/m)
HR_{max} = 1.01 (kN/m)
HR_{act} = 1.01 (kN/m)
SF =(V*f'+HR_{max})/ H = 1.13 > 1.0 Safe !!

Overturning,

Mr_{max} = 2.56 (kN-m/m)
Mr = 2.56 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 2.01 (kN-m/m)
SF = Mr_{max}/M_o = 1.27 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.158 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.18 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.158 m
α = 1.0
k = 1+0.3*D/B = 1.12
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.510

= 16 (kN/m)
Qa = 7.9 (kN/m) > V = 5.92 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 42.846 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		6.86	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	2.40	0.23	0.56	Water pressure
Total		2.40		0.56	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.03	0.00	
Soil	γsat(a6)(a5)	0.00	0.03	0.00	
Footing	γc(t3)(a5)	0.29	0.03	0.01	
Uplift	-1/2(p5)(a5)	-0.26	0.02	-0.01	
	-(t2p5+a5p6)(a5)/2B	-0.24	0.04	-0.01	
Reaction	-1/2(q2)(a5)	-1.01	0.02	-0.02	
	-(t2q2+a5q1)(a5)/2B	-1.29	0.04	-0.05	
Total		-2.51		-0.08	

4. Case 3 : Seismic condition

Location = STA. 0.6~0.70

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.04	0.150	0.76	0.550	2.77
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.176	0.347	0.41	0.433	0.51
Footing	(B)(t3)γc	2.4	0.250	0.60	0.100	0.24
Soil-1	1/2(a5)(a6)γs	0	0.480	0.00	0.200	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.460	0.00	0.200	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		8.62	0.205	1.76	0.409	3.52

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.20	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.20	3.85	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.22	0.13	0.03	Active force
F4	1/2(p4)h	0.38	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	1.72	0.41	0.70	Seismic force
Total of active forces		2.33		0.76	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 8.62 (kN/m)
H = 2.33 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f' + HR_{max})/ H = 2.22 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.76 (kN-m/m)
Mr_{act} = 1.76 (kN-m/m)
Mo = 0.76 (kN-m/m)
d = (Mr-Mo)/V = 0.12 (m)
SF =Mr_{max}/ M_o = 2.32 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.133 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.233 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.133 m
α = 1.0
k = 1+0.3*D/B = 1.12
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.271

= 21 (kN/m)
Qa = 10 (kN/m) > V = 8.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 49.300 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.01	0.35	0.35	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.24	0.23	0.05	Seismic force
Total		1.24		0.41	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.03	0.00	
Footing	γc(t3)(a5)	0.29	0.03	0.01	
Reaction	-q1(3d-t2)^2/6d	-0.58	-0.03	0.02	
		0.00	0.00	0.00	
Total		-0.29		0.03	

5. Case 4 : Wind condition

Location = STA. 0.6~0.70

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.04	0.150	0.76
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.176	0.347	0.41
Footing	(B)(t3)γc	2.4	0.250	0.60
Soil-1	1/2(a5)(a6)γs	0	0.480	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.460	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		8.62	0.205	1.76

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.20	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.20	4.13	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.13	0.00	Resisting force
F2	1/2(p2)h	0.00	0.07	0.00	Resisting force
F3	1/2(p3)h	0.30	0.13	0.04	Active force
F4	1/2(p4)h	0.41	0.07	0.03	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.47	0.55	0.81	Wind force
Total of active forces		2.19		0.88	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 8.62 (kN/m)
H = 2.19 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.36 > 1.2 Safe !!

Overturning,

Mr_{max} = 1.76 (kN-m/m)
Mr_{act} = 1.76 (kN-m/m)
Mo = 0.88 (kN-m/m)
d = (Mr-Mo)/V = 0.10 (m)
SF =Mr_{max})/ M_o = 2.01 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.147 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.205 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.147 (m)
α = 1.0
k = 1+0.3*D/B = 1.12
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.254 0
= 18 (kN/m)
Qa = 9 (kN/m) > V = 8.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 55.932 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		1.47	0.35	0.52	
Total		1.47		0.52	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.03	0.00	
Footing	γc(t3)(a5)	0.29	0.03	0.01	
Reaction	-1/2(q2)(a5)	-1.58	-0.04	0.07	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-1.29		0.08	

9. Summary of stability analysis

HT. OF WALL 0.6~0.70
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	7.21	1.5	0.05	0.08	8.6	13
Flood	1.13	1	0.16	0.17	5.9	8
Seismic-2	2.22	1.2	0.13	0.17	8.6	10
Wind-2	2.36	1.2	0.15	0.17	8.6	9

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.7~0.80

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

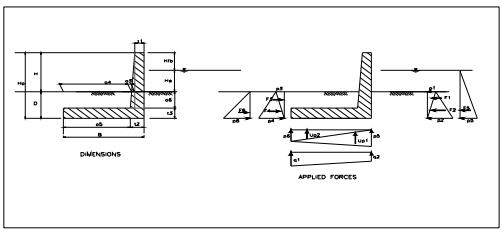
Dimensions of wall and water depth :

Height of wall	H =	0.80	(m)
Embedment of wall	D =	0.30	(m)
Total height of wall	Ho=	1.10	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.80	(m)
Width of footing	B =	0.60	(m)

Thickness of wall members :

t1= 0.30 (m)
t2= 0.46 (m)
t3= 0.30 (m)

a1= 0.000 (m)
a2= 0.300 (m)
a3= 0.160 (m)
a4= 0.140 (m)
a5= 0.140 (m)
a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL	0.7~0.80

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.150	0.86	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.536	0.353	0.54	
Footing	(B)(t3)γc	4.32	0.300	1.30	
Soil-1	1/2(a5)(a6)γs	0	0.553	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.507	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		11.62	0.233	2.70	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.30	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.30	4.68	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.20	0.00	Resisting force
F2	1/2(p2)h	0.00	0.10	0.00	Resisting force
F3	1/2(p3)h	0.46	0.20	0.09	Active force
F4	1/2(p4)h	0.70	0.10	0.07	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.16		0.16	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.07	0.00	
Footing	γc(t3)(a5)	1.01	0.07	0.07	
Reaction	-1/2(q2)(a5)	-0.25	0.09	-0.02	
	-(t2q2+a5q1)(a5)/2B	-0.77	0.05	-0.04	
Total		-0.01		0.01	

3. Case 2 : Flood condition

Location = STA.	0.7~0.80
	0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.450	2.59	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.536	0.193	0.30	
Footing	(B)(t3)γc	4.32	0.300	1.30	
Soil-1	1/2(a5)(a6)γsat	0.00	0.047	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.093	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.553	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.400	0.00	
Sub-Total		11.62	0.360	4.18	
Uplift-1	-1/2B(D+Hw)γw	-3.23	0.400	-1.29	
Uplift-2	-1/2B(D)γw	-0.88	0.200	-0.18	
Sub-Total		-4.12		-1.47	
Total		7.50		2.71	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.30	0.91	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.30	12.24	Passive earth press.

(3) Stability

Sliding,

V = 11.62 (kN/m)
H = 1.16 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.02 > 1.5 Safe !!

Overturning,

Mr_{max} = 2.70 (kN-m/m)
Mr_{act} = 2.70 (kN-m/m)
Mo = 0.16 (kN-m/m)
SF =Mr_{max})/ M_o = 16.76 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.08 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.44 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.08 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.100

= 62 (kN/m)
Qa = 21 (kN/m) > V = 11.62 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 35.083 (kN/m2)

q2 = V/B*(1-6e/B) = 3.637 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.20	0.00	Active force
F2	1/2(p2)h	0.14	0.10	0.01	Active force
F3	1/2(p3)h	0.00	0.20	0.00	Resisting force
F4	1/2(p4)h	1.84	0.10	0.18	Resisting force
F5	1/2γw(D+Hw)^2	5.93	0.37	2.17	Active force
F6	1/2γw(D)^2	0.44	0.10	0.04	Resisting force
Total of active forces		6.07		2.19	
Total of maximum resisting forces		2.28		0.23	
Actual resisting forces		2.28		0.23	

(3) Stability

Sliding,

V = 7.50 (kN/m)
H = 6.07 (kN/m)
HR_{max} = 2.28 (kN/m)
HR_{act} = 2.28 (kN/m)
SF =(V*f +HR_{max})/ H = 1.12 > 1.0 Safe !!

Overturning,

Mr_{max} = 4.41 (kN-m/m)
Mr = 4.41 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 3.66 (kN-m/m)
SF = Mr_{max}/M_o = 1.21 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.199 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.20 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.199 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.505

= 25 (kN/m)
Qa = 12.7 (kN/m) > V = 7.50 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 49.666 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		7.84	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	3.14	0.27	0.84	Water pressure
Total		3.14		0.84	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.07	0.00	
Soil	γsat(a6)(a5)	0.00	0.07	0.00	
Footing	γc(t3)(a5)	1.01	0.07	0.07	
Uplift	-1/2(p5)(a5)	-0.75	0.05	-0.04	
	-(t2p5+a5p6)(a5)/2B	-0.63	0.09	-0.06	
Reaction	-1/2(q2)(a5)	-1.87	0.05	-0.09	
	-(t2q2+a5q1)(a5)/2B	-3.48	0.09	-0.32	
Total		-5.71		-0.43	

4. Case 3 : Seismic condition

(Direction of forces : Active forces are applied from land side)

Location = STA. 0.7~0.80

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.150	0.86	0.700	4.03
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.536	0.353	0.54	0.567	0.87
Footing	(B)(t3)γc	4.32	0.300	1.30	0.150	0.65
Soil-1	1/2(a5)(a6)γs	0	0.553	0.00	0.300	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.507	0.00	0.300	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		11.62	0.233	2.70	0.478	5.55

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.251 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.175 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.289

= 32 (kN/m)

Qa = 16 (kN/m) > V = 11.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 61.795 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.15	0.40	0.46	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.31	0.27	0.08	Seismic force
Total		1.46		0.54	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.30	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.20	0.00	Resisting force
F2	1/2(p2)h	0.00	0.10	0.00	Resisting force
F3	1/2(p3)h	0.34	0.20	0.07	Active force
F4	1/2(p4)h	0.70	0.10	0.07	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	2.32	0.48	1.11	Seismic force
Total of active forces		3.36		1.25	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 11.62 (kN/m)

H = 3.36 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 2.08 > 1.2 Safe !!

Overturning,

Mr_{max} = 2.70 (kN-m/m)

Mr_{act} = 2.70 (kN-m/m)

Mo = 1.25 (kN-m/m)

d = (Mr-Mo)/V = 0.13 (m)

SF =Mr_{max}/ M_o = 2.17 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.175 (m) < B/3 Safe !!

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.07	0.00	
Footing	γc(t3)(a5)	1.01	0.07	0.07	
Reaction	-q1(3d-t2)^2/6d	-0.58	-0.03	0.02	
		0.00	0.00	0.00	
Total		0.43		0.09	

5. Case 4 : Wind condition

Wind from the land side

Location = STA. 0.7~0.80

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.150	0.86
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.536	0.353	0.54
Footing	(B)(t3)γc	4.32	0.300	1.30
Soil-1	1/2(a5)(a6)γs	0	0.553	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.507	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		11.62	0.233	2.70

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.30	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.30	4.68	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.20	0.00	Resisting force
F2	1/2(p2)h	0.00	0.10	0.00	Resisting force
F3	1/2(p3)h	0.46	0.20	0.09	Active force
F4	1/2(p4)h	0.70	0.10	0.07	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.68	0.70	1.18	Wind force
Total of active forces		2.84		1.34	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 11.62 (kN/m)
H = 2.84 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.45 > 1.2 Safe !!

Overturning,

Mr_{max} = 2.70 (kN-m/m)
Mr_{act} = 2.70 (kN-m/m)
Mo = 1.34 (kN-m/m)
d = (Mr-Mo)/V = 0.12 (m)
SF =Mr_{max}/ M_o = 2.02 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.183 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.235 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.183 (m)
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.245 0
= 30 (kN/m)
Qa = 15 (kN/m) > V = 11.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 66.043 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		1.68	0.40	0.67	
Total		1.68		0.67	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.07	0.00	
Footing	γc(t3)(a5)	1.01	0.07	0.07	
Reaction	-1/2(q2)(a5)	-1.10	-0.04	0.04	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-0.09		0.11	

9. Summary of stability analysis

HT. OF WALL 0.7~0.80
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-2	6.02	1.5	0.08	0.10	11.6	21
Flood	1.12	1	0.20	0.20	7.5	13
Seismic-2	2.08	1.2	0.17	0.20	11.6	16
Wind-2	2.45	1.2	0.18	0.20	11.6	15

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.8~0.90

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

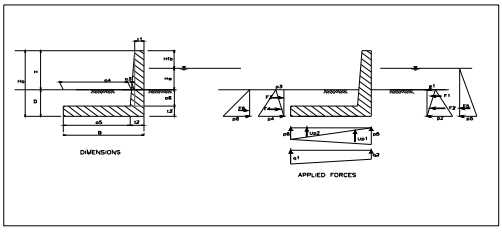
Dimensions of wall and water depth :

Height of wall	H =	0.90 (m)
Embedment of wall	D =	0.40 (m)
Total height of wall	Ho=	1.30 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.90 (m)
Width of footing	B =	0.75 (m)

Thickness of wall members :

t1= 0.30 (m)
t2= 0.48 (m)
t3= 0.40 (m)

a1= 0.000 (m)
a2= 0.450 (m)
a3= 0.180 (m)
a4= 0.270 (m)
a5= 0.270 (m)
a6= 0.000 (m)



2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

HT. OF WALL 0.8~0.90

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.48	0.150	0.97	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.944	0.360	0.70	
Footing	(B)(t3)γc	7.2	0.375	2.70	
Soil-1	1/2(a5)(a6)γs	0	0.660	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.570	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		15.62	0.280	4.37	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.40	0.00	Passive press.
p3	Ka(γh+q)-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c$\sqrt{}$Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 15.62 (kN/m)
H = 1.65 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 5.67 > 1.5 Safe !!

Overturning,

Mr_{max} = 4.37 (kN-m/m)
Mr_{act} = 4.37 (kN-m/m)
Mo = 0.30 (kN-m/m)
SF =Mr_{max})/ M_o = 14.51 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.11 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γ_s D Nq + 1/2 γ_s' βBe Nr)
Be = B - 2 e = 0.52 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.11 m
α = 1.0
k = 1+0.3*D/B = 1.16
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.106

= 97 (kN/m)
Qa = 32 (kN/m) > V = 15.62 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 39.909 (kN/m2)

q2 = V/B*(1-6e/B) = 1.755 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.24	0.13	0.03	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	8.28	0.43	3.59	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		8.52		3.62	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 9.38 (kN/m)
H = 8.52 (kN/m)
HR_{max} = 4.05 (kN/m)
HR_{act} = 4.05 (kN/m)
SF =(V*f +HR_{max})/ H = 1.13 > 1.0 Safe !!

Overturning,

Mr_{max} = 7.77 (kN-m/m)
Mr = 7.77 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 6.38 (kN-m/m)
SF = Mr_{max}/M_o = 1.22 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.227 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γ_s D Nq + 1/2 γ_s' βBe Nr)
where,
Be = B - 2 e = 0.30 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.227 m
α = 1.0
k = 1+0.3*D/B = 1.16
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.477

= 51 (kN/m)
Qa = 25.4 (kN/m) > V = 9.38 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 42.100 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γ_s(a6)(a5)	0.00	0.14	0.00	
Footing	γ_c(t3)(a5)	2.59	0.14	0.35	
Reaction	-1/2(q2)(a5)	-0.24	0.18	-0.04	
	-(t2q2+a5q1)(a5)/2B	-2.09	0.09	-0.19	
Total		0.26		0.12	

3. Case 2 : Flood condition

Location = STA. 0.8~0.90
0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γ_c	6.48	0.600	3.89	
Wall-2	1/2(t2-t1)(Ho-t3)γ_c	1.944	0.330	0.64	
Footing	(B)(t3)γ_c	7.2	0.375	2.70	
Soil-1	1/2(a5)(a6)γ_{sat}	0.00	0.090	0.00	
Soil-2	1/2(a4)(a6)γ_{sat}	0.00	0.180	0.00	
Water-1	1/2(a4)(Hw)γ_w	0.00	0.660	0.00	
Water-2	1/2(a2)(Hw)γ_w	0.00	0.450	0.00	
Sub-Total		15.62	0.463	7.23	
Uplift-1	-1/2B(D+Hw)γ_w	-4.78	0.500	-2.39	
Uplift-2	-1/2B(D)γ_w	-1.47	0.250	-0.37	
Sub-Total		-6.25		-2.76	
Total		9.38		4.47	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{}$Ka	0.40	1.22	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{}$Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{}$Kp	0.40	16.32	Passive earth press.

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		8.82	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	3.97	0.30	1.19	Water pressure
Total		3.97		1.19	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γ_w(Hw)(a5)	0.00	0.14	0.00	
Soil	γ_{sat}(a6)(a5)	0.00	0.14	0.00	
Footing	γ_c(t3)(a5)	2.59	0.14	0.35	
Uplift	-1/2(p5)(a5)	-1.72	0.09	-0.15	
	-(t2p5+a5p6)(a5)/2B	-1.29	0.18	-0.23	
Reaction	-1/2(q2)(a5)	-2.24	0.09	-0.20	
	-(t2q2+a5q1)(a5)/2B	-5.68	0.18	-1.02	
Total		-8.34		-1.26	

4. Case 3 : Seismic condition

Location = STA. 0.8~0.90

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γ_c	6.48	0.150	0.97	0.850	5.51
Wall-2	1/2(t2-t1)(Ho-t3)γ_c	1.944	0.360	0.70	0.700	1.36
Footing	(B)(t3)γ_c	7.2	0.375	2.70	0.200	1.44
Soil-1	1/2(a5)(a6)γ_s	0	0.660	0.00	0.400	0.00
Soil-2	1/2(a4)(a6)γ_s	0.00	0.570	0.00	0.400	0.00
Water-1	1/2(a4)(Hw)γ_w	-	-	0		0
Water-2	1/2(a2)(Hw)γ_w	-	-	0		0
Total		15.62	0.280	4.37	0.532	8.31

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.40	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	3.12	0.53	1.66	Seismic force
Total of active forces		4.66		1.93	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 15.62 (kN/m)
H = 4.66 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.01 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.37 (kN-m/m)
Mr_{act} = 4.37 (kN-m/m)
Mo = 1.93 (kN-m/m)
d = (Mr-Mo)/V = 0.16 (m)
SF =Mr_{max}/ M_o = 2.27 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.219 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.313 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.219 m
α = 1.0
k = 1+0.3*D/B = 1.16
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.299

= 54 (kN/m)
Qa = 27 (kN/m) > V = 15.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 66.556 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.30	0.45	0.58	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.39	0.30	0.12	Seismic force
Total		1.68		0.70	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.14	0.00	
Footing	γc(t3)(a5)	2.59	0.14	0.35	
Reaction	-q1(3d-t2)^2/6d	-0.01	0.00	0.00	
		0.00	0.00	0.00	
Total		2.58		0.35	

5. Case 4 : Wind condition
Wind from the land side

Location = STA. 0.8~0.90

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.48	0.150	0.97
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.944	0.360	0.70
Footing	(B)(t3)γc	7.2	0.375	2.70
Soil-1	1/2(a5)(a6)γs	0	0.660	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.570	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		15.62	0.280	4.37

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.40	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.90	0.85	1.61	Wind force
Total of active forces		3.55		1.91	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 15.62 (kN/m)
H = 3.55 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.64 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.37 (kN-m/m)
Mr_{act} = 4.37 (kN-m/m)
Mo = 1.91 (kN-m/m)
d = (Mr-Mo)/V = 0.16 (m)
SF =Mr_{max}/ M_o = 2.29 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.218 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.315 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.218 (m)
α = 1.0
k = 1+0.3*D/B = 1.16
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.227 0

= 54 (kN/m)
Qa = 27 (kN/m) > V = 15.62 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 66.170 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
$C_eC_q\ q_s$ I H		1.90	0.45	0.85	
Total		1.90		0.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.14	0.00	
Footing	γc(t3)(a5)	2.59	0.14	0.35	
Reaction	-1/2(q2)(a5)	0.00	0.00	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		2.59		0.35	

9. Summary of stability analysis

HT. OF WALL 0.8~0.90 0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	5.67	1.5	0.11	0.13	15.6	32
Flood	1.13	1	0.23	0.25	9.4	25
Seismic-2	2.01	1.2	0.22	0.25	15.6	27
Wind-2	2.64	1.2	0.22	0.25	15.6	27

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 0.9~1.00

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

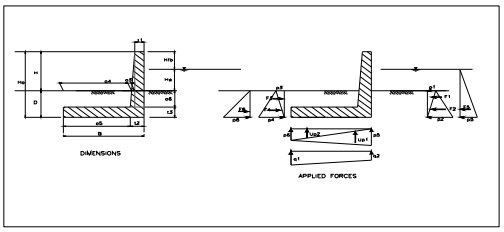
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.00	(m)
Embedment of wall	D =	0.40	(m)
Total height of wall	Ho=	1.40	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.00	(m)
Width of footing	B =	0.85	(m)

Thickness of wall members :

t1=	0.30	(m)	
t2=	0.50	(m)	
t3=	0.40	(m)	
a1=	0.000	(m)	
a2=	0.550	(m)	
a3=	0.200	(m)	
a4=	0.350	(m)	
a5=	0.350	(m)	
a6=	0.000	(m)	



2. Case 1 : Normal condition

HT. OF WALL 0.9~1.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.150	1.08	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.4	0.367	0.88	
Footing	(B)(t3)γc	8.16	0.425	3.47	
Soil-1	1/2(a5)(a6)γs	0	0.733	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.617	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		17.76	0.306	5.43	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.40	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 17.76 (kN/m)
H = 1.65 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.45 > 1.5 Safe !!

Overturning,

Mr_{max} = 5.43 (kN-m/m)
Mr_{act} = 5.43 (kN-m/m)
Mo = 0.30 (kN-m/m)
SF =Mr_{max})/ M_o = 18.01 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.14 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.58 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.14 m
α = 1.0
k = 1+0.3*D/B = 1.14118
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.093

= 109 (kN/m)
Qa = 36 (kN/m) > V = 17.76 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 41.002 (kN/m2)

q2 = V/B*(1-6e/B) = 0.786 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.18	0.00	
Footing	γc(t3)(a5)	3.36	0.18	0.59	
Reaction	-1/2(q2)(a5)	-0.14	0.23	-0.03	
	-(t2q2+a5q1)(a5)/2B	-3.04	0.12	-0.35	
Total		0.19		0.20	

3. Case 2 : Flood condition

Location = STA. 0.9~1.00 0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.700	5.04	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.4	0.417	1.00	
Footing	(B)(t3)γc	8.16	0.425	3.47	
Soil-1	1/2(a5)(a6)γsat	0.00	0.117	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.233	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.733	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.483	0.00	
Sub-Total		17.76	0.535	9.51	
Uplift-1	-1/2B(D+Hw)γw	-5.83	0.567	-3.30	
Uplift-2	-1/2B(D)γw	-1.67	0.283	-0.47	
Sub-Total		-7.50		-3.78	
Total		10.26		5.73	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.40	1.22	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.24	0.13	0.03	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	9.60	0.47	4.48	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		9.85		4.51	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 10.26 (kN/m)
H = 9.85 (kN/m)
HR_{max} = 4.05 (kN/m)
HR_{act} = 4.05 (kN/m)
SF =(V*f +HR_{max})/ H = 1.04 > 1.0 Safe !!

Overturning,

Mr_{max} = 10.05 (kN-m/m)
Mr = 10.05 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 8.29 (kN-m/m)
SF = Mr_{max}/M_o = 1.21 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.254 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.34 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.254 m
α = 1.0
k = 1+0.3*D/B = 1.14118
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.565
= 59 (kN/m)
Qa = 29.4 (kN/m) > V = 10.26 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 39.960 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		9.80	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	4.90	0.33	1.63	Water pressure
Total		4.90		1.63	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.18	0.00	
Soil	γsat(a6)(a5)	0.00	0.18	0.00	
Footing	γc(t3)(a5)	3.36	0.18	0.59	
Uplift	-1/2(p5)(a5)	-2.40	0.12	-0.28	
	-(t2p5+a5p6)(a5)/2B	-1.69	0.23	-0.40	
Reaction	-1/2(q2)(a5)	-2.23	0.12	-0.26	
	-(t2q2+a5q1)(a5)/2B	-6.99	0.23	-1.63	
Total		-9.96		-1.98	

4. Case 3 : Seismic condition

Location = STA. 0.9~1.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.150	1.08	0.900	6.48
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.4	0.367	0.88	0.733	1.76
Footing	(B)(t3)γc	8.16	0.425	3.47	0.200	1.63
Soil-1	1/2(a5)(a6)γs	0	0.733	0.00	0.400	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.617	0.00	0.400	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		17.76	0.306	5.43	0.556	9.87

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.40	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	3.55	0.56	1.97	Seismic force
Total of active forces		5.09		2.24	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 17.76 (kN/m)
H = 5.09 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.09 > 1.2 Safe !!

Overturning,

Mr_{max} = 5.43 (kN-m/m)
Mr_{act} = 5.43 (kN-m/m)
Mo = 2.24 (kN-m/m)
d = (Mr-Mo)/V = 0.18 (m)
SF =Mr_{max}/ M_o = 2.42 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.245 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.359 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.245 m

α = 1.0

k = 1+0.3*D/B = 1.14118

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.287

= 62 (kN/m)

Qa = 31 (kN/m) > V = 17.76 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 65.946 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.44	0.50	0.72	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.48	0.33	0.16	Seismic force
Total		1.92		0.88	

(3) Stability

Sliding,

V = 17.76 (kN/m)

H = 3.76 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 2.84 > 1.2 Safe !!

Overturning,

Mr_{max} = 5.43 (kN-m/m)

Mr_{act} = 5.43 (kN-m/m)

Mo = 2.20 (kN-m/m)

d = (Mr-Mo)/V = 0.18 (m)

SF =Mr_{max}/ M_o = 2.47 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.243 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.364 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.243 (m)

α = 1.0

k = 1+0.3*D/B = 1.14118

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.212 0

= 63 (kN/m)

Qa = 32 (kN/m) > V = 17.76 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 65.076 (kN/m2)

q2 = 0.000 (kN/m2)

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.18	0.00	
Footing	γc(t3)(a5)	3.36	0.18	0.59	
Reaction	-q1(3d-t2)^2/6d	-0.09	0.01	0.00	
		0.00	0.00	0.00	
Total		3.27		0.59	

5. Case 4 : Wind condition

Location = STA. 0.9~1.00

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.150	1.08
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.4	0.367	0.88
Footing	(B)(t3)γc	8.16	0.425	3.47
Soil-1	1/2(a5)(a6)γs	0	0.733	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.617	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		17.76	0.306	5.43

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.40	0.00	Passive press.
p3	Ka(γh+q')-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{}$Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	0.00	0.13	0.00	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	2.11	0.90	1.90	Wind force
Total of active forces		3.76		2.20	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		2.11	0.50	1.05	
Total		2.11		1.05	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.18	0.00	
Footing	γc(t3)(a5)	3.36	0.18	0.59	
Reaction	-1/2(q2)(a5)	-0.13	0.02	0.00	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		3.23		0.59	

9. Summary of stability analysis

HT. OF WALL 0.9~1.00

0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	6.45	1.5	0.14	0.14	17.8	36
Flood	1.04	1	0.25	0.28	10.3	29
Seismic-2	2.09	1.2	0.25	0.28	17.8	31
Wind-2	2.84	1.2	0.24	0.28	17.8	32

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.0~1.10

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

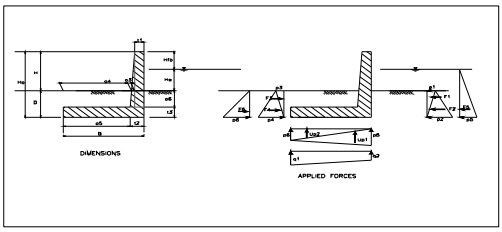
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.20	(m)
Embedment of wall	D =	0.55	(m)
Total height of wall	Ho=	1.75	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.20	(m)
Width of footing	B =	1.10	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.55 (m)	a2=	0.800 (m)
t3=	0.50 (m)	a3=	0.240 (m)
		a4=	0.560 (m)
		a5=	0.550 (m)
		a6=	0.050 (m)



(3) Stability

Sliding,

V = 26.45 (kN/m)
H = 2.50 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.35 > 1.5 Safe !!

Overturning,

Mr_{max} = 10.46 (kN-m/m)
Mr_{act} = 10.46 (kN-m/m)
Mo = 0.61 (kN-m/m)
SF =Mr_{max})/ M_o = 17.11 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.18 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.74 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.18 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.094

= 191 (kN/m)
Qa = 64 (kN/m) > V = 26.45 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 47.355 (kN/m2)

q2 = V/B*(1-6e/B) = 0.735 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.05	3.31	Active earth press.

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

HT. OF WALL 1.0~1.10

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9	0.150	1.35	
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.75	0.383	1.44	
Footing	(B)(t3)γc	13.2	0.550	7.26	
Soil-1	1/2(a5)(a6)γs	0.2475	0.917	0.23	
Soil-2	1/2(a4)(a6)γs	0.25	0.727	0.18	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		26.45	0.395	10.46	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.55	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.55	6.05	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.37	0.00	Resisting force
F2	1/2(p2)h	0.00	0.18	0.00	Resisting force
F3	1/2(p3)h	0.84	0.37	0.31	Active force
F4	1/2(p4)h	1.66	0.18	0.30	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.50		0.61	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.08	0.03	0.00	Active force
F2'	1/2(p2')(a6)	0.08	0.02	0.00	Active force
Total		0.16		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.50	0.28	0.14	
Footing	γc(t3)(a5)	6.60	0.28	1.82	
Reaction	-1/2(q2)(a5)	-0.20	0.37	-0.07	
	-(t2q2+a5q1)(a5)/2B	-6.61	0.18	-1.21	
Total		0.28		0.66	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

Location = STA. 1.0~1.10
0

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9	0.950	8.55	
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.75	0.633	2.38	
Footing	(B)(t3)γc	13.2	0.550	7.26	
Soil-1	1/2(a5)(a6)γsat	0.28	0.183	0.05	
Soil-2	1/2(a4)(a6)γsat	0.28	0.373	0.10	
Water-1	1/2(a4)(Hw)γw	0.00	0.913	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.567	0.00	
Sub-Total		26.51	0.692	18.34	
Uplift-1	-1/2B(D+Hw)γw	-9.43	0.733	-6.92	
Uplift-2	-1/2B(D)γw	-2.96	0.367	-1.09	
Sub-Total		-12.40		-8.00	
Total		14.11		10.34	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.55	1.67	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.55	22.44	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.37	0.00	Active force
F2	1/2(p2)h	0.46	0.18	0.08	Active force
F3	1/2(p3)h	0.00	0.37	0.00	Resisting force
F4	1/2(p4)h	6.17	0.18	1.13	Resisting force
F5	1/2γw(D+Hw)^2	15.01	0.58	8.75	Active force
F6	1/2γw(D)^2	1.48	0.18	0.27	Resisting force
Total of active forces		15.47		8.84	
Total of maximum resisting forces		7.65		1.40	
Actual resisting forces		7.65		1.40	

(3) Stability

Sliding,

V = 14.11 (kN/m)
H = 15.47 (kN/m)
HR_{max} = 7.65 (kN/m)
HR_{act} = 7.65 (kN/m)
SF =(V*f'+HR_{max})/ H = 1.04 > 1.0 Safe !!

Overturning,

Mr_{max} = 19.74 (kN-m/m)
Mr = 19.74 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 16.84 (kN-m/m)
SF = Mr_{max}/M_o = 1.17 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.344 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.41 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.344 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.554

= 96 (kN/m)
Qa = 48.1 (kN/m) > V = 14.11 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 45.738 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.05	0.15	Active earth press.
p5'	γw(Hw+a6)		12.25	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.03	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.02	0.00	Active force
F5'	1/2(p5')(Hw+a6)	7.66	0.42	3.19	Water pressure
Total		7.66		3.19	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.28	0.00	
Soil	γsat(a6)(a5)	0.55	0.28	0.15	
Footing	γc(t3)(a5)	6.60	0.28	1.82	
Uplift	-1/2(p5)(a5)	-4.72	0.18	-0.86	
	-(t2p5+a5p6)(a5)/2B	-3.10	0.37	-1.14	
Reaction	-1/2(q2)(a5)	-1.36	0.18	-0.25	
	-(t2q2+a5q1)(a5)/2B	-12.58	0.37	-4.61	
Total		-14.61		-4.90	

4. Case 3 : Seismic condition

Location = STA. 1.0~1.10

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9	0.150	1.35	1.125	10.13
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.75	0.383	1.44	0.917	3.44
Footing	(B)(t3)γc	13.2	0.550	7.26	0.250	3.30
Soil-1	1/2(a5)(a6)γs	0.2475	0.917	0.23	0.517	0.13
Soil-2	1/2(a4)(a6)γs	0.25	0.727	0.18	0.533	0.13
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		26.45	0.395	10.46	0.647	17.12

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.55	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.55	6.67	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.37	0.00	Resisting force
F2	1/2(p2)h	0.00	0.18	0.00	Resisting force
F3	1/2(p3)h	0.62	0.37	0.23	Active force
F4	1/2(p4)h	1.83	0.18	0.34	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	5.29	0.65	3.42	Seismic force
Total of active forces		7.74		3.99	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 26.45 (kN/m)
H = 7.74 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f' + HR_{max})/ H = 2.05 > 1.2 Safe !!

Overturning,

Mr_{max} = 10.46 (kN-m/m)
Mr_{act} = 10.46 (kN-m/m)
Mo = 3.99 (kN-m/m)
d = (Mr-Mo)/V = 0.24 (m)
SF =Mr_{max}/ M_o = 2.62 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.305 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.489 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.305 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.293

= 117 (kN/m)
Qa = 59 (kN/m) > V = 26.45 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 72.076 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.05	2.64	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.06	0.03	0.00	Active force
F2'	1/2(p2')(a6)	0.07	0.02	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.80	0.63	1.13	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.75	0.42	0.31	Seismic force
Total		2.67		1.44	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.50	0.28	0.14	
Footing	γc(t3)(a5)	6.60	0.28	1.82	
Reaction	-q1(3d-t2)^2/6d	-1.66	0.06	-0.10	
		0.00	0.00	0.00	
Total		5.43		1.85	

5. Case 4 : Wind condition

Location = STA. 1.0~1.10

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9	0.150	1.35
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.75	0.383	1.44
Footing	(B)(t3)γc	13.2	0.550	7.26
Soil-1	1/2(a5)(a6)γs	0.2475	0.917	0.23
Soil-2	1/2(a4)(a6)γs	0.25	0.727	0.18
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		26.45	0.395	10.46

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.55	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.55	6.05	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.37	0.00	Resisting force
F2	1/2(p2)h	0.00	0.18	0.00	Resisting force
F3	1/2(p3)h	0.84	0.37	0.31	Active force
F4	1/2(p4)h	1.66	0.18	0.30	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	2.53	1.15	2.91	Wind force
Total of active forces		5.03		3.52	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 26.45 (kN/m)
H = 5.03 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 3.16 > 1.2 Safe !!

Overturning,

Mr_{max} = 10.46 (kN-m/m)
Mr_{act} = 10.46 (kN-m/m)
Mo = 3.52 (kN-m/m)
d = (Mr-Mo)/V = 0.26 (m)
SF =Mr_{max})/ M_o = 2.97 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.288 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.525 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.288 (m)
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.190 0
= 127 (kN/m)
Qa = 63 (kN/m) > V = 26.45 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 67.201 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.05	3.31	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.08	0.03	0.00	Active force
F2'	1/2(p2')(a6)	0.08	0.02	0.00	Active force
C_eC_q q_s I H		2.53	0.65	1.64	
Total		2.69		1.65	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.50	0.28	0.14	
Footing	γc(t3)(a5)	6.60	0.28	1.82	
Reaction	-1/2(q2)(a5)	-2.40	0.08	-0.19	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		4.69		1.76	

9. Summary of stability analysis

HT. OF WALL 1.0~1.10
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	6.35	1.5	0.18	0.18	26.4	64
Flood	1.04	1	0.34	0.37	14.1	48
Seismic-2	2.05	1.2	0.31	0.37	26.4	59
Wind-2	3.16	1.2	0.29	0.37	26.4	63

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.10~1.20

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

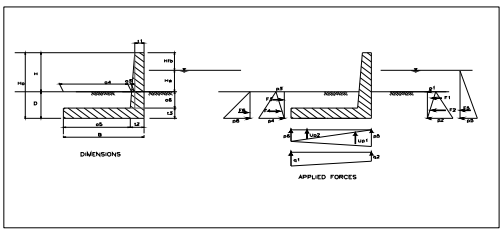
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.20	(m)
Embedment of wall	D =	0.50	(m)
Total height of wall	Ho=	1.70	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.20	(m)
Width of footing	B =	1.35	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.54 (m)	a2=	1.050 (m)
t3=	0.50 (m)	a3=	0.240 (m)
		a4=	0.810 (m)
		a5=	0.810 (m)
		a6=	0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL	1.10~1.20

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	0.150	1.30	
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.456	0.380	1.31	
Footing	(B)(t3)γc	16.2	0.675	10.94	
Soil-1	1/2(a5)(a6)γs	0	1.080	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.810	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		28.30	0.479	13.54	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	0.00	0.17	0.00	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 28.30 (kN/m)
H = 2.20 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 7.71 > 1.5 Safe !!

Overturning,

Mr_{max} = 13.54 (kN-m/m)
Mr_{act} = 13.54 (kN-m/m)
Mo = 0.49 (kN-m/m)
SF =Mr_{max})/ M_o = 27.44 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.21 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.92 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.21 m
α = 1.0
k = 1+0.3*D/B = 1.11111
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.078

= 226 (kN/m)
Qa = 75 (kN/m) > V = 28.30 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 40.875 (kN/m2)

q2 = V/B*(1-6e/B) = 1.045 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	9.72	0.41	3.94	
Reaction	-1/2(q2)(a5)	-0.42	0.54	-0.23	
	-(t2q2+a5q1)(a5)/2B	-10.10	0.27	-2.73	
Total		-0.81		0.98	

3. Case 2 : Flood condition

Location = STA.	1.10~1.20
	0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	1.200	10.37	
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.456	0.890	3.08	
Footing	(B)(t3)γc	16.2	0.675	10.94	
Soil-1	1/2(a5)(a6)γsat	0.00	0.270	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.540	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.080	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.650	0.00	
Sub-Total		28.30	0.862	24.38	
Uplift-1	-1/2B(D+Hw)γw	-11.25	0.900	-10.12	
Uplift-2	-1/2B(D)γw	-3.31	0.450	-1.49	
Sub-Total		-14.55		-11.61	
Total		13.74		12.77	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	14.16	0.57	8.02	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		14.54		8.09	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 13.74 (kN/m)
H = 14.54 (kN/m)
HR_{max} = 6.33 (kN/m)
HR_{act} = 6.33 (kN/m)
SF =(V*f +HR_{max})/ H = 1.00 > 1.0 Safe !!

Overturning,

Mr_{max} = 25.43 (kN-m/m)
Mr = 25.43 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 19.70 (kN-m/m)
SF = Mr_{max}/M_o = 1.29 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.258 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.83 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.258 m
α = 1.0
k = 1+0.3*D/B = 1.11111
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.598

= 199 (kN/m)
Qa = 99.5 (kN/m) > V = 13.74 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 21.952 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		11.76	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	7.06	0.40	2.82	Water pressure
Total		7.06		2.82	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.41	0.00	
Soil	γsat(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	9.72	0.41	3.94	
Uplift	-1/2(p5)(a5)	-6.75	0.27	-1.82	
	-(t2p5+a5p6)(a5)/2B	-3.89	0.54	-2.10	
Reaction	-1/2(q2)(a5)	-3.14	0.27	-0.85	
	-(t2q2+a5q1)(a5)/2B	-8.89	0.54	-4.80	
Total		-12.95		-5.63	

4. Case 3 : Seismic condition

(Direction of forces : Active forces are applied from land side)

Location = STA. 1.10~1.20

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	0.150	1.30	1.100	9.50
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.456	0.380	1.31	0.900	3.11
Footing	(B)(t3)γc	16.2	0.675	10.94	0.250	4.05
Soil-1	1/2(a5)(a6)γs	0	1.080	0.00	0.500	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.810	0.00	0.500	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		28.30	0.479	13.54	0.589	16.66

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.690 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.330 m

α = 1.0

k = 1+0.3*D/B = 1.11111

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.275

= 158 (kN/m)

Qa = 79 (kN/m) > V = 28.30 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 54.668 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.73	0.60	1.04	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.69	0.40	0.28	Seismic force
Total		2.42		1.31	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	0.00	0.17	0.00	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	5.66	0.59	3.33	Seismic force
Total of active forces		7.78		3.78	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 28.30 (kN/m)

H = 7.78 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 2.18 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.54 (kN-m/m)

Mr_{act} = 13.54 (kN-m/m)

Mo = 3.78 (kN-m/m)

d = (Mr-Mo)/V = 0.35 (m)

SF =Mr_{max}/ M_o = 3.58 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.330 (m) < B/3 Safe !!

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	9.72	0.41	3.94	
Reaction	-q1(3d-t2)^2/6d	-6.47	0.17	-1.07	
		0.00	0.00	0.00	
Total		3.25		2.87	

5. Case 4 : Wind condition

Wind from the land side

Location = STA. 1.10~1.20

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	0.150	1.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.456	0.380	1.31
Footing	(B)(t3)γc	16.2	0.675	10.94
Soil-1	1/2(a5)(a6)γs	0	1.080	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.810	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		28.30	0.479	13.54

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	0.00	0.17	0.00	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	2.53	1.10	2.78	Wind force
Total of active forces		4.73		3.27	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 28.30 (kN/m)
H = 4.73 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 3.59 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.54 (kN-m/m)
Mr_{act} = 13.54 (kN-m/m)
Mo = 3.27 (kN-m/m)
d = (Mr-Mo)/V = 0.36 (m)
SF =Mr_{max}/ M_o = 4.14 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.312 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.726 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.312 (m)
α = 1.0
k = 1+0.3*D/B = 1.11111
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.167 0
= 168 (kN/m)
Qa = 84 (kN/m) > V = 28.30 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 51.971 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		2.53	0.60	1.52	
Total		2.53		1.52	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	9.72	0.41	3.94	
Reaction	-1/2(q2)(a5)	-7.19	0.18	-1.32	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		2.53		2.62	

9. Summary of stability analysis

HT. OF WALL 1.10~1.20
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	7.71	1.5	0.21	0.23	28.3	75
Flood	1.00	1	0.26	0.45	13.7	100
Seismic-2	2.18	1.2	0.33	0.45	28.3	79
Wind-2	3.59	1.2	0.31	0.45	28.3	84

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.20~1.30

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

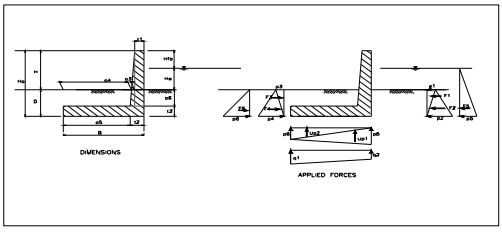
Dimensions of wall and water depth :

Height of wall	H =	1.30 (m)
Embedment of wall	D =	0.60 (m)
Total height of wall	Ho=	1.90 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.30 (m)
Width of footing	B =	1.20 (m)

Thickness of wall members :

t1= 0.30 (m)
t2= 0.56 (m)
t3= 0.60 (m)

a1= 0.000 (m)
a2= 0.900 (m)
a3= 0.260 (m)
a4= 0.640 (m)
a5= 0.640 (m)
a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 1.20~1.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.36	0.150	1.40	
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.056	0.387	1.57	
Footing	(B)(t3)γc	17.28	0.600	10.37	
Soil-1	1/2(a5)(a6)γs	0	0.987	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.773	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		30.70	0.435	13.34	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.60	0.00	Passive press.
p3	Ka(γh+q)-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c$\sqrt{}$Ka	0.60	6.32	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.40	0.00	Resisting force
F2	1/2(p2)h	0.00	0.20	0.00	Resisting force
F3	1/2(p3)h	0.91	0.40	0.36	Active force
F4	1/2(p4)h	1.90	0.20	0.38	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.81		0.74	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 30.70 (kN/m)
H = 2.81 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.56 > 1.5 Safe !!

Overturning,

Mr_{max} = 13.34 (kN-m/m)
Mr_{act} = 13.34 (kN-m/m)
Mo = 0.74 (kN-m/m)
SF =Mr_{max})/ M_o = 17.94 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.19 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)
Be = B - 2 e = 0.82 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.19 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.091

= 231 (kN/m)
Qa = 77 (kN/m) > V = 30.70 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 49.834 (kN/m2)

q2 = V/B*(1-6e/B) = 1.326 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.40	0.00	Active force
F2	1/2(p2)h	0.55	0.20	0.11	Active force
F3	1/2(p3)h	0.00	0.40	0.00	Resisting force
F4	1/2(p4)h	7.34	0.20	1.47	Resisting force
F5	1/2γw(D+Hw)^2	17.69	0.63	11.20	Active force
F6	1/2γw(D)^2	1.76	0.20	0.35	Resisting force
Total of active forces		18.24		11.31	
Total of maximum resisting forces		9.11		1.82	
Actual resisting forces		9.11		1.82	

(3) Stability

Sliding,

V = 16.00 (kN/m)
H = 18.24 (kN/m)
HR_{max} = 9.11 (kN/m)
HR_{act} = 9.11 (kN/m)
SF =(V*f +HR_{max})/ H = 1.03 > 1.0 Safe !!

Overturning,

Mr_{max} = 24.97 (kN-m/m)
Mr = 24.97 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 21.66 (kN-m/m)
SF = Mr_{max}/M_o = 1.15 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.393 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)
where,
Be = B - 2 e = 0.41 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.393 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.571

= 104 (kN/m)
Qa = 52.1 (kN/m) > V = 16.00 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 51.630 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	0.00	0.32	0.00	
Footing	γ_C(t3)(a5)	9.22	0.32	2.95	
Reaction	-1/2(q2)(a5)	-0.42	0.43	-0.18	
	-(t2q2+a5q1)(a5)/2B	-8.70	0.21	-1.86	
Total		0.09		0.91	

3. Case 2 : Flood condition

Location = STA. 1.20~1.30
0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γ_C	9.36	1.050	9.83	
Wall-2	1/2(t2-t1)(Ho-t3)γ_C	4.056	0.727	2.95	
Footing	(B)(t3)γ_C	17.28	0.600	10.37	
Soil-1	1/2(a5)(a6)γ_{sat}	0.00	0.213	0.00	
Soil-2	1/2(a4)(a6)γ_{sat}	0.00	0.427	0.00	
Water-1	1/2(a4)(Hw)γ_W	0.00	0.987	0.00	
Water-2	1/2(a2)(Hw)γ_W	0.00	0.600	0.00	
Sub-Total		30.70	0.754	23.14	
Uplift-1	-1/2B(D+Hw)γ_W	-11.17	0.800	-8.94	
Uplift-2	-1/2B(D)γ_W	-3.53	0.400	-1.41	
Sub-Total		-14.70		-10.35	
Total		16.00		12.79	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{}$Ka	0.60	1.82	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{}$Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{}$Kp	0.60	24.48	Passive earth press.

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		12.74	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	8.28	0.43	3.59	Water pressure
Total		8.28		3.59	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γ_W(Hw)(a5)	0.00	0.32	0.00	
Soil	γ_{sat}(a6)(a5)	0.00	0.32	0.00	
Footing	γ_C(t3)(a5)	9.22	0.32	2.95	
Uplift	-1/2(p5)(a5)	-5.96	0.21	-1.27	
	-(t2p5+a5p6)(a5)/2B	-3.78	0.43	-1.61	
Reaction	-1/2(q2)(a5)	-16.00	0.43	-6.93	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		-16.52		-6.87	

4. Case 3 : Seismic condition

Location = STA. 1.20~1.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γ_C	9.36	0.150	1.40	1.250	11.70
Wall-2	1/2(t2-t1)(Ho-t3)γ_C	4.056	0.387	1.57	1.033	4.19
Footing	(B)(t3)γ_C	17.28	0.600	10.37	0.300	5.18
Soil-1	1/2(a5)(a6)γ_S	0	0.987	0.00	0.600	0.00
Soil-2	1/2(a4)(a6)γ_S	0.00	0.773	0.00	0.600	0.00
Water-1	1/2(a4)(Hw)γ_W	-	-	0		0
Water-2	1/2(a2)(Hw)γ_W	-	-	0		0
Total		30.70	0.435	13.34	0.687	21.08

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.60	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.60	7.07	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.40	0.00	Resisting force
F2	1/2(p2)h	0.00	0.20	0.00	Resisting force
F3	1/2(p3)h	0.67	0.40	0.27	Active force
F4	1/2(p4)h	2.12	0.20	0.42	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	6.14	0.69	4.22	Seismic force
Total of active forces		8.93		4.91	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 30.70 (kN/m)
H = 8.93 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.06 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.34 (kN-m/m)
Mr_{act} = 13.34 (kN-m/m)
Mo = 4.91 (kN-m/m)
d = (Mr-Mo)/V = 0.27 (m)
SF =Mr_{max}/ M_o = 2.72 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.325 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.549 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.325 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.291

= 144 (kN/m)
Qa = 72 (kN/m) > V = 30.70 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 74.493 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.87	0.65	1.22	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.81	0.43	0.35	Seismic force
Total		2.68		1.57	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.32	0.00	
Footing	γc(t3)(a5)	9.22	0.32	2.95	
Reaction	-q1(3d-t2)^2/6d	-3.15	0.09	-0.28	
		0.00	0.00	0.00	
Total		6.06		2.67	

5. Case 4 : Wind condition
Wind from the land side

Location = STA. 1.20~1.30

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.36	0.150	1.40
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.056	0.387	1.57
Footing	(B)(t3)γc	17.28	0.600	10.37
Soil-1	1/2(a5)(a6)γs	0	0.987	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.773	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		30.70	0.435	13.34

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.60	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.60	6.32	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.40	0.00	Resisting force
F2	1/2(p2)h	0.00	0.20	0.00	Resisting force
F3	1/2(p3)h	0.91	0.40	0.36	Active force
F4	1/2(p4)h	1.90	0.20	0.38	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.74	1.25	3.42	Wind force
Total of active forces		5.54		4.17	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 30.70 (kN/m)
H = 5.54 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 3.32 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.34 (kN-m/m)
Mr_{act} = 13.34 (kN-m/m)
Mo = 4.17 (kN-m/m)
d = (Mr-Mo)/V = 0.30 (m)
SF =Mr_{max}/ M_o = 3.20 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.301 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.598 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.301 (m)
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.181 0

= 159 (kN/m)
Qa = 79 (kN/m) > V = 30.70 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 68.469 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
$C_eC_q\,q_s$ l H		2.74	0.65	1.78	
Total		2.74		1.78	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.32	0.00	
Footing	γc(t3)(a5)	9.22	0.32	2.95	
Reaction	-1/2(q2)(a5)	-4.33	0.11	-0.49	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		4.89		2.46	

9. Summary of stability analysis

HT. OF WALL 1.20~1.30 0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	6.56	1.5	0.19	0.20	30.7	77
Flood	1.03	1	0.39	0.40	16.0	52
Seismic-2	2.06	1.2	0.33	0.40	30.7	72
Wind-2	3.32	1.2	0.30	0.40	30.7	79

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.30~1.40

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

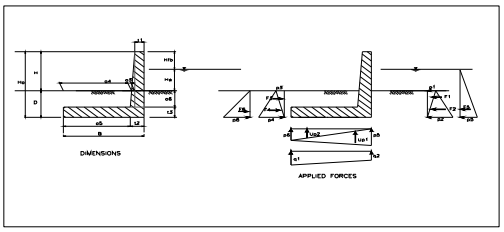
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.40	(m)
Embedment of wall	D =	0.70	(m)
Total height of wall	Ho=	2.10	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.40	(m)
Width of footing	B =	1.40	(m)

Thickness of wall members :

t1=	0.30	(m)	a1= 0.000 (m)
t2=	0.58	(m)	a2= 1.100 (m)
t3=	0.70	(m)	a3= 0.280 (m)
			a4= 0.820 (m)
			a5= 0.820 (m)
			a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	0.150	1.51	
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.704	0.393	1.85	
Footing	(B)(t3)γc	23.52	0.700	16.46	
Soil-1	1/2(a5)(a6)γs	0	1.127	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.853	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		38.30	0.518	19.83	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		3.47		1.06	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 38.30 (kN/m)
H = 3.47 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 6.63 > 1.5 Safe !!

Overturning,

Mr_{max} = 19.83 (kN-m/m)
Mr_{act} = 19.83 (kN-m/m)
Mo = 1.06 (kN-m/m)
SF =Mr_{max})/ M_o = 18.76 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.21 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 0.98 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.21 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.090

= 323 (kN/m)
Qa = 108 (kN/m) > V = 38.30 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 51.983 (kN/m2)

q2 = V/B*(1-6e/B) = 2.737 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.78	0.41	5.65	
Reaction	-1/2(q2)(a5)	-1.12	0.55	-0.61	
	-(t2q2+a5q1)(a5)/2B	-12.95	0.27	-3.54	
Total		-0.29		1.50	

3. Case 2 : Flood condition

Location = STA. 1.30~1.40 0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	1.250	12.60	
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.704	0.913	4.30	
Footing	(B)(t3)γc	23.52	0.700	16.46	
Soil-1	1/2(a5)(a6)γsat	0.00	0.273	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.547	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.127	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.667	0.00	
Sub-Total		38.30	0.871	33.36	
Uplift-1	-1/2B(D+Hw)γw	-14.41	0.933	-13.45	
Uplift-2	-1/2B(D)γw	-4.80	0.467	-2.24	
Sub-Total		-19.21		-15.69	
Total		19.10		17.67	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Active force
F2	1/2(p2)h	0.74	0.23	0.17	Active force
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	21.61	0.70	15.13	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		22.35		15.30	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Sliding,

V = 19.10 (kN/m)
H = 22.35 (kN/m)
HR_{max} = 12.40 (kN/m)
HR_{act} = 12.40 (kN/m)
SF =(V*f +HR_{max})/ H = 1.07 > 1.0 Safe !!

Overturning,

Mr_{max} = 36.25 (kN-m/m)
Mr = 36.25 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 30.99 (kN-m/m)
SF = Mr_{max}/M_o = 1.17 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.424 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.55 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.424 m
α = 1.0
k = 1+0.3*D/B = 1.15
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.521

= 165 (kN/m)
Qa = 82.6 (kN/m) > V = 19.10 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 46.159 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		13.72	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	9.60	0.47	4.48	Water pressure
Total		9.60		4.48	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.41	0.00	
Soil	γsat(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.78	0.41	5.65	
Uplift	-1/2(p5)(a5)	-8.44	0.27	-2.31	
	-(t2p5+a5p6)(a5)/2B	-5.14	0.55	-2.81	
Reaction	-1/2(q2)(a5)	-0.17	0.27	-0.05	
	-(t2q2+a5q1)(a5)/2B	-18.93	0.55	-10.35	
Total		-18.90		-9.86	

4. Case 3 : Seismic condition

Location = STA. 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	0.150	1.51	1.400	14.11
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.704	0.393	1.85	1.167	5.49
Footing	(B)(t3)γc	23.52	0.700	16.46	0.350	8.23
Soil-1	1/2(a5)(a6)γs	0	1.127	0.00	0.700	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.853	0.00	0.700	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		38.30	0.518	19.83	0.727	27.83

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.70	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.70	7.88	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	0.78	0.47	0.37	Active force
F4	1/2(p4)h	2.76	0.23	0.64	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	7.66	0.73	5.57	Seismic force
Total of active forces		11.20		6.58	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 38.30 (kN/m)
H = 11.20 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.05 > 1.2 Safe !!

Overturning,

Mr_{max} = 19.83 (kN-m/m)
Mr_{act} = 19.83 (kN-m/m)
Mo = 6.58 (kN-m/m)
d = (Mr-Mo)/V = 0.35 (m)
SF =Mr_{max}/ M_o = 3.02 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.354 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.692 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.354 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.292

= 214 (kN/m)

Qa = 107 (kN/m) > V = 38.30 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 73.815 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.02	0.70	1.41	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.94	0.47	0.44	Seismic force
Total		2.96		1.85	

(3) Stability

Sliding,

V = 38.30 (kN/m)

H = 6.41 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 3.58 > 1.2 Safe !!

Overturning,

Mr_{max} = 19.83 (kN-m/m)

Mr_{act} = 19.83 (kN-m/m)

Mo = 5.18 (kN-m/m)

d = (Mr-Mo)/V = 0.38 (m)

SF =Mr_{max}/ M_o = 3.82 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.318 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.764 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.318 (m)

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.167 0

= 240 (kN/m)

Qa = 120 (kN/m) > V = 38.30 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 66.805 (kN/m2)

q2 = 0.000 (kN/m2)

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.78	0.41	5.65	
Reaction	-q1(3d-t2)^2/6d	-7.45	0.15	-1.14	
		0.00	0.00	0.00	
Total		6.32		4.51	

5. Case 4 : Wind condition

Location = STA. 1.30~1.40

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	0.150	1.51
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.704	0.393	1.85
Footing	(B)(t3)γc	23.52	0.700	16.46
Soil-1	1/2(a5)(a6)γs	0	1.127	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.853	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		38.30	0.518	19.83

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.70	0.00	Passive press.
p3	Ka(γh+q')-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{}$Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	2.95	1.40	4.13	Wind force
Total of active forces		6.41		5.18	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		2.95	0.70	2.06	
Total		2.95		2.06	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.78	0.41	5.65	
Reaction	-1/2(q2)(a5)	-9.36	0.19	-1.77	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		4.42		3.88	

9. Summary of stability analysis

HT. OF WALL 1.30~1.40

0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	6.63	1.5	0.21	0.23	38.3	108
Flood	1.07	1	0.42	0.47	19.1	83
Seismic-2	2.05	1.2	0.35	0.47	38.3	107
Wind-2	3.58	1.2	0.32	0.47	38.3	120

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.40~1.50

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

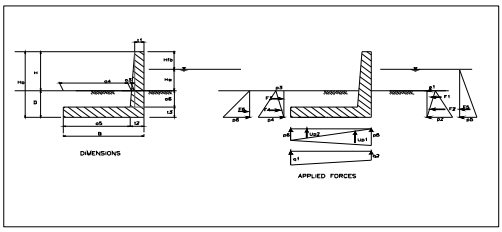
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.50	(m)
Embedment of wall	D =	0.70	(m)
Total height of wall	Ho=	2.20	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.50	(m)
Width of footing	B =	1.60	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.60 (m)	a2=	1.300 (m)
t3=	0.70 (m)	a3=	0.300 (m)
		a4=	1.000 (m)
		a5=	1.000 (m)
		a6=	0.000 (m)



(3) Stability

Sliding,

V = 43.08 (kN/m)
H = 3.47 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 7.46 > 1.5 Safe !!

Overturning,

Mr_{max} = 25.28 (kN-m/m)
Mr_{act} = 25.28 (kN-m/m)
Mo = 1.06 (kN-m/m)
SF =Mr_{max})/ M_o = 23.92 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.24 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 1.12 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.24 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.080

= 377 (kN/m)
Qa = 126 (kN/m) > V = 43.08 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 50.918 (kN/m2)

q2 = V/B*(1-6e/B) = 2.932 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

HT. OF WALL 1.40~1.50

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.8	0.150	1.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	5.4	0.400	2.16	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γs	0	1.267	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	0.933	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		43.08	0.587	25.28	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		3.47		1.06	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.50	0.00	
Footing	γc(t3)(a5)	16.80	0.50	8.40	
Reaction	-1/2(q2)(a5)	-1.47	0.67	-0.98	
	-(t2q2+a5q1)(a5)/2B	-16.46	0.33	-5.49	
Total		-1.13		1.94	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

Location = STA. 1.40~1.50
0

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.8	1.450	15.66	
Wall-2	1/2(t2-t1)(Ho-t3)γc	5.4	1.100	5.94	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γsat	0.00	0.333	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.667	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.267	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.733	0.00	
Sub-Total		43.08	1.001	43.10	
Uplift-1	-1/2B(D+Hw)γw	-17.25	1.067	-18.40	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-22.74		-21.32	
Total		20.34		21.78	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Active force
F2	1/2(p2)h	0.74	0.23	0.17	Active force
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	23.72	0.73	17.39	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		24.46		17.57	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Sliding,

V = 20.34 (kN/m)
H = 24.46 (kN/m)
HR_{max} = 12.40 (kN/m)
HR_{act} = 12.40 (kN/m)
SF =(V*f'+HR_{max})/ H = 1.01 > 1.0 Safe !!

Overturning,

Mr_{max} = 46.00 (kN-m/m)
Mr = 46.00 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 38.89 (kN-m/m)
SF = Mr_{max}/M_o = 1.18 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.451 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.70 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.451 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.593

= 213 (kN/m)
Qa = 106.7 (kN/m) > V = 20.34 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 38.825 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	11.03	0.50	5.51	Water pressure
Total		11.03		5.51	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.50	0.00	
Soil	γsat(a6)(a5)	0.00	0.50	0.00	
Footing	γc(t3)(a5)	16.80	0.50	8.40	
Uplift	-1/2(p5)(a5)	-10.78	0.33	-3.59	
	-(t2p5+a5p6)(a5)/2B	-6.19	0.67	-4.12	
Reaction	-1/2(q2)(a5)	-0.89	0.33	-0.30	
	-(t2q2+a5q1)(a5)/2B	-19.41	0.67	-12.94	
Total		-20.47		-12.56	

4. Case 3 : Seismic condition

Location = STA. 1.40~1.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.8	0.150	1.62	1.450	15.66
Wall-2	1/2(t2-t1)(Ho-t3)γc	5.4	0.400	2.16	1.200	6.48
Footing	(B)(t3)γc	26.88	0.800	21.50	0.350	9.41
Soil-1	1/2(a5)(a6)γs	0	1.267	0.00	0.700	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.933	0.00	0.700	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		43.08	0.587	25.28	0.732	31.55

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.70	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.70	7.88	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	0.78	0.47	0.37	Active force
F4	1/2(p4)h	2.76	0.23	0.64	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	8.62	0.73	6.31	Seismic force
Total of active forces		12.16		7.32	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 43.08 (kN/m)
H = 12.16 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f' + HR_{max})/ H = 2.13 > 1.2 Safe !!

Overturning,

Mr_{max} = 25.28 (kN-m/m)
Mr_{act} = 25.28 (kN-m/m)
Mo = 7.32 (kN-m/m)
d = (Mr-Mo)/V = 0.42 (m)
SF =Mr_{max}/ M_o = 3.45 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.383 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.834 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.383 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.282

= 263 (kN/m)
Qa = 131 (kN/m) > V = 43.08 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 68.868 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.16	0.75	1.62	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	1.08	0.50	0.54	Seismic force
Total		3.24		2.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.50	0.00	
Footing	γc(t3)(a5)	16.80	0.50	8.40	
Reaction	-q1(3d-t2)^2/6d	-11.67	0.22	-2.53	
		0.00	0.00	0.00	
Total		5.13		5.87	

5. Case 4 : Wind condition

Location = STA. 1.40~1.50

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.8	0.150	1.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	5.4	0.400	2.16
Footing	(B)(t3)γc	26.88	0.800	21.50
Soil-1	1/2(a5)(a6)γs	0	1.267	0.00
Soil-2	1/2(a4)(a6)γs	0.00	0.933	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		43.08	0.587	25.28

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_eC_q\ q_s\ I\ H$	3.16	1.45	4.58	Wind force
Total of active forces		6.63		5.64	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 43.08 (kN/m)
H = 6.63 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 3.90 > 1.2 Safe !!

Overturning,

Mr_{max} = 25.28 (kN-m/m)
Mr_{act} = 25.28 (kN-m/m)
Mo = 5.64 (kN-m/m)
d = (Mr-Mo)/V = 0.46 (m)
SF =Mr_{max})/ M_o = 4.49 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.344 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.912 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.344 (m)
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.154 0
= 292 (kN/m)
Qa = 146 (kN/m) > V = 43.08 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 62.976 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
$C_eC_q\ q_s\ I\ H$		3.16	0.75	2.37	
Total		3.16		2.37	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.50	0.00	
Footing	γc(t3)(a5)	16.80	0.50	8.40	
Reaction	-1/2(q2)(a5)	-13.58	0.26	-3.48	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		3.22		4.92	

9. Summary of stability analysis

HT. OF WALL 1.40~1.50
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	7.46	1.5	0.24	0.27	43.1	126
Flood	1.01	1	0.45	0.53	20.3	107
Seismic-2	2.13	1.2	0.38	0.53	43.1	131
Wind-2	3.90	1.2	0.34	0.53	43.1	146

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.50~1.60

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

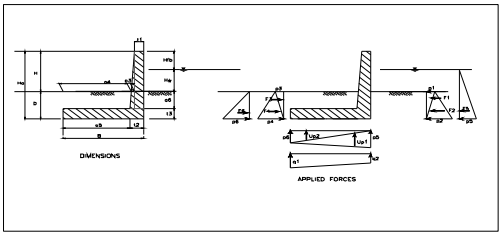
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.60	(m)
Embedment of wall	D =	0.70	(m)
Total height of wall	Ho=	2.30	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.60	(m)
Width of footing	B =	1.60	(m)

Thickness of wall members :

t1=	0.40	(m)	
t2=	0.72	(m)	
t3=	0.70	(m)	
a1=	0.000	(m)	
a2=	1.200	(m)	
a3=	0.320	(m)	
a4=	0.880	(m)	
a5=	0.880	(m)	
a6=	0.000	(m)	



2. Case 1 : Normal condition

HT. OF WALL	1.50~1.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	15.36	0.200	3.07	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.144	0.507	3.11	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γs	0	1.307	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	1.013	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		48.38	0.572	27.69	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		3.47		1.06	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 48.38 (kN/m)
H = 3.47 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 8.38 > 1.5 Safe !!

Overturning,

Mr_{max} = 27.69 (kN-m/m)
Mr_{act} = 27.69 (kN-m/m)
Mo = 1.06 (kN-m/m)
SF =Mr_{max})/ M_o = 26.20 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.25 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 1.10 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.25 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.072

= 367 (kN/m)
Qa = 122 (kN/m) > V = 48.38 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 58.541 (kN/m2)

q2 = V/B*(1-6e/B) = 1.939 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.44	0.00	
Footing	γc(t3)(a5)	14.78	0.44	6.50	
Reaction	-1/2(q2)(a5)	-0.85	0.59	-0.50	
	-(t2q2+a5q1)(a5)/2B	-14.55	0.29	-4.27	
Total		-0.62		1.74	

3. Case 2 : Flood condition

Location = STA.	1.50~1.60
	0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	15.36	1.400	21.50	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.144	0.987	6.06	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γsat	0.00	0.293	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.587	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.307	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.800	0.00	
Sub-Total		48.38	1.014	49.07	
Uplift-1	-1/2B(D+Hw)γw	-18.03	1.067	-19.23	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-23.52		-22.16	
Total		24.86		26.91	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Active force
F2	1/2(p2)h	0.74	0.23	0.17	Active force
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	25.92	0.77	19.87	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		26.67		20.05	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Sliding,

V = 24.86 (kN/m)
H = 26.67 (kN/m)
HR_{max} = 12.40 (kN/m)
HR_{act} = 12.40 (kN/m)
SF =(V*f +HR_{max})/ H = 1.02 > 1.0 Safe !!

Overturning,

Mr_{max} = 51.96 (kN-m/m)
Mr = 51.96 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 42.21 (kN-m/m)
SF = Mr_{max}/M_o = 1.23 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.408 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.78 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.408 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.574

= 244 (kN/m)
Qa = 122.2 (kN/m) > V = 24.86 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 42.248 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		15.68	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	12.54	0.53	6.69	Water pressure
Total		12.54		6.69	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.44	0.00	
Soil	γsat(a6)(a5)	0.00	0.44	0.00	
Footing	γc(t3)(a5)	14.78	0.44	6.50	
Uplift	-1/2(p5)(a5)	-9.92	0.29	-2.91	
	-(t2p5+a5p6)(a5)/2B	-6.12	0.59	-3.59	
Reaction	-1/2(q2)(a5)	-4.69	0.29	-1.38	
	-(t2q2+a5q1)(a5)/2B	-18.59	0.59	-10.91	
Total		-24.54		-12.28	

4. Case 3 : Seismic condition

(Direction of forces : Active forces are applied from land side)

Location = STA. 1.50~1.60

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	15.36	0.200	3.07	1.500	23.04
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.144	0.507	3.11	1.233	7.58
Footing	(B)(t3)γc	26.88	0.800	21.50	0.350	9.41
Soil-1	1/2(a5)(a6)γs	0	1.307	0.00	0.700	0.00
Soil-2	1/2(a4)(a6)γs	0.00	1.013	0.00	0.700	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		48.38	0.572	27.69	0.827	40.03

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.772 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.414 m

α = 1.0

k = 1+0.3*D/B = 1.13125

β = 1.0

Nc = 30

Nq = 18

Nr = 14

tan θ= (H-HR_{act})/V = 0.273

= 240 (kN/m)

Qa = 120 (kN/m) > V = 48.38 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 83.570 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	3.07	0.80	2.46	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	1.23	0.53	0.66	Seismic force
Total		4.30		3.11	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.70	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.70	7.88	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	0.78	0.47	0.37	Active force
F4	1/2(p4)h	2.76	0.23	0.64	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	9.68	0.83	8.01	Seismic force
Total of active forces		13.22		9.01	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 48.38 (kN/m)

H = 13.22 (kN/m)

HR_{max} = 0.00 (kN/m)

HR_{act} = 0.00 (kN/m)

SF =(V*f + HR_{max})/ H = 2.20 > 1.2 Safe !!

Overturning,

Mr_{max} = 27.69 (kN-m/m)

Mr_{act} = 27.69 (kN-m/m)

Mo = 9.01 (kN-m/m)

d = (Mr-Mo)/V = 0.39 (m)

SF =Mr_{max}/ M_o = 3.07 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.414 (m) < B/3 Safe !!

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.44	0.00	
Footing	γc(t3)(a5)	14.78	0.44	6.50	
Reaction	-q1(3d-t2)^2/6d	-6.92	0.15	-1.01	
		0.00	0.00	0.00	
Total		7.86		5.49	

5. Case 4 : Wind condition

Wind from the land side

Location = STA. 1.50~1.60

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	15.36	0.200	3.07
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.144	0.507	3.11
Footing	(B)(t3)γc	26.88	0.800	21.50
Soil-1	1/2(a5)(a6)γs	0	1.307	0.00
Soil-2	1/2(a4)(a6)γs	0.00	1.013	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		48.38	0.572	27.69

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q$ q_s I H	3.37	1.50	5.05	Wind force
Total of active forces		6.84		6.11	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 48.38 (kN/m)
H = 6.84 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 4.25 > 1.2 Safe !!

Overturning,

Mr_{max} = 27.69 (kN-m/m)
Mr_{act} = 27.69 (kN-m/m)
Mo = 6.11 (kN-m/m)
d = (Mr-Mo)/V = 0.45 (m)
SF =Mr_{max})/ M_o = 4.53 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.354 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.892 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.354 (m)
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.141 0

= 285 (kN/m)
Qa = 142 (kN/m) > V = 48.38 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 72.328 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$ Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		3.37	0.80	2.70	
Total		3.37		2.70	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.44	0.00	
Footing	γc(t3)(a5)	14.78	0.44	6.50	
Reaction	-1/2(q2)(a5)	-10.32	0.21	-2.13	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		4.46		4.38	

9. Summary of stability analysis

HT. OF WALL 1.50~1.60
0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	8.38	1.5	0.25	0.27	48.4	122
Flood	1.02	1	0.41	0.53	24.9	122
Seismic-2	2.20	1.2	0.41	0.53	48.4	120
Wind-2	4.25	1.2	0.35	0.53	48.4	142

ANALYSIS AND DESIGN OF PARAPET WALL

HT. OF WALL 1.60~1.70

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

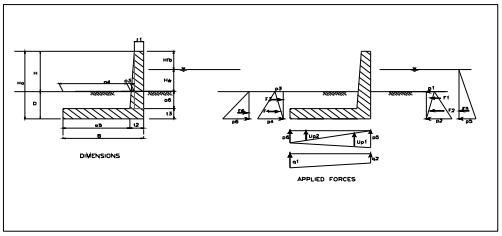
Dimensions of wall and water depth :

Height of wall	H =	1.70 (m)
Embedment of wall	D =	0.70 (m)
Total height of wall	Ho=	2.40 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.70 (m)
Width of footing	B =	1.60 (m)

Thickness of wall members :

t1= 0.45 (m)
t2= 0.79 (m)
t3= 0.70 (m)

a1= 0.000 (m)
a2= 1.150 (m)
a3= 0.340 (m)
a4= 0.810 (m)
a5= 0.810 (m)
a6= 0.000 (m)



2. Case 1 : Normal condition

HT. OF WALL 1.60~1.70

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	18.36	0.225	4.13	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.936	0.563	3.91	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γs	0	1.330	0.00	
Soil-2	1/2(a4)(a6)γs	0.00	1.060	0.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		52.18	0.566	29.54	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$ Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$ Kp	0.70	0.00	Passive press.
p3	Ka(γh+q)-2c$\sqrt{}$ Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c$\sqrt{}$ Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		3.47		1.06	
Total of maximum resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 52.18 (kN/m)
H = 3.47 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 9.03 > 1.5 Safe !!

Overturning,

Mr_{max} = 29.54 (kN-m/m)
Mr_{act} = 29.54 (kN-m/m)
Mo = 1.06 (kN-m/m)
SF =Mr_{max})/ M_o = 27.95 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.25 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
Be = B - 2 e = 1.09 (m)
where,
e =actual eccen. = B/2 - (Mr_{act}-Mo) / V 0.25 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.066

= 364 (kN/m)
Qa = 121 (kN/m) > V = 52.18 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 63.677 (kN/m2)

q2 = V/B*(1-6e/B) = 1.543 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Active force
F2	1/2(p2)h	0.74	0.23	0.17	Active force
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	28.22	0.80	22.58	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		28.97		22.75	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Sliding,

V = 27.87 (kN/m)
H = 28.97 (kN/m)
HR_{max} = 12.40 (kN/m)
HR_{act} = 12.40 (kN/m)
SF =(V*f+HR_{max})/ H = 1.01 > 1.0 Safe !!

Overturning,

Mr_{max} = 56.05 (kN-m/m)
Mr = 56.05 (kN-m/m) (=ΣW*x + ΣFR*y)
Mo = 45.75 (kN-m/m)
SF = Mr_{max}/M_o = 1.23 <1.5 Fails!!!
e = B/2 - (Mr_{max}-Mo) / V = 0.431 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.74 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.431 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.595

= 228 (kN/m)
Qa = 113.9 (kN/m) > V = 27.87 (kN/m) Safe !!

Reaction on foundation,

q1 = V/B*(1+6e/B) = 50.302 (kN/m2)

q2 = V/B*(1-6e/B) = 0.000 (kN/m2)

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
Total		0.00		0.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.61	0.41	5.51	
Reaction	-1/2(q2)(a5)	-0.62	0.54	-0.34	
	-(t2q2+a5q1)(a5)/2B	-13.36	0.27	-3.61	
Total		-0.38		1.57	

3. Case 2 : Flood condition

Location = STA. 1.60~1.70
0

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	18.36	1.375	25.25	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.936	0.923	6.40	
Footing	(B)(t3)γc	26.88	0.800	21.50	
Soil-1	1/2(a5)(a6)γsat	0.00	0.270	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.540	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.330	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.833	0.00	
Sub-Total		52.18	1.019	53.15	
Uplift-1	-1/2B(D+Hw)γw	-18.82	1.067	-20.07	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-24.30		-23.00	
Total		27.87		30.16	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p5'	γw(Hw+a6)		16.66	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
F5'	1/2(p5')(Hw+a6)	14.16	0.57	8.02	Water pressure
Total		14.16		8.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Water	γw(Hw)(a5)	0.00	0.41	0.00	
Soil	γsat(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.61	0.41	5.51	
Uplift	-1/2(p5)(a5)	-9.53	0.27	-2.57	
	-(t2p5+a5p6)(a5)/2B	-6.11	0.54	-3.30	
Reaction	-1/2(q2)(a5)	-5.48	0.27	-1.48	
	-(t2q2+a5q1)(a5)/2B	-20.37	0.54	-11.00	
Total		-27.88		-12.84	

4. Case 3 : Seismic condition

Location = STA. 1.60~1.70

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	18.36	0.225	4.13	1.550	28.46
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.936	0.563	3.91	1.267	8.79
Footing	(B)(t3)γc	26.88	0.800	21.50	0.350	9.41
Soil-1	1/2(a5)(a6)γs	0	1.330	0.00	0.700	0.00
Soil-2	1/2(a4)(a6)γs	0.00	1.060	0.00	0.700	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		52.18	0.566	29.54	0.894	46.65

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.70	0.00	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.70	7.88	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	0.78	0.47	0.37	Active force
F4	1/2(p4)h	2.76	0.23	0.64	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	γWi*kh	10.44	0.89	9.33	Seismic force
Total of active forces		13.98		10.34	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 52.18 (kN/m)
H = 13.98 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 2.24 > 1.2 Safe !!

Overturning,

Mr_{max} = 29.54 (kN-m/m)
Mr_{act} = 29.54 (kN-m/m)
Mo = 10.34 (kN-m/m)
d = (Mr-Mo)/V = 0.37 (m)
SF =Mr_{max}/ M_o = 2.86 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.432 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.736 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.432 m
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.268

= 227 (kN/m)
Qa = 113 (kN/m) > V = 52.18 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 94.510 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2	1/2(p2)(a6)	0.00	0.00	0.00	Active force
Wall-1	γc(t1)(Ho-t3)kh	3.67	0.85	3.12	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	1.39	0.57	0.79	Seismic force
Total		5.06		3.91	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.61	0.41	5.51	
Reaction	-q1(3d-t2)^2/6d	-4.22	0.10	-0.44	
		0.00	0.00	0.00	
Total		9.38		5.07	

5. Case 4 : Wind condition

Location = STA. 1.60~1.70

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	18.36	0.225	4.13
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.936	0.563	3.91
Footing	(B)(t3)γc	26.88	0.800	21.50
Soil-1	1/2(a5)(a6)γs	0	1.330	0.00
Soil-2	1/2(a4)(a6)γs	0.00	1.060	0.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		52.18	0.566	29.54

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.70	0.00	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.70	6.87	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.47	0.00	Resisting force
F2	1/2(p2)h	0.00	0.23	0.00	Resisting force
F3	1/2(p3)h	1.06	0.47	0.50	Active force
F4	1/2(p4)h	2.40	0.23	0.56	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	3.58	1.55	5.55	Wind force
Total of active forces		7.05		6.61	
Total of max. resisting forces		0.00		0.00	
Actual resisting forces		0.00		0.00	

(3) Stability

Sliding,

V = 52.18 (kN/m)
H = 7.05 (kN/m)
HR_{max} = 0.00 (kN/m)
HR_{act} = 0.00 (kN/m)
SF =(V*f + HR_{max})/ H = 4.44 > 1.2 Safe !!

Overturning,

Mr_{max} = 29.54 (kN-m/m)
Mr_{act} = 29.54 (kN-m/m)
Mo = 6.61 (kN-m/m)
d = (Mr-Mo)/V = 0.44 (m)
SF =Mr_{max}/ M_o = 4.47 > 1.5 Safe !!
e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.360 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 0.879 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.360 (m)
α = 1.0
k = 1+0.3*D/B = 1.13125
β = 1.0
Nc = 30
Nq = 18
Nr = 14
tan θ= (H-HR_{act})/V = 0.135 0

= 280 (kN/m)
Qa = 140 (kN/m) > V = 52.18 (kN/m) Safe !!

Reaction on foundation,

q1 = 2V/3d = 79.128 (kN/m2)

q2 = 0.000 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Active force
F2'	1/2(p2')(a6)	0.00	0.00	0.00	Active force
C_eC_q q_s I H		3.58	0.85	3.04	
Total		3.58		3.04	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	0.00	0.41	0.00	
Footing	γc(t3)(a5)	13.61	0.41	5.51	
Reaction	-1/2(q2)(a5)	-8.39	0.18	-1.48	
	-(t2q2+a5q1)(a5)/2B	0.00	0.00	0.00	
Total		5.22		4.03	

9. Summary of stability analysis | HT. OF WALL 1.60~1.70 0

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-2	9.03	1.5	0.25	0.27	52.2	121
Flood	1.01	1	0.43	0.53	27.9	114
Seismic-2	2.24	1.2	0.43	0.53	52.2	113
Wind-2	4.44	1.2	0.36	0.53	52.2	140

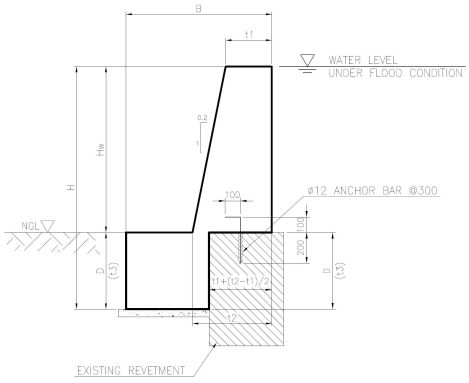
[Check Point of Stability Analysis of Parapet Wall Type-III]

Basic sectional shape of Parapet Wall (PW) Type-III is same as PW Type-III. Therefore stability analysis for dimensional study of PW Type-III is not necessary.

As the significant stability analysis of PW Type-III, check of capacity of tensile stress acting to the anchor bars installed under the vertical wall shall be conducted under "Flood Condition" that is critical condition to generate the maximum overturning force to landside.

Study condition of the check of capacity analysis is set as below:

- Sectional shape of PW Type-III for the check of capacity of the anchor bars is assumed as following figure.
- The check of capacity shall be implemented in each size that is applied to stability analysis of PW Type-II.



Assumed Sectional Shape of Parapet Wall Type-III for the Check of Capacity of Anchor Bars

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.00~0.30

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

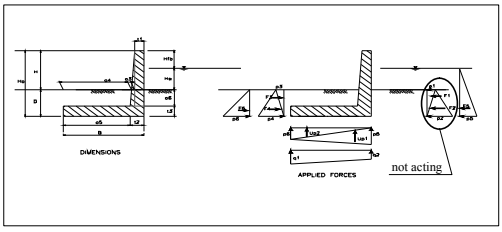
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.30 (m)
Embedment of wall	D =	0.20 (m)
Total height of wall	Ho=	0.50 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.30 (m)
Width of footing	B =	0.36 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.36 (m)	a2=	0.060 (m)
t3=	0.20 (m)	a3=	0.060 (m)
		a4=	0.000 (m)
		a5=	0.000 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.00~0.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.16	0.210	0.45	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.216	0.020	0.00	
Footing	(B)(t3)γc	0.144	0.015	0.00	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.360	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.320	0.00	
Sub-Total		2.52	0.183	0.46	
Uplift-1	-1/2B(D+Hw)γw	-0.88	0.240	-0.21	
Uplift-2	-1/2B(D)γw	-0.35	0.120	-0.04	
Sub-Total		-1.23		-0.25	
Total		1.29		0.21	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.17	0.20	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		1.23		0.21	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 0.53 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 0.46 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.000 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.195 m

Tensile stress acting to anchor bar
F_t = 0.00 kN/m
= 0.00 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.00 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) HT. OF WALL 0.30~0.40

1. Design Criteria

Unit weight :

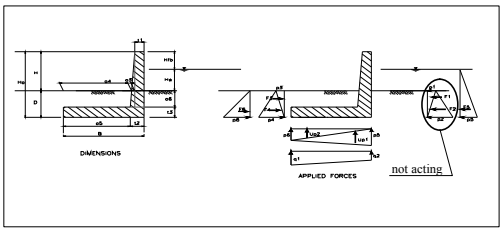
Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.40	(m)		
Embedment of wall	D =	0.20	(m)		
Total height of wall	Ho=	0.60	(m)		
Freeboard	Hfb=	0.00	(m)		
Water depth under flood condition	Hw=	0.40	(m)		
Width of footing	B =	0.38	(m)		
Thickness of wall members :					
t1=	0.30	(m)		a1=	0.000 (m)
t2=	0.38	(m)		a2=	0.080 (m)
t3=	0.20	(m)		a3=	0.080 (m)
				a4=	0.000 (m)
				a5=	0.000 (m)
				a6=	0.000 (m)



2. Check case : Flood Condition Location = STA. 0.30~0.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	2.88	0.230	0.66	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.384	0.027	0.01	
Footing	(B)(t3)γc	0.192	0.020	0.00	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.380	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.327	0.00	
Sub-Total		3.46	0.196	0.68	
Uplift-1	-1/2B(D+Hw)γw	-1.12	0.253	-0.28	
Uplift-2	-1/2B(D)γw	-0.37	0.127	-0.05	
Sub-Total		-1.49		-0.33	
Total		1.97		0.35	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	1.76	0.20	0.35	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		1.76		0.36	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 0.74 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 0.69 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.000 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.210 m

Tensile stress acting to anchor bar
F_t = 0.00 kN/m
= 0.00 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.00 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.40~0.50

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

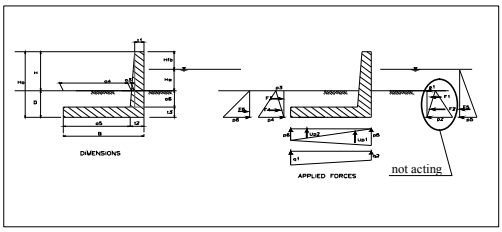
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.50 (m)
Embedment of wall	D =	0.20 (m)
Total height of wall	Ho=	0.70 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.50 (m)
Width of footing	B =	0.40 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.40 (m)	a2=	0.100 (m)
t3=	0.20 (m)	a3=	0.100 (m)
		a4=	0.000 (m)
		a5=	0.000 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.40~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.6	0.250	0.90	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.6	0.033	0.02	
Footing	(B)(t3)γc	0.24	0.025	0.01	
Soil-1	1/2(a5)(a6)γsat	0.00	0.000	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.000	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.400	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.333	0.00	
Sub-Total		4.44	0.209	0.93	
Uplift-1	-1/2B(D+Hw)γw	-1.37	0.267	-0.37	
Uplift-2	-1/2B(D)γw	-0.39	0.133	-0.05	
Sub-Total		-1.76		-0.42	
Total		2.68		0.51	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	2.40	0.23	0.56	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		2.40		0.56	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 0.99 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 0.98 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.000 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.225 m

Tensile stress acting to anchor bar
F_t = 0.00 kN/m
= 0.00 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.00 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.50~0.60

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

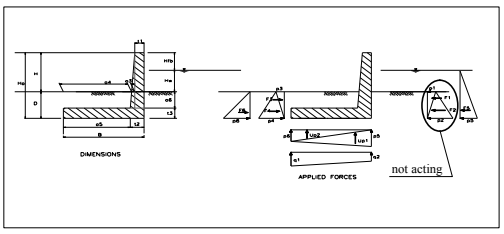
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.60 (m)
Embedment of wall	D =	0.20 (m)
Total height of wall	Ho=	0.80 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.60 (m)
Width of footing	B =	0.45 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.42 (m)	a2=	0.150 (m)
t3=	0.20 (m)	a3=	0.120 (m)
		a4=	0.030 (m)
		a5=	0.030 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.50~0.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.300	1.30	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0.864	0.070	0.06	
Footing	(B)(t3)γc	0.432	0.045	0.02	
Soil-1	1/2(a5)(a6)γsat	0.00	0.010	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.020	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.440	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.350	0.00	
Sub-Total		5.62	0.245	1.38	
Uplift-1	-1/2B(D+Hw)γw	-1.76	0.300	-0.53	
Uplift-2	-1/2B(D)γw	-0.44	0.150	-0.07	
Sub-Total		-2.21		-0.60	
Total		3.41		0.78	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	3.14	0.27	0.84	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		3.14		0.84	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 1.44 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 1.44 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.000 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.270 m

Tensile stress acting to anchor bar
F_t = 0.00 kN/m
= 0.00 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.00 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.60~0.70

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

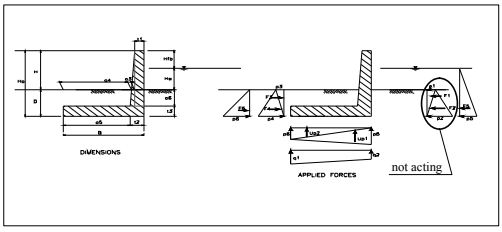
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.70	(m)	
Embedment of wall	D =	0.20	(m)	
Total height of wall	Ho=	0.90	(m)	
Freeboard	Hfb=	0.00	(m)	
Water depth under flood condition	Hw=	0.70	(m)	
Width of footing	B =	0.50	(m)	

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.44 (m)	a2=	0.200 (m)
t3=	0.20 (m)	a3=	0.140 (m)
		a4=	0.060 (m)
		a5=	0.060 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.60~0.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.04	0.350	1.76	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.176	0.107	0.13	
Footing	(B)(t3)γc	0.624	0.065	0.04	
Soil-1	1/2(a5)(a6)γsat	0.00	0.020	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.040	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.480	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.367	0.00	
Sub-Total		6.84	0.282	1.93	
Uplift-1	-1/2B(D+Hw)γw	-2.21	0.333	-0.74	
Uplift-2	-1/2B(D)γw	-0.49	0.167	-0.08	
Sub-Total		-2.70		-0.82	
Total		4.15		1.11	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.20	0.61	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.20	8.16	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.13	0.00	Resisting force
F4	1/2(p4)h	0.82	0.07	0.05	Resisting force
F5	1/2γw(D+Hw)^2	3.97	0.30	1.19	Active force
F6	1/2γw(D)^2	0.20	0.07	0.01	Resisting force
Total of active forces		3.97		1.19	
Total of maximum resisting forces		1.01		0.07	
Actual resisting forces		1.01		0.07	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 2.00 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 2.01 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.014 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.315 m

Tensile stress acting to anchor bar
F_t = 0.04 kN/m
= 0.01 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.01 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) HT. OF WALL 0.70~0.80

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

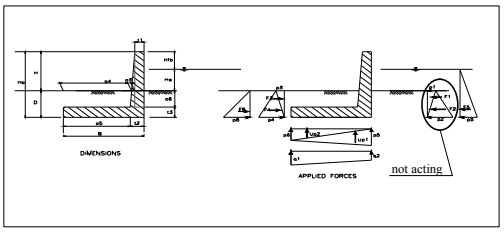
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.80	(m)
Embedment of wall	D =	0.30	(m)
Total height of wall	Ho=	1.10	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	0.80	(m)
Width of footing	B =	0.60	(m)

Thickness of wall members :

t1=	0.30	(m)	a1= 0.000 (m)
t2=	0.46	(m)	a2= 0.300 (m)
t3=	0.30	(m)	a3= 0.160 (m)
			a4= 0.140 (m)
			a5= 0.140 (m)
			a6= 0.000 (m)



2. Check case : Flood Condition Location = STA. 0.70~0.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.450	2.59	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.536	0.193	0.30	
Footing	(B)(t3)γc	1.584	0.110	0.17	
Soil-1	1/2(a5)(a6)γsat	0.00	0.047	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.093	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.553	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.400	0.00	
Sub-Total		8.88	0.345	3.06	
Uplift-1	-1/2B(D+Hw)γw	-3.23	0.400	-1.29	
Uplift-2	-1/2B(D)γw	-0.88	0.200	-0.18	
Sub-Total		-4.12		-1.47	
Total		4.76		1.59	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.30	0.91	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.30	12.24	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.20	0.00	Resisting force
F4	1/2(p4)h	1.84	0.10	0.18	Resisting force
F5	1/2γw(D+Hw)^2	5.93	0.37	2.17	Active force
F6	1/2γw(D)^2	0.44	0.10	0.04	Resisting force
Total of active forces		5.93		2.19	
Total of maximum resisting forces		2.28		0.23	
Actual resisting forces		2.28		0.23	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 3.29 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 3.66 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.367 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.410 m

Tensile stress acting to anchor bar
F_t = 0.89 kN/m
= 0.27 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.27 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.80~0.90

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

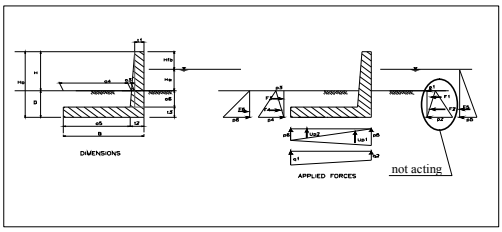
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.90 (m)
Embedment of wall	D =	0.40 (m)
Total height of wall	Ho=	1.30 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	0.90 (m)
Width of footing	B =	0.75 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.48 (m)	a2=	0.450 (m)
t3=	0.40 (m)	a3=	0.180 (m)
		a4=	0.270 (m)
		a5=	0.270 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.80~0.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.48	0.600	3.89	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.944	0.330	0.64	
Footing	(B)(t3)γc	3.456	0.180	0.62	
Soil-1	1/2(a5)(a6)γsat	0.00	0.090	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.180	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.660	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.450	0.00	
Sub-Total		11.88	0.434	5.15	
Uplift-1	-1/2B(D+Hw)γw	-4.78	0.500	-2.39	
Uplift-2	-1/2B(D)γw	-1.47	0.250	-0.37	
Sub-Total		-6.25		-2.76	
Total		5.63		2.40	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.40	1.22	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	8.28	0.43	3.59	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		8.28		3.62	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 5.69 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 6.38 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.686 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.555 m

Tensile stress acting to anchor bar
F_t = 1.24 kN/m
= 0.37 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.37 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 0.90~1.00

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

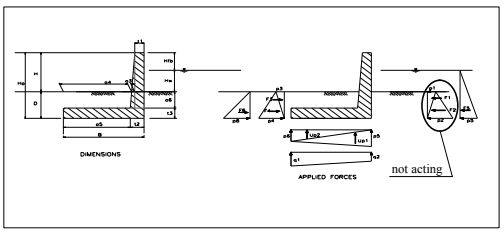
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.00 (m)
Embedment of wall	D =	0.40 (m)
Total height of wall	Ho=	1.40 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.00 (m)
Width of footing	B =	0.85 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.50 (m)	a2=	0.550 (m)
t3=	0.40 (m)	a3=	0.200 (m)
		a4=	0.350 (m)
		a5=	0.350 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 0.90~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.700	5.04	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.4	0.417	1.00	
Footing	(B)(t3)γc	4.32	0.225	0.97	
Soil-1	1/2(a5)(a6)γsat	0.00	0.117	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.233	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.733	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.483	0.00	
Sub-Total		13.92	0.504	7.01	
Uplift-1	-1/2B(D+Hw)γw	-5.83	0.567	-3.30	
Uplift-2	-1/2B(D)γw	-1.67	0.283	-0.47	
Sub-Total		-7.50		-3.78	
Total		6.42		3.24	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.40	1.22	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	9.60	0.47	4.48	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		9.60		4.51	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 7.55 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 8.29 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 0.739 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.650 m

Tensile stress acting to anchor bar
F_t = 1.14 kN/m
= 0.34 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.34 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 1.00~1.10

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

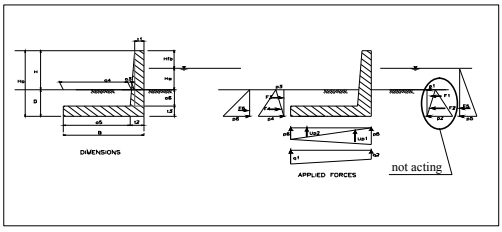
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.10	(m)	
Embedment of wall	D =	0.50	(m)	
Total height of wall	Ho=	1.60	(m)	
Freeboard	Hfb=	0.00	(m)	
Water depth under flood condition	Hw=	1.10	(m)	
Width of footing	B =	0.95	(m)	

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.52 (m)	a2=	0.650 (m)
t3=	0.50 (m)	a3=	0.220 (m)
		a4=	0.430 (m)
		a5=	0.430 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.92	0.800	6.34	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.904	0.503	1.46	
Footing	(B)(t3)γc	6.48	0.270	1.75	
Soil-1	1/2(a5)(a6)γsat	0.00	0.143	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.287	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.807	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.517	0.00	
Sub-Total		17.30	0.552	9.55	
Uplift-1	-1/2B(D+Hw)γw	-7.45	0.633	-4.72	
Uplift-2	-1/2B(D)γw	-2.33	0.317	-0.74	
Sub-Total		-9.78		-5.45	
Total		7.53		4.09	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	12.54	0.53	6.69	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		12.54		6.75	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 10.60 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 12.21 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 1.606 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.745 m

Tensile stress acting to anchor bars
F_t = 2.16 kN/m
= 0.65 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.65 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) HT. OF WALL 1.10~1.20

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

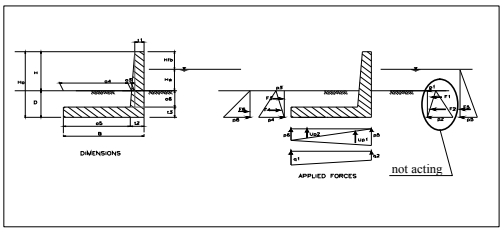
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.20	(m)
Embedment of wall	D =	0.55	(m)
Total height of wall	Ho=	1.75	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.20	(m)
Width of footing	B =	1.10	(m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.54 (m)	a2=	0.800 (m)
t3=	0.55 (m)	a3=	0.240 (m)
		a4=	0.560 (m)
		a5=	0.560 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition Location = STA. 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	0.950	8.21	
Wall-2	1/2(t2-t1)(Ho-t3)γc	3.456	0.640	2.21	
Footing	(B)(t3)γc	8.976	0.340	3.05	
Soil-1	1/2(a5)(a6)γsat	0.00	0.187	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.373	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.913	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.567	0.00	
Sub-Total		21.07	0.639	13.47	
Uplift-1	-1/2B(D+Hw)γw	-9.43	0.733	-6.92	
Uplift-2	-1/2B(D)γw	-2.96	0.367	-1.09	
Sub-Total		-12.40		-8.00	
Total		8.68		5.47	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.55	1.67	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.55	22.44	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.37	0.00	Resisting force
F4	1/2(p4)h	6.17	0.18	1.13	Resisting force
F5	1/2γw(D+Hw)^2	15.01	0.58	8.75	Active force
F6	1/2γw(D)^2	1.48	0.18	0.27	Resisting force
Total of active forces		15.01		8.84	
Total of maximum resisting forces		7.65		1.40	
Actual resisting forces		7.65		1.40	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 14.87 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 16.84 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 1.967 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.890 m

Tensile stress acting to anchor bars
F_t = 2.21 kN/m
= 0.66 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.66 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 1.20~1.30

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

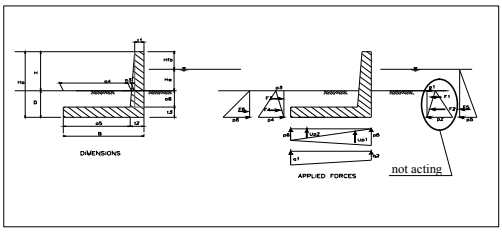
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.30 (m)
Embedment of wall	D =	0.60 (m)
Total height of wall	Ho=	1.90 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.30 (m)
Width of footing	B =	1.20 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.56 (m)	a2=	0.900 (m)
t3=	0.60 (m)	a3=	0.260 (m)
		a4=	0.640 (m)
		a5=	0.640 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition | Location = STA. 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.36	1.050	9.83	
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.056	0.727	2.95	
Footing	(B)(t3)γc	11.088	0.385	4.27	
Soil-1	1/2(a5)(a6)γsat	0.00	0.213	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.427	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	0.987	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.600	0.00	
Sub-Total		24.50	0.696	17.04	
Uplift-1	-1/2B(D+Hw)γw	-11.17	0.800	-8.94	
Uplift-2	-1/2B(D)γw	-3.53	0.400	-1.41	
Sub-Total		-14.70		-10.35	
Total		9.80		6.70	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.60	1.82	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.60	24.48	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.40	0.00	Resisting force
F4	1/2(p4)h	7.34	0.20	1.47	Resisting force
F5	1/2γw(D+Hw)^2	17.69	0.63	11.20	Active force
F6	1/2γw(D)^2	1.76	0.20	0.35	Resisting force
Total of active forces		17.69		11.31	
Total of maximum resisting forces		9.11		1.82	
Actual resisting forces		9.11		1.82	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 18.87 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 21.66 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 2.795 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 0.985 m

Tensile stress acting to anchor bars
F_t = 2.84 kN/m
= 0.85 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.85 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 1.30~1.40

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

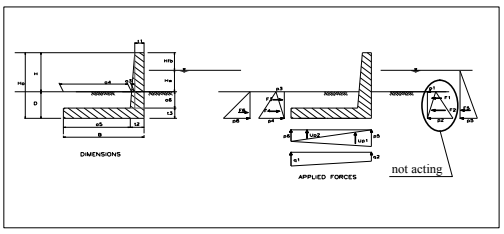
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.40 (m)
Embedment of wall	D =	0.70 (m)
Total height of wall	Ho=	2.10 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.40 (m)
Width of footing	B =	1.40 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.58 (m)	a2=	1.100 (m)
t3=	0.70 (m)	a3=	0.280 (m)
		a4=	0.820 (m)
		a5=	0.820 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition Location = STA. 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	1.250	12.60	
Wall-2	1/2(t2-t1)(Ho-t3)γc	4.704	0.913	4.30	
Footing	(B)(t3)γc	16.128	0.480	7.74	
Soil-1	1/2(a5)(a6)γsat	0.00	0.273	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.547	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.127	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.667	0.00	
Sub-Total		30.91	0.797	24.64	
Uplift-1	-1/2B(D+Hw)γw	-14.41	0.933	-13.45	
Uplift-2	-1/2B(D)γw	-4.80	0.467	-2.24	
Sub-Total		-19.21		-15.69	
Total		11.70		8.95	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	21.61	0.70	15.13	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		21.61		15.30	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 27.53 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 30.99 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 3.456 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 1.180 m

Tensile stress acting to anchor bars
F_t = 2.93 kN/m
= 0.88 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.88 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) HT. OF WALL 1.40~1.50

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

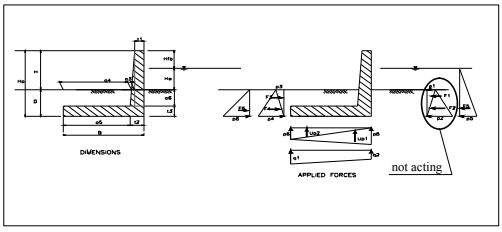
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.50 (m)
Embedment of wall	D =	0.70 (m)
Total height of wall	Ho=	2.20 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.50 (m)
Width of footing	B =	1.60 (m)

Thickness of wall members :

t1=	0.30 (m)	a1=	0.000 (m)
t2=	0.60 (m)	a2=	1.300 (m)
t3=	0.70 (m)	a3=	0.300 (m)
		a4=	1.000 (m)
		a5=	1.000 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition Location = STA. 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.8	1.450	15.66	
Wall-2	1/2(t2-t1)(Ho-t3)γc	5.4	1.100	5.94	
Footing	(B)(t3)γc	19.32	0.575	11.11	
Soil-1	1/2(a5)(a6)γsat	0.00	0.333	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.667	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.267	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.733	0.00	
Sub-Total		35.52	0.921	32.71	
Uplift-1	-1/2B(D+Hw)γw	-17.25	1.067	-18.40	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-22.74		-21.32	
Total		12.78		11.38	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	23.72	0.73	17.39	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		23.72		17.57	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 35.60 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 38.89 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 3.288 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 1.375 m

Tensile stress acting to anchor bars
F_t = 2.39 kN/m
= 0.72 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.72 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) HT. OF WALL 1.50~1.60

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

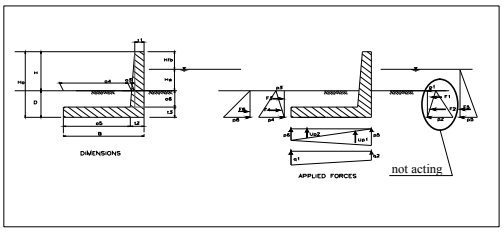
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.60	(m)
Embedment of wall	D =	0.70	(m)
Total height of wall	Ho=	2.30	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.60	(m)
Width of footing	B =	1.60	(m)

Thickness of wall members :

t1=	0.40 (m)	a1=	0.000 (m)
t2=	0.72 (m)	a2=	1.200 (m)
t3=	0.70 (m)	a3=	0.320 (m)
		a4=	0.880 (m)
		a5=	0.880 (m)
		a6=	0.000 (m)



2. Check case : Flood Condition Location = STA. 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	15.36	1.400	21.50	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.144	0.987	6.06	
Footing	(B)(t3)γc	17.472	0.520	9.09	
Soil-1	1/2(a5)(a6)γsat	0.00	0.293	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.587	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.307	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.800	0.00	
Sub-Total		38.98	0.940	36.65	
Uplift-1	-1/2B(D+Hw)γw	-18.03	1.067	-19.23	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-23.52		-22.16	
Total		15.46		14.49	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	25.92	0.77	19.87	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		25.92		20.05	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 39.54 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 42.21 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 2.663 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 1.320 m

Tensile stress acting to anchor bars
F_t = 2.02 kN/m
= 0.61 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.61 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

ANALYSIS AND DESIGN OF PARAPET WALL (TYPE-III) | HT. OF WALL 1.60~1.70

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

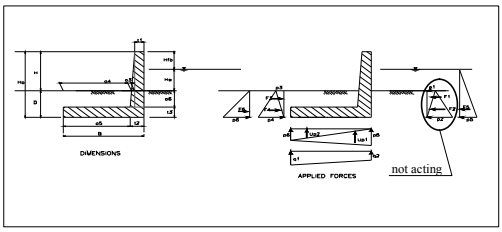
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.70 (m)
Embedment of wall	D =	0.70 (m)
Total height of wall	Ho=	2.40 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.70 (m)
Width of footing	B =	1.60 (m)

Thickness of wall members :

t1=	0.45 (m)	a1=	0.000 (m)
t2=	0.79 (m)	a2=	1.150 (m)
t3=	0.70 (m)	a3=	0.340 (m)
		a4=	0.810 (m)
		a5=	0.810 (m)
		a6=	0.000 (m)



Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F3	1/2(p3)h	0.00	0.47	0.00	Resisting force
F4	1/2(p4)h	10.00	0.23	2.33	Resisting force
F5	1/2γw(D+Hw)^2	28.22	0.80	22.58	Active force
F6	1/2γw(D)^2	2.40	0.23	0.56	Resisting force
Total of active forces		28.22		22.75	
Total of maximum resisting forces		12.40		2.89	
Actual resisting forces		12.40		2.89	

(3) Stability

Check of Tensile Stress acting to Anchor Bar

M_P = 42.61 (kN-m/m)
moment to overturn the revetment to riverside

M_A = 45.75 (kN-m/m)
moment to overturn the revetment to landside

Balance of moment to overturn the revetment to landside
M_B = 3.141 (kN-m/m) = M_A-M_P

Distance from landside end to installation position of anchor bar
L_a = 1.290 m

Tensile stress acting to anchor bars
F_t = 2.43 kN/m
= 0.73 kN/bar installation pitch of anchor bar : 0.3m

Allowable adhesive stress of concrete (21N/mm^2) : 1.40 N/mm^2
Allowable adhesive stress of anchor bar (D12, 200mm) 10.56 kN/bar

Allowable tensile stress of anchor bar (D12, L=200mm) which is fixed in a anchor hole by concrete is 10.56 kN/bar. In consideration of tensile stress acting to the anchor bar, 0.73 kN/bar, the stability of Parapet Wall Type-III is sucured under even "Flood Condition" which is critical condition to overturn the revetment to landside.

2. Check case : Flood Condition | Location = STA. 1.60~1.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

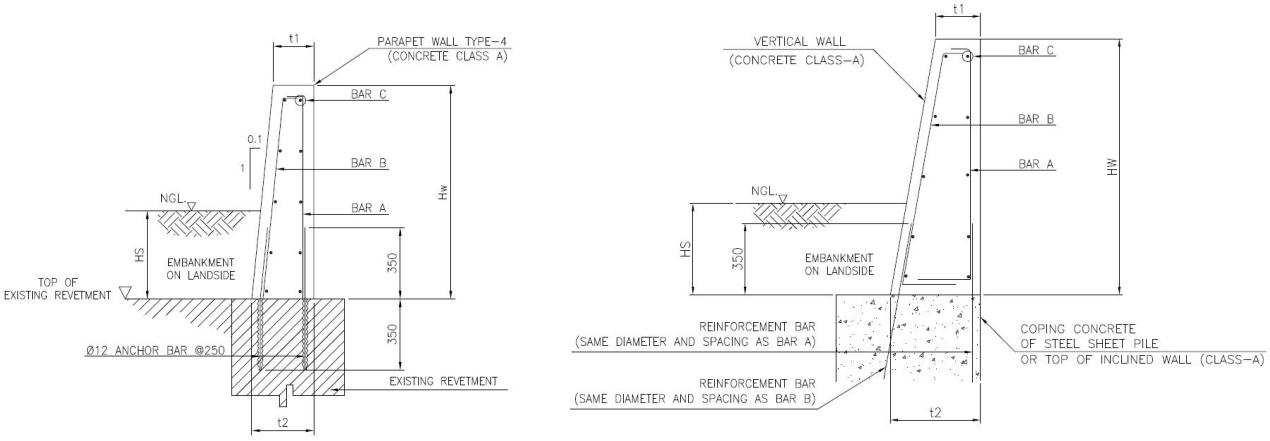
Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	18.36	1.375	25.25	
Wall-2	1/2(t2-t1)(Ho-t3)γc	6.936	0.923	6.40	
Footing	(B)(t3)γc	16.464	0.490	8.07	
Soil-1	1/2(a5)(a6)γsat	0.00	0.270	0.00	
Soil-2	1/2(a4)(a6)γsat	0.00	0.540	0.00	
Water-1	1/2(a4)(Hw)γw	0.00	1.330	0.00	
Water-2	1/2(a2)(Hw)γw	0.00	0.833	0.00	
Sub-Total		41.76	0.951	39.72	
Uplift-1	-1/2B(D+Hw)γw	-18.82	1.067	-20.07	
Uplift-2	-1/2B(D)γw	-5.49	0.533	-2.93	
Sub-Total		-24.30		-23.00	
Total		17.46		16.72	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.70	2.13	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.70	28.56	Passive earth press.

3.2 Parapet Wall Type-IV and Vertical Wall



[Parapet Wall Type-IV] [Vertical Wall]

Figure 3.2.1 Typical Cross Section of Parapet Wall Type-IV and Vertical Wall

Table 3.2.1 Standard Dimensions of Parapet Wall Type-IV and Vertical Wall

Height Range		Thickness		Reinforcement					
				BAR A		BAR B		BAR C	
HW (m)	HS (m)	t1 (m)	t2 (m)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)
0.0~1.5	0.0~0.5	0.20	t1 + HW*0.1	12	250	12	250	12	300
0.0~1.5	0.5~1.0	0.20	t1 + HW*0.1	12	250	12	250	12	300
0.0~1.5	1.0~1.5	0.20	t1 + HW*0.1	12	250	12	250	12	300

DESIGN OF VERTICAL WALL

WALL HEIGHT	1.50
SOIL HEIGHT	0.50

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

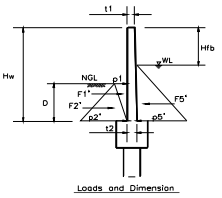
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.50	(m)
Embedment of wall	D =	0.50	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.50	(m)

Thickness of wall members :

t1= 0.20 (m)
t2= 0.20 (m)



Loads and Dimension

2. Case 1 : Normal condition

WALL HEIGHT	1.5
SOIL HEIGHT	0.50

(Direction of forces : Active forces are applied from land side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	0.50	5.77	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	0.76	0.33	0.25	Active force
F2'	1/2(p2')(D)	1.44	0.17	0.24	Active force
Total		2.20		0.49	

3. Case 2 : Flood condition

WALL HEIGHT	1.5
	0

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Kp	0.50	20.40	Passive earth press.
p5'	γw(hw)	1.50	14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	5.10	0.17	0.85	Passive earth press.
F5'	1/2(p5')(hw)	-11.03	0.50	-5.51	Water pressure
Active Forces		-11.03		-5.51	
Actual Resisting force		5.10		0.85	
Total		-5.92		-4.66	

4. Case 3 : Seismic condition-1

WALL HEIGHT :	1.50
SOIL HEIGHT:	0.50

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√Kep	0.50	31.02	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	7.75	0.17	1.29	Passive force
Wall-1	γc(t1)(H)kh	-1.44	0.75	-1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.44		-1.08	
Resisting force		7.75		1.29	
Actual Resisting force		1.44		0.24	
Total		0.00		-0.84	

5. Case 4 : Seismic condition-2

WALL HEIGHT :	1.50
SOIL HEIGHT:	0.50

(Direction of forces : Active forces are applied from land side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.56	0.33	0.19	Active force
F2'	1/2(p2')(a6)	1.57	0.17	0.26	Active force
Wall-1	γc(t1)(H)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.50	0.00	Seismic force
Total		3.57		1.53	

6. Case 5 : Wind condition 1

WALL HEIGHT :	1.50
SOIL HEIGHT:	0.50

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Ka	0.50	36.72	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.33	0.00	Passive force
F2'	1/2(p2')(a6)	9.18	0.17	1.53	Passive force
Wind Load	Cc Cq qs I Hw	-3.16	0.75	-2.37	
Active force		-3.16		-2.37	
Resisting force		9.18		1.53	
Actual Resisting force		3.16		0.53	
Total		0.00		-1.84	

7. Case 6 : Wind condition 2

WALL HEIGHT :	1.50
SOIL HEIGHT:	0.50

Wind from the land side

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	0.50	5.77	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.76	0.33	0.25	Active force
F2'	1/2(p2')(a6)	1.44	0.17	0.24	Active force
Wind Load		2.11	1.00	2.11	Active force
Total		4.31		2.60	

8. Design of RC members

WALL HEIGHT :	1.50
SOIL HEIGHT:	0.50

(1) Design Criteria

Concrete strength	fc' =	20.7	(MPa)
Steel strength	fy =	275	(MPa)
Modular ratio	n=Es/Ec=	9	
Allowable stress :			
Fiber stress in flexural compress.	0.45fc'	9.315	(MPa)
Shear stress	0.079√fc'	0.36	(MPa)
Tensile stress in reinforcement		137.9	(MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Wall Remarks
Normal-1		0.49	2.20	
Flood		-4.66	-5.92	
Seismic-1	*	-0.63	0.00	*: divided by 1.33
Seismic-2	*	1.15	2.68	*: divided by 1.33
Wind-1	*	-1.39	0.00	*: divided by 1.33
Wind-2	*	1.95	3.24	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	1.95	5.92	0.96	32.28	0.04

Calculation of required reinforcements

	Wall			
	Main Vertical Bar		Horizontal Bar	
Parameters	Required	Minimum	Minimum	
Diameter	12	12	12	
Spacing	250	565.49	565.49	
As/m	452.39	200.00	200.00	
Circum.	150.7968			
d'	0.056			
d	0.144			
Coefficients				
$p = As/bd$	0.0031416			
$k=\sqrt{pn(2+pn)}-pn$	0.211200529			
j= 1- k/3	0.929599824			
Actual Stresses, (Mpa)				
fs (steel)	32.28			
fc (concrete)	0.96			
v (shear)	0.04			
u (bond)	0.29			
Code Requirements				
ratio (min.)		0.001	0.001	
As (min.) = ratio x b x h		200	200	

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	4.66	5.92	2.29	76.99	0.04

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{pn'+2pn}-pn$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	76.99	
fc (concrete)	2.29	
v (shear)	0.04	
u (bond)	0.29	
Code Minimum reinforcements		
ratio (min.)	0.001	
As (min.) = ratio x b x h	200	

DESIGN OF VERTICAL WALL

WALL HEIGHT	1.50
SOIL HEIGHT	1.00

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

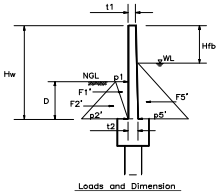
Dimensions of wall and water depth :

Height of wall	H =	1.50 (m)
Embedment of wall	D =	1.00 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	1.50 (m)

Thickness of wall members :

t1= 0.20 (m)

t2= 0.20 (m)



Loads and Dimension

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT	1.5
SOIL HEIGHT	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(D)	4.25	0.33	1.42	Active force
Total		5.77		2.43	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT	1.5
	0

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Kp	1.00	40.80	Passive earth press.
p5'	γw(hw)	1.50	14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	20.40	0.33	6.80	Passive earth press.
F5'	1/2(p5')(hw)	-11.03	0.50	-5.51	Water pressure
Active Forces		-11.03		-5.51	
Actual Resisting force		11.03		3.68	
Total		0.00		-1.84	

4. Case 3 : Seismic condition-1

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√Kep	1.00	62.03	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	31.02	0.33	10.34	Passive force
Wall-1	γc(t1)(H)kh	-1.44	0.75	-1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.44		-1.08	
Resisting force		31.02		10.34	
Actual Resisting force		1.44		0.48	
Total		0.00		-0.60	

5. Case 4 : Seismic condition-2

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.00	10.29	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.12	0.67	0.75	Active force
F2'	1/2(p2')(a6)	5.15	0.33	1.72	Active force
Wall-1	γc(t1)(H)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.50	0.00	Seismic force
Total		7.71		3.54	

6. Case 5 : Wind condition 1

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Ka	1.00	73.45	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Passive force
F2'	1/2(p2')(a6)	36.72	0.33	12.24	Passive force
Wind Load	Ce Cq qs I Hw	-3.16	0.75	-2.37	
Active force		-3.16		-2.37	
Resisting force		36.72		12.24	
Actual Resisting force		3.16		1.05	
Total		0.00		-1.32	

7. Case 6 : Wind condition 2

Wind from the land side

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(a6)	4.25	0.33	1.42	Active force
Wind Load		1.05	1.25	1.32	Active force
Total		6.82		3.75	

8. Design of RC members

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.00

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.45fc'	9.315 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		137.9 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Wall Remarks
Normal-1		2.43	5.77	
Flood		-1.84	0.00	
Seismic-1	*	-0.45	0.00	*: divided by 1.33
Seismic-2	*	2.66	5.79	*: divided by 1.33
Wind-1	*	-0.99	0.00	*: divided by 1.33
Wind-2	*	2.82	5.13	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.82	5.79	1.38	46.52	0.04

Calculation of required reinforcements

	Wall		
	Main Vertical Bar		Horizontal Bar
Parameters	Required	Minimum	Minimum
Diameter	12	12	12
Spacing	250	565.49	565.49
As/m	452.39	200.00	200.00
Circum.	150.7968		
d'	0.056		
d	0.144		
Coefficients			
p = As/bd	0.0031416		
$k=\sqrt{(np)^2+2np}-np$	0.211200529		
j= 1- k/3	0.929599824		
Actual Stresses, (Mpa)			
fs (steel)	46.52		
fc (concrete)	1.38		
v (shear)	0.04		
u (bond)	0.29		
Code Requirements			
ratio (min.)		0.001	0.001
As (min.) = ratio x b x h		200	200

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	1.84	5.79	0.90	30.34	0.04

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{(np)^2+2np}-np$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	30.34	
fc (concrete)	0.90	
v (shear)	0.04	
u (bond)	0.29	
Code Minimum reinforcements		
ratio (min.)	0.001	
As (min.) = ratio x b x h	200	

DESIGN OF VERTICAL WALL

WALL HEIGHT	1.50
SOIL HEIGHT	1.50

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

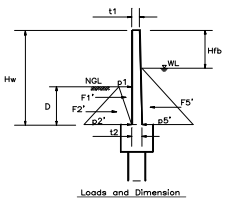
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.50	(m)
Embedment of wall	D =	1.50	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	1.50	(m)

Thickness of wall members :

t1 = 0.20 (m)
t2 = 0.20 (m)



2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT	1.5
SOIL HEIGHT	1.50

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√ Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(D)	8.43	0.50	4.21	Active force
Total		10.71		6.49	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT	1.5
	0

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√ Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√ Kp	1.50	61.21	Passive earth press.
p5'	γw(hw)	1.50	14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	45.90	0.50	22.95	Passive earth press.
F5'	1/2(p5')(hw)	-11.03	0.50	-5.51	Water pressure
Active Forces		-11.03		-5.51	
Actual Resisting force		11.03		5.51	
Total		0.00		0.00	

4. Case 3 : Seismic condition-1

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.50

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√ Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√ Kep	1.50	93.05	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	69.79	0.50	34.89	Passive force
Wall-1	γc(t1)(H)kh	-1.44	0.75	-1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.44		-1.08	
Resisting force		69.79		34.89	
Actual Resisting force		1.44		0.72	
Total		0.00		-0.36	

5. Case 4 : Seismic condition-2

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.50

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√ Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√ Kea	1.50	14.32	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.68	1.00	1.68	Active force
F2'	1/2(p2')(a6)	10.74	0.50	5.37	Active force
Wall-1	γc(t1)(H)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.50	0.00	Seismic force
Total		13.86		8.13	

6. Case 5 : Wind condition 1
(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.50

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√ Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√ Ka	1.50	110.17	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Passive force
F2'	1/2(p2')(a6)	82.63	0.50	41.31	Passive force
Wind Load	Ce Cq qs I Hw	-3.16	0.75	-2.37	
Active force		-3.16		-2.37	
Resisting force		82.63		41.31	
Actual Resisting force		3.16		1.58	
Total		0.00		-0.79	

7. Case 6 : Wind condition 2
Wind from the land side

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.50

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√ Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(a6)	8.43	0.50	4.21	Active force
Wind Load		0.00	1.50	0.00	Active force
Total		10.71		6.49	

8. Design of RC members

WALL HEIGHT :	1.50
SOIL HEIGHT:	1.50

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.45fc'	9.315 (MPa)
Shear stress	0.079√ fc'	0.36 (MPa)
Tensile stress in reinforcement		137.9 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Remarks
Normal-1		6.49	10.71	
Flood		0.00	0.00	
Seismic-1	*	-0.27	0.00	*: divided by 1.33
Seismic-2	*	6.11	10.42	*: divided by 1.33
Wind-1	*	-0.59	0.00	*: divided by 1.33
Wind-2	*	4.88	8.05	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	6.49	10.71	3.19	107.22	0.07

Calculation of required reinforcements

	Wall		
	Main Vertical Bar		Horizontal Bar
Parameters	Required	Minimum	Minimum
Diameter	12	12	12
Spacing	250	565.49	565.49
As/m	452.39	200.00	200.00
Circum.	150.7968		
d'	0.056		
d	0.144		
Coefficients			
p = As/bd	0.0031416		
$k=\sqrt{(np)^2+2p+p}-n$	0.211200529		
j= 1- k/3	0.929599824		
Actual Stresses, (Mpa)			
fs (steel)	107.22		
fc (concrete)	3.19		
v (shear)	0.07		
u (bond)	0.53		
Code Requirements			
ratio (min.)		0.001	0.001
As (min.) = ratio x b x h		200	200

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE
Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	0.59	10.71	0.29	9.81	0.07

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{(np)^2+2p+p}-n$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	9.81	
fc (concrete)	0.29	
v (shear)	0.07	
u (bond)	0.53	
Code Minimum reinforcements		
ratio (min.)		0.001
As (min.) = ratio x b x h		200

DESIGN OF VERTICAL WALL

WALL HEIGHT	2.00
SOIL HEIGHT	1.00

1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

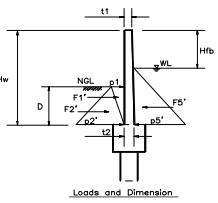
Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	2.00 (m)
Embedment of wall	D =	1.00 (m)
Freeboard	Hfb=	0.00 (m)
Water depth under flood condition	Hw=	2.00 (m)

Thickness of wall members :
t1= 0.20 (m)
t2= 0.20 (m)



Loads and Dimension

2. Case 1 : Normal condition
(Direction of forces : Active forces are applied from land side)

WALL HEIGHT	2
SOIL HEIGHT	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√ Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(D)	4.25	0.33	1.42	Active force
Total		5.77		2.43	

3. Case 2 : Flood condition
(Direction of forces : Active forces are applied from river side)

WALL HEIGHT	2
	0

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Kp	1.00	40.80	Passive earth press.
p5'	γw(hw)	2.00	19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	20.40	0.33	6.80	Passive earth press.
F5'	1/2(p5')(hw)	-19.60	0.67	-13.07	Water pressure
Active Forces		-19.60		-13.07	
Actual Resisting force		19.60		6.53	
Total		0.00		-6.53	

4. Case 3 : Seismic condition-1
(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√Kep	1.00	62.03	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	31.02	0.33	10.34	Passive force
Wall-1	γc(t1)(H)kh	-1.92	1.00	-1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.92		-1.92	
Resisting force		31.02		10.34	
Actual Resisting force		1.92		0.64	
Total		0.00		-1.28	

5. Case 4 : Seismic condition-2
(Direction of forces : Active forces are applied from land side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.00	10.29	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.12	0.67	0.75	Active force
F2'	1/2(p2')(a6)	5.15	0.33	1.72	Active force
Wall-1	γc(t1)(H)kh	1.92	1.00	1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.67	0.00	Seismic force
Total		8.19		4.38	

6. Case 5 : Wind condition 1
(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Ka	1.00	73.45	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Passive force
F2'	1/2(p2')(a6)	36.72	0.33	12.24	Passive force
Wind Load	Cc Cq qs I Hw	-4.21	1.00	-4.21	
Active force		-4.21		-4.21	
Resisting force		36.72		12.24	
Actual Resisting force		4.21		1.40	
Total		0.00		-2.81	

7. Case 6 ; Wind condition 2
Wind from the land side

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(a6)	4.25	0.33	1.42	Active force
Wind Load		2.11	1.50	3.16	Active force
Total		7.88		5.59	

8. Design of RC members

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.00

(1) Design Criteria

Concrete strength	fc' =	20.7	(MPa)
Steel strength	fy =	275	(MPa)
Modular ratio	n=Es/Ec=	9	
Allowable stress :			
Fiber stress in flexural compress.	0.45fc'	9.315	(MPa)
Shear stress	0.079√fc'	0.36	(MPa)
Tensile stress in reinforcement		137.9	(MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Wall Remarks
Normal-1		2.43	5.77	
Flood		-6.53	0.00	
Seismic-1	*	-0.96	0.00	*: divided by 1.33
Seismic-2	*	3.29	6.15	*: divided by 1.33
Wind-1	*	-2.11	0.00	*: divided by 1.33
Wind-2	*	4.20	5.92	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	4.20	6.15	2.06	69.40	0.04

Calculation of required reinforcements

	Wall		
	Main Vertical Bar		Horizontal Bar
Parameters	Required	Minimum	Minimum
Diameter	12	12	12
Spacing	250	565.49	565.49
As/m	452.39	200.00	200.00
Circum.	150.7968		
d'	0.056		
d	0.144		
Coefficients			
p = As/bd	0.0031416		
$k=\sqrt{(np)^2+2p*n}-np$	0.211200529		
j= 1- k/3	0.929599824		
Actual Stresses, (Mpa)			
fs (steel)	69.40		
fc (concrete)	2.06		
v (shear)	0.04		
u (bond)	0.30		
Code Requirements			
ratio (min.)		0.001	0.001
As (min.) = ratio x b x h		200	200

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE
Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	6.53	6.15	3.21	107.89	0.04

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{(np)^2+2p*n}-np$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	107.89	
fc (concrete)	3.21	
v (shear)	0.04	
u (bond)	0.30	
Code Minimum reinforcements		
ratio (min.)		0.001
As (min.) = ratio x b x h		200

DESIGN OF VERTICAL WALL

WALL HEIGHT	2.00
SOIL HEIGHT	1.50

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

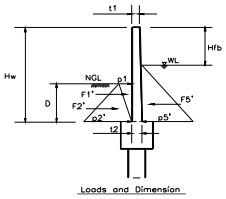
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	2.00	(m)
Embedment of wall	D =	1.50	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	2.00	(m)

Thickness of wall members :

t1= 0.20 (m)
t2= 0.20 (m)



Loads and Dimension

2. Case 1 : Normal condition

WALL HEIGHT	2
SOIL HEIGHT	1.50

(Direction of forces : Active forces are applied from land side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√ Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(D)	8.43	0.50	4.21	Active force
Total		10.71		6.49	

3. Case 2 : Flood condition

WALL HEIGHT	2
	0

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√ Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√ Kp	1.50	61.21	Passive earth press.
p5'	γw(hw)	2.00	19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	45.90	0.50	22.95	Passive earth press.
F5'	1/2(p5')(hw)	-19.60	0.67	-13.07	Water pressure
Active Forces		-19.60		-13.07	
Actual Resisting force		19.60		9.80	
Total		0.00		-3.27	

4. Case 3 : Seismic condition-1

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.50

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√ Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√ Kep	1.50	93.05	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	69.79	0.50	34.89	Passive force
Wall-1	γc(t1)(H)kh	-1.92	1.00	-1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.92		-1.92	
Resisting force		69.79		34.89	
Actual Resisting force		1.92		0.96	
Total		0.00		-0.96	

5. Case 4 : Seismic condition-2

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.50

(Direction of forces : Active forces are applied from land side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√ Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√ Kea	1.50	14.32	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.68	1.00	1.68	Active force
F2'	1/2(p2')(a6)	10.74	0.50	5.37	Active force
Wall-1	γc(t1)(H)kh	1.92	1.00	1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.67	0.00	Seismic force
Total		14.34		8.97	

6. Case 5 : Wind condition 1

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.50

(Direction of forces : Active forces are applied from river side)

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√ Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√ Ka	1.50	110.17	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Passive force
F2'	1/2(p2')(a6)	82.63	0.50	41.31	Passive force
Wind Load	Ce Cq qs l Hw	-4.21	1.00	-4.21	
Active force		-4.21		4.21	
Resisting force		82.63		41.31	
Actual Resisting force		4.21		2.11	
Total		0.00		-2.11	

7. Case 6 : Wind condition 2

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.50

Wind from the land side

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√ Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√ Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(a6)	8.43	0.50	4.21	Active force
Wind Load		1.05	1.75	1.84	Active force
Total		11.76		8.34	

8. Design of RC members

WALL HEIGHT :	2.00
SOIL HEIGHT:	1.50

(1) Design Criteria

Concrete strength	fc' =	20.7	(MPa)
Steel strength	fy =	275	(MPa)
Modular ratio	n=Es/Ec=	9	
Allowable stress :			
Fiber stress in flexural compress.	0.45fc'	9.315	(MPa)
Shear stress	0.079√ fc'	0.36	(MPa)
Tensile stress in reinforcement		137.9	(MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Wall Remarks
Normal-1		6.49	10.71	
Flood		-3.27	0.00	
Seismic-1	*	-0.72	0.00	*: divided by 1.33
Seismic-2	*	6.74	10.78	*: divided by 1.33
Wind-1	*	-1.58	0.00	*: divided by 1.33
Wind-2	*	6.27	8.84	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	6.74	10.78	3.31	111.35	0.07

Calculation of required reinforcements

	Wall		
	Main Vertical Bar		Horizontal Bar
Parameters	Required	Minimum	Minimum
Diameter	12	12	12
Spacing	250	565.49	565.49
As/m	452.39	200.00	200.00
Circum.	150.7968		
d'	0.056		
d	0.144		
Coefficients			
$p = As/bd$	0.0031416		
$k=\sqrt{(pn)^2+2pn}-pn$	0.211200529		
$j = 1 - k/3$	0.929599824		
Actual Stresses, (Mpa)			
fs (steel)	111.35		
fc (concrete)	3.31		
v (shear)	0.07		
u (bond)	0.53		
Code Requirements			
ratio (min.)	0.001		0.001
As (min.) = ratio x b x h	200		200

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	3.27	10.78	1.60	53.94	0.07

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{(pn)^2+2p+pn}-pn$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	53.94	
fc (concrete)	1.60	
v (shear)	0.07	
u (bond)	0.53	
Code Minimum reinforcements		
ratio (min.)		0.001
As (min.) = ratio x b x h		200

DESIGN OF VERTICAL WALL

WALL HEIGHT	2.00
SOIL HEIGHT	2.00

1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	

Coefficient of soil pressure :

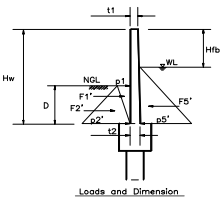
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	2.00	(m)
Embedment of wall	D =	2.00	(m)
Freeboard	Hfb=	0.00	(m)
Water depth under flood condition	Hw=	2.00	(m)

Thickness of wall members :

t1= 0.20 (m)
t2= 0.20 (m)



Loads and Dimension

2. Case 1 : Normal condition

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT	2
SOIL HEIGHT	2.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	2.00	13.97	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(D)	3.04	1.33	4.05	Active force
F2'	1/2(p2')(D)	13.97	0.67	9.32	Active force
Total		17.01		13.37	

3. Case 2 : Flood condition

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT	2
	0

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Kp	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Kp	2.00	81.61	Passive earth press.
p5'	γw(hw)	2.00	19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(h)	0.00	0.00	0.00	Passive earth press.
F2'	1/2(p2')(h)	81.61	0.67	54.40	Passive earth press.
F5'	1/2(p5')(hw)	-19.60	0.67	-13.07	Water pressure
Active Forces		-19.60		-13.07	
Actual Resisting force		19.60		13.07	
Total		0.00		0.00	

4. Case 3 : Seismic condition-1

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	2.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)-2c√Kep	0.00	0.00	Passive earth press.
p2'	Kep(γh)-2c√Kep	2.00	124.07	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.00	0.00	Passive force
F2'	1/2(p2')(a6)	124.07	0.67	82.71	Passive force
Wall-1	γc(t1)(H)kh	-1.92	1.00	-1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.00	0.00	Seismic force
Active force		-1.92		-1.92	
Resisting force		124.07		82.71	
Actual Resisting force		1.92		1.28	
Total		0.00		-0.64	

5. Case 4 : Seismic condition-2

(Direction of forces : Active forces are applied from land side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	2.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	2.00	18.35	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.24	1.33	2.98	Active force
F2'	1/2(p2')(a6)	18.35	0.67	12.23	Active force
Wall-1	γc(t1)(H)kh	1.92	1.00	1.92	Seismic force
Wall-2	γc(t2-t1)(H)kh/2	0.00	0.67	0.00	Seismic force
Total		22.51		17.14	

6. Case 5 : Wind condition 1

(Direction of forces : Active forces are applied from river side)

WALL HEIGHT :	2.00
SOIL HEIGHT:	2.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)-2c√Ka	0.00	0.00	Passive earth press.
p2'	Kp(γh)-2c√Ka	2.00	146.89	Passive earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.33	0.00	Passive force
F2'	1/2(p2')(a6)	146.89	0.67	97.93	Passive force
Wind Load	Ce Cq qs l Hw	-4.21	1.00	-4.21	
Active force		-4.21		-4.21	
Resisting force		146.89		97.93	
Actual Resisting force		4.21		2.81	
Total		0.00		-1.40	

7. Case 6 : Wind condition 2

Wind from the land side

WALL HEIGHT :	2.00
SOIL HEIGHT:	2.00

(1) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh+q)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh+q)-2c√Ka	2.00	13.97	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	3.04	1.33	4.05	Active force
F2'	1/2(p2')(a6)	13.97	0.67	9.32	Active force
Wind Load		0.00	2.00	0.00	Active force
Total		17.01		13.37	

8. Design of RC members

WALL HEIGHT :	2.00
SOIL HEIGHT:	2.00

(1) Design Criteria

Concrete strength	fc' =	20.7	(MPa)
Steel strength	fy =	275	(MPa)
Modular ratio	n=Es/Ec=	9	
Allowable stress :			
Fiber stress in flexural compress.	0.45fc'	9.315	(MPa)
Shear stress	0.079√fc'	0.36	(MPa)
Tensile stress in reinforcement		137.9	(MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Wall Remarks
Normal-1		13.37	17.01	
Flood		0.00	0.00	
Seismic-1	*	-0.48	0.00	*: divided by 1.33
Seismic-2	*	12.88	16.92	*: divided by 1.33
Wind-1	*	-1.06	0.00	*: divided by 1.33
Wind-2	*	10.05	12.79	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.142	16	250	804.25

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	13.37	17.01	5.35	128.73	0.12

Calculation of required reinforcements

	Wall		
	Main Vertical Bar		Horizontal Bar
Parameters	Required	Minimum	Minimum
Diameter	16	16	12
Spacing	250	1005.31	565.49
As/m	804.25	200.00	200.00
Circum.	201.0624		
d'	0.058		
d	0.142		
Coefficients			
p = As/bd	0.00566373		
$k=\sqrt{(pn)^2+2p_1n}-p_1n$	0.272361302		
j= 1- k/3	0.909212899		
Actual Stresses, (Mpa)			
fs (steel)	128.73		
fc (concrete)	5.35		
v (shear)	0.12		
u (bond)	0.66		
Code Requirements			
ratio (min.)		0.001	0.001
As (min.) = ratio x b x h		200	200

Spacing (wall), MAX. = 3t or 450
450
S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	1.06	17.01	0.52	17.43	0.12

	Wall	
	Main Vertical Bar	
Parameters	Required	Minimum
Diameter	12	12
Spacing	250	565.49
As/m	452.39	200.00
Circum.	150.7968	
d'	0.056	
d	0.14	
Coefficients		
p = As/bd	0.0031416	
$k=\sqrt{(pn)^2+2p_1n}-p_1n$	0.211200529	
j= 1- k/3	0.929599824	
Actual Stresses, (Mpa)		
fs (steel)	17.43	
fc (concrete)	0.52	
v (shear)	0.12	
u (bond)	0.84	
Code Minimum reinforcements		
ratio (min.)		0.001
As (min.) = ratio x b x h		200

3.3 Inclined Wall

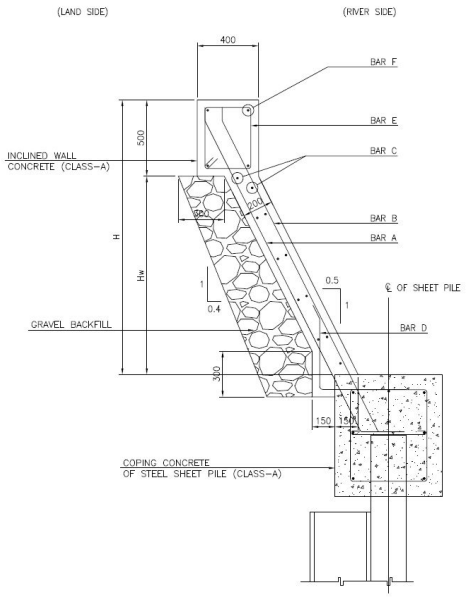


Figure 3.3.1 Typical Cross Section of Inclined Wall

Table 3.3.1 Standard Dimensions of Inclined Wall

Height Range		Reinforcement											
		BAR A		BAR B		BAR C		BAR D		BAR E		BAR F	
HW (m)	H (m)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)	DIA (mm)	SPACING (mm)
0.0~1.5	0.0~2.0	16	250	16	250	12	300	12	250	12	250	12	-
1.5~2.5	2.0~3.0	16	125	16	125	12	300	12	125	12	125	12	-
2.5~2.75	3.0~3.25	16	125	16	125	12	300	12	125	12	125	12	-
2.75~3.0	3.25~3.5	20	125	20	125	12	300	12	125	12	125	12	-

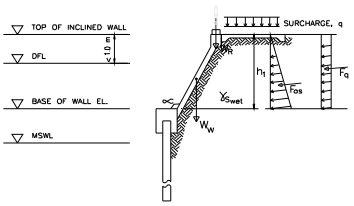
DESIGN OF INCLINED WALL (HEIGHT = 1.5 M)

A. Design Data:

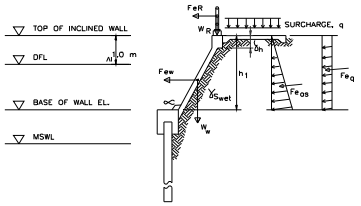
wall inclination (H:V);	0.50:1.00	
γ_s (wet):	18.00 kn/m^3	
h1:	1.500	
h_2:	1.500	
δ h:	0.00	
α :	116.56 deg	2.03 rad
ϕ (angle of soil internal friction):	30.00 deg	0.52 rad
δ (wall frictionangle):		
for normal (1/3*ϕ)	10.00 deg	0.17 rad
for earthquake	10.00 deg	0.17 rad
β (backfill slope):	0.00 deg	0.00 rad
t_c (thickness of wall)	0.20 m	
thickness of backfill; t_b	3.28 m	
surcharge (@ normal condition)	10.00 kpa	

Load Conditions;

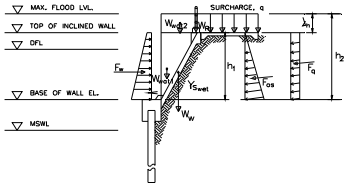
a. NORMAL CONDITION



b. EARTHQUAKE CONDITION



c. FLOOD CONDITION



B.1.1 Main Reinforcements (vertical)

a. Normal Condition 1

surcharge 10.00 kpa

Coulomb's Formula

K_a = $\sin^2(\alpha+\phi)/ ((\sin^2\alpha \sin(\alpha-\delta) (1 + \text{sqrt } (A))^2)$

where A = $(\sin(\phi+\delta) \sin(\phi-\beta))/ (\sin(\alpha-\delta) \sin(\alpha+\beta))$

K_a = 0.15

Active forces on wall due to soil:

effective active soil pressure:

Length of full failure wedge from top wall; L_{ffw} = $h/(\tan\phi) - h/(\tan(180-\alpha)$

= 1.85 m ~ 1.0

effectivity of active soil pressure; $e_{as} = t_b / L_{ffw} * FS$ = 3.55 use 1.00

FS = 2.00

Force

$Fa_s = (1/2) K_a \gamma_{s(wet)} h^2 e_{as}$ = 3.08 kn

Fa_{st} (transverse) = $Fa_s * \cos(\delta)$ = 3.04 kn

distance from base = $(h/3)/\sin(180-\alpha)$ = 0.56 m

Moment @ base (Ma_s) = 1.70 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a q h e_{as}$ = 2.28 kn

Fa_{qt} (transverse) = $Fa_q * \cos(\delta)$ = 2.25 kn

distance from base = $(h/2)/(\sin(180-\alpha)$ = 0.84

Moment @ base (M_{qs})= 1.89 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha -90)*t_w$ = 8.05 kn

t_w = 0.20 m

Ww_t (transverse) = $Ww * \sin(\alpha-90)$ = 3.60 kn

dist. from base = $(h_1/2)/(\sin(180-\alpha)$ = 0.84

Moment @ base (Mw_w)= 3.02 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5$ = 1.20 kn

Wr_t (transverse) = $Ww * \sin(\alpha-90)$ = 0.54 kn

dist. from base = $(h_1)/(\sin(180-\alpha)$ = 1.68

Moment @ base (Mw_r)= 0.90 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r$ = 3.92 kn-m > M_{qs}

therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :

ρ_{min} = 1.4/fy = 0.005

conc. Cover = 75.00 mm

using 16 mm ϕ bar max. reinforcement:

d_{eff} = 117.00 mm

bar spacing, S_b= 337.45 mm

b. Seismic Condition

surcharge: 5.00 kpa

θ_o = $\tan^{-1}$ (Kh/(1-Kv))

Kh = 0.20

Kv ~ 0.00

θ_o = 0.20

K_{ea} = $((\cos^2(\phi-\theta_o+(90-\alpha)))/\cos\theta_o \cos^2(90-\alpha) \cos(90-\alpha+\theta_o+\delta)(1+A^{0.5})^2)$

where A = $(\sin(\phi+\delta) \sin(\phi-\beta-\theta_o))/ (\cos(90-\alpha+\theta_o+\delta) \cos(90-\alpha-\beta))$

A = 0.23

K_{ea} = 0.29

From Whitman approximation:

K_{ea} = K_a + 0.75 kh = 0.30

use K_{ea} = 0.29

Active forces on wall due to soil:

Force

$Fea_s = (1/2) K_{ea} \gamma_{s(wet)} h^2 e_{as}$= 5.86 kn

Fea_{st} (transverse) = $F_{as} * \cos(\delta)$ = 5.77 kn

distance from base = $(h/3)/\sin(180-\alpha)$ = 0.56 m

Moment @ base (Mea_s) = 3.22 kn-m

Active force on wall due to surcharge:

$Fa_{qs} = K_{ea} q_s h e_{as}$ = 2.17 kn

Fa_{qst} (transverse)= $Fa_{qs} * \cos(\delta)$ = 2.14 kn

distance from base = $(h/2)/(\sin(180-\alpha)$ = 0.84

Moment @ base (M_{qs})= 1.79 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha -90)*t_w$ = 8.05 kn

t_w = 0.20 m

Ww_t (transverse) = $Ww * \sin(\alpha-90)$ = 3.60 kn

dist. from base = $(h_1/2)/(\sin(180-\alpha)$ = 0.84

Moment @ base (Mw_w)= 3.02 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5$ = 1.20 kn

Wr_t (transverse) = $Wr * \sin(\alpha-3.1416/2)$ = 0.54 kn

dist. from base = $(h_1)/(\sin(180-\alpha)$ = 1.68

Moment @ base (Mw_r)= 0.90 kn-m

Fe_w = 0.20* W_w = 1.61 kn

Fe_{wt} (transverse) = $Fe_w * \cos(\alpha-90)$ = 1.44 kn

dist. from base = $(h_1/2)/(\sin(180-\alpha)$ = 0.84 m

Moment @ base (Me_w)= 1.21 kn-m

Fe_r = 0.20* W_r = 0.24 kn

Fe_{rt} (transverse) = $Fe_r * \cos(\alpha-90)$ = 0.21 kn

dist. from base = $(h_1)/(\sin(180-\alpha)$ = 1.68 m

Moment @ base (Me_r)= 0.36 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r$ = 3.92 kn-m

$M_{qs} + M_{as} + Mfe_w + Mfe_r$ = 6.58 kn-m > $Mw_w + Mw_r$

therefore soil pressure is active and wall has stresses

Ultimate loads:

$Mu = 1.3*(1.67*M_{qs} + 1.3*M_{as} + 1.0*Mfe_w + 1.0*Mfe_r - 1.0*Mw_w - 1.0*Mw_r)$

Mu = 6.28 kn-m

$Vu = 1.3*(1.67*Fa_{qst} + 1.3* Fa_{qs} + 1.0*Fe_w + 1.0*Fe_{rt} - 1.0*Ww_t - 1.0*Wr_t)$

Vu = 11.16 kn

using t_c = 0.20 m

conc. cover = 75.00 mm

using 16 dia. Mm reinf. Max.

d_{eff} = 117.00 mm for top bar

check sufficiency of thickness against shear:

allowable shear, $V_u = \phi*1.6* \text{sqrt } (f'c)$ = 0.64 mpa

v_u = Vu / (d_{eff} - 1000) = 0.10 mpa< 0.64 mpa okay

design of flexural reinforcement:

try ϕ 16 mm @ 250 o.c.

As/ meter strip: = 804.00 mm^2

ρ = As / (b * d_{eff}) = 0.007

ρ_{min} = 0.002

$a = \rho * fy / (0.85 * fc') * d_{eff}$ = 12.58 mm

$Mu = 0.90*As*fy*(d_{eff} - a/2)/1000^2$

= 22.03 kn-m > 6.28 kn-m

use ϕ 16 mm @ 250 o.c. @ base:

c. Flood Condition

surcharge: (from water) 0.00 kpa

K_a = 0.15

Active forces on wall due to soil:

Force

$Fa_s = (1/2)\, K_a\, \gamma_{s(wet)}\, h^2\, e_{as}$ = 3.08 kn

$Fa_{st} = Fa_s * \cos(\delta)$ = 3.04 kn (transverse to wall

distance from base = $(h/3)/\sin(180-\alpha)$ 0.56 m

Moment @ base (M_{as}) = 1.70 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a\, q\, h\, e_{as}$ = 0.00 kn

Fa_{qt} (transverse) = $Fa_q * \cos(\delta)$ = 0.00 kn

distance from base = $(h/2)/(\sin(180-\alpha)$ = 0.84

Moment @ base (M_{qs})= 0.00 kn-m

Hydraulic Forces

$W_{wat1} = (1/2) * \gamma_{water} * ((h1)^2)/2$ = 5.52 kn

$Wwat1_t = W_w \sin(\alpha - 90$ = 2.47 kn

dist. Fr. base = $(h_1/6)/\cos(180-\alpha)$ = 0.56 m

Moment @ base (Mw_{wat2}) = 1.38 kn-m

$W_{wat2} = \gamma_{water} * (h_1/2) * \delta_h$ = 0.00 kn

$Wwat2_t = W_w \sin(\alpha - 90$ = 0.00 kn

dist. Fr. base = $(h_1/4)/\cos(180-\alpha)$ = 0.84 m

Moment @ base (Mw_{wat2}) = 0.00 kn-m

$F_{wat} = ((\delta_h+h2)/2) * \gamma_{water} * (h1)$ = 11.04 kn

$Ww_t = W_w \cos(\alpha - 90)$ = 9.87 kn

dist. Fr. base = $(h_1/3)(2*\delta_h/+h_2)/(\delta_h+h_2)\sin(180-\alpha)$ =

0.45 m

Moment @ base (Mf_{wat}) = 4.41 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha -90) * t_w$ = 8.05 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* $\sin(\alpha-90)$ = 3.60 kn

dist. from base = $(h_1/2)/(\sin(180-\alpha)$ = 1.68

Moment @ base (Mw_w)= 6.04 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5$ = 1.20 kn

Wr_t (transverse) = Wr* $\sin(\alpha-3.1416/2)$ = 0.54 kn

dist. from base = $(h_1)/(\sin(180-\alpha)$ = 1.68

Moment @ base (Mw_r)= 0.90 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r + Mwat_1 + Mwat_2 + Mfw$ = 12.73 kn-m> $M_{qs}+M_{as}$

$M_{qs} + M_{as}$ 1.70 kn-m

therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :

ρ_{min} = 1.4/fy = 0.005

conc. Cover = 50.00 mm

using 16 mm ϕ bar max. reinforcement:

d_{eff} = 142.00 mm

bar spacing, S_b= 278.04 mm

2. Shrinkage and Temperature bars (horizontal)

As_{st} = $0.002 * t_c * S_b$ (for fy = 275 mpa)

using 2-dia. 12 mm bars

As_{st} = 226.00 mm^2

for S_b = 565.00 mm use 300 mm

a.2 Secondary Reinforcements

2-ϕ12 mm @ 450 mm O.C.

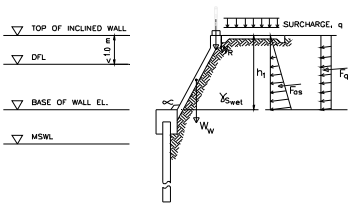
DESIGN OF INCLINED WALL **(HEIGHT = 2.5 M)**

A. Design Data:

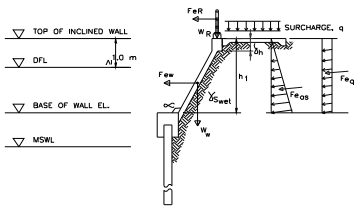
wall inclination (H:V);	0.50:1.00	
γ_s (wet):	18.00 kn/m^3	
h1:	2.500	
h_2:	2.500	
δ h:	0.00	
α :	116.56 deg	2.03 rad
ϕ (angle of soil internal friction):	30.00 deg	0.52 rad
δ (wall frictionangle):		
for normal (1/3*ϕ)	10.00 deg	0.17 rad
for earthquake	10.00 deg	0.17 rad
β (backfill slope):	0.00 deg	0.00 rad
t_c (thickness of wall)	0.20 m	
thickness of backfill; t_b	3.28 m	
surcharge (@ normal condition)	10.00 kpa	

Load Conditions;

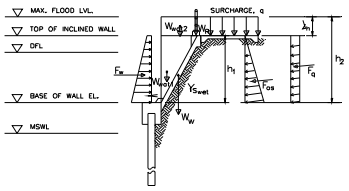
a. NORMAL CONDITION



b. EARTHQUAKE CONDITION



c. FLOOD CONDITION



B.1.1 Main Reinforcements (vertical)

a. Normal Condition 1

surcharge 10.00 kpa

Coulomb's Formula

K_a = $\sin^2(\alpha+\phi)/((\sin^2\alpha\ \sin(\alpha-\delta)\ (1+\text{sqrt}(A))^2)$

where $A = (\sin(\phi+\delta)\ \sin(\phi-\beta))/(\sin(\alpha-\delta)\ \sin(\alpha+\beta))$

K_a = 0.15

Active forces on wall due to soil:

effective active soil pressure:

Length of full failure wedge from top wall; L_{ffw}= $h/(\tan\phi) - h/(\tan(180-\alpha)$

= 3.08 m ~ 1.0

effectivity of active soil pressure; $e_{as} = t_b/L_{ffw} * FS$= 2.13 use 1.00

FS = 2.00

Force

$Fa_s = (1/2)\, K_a\, \gamma_{s(wet)}\, h^2\, e_{as}$ = 8.57 kn

Fa_{st} (transverse) = $Fa_s * \cos(\delta)$ = 8.44 kn

distance from base = $(h/3)/\sin(180-\alpha)$ 0.93 m

Moment @ base (Ma_s) = 7.86 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a\, q\, h\, e_{as}$ = 3.81 kn

Fa_{qt} (transverse) = $Fa_q * \cos(\delta)$ = 3.75 kn

distance from base = $(h/2)/(\sin(180-\alpha)$ = 1.40

Moment @ base (M_{qs})= 5.24 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha -90) * t_w$ = 13.42 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* $\sin(\alpha-90)$ = 6.00 kn

dist. from base = $(h_1/2)/(\sin(180-\alpha)$ = 1.40

Moment @ base (Mw_w)= 8.39 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = Ww* sin(α-90) = 0.54 kn
dist. from base = (h_1)/(sin(180-α) = 2.80
Moment @ base (Mw_r)= 1.50 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r =$ 9.89 kn-m > M_{qs}
therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :
ρ_{min} = 1.4/fy = 0.005
conc. Cover = 75.00 mm
using 16 mm ϕ bar max. reinforcement:
d_{eff} = 117.00 mm
bar spacing, S_b= 337.45 mm

b. Seismic Condition

surcharge: 5.00 kpa
θ_o = $\tan^{-1}$ (Kh/(1-Kv))
Kh = 0.20
Kv ~ 0.00
θ_o = 0.20

$K_{ea} = ((\cos^2(\phi-\theta_o+(90-\alpha)))/\cos\theta_o\cos^2(90-\alpha)\cos(90-\alpha+\theta_o+\delta)(1+A^{0.5})^2)$
where A = (sin($\phi+\delta$) sin($\phi-\beta-\theta_o$))/ (cos(90-$\alpha+\theta_o+\delta$) cos (90-$\alpha-\beta$))
A = 0.23
K_{ea} = 0.29

From Whitman approximation:
K_{ea} = K_{a+} + 0.75 kh = 0.30
use K_{ea} = 0.29
Active forces on wall due to soil:
Force
$Fea_s = (1/2)\ K_{ea}\ \gamma_{s(wet)}\ h^2\ e_{as}$ = 16.27 kn
Fea_{st} (transverse) = F_{as}* cos(δ) = 16.02 kn
distance from base = (h/3)/sin(180-α) = 0.93 m
Moment @ base (Mea_s) = 14.93 kn-m

Active force on wall due to surcharge:
$Fa_{qs} = K_{ea}\ q_s\ h\ e_{as}$ = 3.62 kn
Fa_{qst} (transverse)= Fa_{qs}* cos(δ) = 3.56 kn
distance from base = (h/2)/(sin(180-α) = 1.40
Moment @ base (M_{qs})= 4.98 kn-m

Forces from wall, rail
$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90)*t_w$ = 13.42 kn
t_w = 0.20 m
Ww_t (transverse) = Ww* sin(α-90) = 6.00 kn
dist. from base = (h_1/2)/(sin(180-α) = 1.40
Moment @ base (Mw_w)= 8.39 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = Wr* sin(α–3.1416/2) = 0.54 kn
dist. from base = (h_1)/(sin(180-α) = 2.80
Moment @ base (Mw_r)= 1.50 kn-m

Fe_w = 0.20* W_w = 2.68 kn
Fe_{wt} (transverse) = Fe_w * cos(α–90) = 2.40 kn
dist. from base = (h_1/2)/(sin(180-α) = 1.40 m
Moment @ base (Me_w)= 3.35 kn-m

Fe_r = 0.20* W_r = 0.24 kn
Fe_{rt} (transverse) = Fe_r * cos(α–90) = 0.21 kn
dist. from base = (h_1)/(sin(180-α) = 2.80 m
Moment @ base (Me_r)= 0.60 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r =$ 9.89 kn-m
$M_{qs} + M_{as} + Mfe_w + Mfe_r =$ 23.86 kn-m > $Mw_w + Mw_r$
therefore soil pressure is active and wall has stresses

Ultimate loads:
$Mu = 1.3*(1.67*M_{qs} + 1.3*M_{as} + 1.0*Mfe_w + 1.0*Mfe_r - 1.0*Mw_w - 1.0*Mw_r)$
Mu = 28.32 kn-m
$Vu = 1.3*(1.67*Fa_{qst} + 1.3*Fa_{qs} + 1.0*Fe_{wt} + 1.0*Fe_{rt} - 1.0*Ww_t - 1.0*Wr_t)$
Vu = 29.71 kn
using t_c = 0.20 m
conc. cover = 75.00 mm
using 16 dia. Mm reinf. Max.
d_{eff} = 117.00 mm for top bar

check sufficiency of thickness against shear:
allowable shear, $V_u = \phi*1/6*$ sqrt (f'c) = 0.64 mpa
v_u = Vu / (d_{eff} - 1000) = 0.25 mpa< 0.64 mpa okay

design of flexural reinforcement:
try ϕ 16 mm @ 125 o.c.
As/ meter strip: = 1634.15 mm^2
ρ = As / (b * d_{eff}) = 0.014
ρ_{min} = 0.002
a = $\rho * fy / (0.85 * fc')*d_{eff}$ = 25.58 mm
$Mu = 0.90*As*fy*(d_{eff} - a/2)/1000^2$
= 42.15 kn-m > 28.32 kn-m
use ϕ 16 mm @ 125 o.c. @ base:

c. Flood Condition

surcharge: (from water) 0.00 kpa

K_a = 0.15

Active forces on wall due to soil:
Force
$Fa_s = (1/2)\ K_a\ \gamma_{s(wet)}\ h^2\ e_{as}$ = 8.57 kn
$Fa_{st} = F_{as}$* cos(δ) = 8.44 kn (transverse to wall
distance from base = (h/3)/sin(180-α) 0.93 m
Moment @ base (M_{as}) = 7.86 kn-m

Active force on wall due to surcharge:
$Fa_q = K_a\ q\ h\ e_{as}$ = 0.00 kn
Fa_{qt} (transverse) = Fa_q* cos(δ) = 0.00 kn
distance from base = (h/2)/(sin(180-α) = 1.40
Moment @ base (M_{qs})= 0.00 kn-m

Hydraulic Forces
W_{wat1} =(1/2)*γ_{water} *((h1)^2)/2 = 15.33 kn
$Wwat1_t = W_w \sin(\alpha - 90$ = 6.85 kn
dist. Fr. base = (h_1/6)/cos(180-α) = 0.93 m
Moment @ base (Mw_{wat2}) = 6.39 kn-m

W_{wat2} =γ_{water} *(h_1/2)*δ_h = 0.00 kn
$Wwat2_t = W_w \sin(\alpha - 90$ = 0.00 kn
dist. Fr. base = (h_1/4)/cos(180-α) = 1.40 m
Moment @ base (Mw_{wat2}) = 0.00 kn-m

F_{wat} =((δ_h+h2)/2)*γ_{water} *(h1) = 30.66 kn
$Ww_t = W_w \cos(\alpha - 90)$ = 27.42 kn
dist. Fr. base = (h_1/3)(2*δ_h/+h_2)/(δ_h+h_2)sin(180-α) =
0.75 m
Moment @ base (Mf_{wat}) = 20.44 kn-m

Forces from wall, rail
$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90)*t_w$ = 13.42 kn
t_w = 0.20 m
Ww_t (transverse) = Ww* sin(α-90) = 6.00 kn
dist. from base = (h_1/2)/(sin(180-α) = 2.80
Moment @ base (Mw_w)= 16.77 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = Wr* sin(α–3.1416/2) = 0.54 kn
dist. from base = (h_1)/(sin(180-α) = 2.80
Moment @ base (Mw_r)= 1.50 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r + Mwat_1 + Mwat_2 + Mfw =$ 45.10 kn-m> $M_{qs}+M_{as}$
$M_{qs} + M_{as}$ 7.86 kn-m
therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :
ρ_{min} = 1.4/fy = 0.005
conc. Cover = 50.00 mm
using 16 mm ϕ bar max. reinforcement:
d_{eff} = 142.00 mm
bar spacing, S_b= 278.04 mm

2. Shrinkage and Temperature bars (horizontal)
As_{st} = 0.002* t_c * S_b (for fy = 275 mpa)
using 2-dia. 12 mm bars
As_{st} = 226.00 mm^2
for S_b = 565.00 mm use 300 mm

a.2 Secondary Reinforcements
2-ϕ12 mm @ 450 mm O.C.

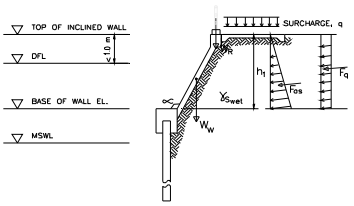
DESIGN OF INCLINED WALL (HEIGHT = 2.75 M)

A. Design Data:

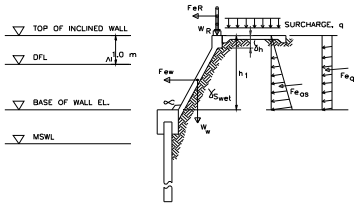
wall inclination (H:V);	0.50:1.00	
γ_s (wet):	18.00 kn/m^3	
h1:	2.750	
h_2:	2.750	
δ h:	0.00	
α :	116.56 deg	2.03 rad
ϕ (angle of soil internal friction):	30.00 deg	0.52 rad
δ (wall frictionangle):		
for normal (1/3*ϕ)	10.00 deg	0.17 rad
for earthquake	10.00 deg	0.17 rad
β (backfill slope):	0.00 deg	0.00 rad
t_c (thickness of wall)	0.20 m	
thickness of backfill; t_b	3.28 m	
surcharge (@ normal condition)	10.00 kpa	

Load Conditions;

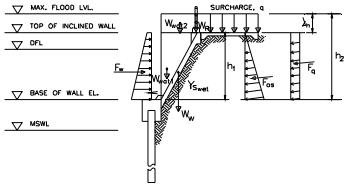
a. NORMAL CONDITION



b. EARTHQUAKE CONDITION



c. FLOOD CONDITION



B.1.1 Main Reinforcements (vertical)

a. Normal Condition 1

surcharge 10.00 kpa

Coulomb's Formula

K_a = $\sin^2(\alpha+\phi)/ ((\sin^2\alpha\ \sin(\alpha-\delta)\ (1 + \text{sqrt}\ (A))^2)$

where $A = (\sin(\phi+\delta)\ \sin(\phi-\beta))/ (\sin(\alpha-\delta)\ \sin(\alpha+\beta))$

K_a = 0.15

Active forces on wall due to soil:

effective active soil pressure:

Length of full failure wedge from top wall; L_{ffw} = $h/(\tan\phi) - h/(\tan(180-\alpha)$

= 3.39 m ~ 1.0

effectivity of active soil pressure; $e_{as} = t_b / L_{ffw}$ * FS= 1.94 use 1.00

FS = 2.00

Force

$Fa_s = (1/2)\ K_a\ \gamma_{s(wet)}\ h^2\ e_{as}$ = 10.37 kn

Fa_{st} (transverse) = Fa_s* cos(δ) = 10.21 kn

distance from base = (h/3)/sin(180-α) 1.02 m

Moment @ base (Ma_s) = 10.46 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a\ q\ h\ e_{as}$ = 4.19 kn

Fa_{qt} (transverse) = Fa_q* cos(δ) = 4.12 kn

distance from base = (h/2)/(sin(180-α) = 1.54

Moment @ base (M_{qs})= 6.34 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.}$* h_1/(cos(α -90)*t_w = 14.76 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* sin(α–90) = 6.60 kn

dist. from base = (h_1/2)/(sin(180-α) = 1.54

Moment @ base (Mw_w)= 10.15 kn-m

$Wr = \gamma_{conc.}$ * 1.0 * 0.10 * 0.5 = 1.20 kn

Wr_t (transverse) = Ww* sin(α-90) = 0.54 kn

dist. from base = (h_1)/(sin(180-α) = 3.07

Moment @ base (Mw_r)= 1.65 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r$ = 11.80 kn-m > M_{qs}

therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :

ρ_{min} = 1.4/fy = 0.005

conc. Cover = 75.00 mm

using 16 mm ϕ bar max. reinforcement:

d_{eff} = 117.00 mm

bar spacing, S_b= 337.45 mm

b. Seismic Condition

surcharge: 5.00 kpa

θ_o = $\tan^{-1}$ (Kh/(1-Kv))

Kh = 0.20

Kv ~ 0.00

θ_o = 0.20

K_{ea} = $((\cos^2(\phi-\theta_o+(90-\alpha)))/\cos\theta_o\cos^2(90-\alpha)\ \cos(90-\alpha+\theta_o+\delta)(1+A^{0.5})^2)$

where $A = (\sin(\phi+\delta)\ \sin(\phi-\beta-\theta_o))/ (\cos(90-\alpha+\theta_o+\delta)\ \cos(90-\alpha-\beta))$

A = 0.23

K_{ea} = 0.29

From Whitman approximation:

K_{ea} = $K_{a\,+}$ + 0.75 kh = 0.30

use K_{ea} = 0.29

Active forces on wall due to soil:

Force

$Fea_s = (1/2)\ K_{ea}\ \gamma_{s(wet)}\ h^2\ e_{as}$= 19.69 kn

Fea_{st} (transverse) = F_{as}* cos(δ) = 19.39 kn

distance from base = (h/3)/sin(180-α) = 1.02 m

Moment @ base (Mea_s) = 19.87 kn-m

Active force on wall due to surcharge:

$Fa_{qs} = K_{ea}\ q_s\ h\ e_{as}$ = 3.98 kn

Fa_{qst} (transverse)= Fa_{qs}* cos(δ) = 3.92 kn

distance from base = (h/2)/(sin(180-α) = 1.54

Moment @ base (M_{qs})= 6.02 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.}$* h_1/(cos(α -90)*t_w = 14.76 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* sin(α-90) = 6.60 kn

dist. from base = (h_1/2)/(sin(180-α) = 1.54

Moment @ base (Mw_w)= 10.15 kn-m

$Wr = \gamma_{conc.}$* 1.0 * 0.10* 0.5 = 1.20 kn

Wr_t (transverse) = Wr* sin(α–3.1416/2) = 0.54 kn

dist. from base = (h_1)/(sin(180-α) = 3.07

Moment @ base (Mw_r)= 1.65 kn-m

Fe_w = 0.20* W_w = 2.95 kn

Fe_{wt} (transverse) = Fe_w* cos(α–90) = 2.64 kn

dist. from base = (h_1/2)/(sin(180-α) = 1.54 m

Moment @ base (Me_w)= 4.06 kn-m

Fe_r = 0.20* W_r = 0.24 kn

Fe_{rt} (transverse) = Fe_r * cos(α–90) = 0.21 kn

dist. from base = (h_1)/(sin(180-α) = 3.07 m

Moment @ base (Me_r)= 0.66 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r$ = 11.80 kn-m

$M_{qs} + M_{as} + Mfe_w + Mfe_r$ = 30.61 kn-m > $Mw_w + Mw_r$

therefore soil pressure is active and wall has stresses

Ultimate loads:

$Mu = 1.3*(1.67*M_{qs} + 1.3*M_{as} + 1.0*Mfe_w + 1.0*Mfe_r - 1.0*Mw_w - 1.0*Mw_r)$

Mu = 37.45 kn-m

$Vu = 1.3*(1.67*Fa_{qst} + 1.3*Fa_{qs} + 1.0*Fe_w + 1.0*Fe_{rt} - 1.0*Ww_t - 1.0*Wr_t)$

Vu = 35.70 kn

using t_c = 0.20 m

conc. cover = 75.00 mm

using 16 dia. Mm reinf. Max.

d_{eff} = 117.00 mm for top bar

check sufficiency of thickness against shear:

allowable shear, $V_u = \phi*1/6*$ sqrt (f'c) = 0.64 mpa

v_u = Vu / (d_{eff} - 1000) = 0.31 mpa< 0.64 mpa okay

design of flexural reinforcement:

try ϕ 16 mm @ 125 o.c.

As/ meter strip: = 1608.00 mm^2

ρ = As / (b * d_{eff}) = 0.014

ρ_{min} = 0.002

$a = \rho * fy / (0.85 * fc')*d_{eff}$ = 25.17 mm

$Mu = 0.90*As*fy*(d_{eff} - a/2)/1000^2$

= 41.56 kn-m > 37.45 kn-m

use ϕ 16 mm @ 125 o.c. @ base:

c. Flood Condition

surcharge: (from water) 0.00 kpa

K_a = 0.15

Active forces on wall due to soil:

Force

$Fa_s = (1/2)\, K_a\, \gamma_{s(wet)}\, h^2\, e_{as}$ = 10.37 kn

$Fa_{st} = Fa_s * \cos(\delta)$ = 10.21 kn (transverse to wall

distance from base = (h/3)/sin(180-α) 1.02 m

Moment @ base (M_{as}) = 10.46 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a\, q\, h\, e_{as}$ = 0.00 kn

Fa_{qt} (transverse) = $Fa_q * \cos(\delta)$ = 0.00 kn

distance from base = (h/2)/(sin(180-α) = 1.54

Moment @ base (M_{qs})= 0.00 kn-m

Hydraulic Forces

$W_{wat1} = (1/2) * \gamma_{water} * ((h1)\hat{}2)/2$ = 18.55 kn

$Wwat1_t = W_w \sin(\alpha - 90$ = 8.29 kn

dist. Fr. base = (h_1/6)/cos(180-α) = 1.02 m

Moment @ base (Mw_{wat2}) = 8.50 kn-m

$W_{wat2} = \gamma_{water} * (h_1/2) * \delta_h$ = 0.00 kn

$Wwat2_t = W_w \sin(\alpha - 90$ = 0.00 kn

dist. Fr. base = (h_1/4)/cos(180-α) = 1.54 m

Moment @ base (Mw_{wat2}) = 0.00 kn-m

$F_{wat} = ((\delta_h + h2)/2) * \gamma_{water} * (h1)$ = 37.09 kn

$Ww_t = W_w \cos(\alpha - 90)$ = 33.18 kn

dist. Fr. base = $(h_1/3)(2*\delta_h/+h_2)/(\delta_h+h_2)\sin(180-\alpha)$ =

0.82 m

Moment @ base (Mf_{wat}) = 27.20 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90) * t_w$ = 14.76 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* sin(α-90) = 6.60 kn

dist. from base = (h_1/2)/(sin(180-α) = 3.07

Moment @ base (Mw_w)= 20.29 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5$ = 1.20 kn

Wr_t (transverse) = Wr* sin(α–3.1416/2) = 0.54 kn

dist. from base = (h_1)/(sin(180-α) = 3.07

Moment @ base (Mw_r)= 1.65 kn-m

Check if soil is active or passive:

$Mw_w + Mw_r + Mwat_1 + Mwat_2 + Mfw$ = 57.65 kn-m> $M_{qs}+M_{as}$

$M_{qs} + M_{as}$ 10.46 kn-m

therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :

$\rho_{min} = 1.4/fy$ = 0.005

conc. Cover = 50.00 mm

using 16 mm ϕ bar max. reinforcement:

d_{eff} = 142.00 mm

bar spacing, S_b= 278.04 mm

2. Shrinkage and Temperature bars (horizontal)

As_{st} = $0.002 * t_c * S_b$ (for fy = 275 mpa)

using 2-dia. 12 mm bars

As_{st} = 226.00 mm^2

for S_b = 565.00 mm use 300 mm

a.2 Secondary Reinforcements

2-ϕ12 mm @ 450 mm O.C.

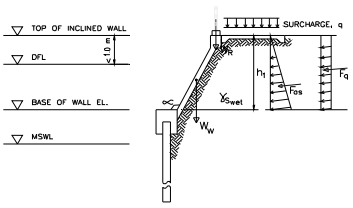
DESIGN OF INCLINED WALL (HEIGHT = 3.0 M)

A. Design Data:

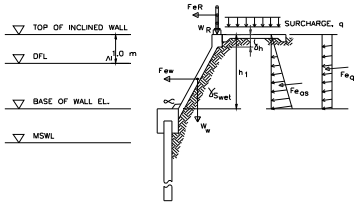
wall inclination (H:V);	0.50:1.00	
γ_s (wet):	18.00 kn/m^3	
h1:	3.000	
h_2:	3.000	
δ h:	0.00	
α :	116.56 deg	2.03 rad
ϕ (angle of soil internal friction):	30.00 deg	0.52 rad
δ (wall frictionangle):		
for normal (1/3*ϕ)	10.00 deg	0.17 rad
for earthquake	10.00 deg	0.17 rad
β (backfill slope):	0.00 deg	0.00 rad
t_c (thickness of wall)	0.20 m	
thickness of backfill; t_b	3.28 m	
surcharge (@ normal condition)	10.00 kpa	

Load Conditions;

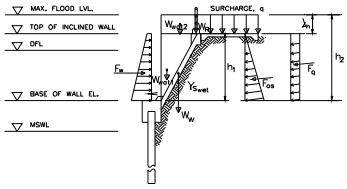
a. NORMAL CONDITION



b. EARTHQUAKE CONDITION



c. FLOOD CONDITION



B.1.1 Main Reinforcements (vertical)

a. Normal Condition 1

surcharge 10.00 kpa

Coulomb's Formula

$K_a = \sin^2(\alpha+\phi)/((\sin^2\alpha\ \sin(\alpha-\delta)\ (1 + \text{sqrt}\ (A))^2)$

where $A = (\sin(\phi+\delta)\ \sin(\phi-\beta))/(\sin(\alpha-\delta)\ \sin(\alpha+\beta))$

K_a = 0.15

Active forces on wall due to soil:

effective active soil pressure:

Length of full failure wedge from top wall; L_{ffw}= h/(tanϕ) -h/(tan(180-α)

= 3.70 m ~ 1.0

effectivity of active soil pressure; $e_{as} = t_b / L_{ffw} * FS$= 1.77 use 1.00

FS = 2.00

Force

$Fa_s = (1/2)\, K_a\, \gamma_{s(wet)}\, h^2\, e_{as}$ = 12.34 kn

Fa_{st} (transverse) = $Fa_s * \cos(\delta)$ = 12.15 kn

distance from base = (h/3)/sin(180-α) 1.12 m

Moment @ base (Ma_s) = 13.58 kn-m

Active force on wall due to surcharge:

$Fa_q = K_a\, q\, h\, e_{as}$ = 4.57 kn

Fa_{qt} (transverse) = $Fa_q * \cos(\delta)$ = 4.50 kn

distance from base = (h/2)/(sin(180-α) = 1.68

Moment @ base (M_{qs})= 7.55 kn-m

Forces from wall, rail

$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90) * t_w$ = 16.10 kn

t_w = 0.20 m

Ww_t (transverse) = Ww* sin(α–90) = 7.20 kn

dist. from base = (h_1/2)/(sin(180-α) = 1.68

Moment @ base (Mw_w)= 12.08 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = $Ww * \sin(\alpha - 90) =$ 0.54 kn
dist. from base = $(h_1)/(\sin(180-\alpha) =$ 3.35
Moment @ base (Mw_r)= 1.80 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r =$ 13.88 kn-m > M_{qs}
therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :
$\rho_{min} = 1.4/fy =$ 0.005
conc. Cover = 75.00 mm
using ϕ 20 mm bar max. reinforcement:
$d_{eff} =$ 117.00 mm
bar spacing, $S_b =$ 527.17 mm

b. Seismic Condition

surcharge: 5.00 kpa
$\theta_o =$ $\tan^{-1}(Kh/(1-Kv))$
Kh = 0.20
Kv ~ 0.00
$\theta_o =$ 0.20

$K_{ea} =$ $((\cos^2(\phi - \theta_o + (90-\alpha)))/\cos\theta_o \cos^2(90-\alpha)\cos(90-\alpha+\theta_o+\delta)(1+A^{0.5})^2)$
where $A = (\sin(\phi+\delta)\sin(\phi-\beta-\theta_o))/(\cos(90-\alpha+\theta_o+\delta)\cos(90-\alpha-\beta))$
A = 0.23
$K_{ea} =$ 0.29

From Whitman approximation:
$K_{ea} = K_{a+} + 0.75$ kh = 0.30
use $K_{ea} =$ 0.29
Active forces on wall due to soil:
Force
$Fea_s = (1/2) K_{ea} \gamma_{s(wet)} h^2 e_{as} =$ 23.43 kn
Fea_{st} (transverse) = $F_{as} * \cos(\delta) =$ 23.07 kn
distance from base = $(h/3)/\sin(180-\alpha) =$ 1.12 m
Moment @ base (Mea_s) = 25.80 kn-m

Active force on wall due to surcharge:
$Fa_{qs} = K_{ea} q_s h e_{as} =$ 4.34 kn
Fa_{qst} (transverse)= $Fa_{qs} * \cos(\delta) =$ 4.27 kn
distance from base = $(h/2)/(\sin(180-\alpha) =$ 1.68
Moment @ base (M_{qs})= 7.17 kn-m

Forces from wall, rail
$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90) * t_w =$ 16.10 kn
$t_w =$ 0.20 m
Ww_t (transverse) = $Ww * \sin(\alpha - 90) =$ 7.20 kn
dist. from base = $(h_1/2)/(\sin(180-\alpha) =$ 1.68
Moment @ base (Mw_w)= 12.08 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = $Wr * \sin(\alpha - 3.1416/2) =$ 0.54 kn
dist. from base = $(h_1)/(\sin(180-\alpha) =$ 3.35
Moment @ base (Mw_r)= 1.80 kn-m

$Fe_w =$ 0.20* $W_w =$ 3.22 kn
Fe_{wt} (transverse) = $Fe_w * \cos(\alpha - 90) =$ 2.88 kn
dist. from base = $(h_1/2)/(\sin(180-\alpha) =$ 1.68 m
Moment @ base (Me_w)= 4.83 kn-m

$Fe_r =$ 0.20* $W_r =$ 0.24 kn
Fe_{rt} (transverse) = $Fe_r * \cos(\alpha - 90) =$ 0.21 kn
dist. from base = $(h_1)/(\sin(180-\alpha) =$ 3.35 m
Moment @ base (Me_r)= 0.72 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r =$ 13.88 kn-m
$M_{qs} + M_{as} + Mfe_w + Mfe_r =$ 38.51 kn-m > $Mw_w + Mw_r$
therefore soil pressure is active and wall has stresses

Ultimate loads:
$Mu = 1.3*(1.67*M_{qs} + 1.3*M_{as} + 1.0*Mfe_w + 1.0*Mfe_r - 1.0*Mw_w - 1.0*Mw_r)$
Mu = 48.33 kn-m
$Vu = 1.3*(1.67*Fa_{qst} + 1.3*Fa_{qs} + 1.0*Fe_{wt} + 1.0*Fe_{rt} - 1.0*Ww_t - 1.0*Wr_t)$
Vu = 42.24 kn
using $t_c = 0.20$ m
conc. cover = 75.00 mm
using 16 dia. Mm reinf. Max.
$d_{eff} =$ 117.00 mm for top bar

check sufficiency of thickness against shear:
allowable shear, $V_u = \phi * 1/6 *$ sqrt (f'c) = 0.64 mpa
$v_u =$ Vu / (d_{eff} - 1000) = 0.36 mpa< 0.64 mpa okay

design of flexural reinforcement:
try ϕ 20 mm @ 125 o.c.
As/ meter strip: = 2512.00 mm^2
$\rho = As / (b * d_{eff}) =$ 0.021
$\rho_{min} =$ 0.002
$a = \rho * fy / (0.85 * fc') * d_{eff} =$ 39.32 mm
$Mu = 0.90 * As * fy * (d_{eff} - a/2)/1000^2$
= 60.52 kn-m > 48.33 kn-m
use ϕ 20 mm @ 125 o.c. @ base:

c. Flood Condition

surcharge: (from water) 0.00 kpa

$K_a =$ 0.15

Active forces on wall due to soil:
Force
$Fa_s = (1/2) K_a \gamma_{s(wet)} h^2 e_{as} =$ 12.34 kn
$Fa_{st} = F_{as} * \cos(\delta) =$ 12.15 kn (transverse to wall
distance from base = $(h/3)/\sin(180-\alpha)$ 1.12 m
Moment @ base (M_{as}) = 13.58 kn-m

Active force on wall due to surcharge:
$Fa_q = K_a q h e_{as} =$ 0.00 kn
$Fa_{qt} = Fa_q * \cos(\delta) =$ 0.00 kn
distance from base = $(h/2)/(\sin(180-\alpha) =$ 1.68
Moment @ base (M_{qs})= 0.00 kn-m

Hydraulic Forces
$W_{wat1} = (1/2) * \gamma_{water} * ((h1)^2)/2 =$ 22.07 kn
$Wwat1_t = W_w \sin(\alpha - 90 =$ 9.87 kn
dist. Fr. base = $(h_1/6)/\cos(180-\alpha) =$ 1.12 m
Moment @ base (Mw_{wat2}) = 11.04 kn-m

$W_{wat2} = \gamma_{water} * (h_1/2) * \delta_h =$ 0.00 kn
$Wwat2_t = W_w \sin(\alpha - 90 =$ 0.00 kn
dist. Fr. base = $(h_1/4)/\cos(180-\alpha) =$ 1.68 m
Moment @ base (Mw_{wat2}) = 0.00 kn-m

$F_{wat} = ((\delta_h + h2)/2) * \gamma_{water} * (h1) =$ 44.15 kn
$Ww_t = W_w \cos(\alpha - 90) =$ 39.48 kn
dist. Fr. base = $(h_1/3)(2*\delta_h + h_2)/(\delta_h + h_2)\sin(180-\alpha) =$
0.89 m
Moment @ base (Mf_{wat}) = 35.32 kn-m

Forces from wall, rail
$Ww = \gamma_{conc.} * h_1/(\cos(\alpha - 90) * t_w =$ 16.10 kn
$t_w =$ 0.20 m
Ww_t (transverse) = $Ww * \sin(\alpha - 90) =$ 7.20 kn
dist. from base = $(h_1/2)/(\sin(180-\alpha) =$ 3.35
Moment @ base (Mw_w)= 24.15 kn-m

$Wr = \gamma_{conc.} * 1.0 * 0.10 * 0.5 =$ 1.20 kn
Wr_t (transverse) = $Wr * \sin(\alpha - 3.1416/2) =$ 0.54 kn
dist. from base = $(h_1)/(\sin(180-\alpha) =$ 3.35
Moment @ base (Mw_r)= 1.80 kn-m

Check if soil is active or passive:
$Mw_w + Mw_r + Mwat_1 + Mwat_2 + Mfw =$ 72.30 kn-m> $M_{qs} + M_{as}$
$M_{qs} + M_{as}$ 13.58 kn-m
therefore soil pressure is passive and just support the weight of the wall; no stresses on the wall

provide minimum reinforcement :
$\rho_{min} = 1.4/fy =$ 0.005
conc. Cover = 50.00 mm
using ϕ 20 mm bar max. reinforcement:
$d_{eff} =$ 142.00 mm
bar spacing, $S_b =$ 434.36 mm

2. Shrinkage and Temperature bars (horizontal)
$As_{st} =$ 0.002* $t_c * S_b$ (for fy = 275 mpa)
using 2-dia. 12 mm bars
$As_{st} =$ 226.00 mm^2
for $S_b =$ 565.00 mm use 300 mm

a.2 Secondary Reinforcements
2-ϕ12 mm @ 450 mm O.C.

3.4 L-type Parapet Wall

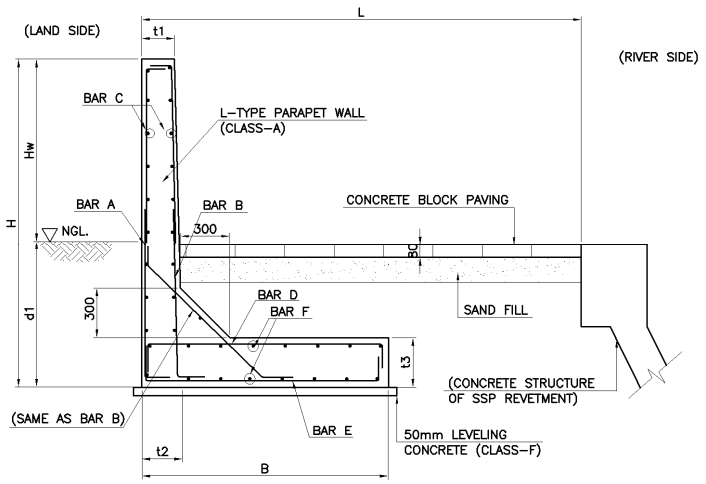


Figure 3.4.1 Typical Cross Section of L-type Parapet Wall

Table 3.4.1 Standard Dimensions of L-Type Parapet Wall

Hw Range (m)	B. base (m)	d1. Embankment (m)	t1 (m)	t2 (m)	t3 (m)	Reinforcement											
						BAR A		BAR B		BAR C		BAR D		BAR E		BAR F	
						Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)
0.00 ~ 0.50	1.00	0.50	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
0.51 ~ 1.00	1.35	0.50	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
1.01 ~ 1.10	1.50	0.50	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
1.11 ~ 1.20	1.65	0.50	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
1.21 ~ 1.30	1.87	0.50	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
1.31 ~ 1.40	1.90	0.50	0.20	0.20	0.20	12	250	16	250	12	300	16	250	12	250	12	300
1.41 ~ 1.50	2.05	0.50	0.20	0.20	0.20	12	250	16	250	12	300	16	250	12	250	12	300
1.51 ~ 1.60	2.20	0.50	0.20	0.20	0.20	12	250	16	250	12	300	16	250	12	250	12	300
1.61 ~ 1.70	2.35	0.50	0.20	0.20	0.20	12	250	12	125	12	300	12	125	12	250	12	300
1.71 ~ 1.80	2.45	0.50	0.20	0.20	0.20	12	250	20	250	12	300	20	250	12	250	12	300
1.81 ~ 1.90	2.60	0.50	0.20	0.20	0.20	12	250	20	250	12	300	20	250	12	250	12	300
1.91 ~ 2.00	2.75	0.50	0.20	0.20	0.20	12	250	16	125	12	300	16	125	12	250	12	300

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 0.00~0.50

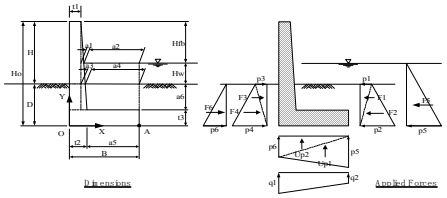
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	0.50	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	1.00	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	0.50	(m)		
Width of footing	B =	1.00	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	0.800	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	0.800	(m)
			a5=	0.800	(m)
			a6=	0.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.83 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.09

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 119 (kN/m)

Qa = 40 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.415 m

q1 = V/B*(1+6e/B)= 19.584 (kN/m2)

q2 = V/B*(1-6e/B) = 6.336 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.934 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-2.534	0.533	-1.352	
	1/2(q3)(a5)	-6.77	0.267	-1.806	
Total		-1.15		0.11	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.00~0.50

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.8	0.500	2.40	
Soil-1	1/2(a5)(a6)γs	2.16	0.733	1.58	
Soil-2	1/2(a4)(a6)γs	2.16	0.467	1.01	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		12.96	0.415	5.38	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 24.81 > 1.5 Safe !!

Overturning,

Mr_{max} = 6.91 (kN-m/m)

Mr_{act} = 5.49 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 60.62 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.02 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 0.00~0.50

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.900	3.46	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.800	0.00	
Footing	(B)(t3)γc	4.8	0.500	2.40	
Soil-1	1/2(a5)(a6)γs	2.16	0.267	0.58	
Soil-2	1/2(a4)(a6)γs	2.16	0.533	1.15	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		12.96	0.585	7.58	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 7.70 > 1.5 Safe !!

Overturning,

Mr_{max} = 9.11 (kN-m/m)

Mr_{act} = 7.95 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 18.46 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.17 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.85 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.08 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 122 (kN/m)

Qa = 41 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.425 m

q1 = V/B*(1-6e/B)= 18.825 (kN/m2)

q2 = V/B*(1+6e/B) = 7.095 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.479 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-2.838	0.533	-1.514	
	1/2(q3)(a5)	-6.59	0.267	-1.758	
Total		-1.27		-0.01	

4. Case 3 : Flood condition-1

Height of wall, Hw= 0.00~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.8	0.500	2.40	
Soil-1	1/2(a5)(a6)γsat	2.40	0.733	1.76	
Soil-2	1/2(a4)(a6)γsat	2.40	0.467	1.12	
Water-1	1/2(a4)(Hw)γw	1.96	0.733	1.44	
Water-2	1/2(a2)(Hw)γw	1.96	0.467	0.91	
Sub-Total		17.36	0.462	8.02	
Uplift-1	-1/2B(D+Hw)γw	-4.90	0.667	-3.27	
Uplift-2	-1/2B(D)γw	-2.45	0.333	-0.82	
Sub-Total		-7.35		-4.08	
Total		10.01		3.93	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	4.90	0.33	1.63	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		5.28		1.70	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		5.28		1.05	

(3) Stability

Sliding,

V = 10.01 (kN/m)

H = 5.28 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 5.28 (kN/m)

SF =(V*f +HR_{max})/ H = 2.34 > 1.0 Safe !!

Overturning,

Mr_{max} = 9.07 (kN-m/m)

Mr = 9.07 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 5.78 (kN-m/m)

SF = Mr_{max}/M_o = 1.57 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.171 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.66 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.171 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 90 (kN/m)

Qa = 45.0 (kN/m) > V = 10.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.329 m

q1 = (2V)/3X = 20.302 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 16.185 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		7.84	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	3.14	0.27	0.84	Water pressure
Total		3.27		0.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	3.92	0.40	1.57	
Soil	γsat(a6)(a5)	4.80	0.40	1.92	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Uplift	-1/2(p5)(a5)	-3.92	0.53	-2.091	
	-1/2(p7)(a5)	-2.352	0.27	-0.627	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.361	0.262	-1.667	
Total		-0.07		0.64	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 0.00~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.8	0.500	2.40	
Soil-1	1/2(a5)(a6)γsat	2.40	0.733	1.76	
Soil-2	1/2(a4)(a6)γsat	2.40	0.467	1.12	
Water-1	1/2(a4)(Hw)γw	1.18	0.733	0.86	
Water-2	1/2(a2)(Hw)γw	1.18	0.467	0.55	
Sub-Total		15.79	0.448	7.08	
Uplift-1	-1/2B(D+Hw)γw	-2.45	0.667	-1.63	
Uplift-2	-1/2B(D)γw	-4.90	0.333	-1.63	
Sub-Total		-7.35		-3.27	
Total		8.44		3.81	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.33	0.41	Active force
F6	1/2γw(D)^2	4.90	0.17	0.82	Resisting force
Total of active forces		1.60		0.47	
Total of maximum resisting forces		10.00		1.67	
Actual resisting forces		1.60		0.47	

(3) Stability

Sliding,

V = 8.44 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 10.00 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f +HR_{max})/ H = 9.39 > 1.0 Safe !!

Overturning,

Mr_{max} = 8.74 (kN-m/m)

Mr = 7.55 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 3.74 (kN-m/m)

SF = Mr_{max}/M_o = 2.34 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.171 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.66 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.171 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 90 (kN/m)

Qa = 45.0 (kN/m) > V = 8.44 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.329 m

q1 = (2V)/3X = 17.122 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 13.649 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		7.84	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	3.14	0.27	0.84	Water pressure
Total		3.27		0.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	3.92	0.40	1.57	
Soil	γsat(a6)(a5)	4.80	0.40	1.92	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Uplift	-1/2(p5)(a5)	-3.92	0.53	-2.091	
	-1/2(p7)(a5)	-2.352	0.27	-0.627	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.365	0.262	-1.406	
Total		0.92		0.90	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 0.00~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	0.600	2.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.467	0.00
Footing	(B)(t3)γc	4.8	0.500	2.40	0.100	0.48
Soil-1	1/2(a5)(a6)γs	2.16	0.733	1.58	0.300	0.65
Soil-2	1/2(a4)(a6)γs	2.16	0.467	1.01	0.400	0.86
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		12.96	0.415	5.38	0.331	4.30

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.59	0.33	0.86	Seismic force
Total of active forces		3.60		1.03	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		3.60		1.03	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 3.60 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 3.60 (kN/m)

SF =(V*f+ HR_{max})/ H = 4.32 > 1.2 Safe !!

Overturning,

Mr_{max} = 6.67 (kN-m/m)

Mr_{act} = 6.40 (kN-m/m)

Mo = 1.03 (kN-m/m)

d = (Mr-Mo)/V = 0.41 (m)

SF =M_{max}/ M_{act} = 6.49 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.06 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.83 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.09 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 119 (kN/m)

Qa = 59 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.415 m

q1 = V/B*(1+6e/B)= 19.584 (kN/m2)

q2 = V/B*(1-6e/B) = 6.336 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.934 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.77	0.40	0.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.27	0.00	Seismic force
Total		1.13		0.34	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-2.5344	0.5333333	-1.352	
	1/2(q3)(a5)	-6.774	0.267	-1.806	
Total		-1.15		0.11	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 0.00~0.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.900	3.46	0.600	2.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.800	0.00	0.467	0.00
Footing	(B)(t3)γc	4.8	0.500	2.40	0.100	0.48
Soil-1	1/2(a5)(a6)γs	2.16	0.267	0.58	0.300	0.65
Soil-2	1/2(a4)(a6)γs	2.16	0.533	1.15	0.400	0.86
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		12.96	0.585	7.58	0.331	4.30

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.59	0.33	0.86	Seismic force
Total of active forces		4.72		1.31	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		4.72		1.29	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 4.72 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 4.72 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.29 > 1.2 Safe !!

Overturning,

Mr_{max} = 8.88 (kN-m/m)

Mr_{act} = 8.88 (kN-m/m)

Mo = 1.31 (kN-m/m)

d = (Mr-Mo)/V = 0.58 (m)

SF =Mr_{max}/ M_o = 6.79 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.084 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.832 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.084 m

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 119 (kN/m)

Qa = 59 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.500

q1 = V/B*(1-6e/B)= 19.498 (kN/m2)

q2 = V/B*(1+6e/B) = 6.422 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.883 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.77	0.40	0.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.27	0.00	Seismic force
Total		1.80		0.44	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-2.569	0.533	-1.370	
	1/2(q3)(a5)	-6.753	0.267	-1.801	
Total		-1.16		0.09	

8. Case 7 : Wind condition 1

Height of wall, Hw= 0.00~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	4.8	0.500	2.40
Soil-1	1/2(a5)(a6)γs	2.16	0.733	1.58
Soil-2	1/2(a4)(a6)γs	2.16	0.467	1.01
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		12.96	0.415	5.38

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.05	0.75	0.79	Wind force
Total of active forces		1.74		0.90	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		1.74		0.90	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 1.74 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 1.74 (kN/m)

SF =(V*f + HR_{max})/ H = 9.76 > 1.2 Safe !!

Overturning,

Mr_{max}= 6.91 (kN-m/m)

Mr_{act}= 6.28 (kN-m/m)

Mo = 0.90 (kN-m/m)

d = (Mr-Mo)/V = 0.41 (m)

SF =Mr_{max}/ M_o = 7.64 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.037 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.830 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.085 (m)

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 119 (kN/m)

Qa = 59 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.415 m

q1 = V/B*(1+6e/B)= 19.584 (kN/m2)

q2 = V/B*(1-6e/B) = 6.336 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.934 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		1.05	0.55	0.58	
Total		1.30		0.60	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-2.534	0.533	-1.352	
	1/2(q3)(a5)	-6.77	0.267	-1.806	
Total		-1.15		0.11	

9. Case 8 : Wind condition 2

Height of wall, Hw= 0.00~0.50

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.900	3.46
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.800	0.00
Footing	(B)(t3)γc	4.8	0.500	2.40
Soil-1	1/2(a5)(a6)γs	2.16	0.267	0.58
Soil-2	1/2(a4)(a6)γs	2.16	0.533	1.15
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		12.96	0.585	7.58

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.05	0.75	0.79	Wind force
Total of active forces		3.26		1.28	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.26		0.54	

(3) Stability

Sliding,

V = 12.96 (kN/m)

H = 3.26 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.26 (kN/m)

SF =(V*f + HR_{max})/ H = 5.21 > 1.2 Safe !!

Overturning,

Mr_{max} = 9.11 (kN-m/m)

Mr_{act} = 8.13 (kN-m/m)

Mo = 1.28 (kN-m/m)

d = (Mr-Mo)/V = 0.53 (m)

SF =Mr_{max}/ M_o = 7.10 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.104 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.944 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.028 (m)

α = 1.0

k = 1+0.3*D/B = 1.15

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 139 (kN/m)

Qa = 69 (kN/m) > V = 12.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.472 m

q1 = V/B*(1-6e/B)= 15.139 (kN/m2)

q2 = V/B*(1+6e/B) = 10.781 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 14.267 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		1.05	0.55	0.58	
Total		2.21		0.74	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.40	1.73	
Footing	γc(t3)(a5)	3.84	0.40	1.54	
Reaction	1/2(q2)(a5)	-4.312	0.533	-2.300	
	1/2(q3)(a5)	-5.71	0.267	-1.522	
Total		-1.86		-0.56	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	0.56	3.27	0.27	9.19	0.02
Footing	**Top bar**	0.64	1.40	0.31	10.56	0.01

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(pn)^2+2pn$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	9.19			10.56	
fc (concrete)	0.27			0.31	
v (shear)	0.02			0.01	
u (bond)	0.16			0.07	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 0.00~0.50

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	24.81	1.5	0.02	0.17	13.0	40
Normal-2	7.70	1.5	0.17	0.17	13.0	41
Flood-1	2.34	1	0.17	0.33	10.0	45
Flood-2	9.39	1	0.17	0.33	8.4	45
Seismic-1	4.32	1.2	0.06	0.33	13.0	59
Seismic-2	3.29	1.2	0.08	0.33	13.0	59
Wind-1	9.76	1.2	0.037	0.33	12.96	59
Wind-2	5.21	1.2	0.104	0.33	12.96	69

11. Design of RC members

(1) Design Criteria

Concrete strength		fc' =	20.7 (MPa)
Steel strength		fy =	275 (MPa)
Modular ratio		n=Es/Ec=	9
Allowable stress :			
Fiber stress in flexural compress.	0.40fc'		8.28 (MPa)
Shear stress	0.079√fc'		0.36 (MPa)
Tensile stress in reinforcement			140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.11	-1.15	
Normal-2		0.16	1.16	-0.01	-1.27	
Flood		0.85	3.27	0.64	-0.07	
Seismic-1	*	0.26	0.85	0.08	-0.86	*: divided by 1.33
Seismic-2	*	0.33	1.35	0.07	-0.87	*: divided by 1.33
Wind-1	*	0.45	0.98	0.08	-0.86	*: divided by 1.33
Wind-2	*	0.56	1.66	-0.42	-1.40	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	0.85	3.27	0.42	14.04	0.02
Footing	**Bot bar**	0.42	1.40	0.28	8.44	0.01

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(pn)^2+2pn$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	14.04			8.44	
fc (concrete)	0.42			0.28	
v (shear)	0.02			0.01	
u (bond)	0.16			0.08	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 0.50~1.00

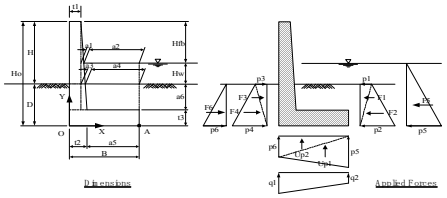
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.00	(m)
Embedment of wall	D =	0.50	(m)
Total height of wall	Ho=	1.50	(m)
Freeboard	Hfb=	1.00	(m)
Water depth under flood condition	Hw=	1.00	(m)
Width of footing	B =	1.35	(m)
Thickness of wall members :			
t1= 0.20 (m)		a1=	0.000 (m)
t2= 0.20 (m)		a2=	1.150 (m)
t3= 0.20 (m)		a3=	0.000 (m)
		a4=	1.150 (m)
		a5=	1.150 (m)
		a6=	0.300 (m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.04 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.16

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 152 (kN/m)

Qa = 51 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.518 m

q1 = V/B*(1+6e/B)= 23.790 (kN/m2)

q2 = V/B*(1-6e/B) = 4.254 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.896 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-2.446	0.767	-1.875	
	1/2(q3)(a5)	-12.02	0.383	-4.606	
Total		-2.73		0.26	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.50~1.00

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	6.48	0.675	4.37	
Soil-1	1/2(a5)(a6)γs	3.105	0.967	3.00	
Soil-2	1/2(a4)(a6)γs	3.11	0.583	1.81	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		18.93	0.518	9.81	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 30.05 > 1.5 Safe !!

Overturning,

Mr_{max} = 11.34 (kN-m/m)

Mr_{act} = 9.92 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 99.55 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.08 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 0.50~1.00

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	1.250	7.80	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.150	0.00	
Footing	(B)(t3)γc	6.48	0.675	4.37	
Soil-1	1/2(a5)(a6)γs	3.105	0.383	1.19	
Soil-2	1/2(a4)(a6)γs	3.11	0.767	2.38	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		18.93	0.832	15.74	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 9.33 > 1.5 Safe !!

Overturning,

Mr_{max} = 17.27 (kN-m/m)

Mr_{act} = 16.11 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 34.99 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.21 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.05 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.15 m

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 154 (kN/m)

Qa = 51 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.525 m

q1 = V/B*(1-6e/B)= 23.373 (kN/m2)

q2 = V/B*(1+6e/B) = 4.671 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.603 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-2.686	0.767	-2.059	
	1/2(q3)(a5)	-11.85	0.383	-4.541	
Total		-2.80		0.14	

4. Case 3 : Flood condition-1

Height of wall, Hw= 0.50~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	6.48	0.675	4.37	
Soil-1	1/2(a5)(a6)γsat	3.45	0.967	3.34	
Soil-2	1/2(a4)(a6)γsat	3.45	0.583	2.01	
Water-1	1/2(a4)(Hw)γw	5.64	0.967	5.45	
Water-2	1/2(a2)(Hw)γw	5.64	0.583	3.29	
Sub-Total		30.89	0.618	19.08	
Uplift-1	-1/2B(D+Hw)γw	-9.92	0.900	-8.93	
Uplift-2	-1/2B(D)γw	-3.31	0.450	-1.49	
Sub-Total		-13.23		-10.42	
Total		17.66		8.66	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	11.03	0.50	5.51	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		11.40		5.58	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 17.66 (kN/m)

H = 11.40 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.48 > 1.0 Safe !!

Overturning,

Mr_{max} = 20.13 (kN-m/m)

Mr = 20.13 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 15.99 (kN-m/m)

SF = Mr_{max}/M_o = 1.26 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.441 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.47 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.441 m

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.288

= 59 (kN/m)

Qa = 29.6 (kN/m) > V = 17.66 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.234 m

q1 = (2V)/3X = 50.227 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 35.942 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		12.74	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	8.28	0.43	3.59	Water pressure
Total		8.42		3.60	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	11.27	0.58	6.48	
Soil	γsat(a6)(a5)	6.90	0.58	3.97	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Uplift	-1/2(p5)(a5)	-8.45	0.77	-6.480	
	-1/2(p7)(a5)	-3.652	0.38	-1.400	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-9.043	0.168	-1.517	
Total		2.54		4.22	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 0.50~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	6.48	0.675	4.37	
Soil-1	1/2(a5)(a6)γsat	3.45	0.967	3.34	
Soil-2	1/2(a4)(a6)γsat	3.45	0.583	2.01	
Water-1	1/2(a4)(Hw)γw	1.69	0.967	1.63	
Water-2	1/2(a2)(Hw)γw	1.69	0.583	0.99	
Sub-Total		23.00	0.564	12.97	
Uplift-1	-1/2B(D+Hw)γw	-3.31	0.900	-2.98	
Uplift-2	-1/2B(D)γw	-9.92	0.450	-4.47	
Sub-Total		-13.23		-7.44	
Total		9.77		5.52	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.50	0.61	Active force
F6	1/2γw(D)^2	11.03	0.17	1.84	Resisting force
Total of active forces		1.60		0.68	
Total of maximum resisting forces		16.13		2.69	
Actual resisting forces		1.60		0.68	

(3) Stability

Sliding,

V = 9.77 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 16.13 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 13.70 > 1.0 Safe !!

Overturning,

Mr_{max} = 15.65 (kN-m/m)

Mr = 13.64 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 8.12 (kN-m/m)

SF = Mr_{max}/M_o = 1.93 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.441 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.47 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.441 m

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 59 (kN/m)

Qa = 29.6 (kN/m) > V = 9.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.234 m

q1 = (2V)/3X = 27.790 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 19.886 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		12.74	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	8.28	0.43	3.59	Water pressure
Total		8.42		3.60	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Water	γw(Hw)(a5)	11.27	0.58	6.48	
Soil	γsat(a6)(a5)	6.90	0.58	3.97	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Uplift	-1/2(p5)(a5)	-8.45	0.77	-6.480	
	-1/2(p7)(a5)	-3.652	0.38	-1.400	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.003	0.168	-0.839	
Total		6.58		4.90	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 0.50~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	0.850	5.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.633	0.00
Footing	(B)(t3)γc	6.48	0.675	4.37	0.100	0.65
Soil-1	1/2(a5)(a6)γs	3.105	0.967	3.00	0.300	0.93
Soil-2	1/2(a4)(a6)γs	3.11	0.583	1.81	0.400	1.24
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		18.93	0.518	9.81	0.429	8.13

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.79	0.43	1.63	Seismic force
Total of active forces		4.79		1.79	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		4.79		1.29	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 4.79 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 4.79 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.99 > 1.2 Safe !!

Overturning,

Mr_{max} = 11.10 (kN-m/m)

Mr_{act} = 11.10 (kN-m/m)

Mo = 1.79 (kN-m/m)

d = (Mr-Mo)/V = 0.49 (m)

SF =M_{max}/ M_{act} = 6.19 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.18 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.98 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.18 m

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 142 (kN/m)

Qa = 71 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.492 m

q1 = V/B*(1+6e/B)= 25.438 (kN/m2)

q2 = V/B*(1-6e/B) = 2.606 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.056 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.43	0.00	Seismic force
Total		1.61		0.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-1.498726	0.7666667	-1.149	
	1/2(q3)(a5)	-12.682	0.383	-4.861	
Total		-2.45		0.73	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 0.50~1.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	1.250	7.80	0.850	5.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.150	0.00	0.633	0.00
Footing	(B)(t3)γc	6.48	0.675	4.37	0.100	0.65
Soil-1	1/2(a5)(a6)γs	3.105	0.383	1.19	0.300	0.93
Soil-2	1/2(a4)(a6)γs	3.11	0.767	2.38	0.400	1.24
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		18.93	0.832	15.74	0.429	8.13

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.79	0.43	1.63	Seismic force
Total of active forces		5.91		2.07	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		5.91		1.29	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 5.91 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 5.91 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.23 > 1.2 Safe !!

Overturning,

Mr_{max} = 17.04 (kN-m/m)

Mr_{act} = 17.04 (kN-m/m)

Mo = 2.07 (kN-m/m)

d = (Mr-Mo)/V = 0.79 (m)

SF =Mr_{max}/ M_o = 8.22 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.116 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.119 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.116 m

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 167 (kN/m)

Qa = 83 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.675

q1 = V/B*(1-6e/B)= 21.221 (kN/m2)

q2 = V/B*(1+6e/B) = 6.823 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.088 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.43	0.00	Seismic force
Total		2.28		0.95	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-3.923	0.767	-3.008	
	1/2(q3)(a5)	-10.976	0.383	-4.207	
Total		-3.17		-0.47	

8. Case 7 : Wind condition 1

Height of wall, Hw= 0.50~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	6.48	0.675	4.37
Soil-1	1/2(a5)(a6)γs	3.105	0.967	3.00
Soil-2	1/2(a4)(a6)γs	3.11	0.583	1.81
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		18.93	0.518	9.81

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.11	1.00	2.11	Wind force
Total of active forces		2.79		2.22	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.79		1.53	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 2.79 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.79 (kN/m)

SF =(V*f + HR_{max})/ H = 7.36 > 1.2 Safe !!

Overturning,

Mr_{max}= 11.34 (kN-m/m)

Mr_{act}= 11.34 (kN-m/m)

Mo = 2.22 (kN-m/m)

d = (Mr-Mo)/V = 0.48 (m)

SF =Mr_{max}/ M_o = 5.11 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.193 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.964 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.193 (m)

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 139 (kN/m)

Qa = 69 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.482 m

q1 = V/B*(1+6e/B)= 26.061 (kN/m2)

q2 = V/B*(1-6e/B) = 1.983 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.494 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		2.11	0.80	1.68	
Total		2.35		1.71	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-1.140	0.767	-0.874	
	1/2(q3)(a5)	-12.93	0.383	-4.958	
Total		-2.34		0.91	

9. Case 8 : Wind condition 2

Height of wall, Hw= 0.50~1.00

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	1.250	7.80
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.150	0.00
Footing	(B)(t3)γc	6.48	0.675	4.37
Soil-1	1/2(a5)(a6)γs	3.105	0.383	1.19
Soil-2	1/2(a4)(a6)γs	3.11	0.767	2.38
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		18.93	0.832	15.74

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.11	1.00	2.11	Wind force
Total of active forces		4.31		2.60	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.31		0.72	

(3) Stability

Sliding,

V = 18.93 (kN/m)

H = 4.31 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.31 (kN/m)

SF =(V*f + HR_{max})/ H = 4.77 > 1.2 Safe !!

Overturning,

Mr_{max} = 17.27 (kN-m/m)

Mr_{act} = 16.46 (kN-m/m)

Mo = 2.60 (kN-m/m)

d = (Mr-Mo)/V = 0.73 (m)

SF =Mr_{max}/ M_o = 6.65 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.100 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.235 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.057 (m)

α = 1.0

k = 1+0.3*D/B = 1.1111111

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 189 (kN/m)

Qa = 95 (kN/m) > V = 18.93 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.618 m

q1 = V/B*(1-6e/B)= 17.596 (kN/m2)

q2 = V/B*(1+6e/B) = 10.449 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.537 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		2.11	0.80	1.68	
Total		3.26		1.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	6.21	0.58	3.57	
Footing	γc(t3)(a5)	5.52	0.58	3.17	
Reaction	1/2(q2)(a5)	-6.008	0.767	-4.606	
	1/2(q3)(a5)	-9.51	0.383	-3.645	
Total		-3.79		-1.51	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	1.39	8.42	0.68	22.92	0.06
Footing	**Top bar**	4.22	2.85	2.08	69.76	0.02

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d' $\sqrt{}$	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(pn)^2+2pn$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	22.92			69.76	
fc (concrete)	0.68			2.08	
v (shear)	0.06			0.02	
u (bond)	0.42			0.14	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 0.50~1.00

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	30.05	1.5	0.08	0.23	18.9	51
Normal-2	9.33	1.5	0.21	0.23	18.9	51
Flood-1	1.48	1	0.44	0.45	17.7	30
Flood-2	13.70	1	0.44	0.45	9.8	30
Seismic-1	3.99	1.2	0.18	0.45	18.9	71
Seismic-2	3.23	1.2	0.12	0.45	18.9	83
Wind-1	7.36	1.2	0.193	0.45	18.93	69
Wind-2	4.77	1.2	0.100	0.45	18.93	95

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{}$fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.26	-2.73	
Normal-2		0.16	1.16	0.14	-2.80	
Flood		3.60	8.42	4.22	2.54	
Seismic-1	*	0.64	1.21	0.55	-1.84	*: divided by 1.33
Seismic-2	*	0.71	1.72	-0.35	-2.38	*: divided by 1.33
Wind-1	*	1.29	1.77	0.69	-1.76	*: divided by 1.33
Wind-2	*	1.39	2.45	-1.13	-2.85	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	3.60	8.42	1.77	59.48	0.06
Footing	**Bot bar**	1.13	2.85	0.75	22.78	0.02

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d' $\sqrt{}$	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(pn)^2+2pn$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	59.48			22.78	
fc (concrete)	1.77			0.75	
v (shear)	0.06			0.02	
u (bond)	0.42			0.17	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.00~1.10

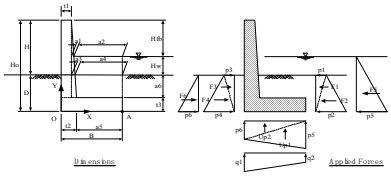
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	φ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.10	(m)
Embedment of wall	D =	0.50	(m)
Total height of wall	Ho=	1.60	(m)
Freeboard	Hfb=	1.00	(m)
Water depth under flood condition	Hw=	1.10	(m)
Width of footing	B =	1.50	(m)
Thickness of wall members :			
t1= 0.20 (m)		a1=	0.000 (m)
t2= 0.20 (m)		a2=	1.300 (m)
t3= 0.20 (m)		a3=	0.000 (m)
		a4=	1.300 (m)
		a5=	1.300 (m)
		a6=	0.300 (m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.15 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.18

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 171 (kN/m)

Qa = 57 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.575 m

q1 = V/B*(1+6e/B)= 23.736 (kN/m2)

q2 = V/B*(1-6e/B) = 4.184 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.129 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-2.720	0.867	-2.357	
	1/2(q3)(a5)	-13.73	0.433	-5.951	
Total		-3.19		0.31	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.00~1.10

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.2	0.750	5.40	
Soil-1	1/2(a5)(a6)γs	3.51	1.067	3.74	
Soil-2	1/2(a4)(a6)γs	3.51	0.633	2.22	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		20.94	0.575	12.04	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f+ HR_{max})/ H = 31.81 > 1.5 Safe !!

Overturning,

Mr_{max} = 13.57 (kN-m/m)

Mr_{act} = 12.15 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 119.11 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.11 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.00~1.10

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	1.400	9.41	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.300	0.00	
Footing	(B)(t3)γc	7.2	0.750	5.40	
Soil-1	1/2(a5)(a6)γs	3.51	0.433	1.52	
Soil-2	1/2(a4)(a6)γs	3.51	0.867	3.04	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		20.94	0.925	19.37	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f+ HR_{max})/ H = 9.87 > 1.5 Safe !!

Overturning,

Mr_{max} = 20.90 (kN-m/m)

Mr_{act} = 19.74 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 42.34 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.22 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k ys D Nq + 1/2 ys' βBe Nr)

Be = B - 2 e = 1.16 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.17 m

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 174 (kN/m)

Qa = 58 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.581 m

q1 = V/B*(1-6e/B)= 23.398 (kN/m2)

q2 = V/B*(1+6e/B) = 4.522 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.882 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-2.939	0.867	-2.547	
	1/2(q3)(a5)	-13.57	0.433	-5.882	
Total		-3.25		0.19	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.2	0.750	5.40	
Soil-1	1/2(a5)(a6)γsat	3.90	1.067	4.16	
Soil-2	1/2(a4)(a6)γsat	3.90	0.633	2.47	
Water-1	1/2(a4)(Hw)γw	7.01	1.067	7.47	
Water-2	1/2(a2)(Hw)γw	7.01	0.633	4.44	
Sub-Total		35.73	0.689	24.61	
Uplift-1	-1/2B(D+Hw)γw	-11.76	1.000	-11.76	
Uplift-2	-1/2B(D)γw	-3.68	0.500	-1.84	
Sub-Total		-15.44		-13.60	
Total		20.30		11.02	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	12.54	0.53	6.69	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		12.92		6.75	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 20.30 (kN/m)

H = 12.92 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.43 > 1.0 Safe !!

Overturning,

Mr_{max} = 25.67 (kN-m/m)

Mr = 25.67 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 20.35 (kN-m/m)

SF = Mr_{max}/M_o = 1.26 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.488 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k ys D Nq + 1/2 ys' βBe Nr)

where,

Be = B - 2 e = 0.52 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.488 m

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.325

= 67 (kN/m)

Qa = 33.3 (kN/m) > V = 20.30 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.262 m

q1 = (2V)/3X = 51.662 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 38.514 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		13.72	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	9.60	0.47	4.48	Water pressure
Total		9.74		4.50	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	14.01	0.65	9.11	
Soil	γsat(a6)(a5)	7.80	0.65	5.07	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Uplift	-1/2(p5)(a5)	-10.19	0.87	-8.833	
	-1/2(p7)(a5)	-4.119	0.43	-1.785	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-11.281	0.195	-2.203	
Total		2.46		5.41	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.2	0.750	5.40	
Soil-1	1/2(a5)(a6)γsat	3.90	1.067	4.16	
Soil-2	1/2(a4)(a6)γsat	3.90	0.633	2.47	
Water-1	1/2(a4)(Hw)γw	1.91	1.067	2.04	
Water-2	1/2(a2)(Hw)γw	1.91	0.633	1.21	
Sub-Total		25.54	0.624	15.95	
Uplift-1	-1/2B(D+Hw)γw	-3.68	1.000	-3.68	
Uplift-2	-1/2B(D)γw	-11.76	0.500	-5.88	
Sub-Total		-15.44		-9.56	
Total		10.11		6.40	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.53	0.65	Active force
F6	1/2γw(D)^2	12.54	0.17	2.09	Resisting force
Total of active forces		1.60		0.72	
Total of maximum resisting forces		17.64		2.94	
Actual resisting forces		1.60		0.72	

(3) Stability

Sliding,

V = 10.11 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 17.64 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 14.77 > 1.0 Safe !!

Overturning,

Mr_{max} = 18.89 (kN-m/m)

Mr = 16.67 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 10.27 (kN-m/m)

SF = Mr_{max}/M_o = 1.84 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.488 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.52 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.488 m

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 67 (kN/m)

Qa = 33.3 (kN/m) > V = 10.11 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.262 m

q1 = (2V)/3X = 25.723 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 19.176 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		13.72	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	9.60	0.47	4.48	Water pressure
Total		9.74		4.50	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	14.01	0.65	9.11	
Soil	γsat(a6)(a5)	7.80	0.65	5.07	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Uplift	-1/2(p5)(a5)	-10.19	0.87	-8.833	
	-1/2(p7)(a5)	-4.119	0.43	-1.785	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.617	0.195	-1.097	
Total		8.13		6.52	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	0.900	6.05
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.667	0.00
Footing	(B)(t3)γc	7.2	0.750	5.40	0.100	0.72
Soil-1	1/2(a5)(a6)γs	3.51	1.067	3.74	0.300	1.05
Soil-2	1/2(a4)(a6)γs	3.51	0.633	2.22	0.400	1.40
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		20.94	0.575	12.04	0.441	9.23

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.19	0.44	1.85	Seismic force
Total of active forces		5.19		2.01	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		5.19		1.29	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 5.19 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 5.19 (kN/m)

SF =(V*f'+ HR_{max})/ H = 3.91 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.33 (kN-m/m)

Mr_{act} = 13.33 (kN-m/m)

Mo = 2.01 (kN-m/m)

d = (Mr-Mo)/V = 0.54 (m)

SF =M_{max}/ M_{act} = 6.62 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.21 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.08 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.21 m

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 159 (kN/m)

Qa = 79 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.541 m

q1 = V/B*(1+6e/B)= 25.657 (kN/m2)

q2 = V/B*(1-6e/B) = 2.263 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.538 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.34	0.70	0.94	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.47	0.00	Seismic force
Total		1.71		0.98	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-1.47085	0.8666667	-1.275	
	1/2(q3)(a5)	-14.650	0.433	-6.348	
Total		-2.86		1.00	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	1.400	9.41	0.900	6.05
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.300	0.00	0.667	0.00
Footing	(B)(t3)γc	7.2	0.750	5.40	0.100	0.72
Soil-1	1/2(a5)(a6)γs	3.51	0.433	1.52	0.300	1.05
Soil-2	1/2(a4)(a6)γs	3.51	0.867	3.04	0.400	1.40
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		20.94	0.925	19.37	0.441	9.23

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.19	0.44	1.85	Seismic force
Total of active forces		6.31		2.29	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		6.31		1.29	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 6.31 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 6.31 (kN/m)

SF =(V*f'+ HR_{max})/ H = 3.22 > 1.2 Safe !!

Overturning,

Mr_{max} = 20.66 (kN-m/m)

Mr_{act} = 20.66 (kN-m/m)

Mo = 2.29 (kN-m/m)

d = (Mr-Mo)/V = 0.88 (m)

SF =Mr_{max}/ M_o = 9.01 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.127 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.245 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.127 m

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 190 (kN/m)

Qa = 95 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.750

q1 = V/B*(1-6e/B)= 21.069 (kN/m2)

q2 = V/B*(1+6e/B) = 6.851 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.173 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.34	0.70	0.94	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.47	0.00	Seismic force
Total		2.38		1.08	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-4.453	0.867	-3.859	
	1/2(q3)(a5)	-12.463	0.433	-5.400	
Total		-3.66		-0.64	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	7.2	0.750	5.40
Soil-1	1/2(a5)(a6)γs	3.51	1.067	3.74
Soil-2	1/2(a4)(a6)γs	3.51	0.633	2.22
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		20.94	0.575	12.04

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.32	1.05	2.43	Wind force
Total of active forces		3.00		2.55	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.00		1.53	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 3.00 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.00 (kN/m)

SF =(V*f'+ HR_{max})/ H = 7.25 > 1.2 Safe !!

Overturning,

Mr_{max}= 13.57 (kN-m/m)

Mr_{act}= 13.57 (kN-m/m)

Mo = 2.55 (kN-m/m)

d = (Mr-Mo)/V = 0.53 (m)

SF =Mr_{max}/ M_o = 5.33 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.224 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.053 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.224 (m)

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 153 (kN/m)

Qa = 77 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.526 m

q1 = V/B*(1+6e/B)= 26.446 (kN/m2)

q2 = V/B*(1-6e/B) = 1.474 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.116 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		2.32	0.85	1.97	
Total		2.56		1.99	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-0.958	0.867	-0.830	
	1/2(q3)(a5)	-15.03	0.433	-6.511	
Total		-2.72		1.28	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.00~1.10

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	1.400	9.41
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.300	0.00
Footing	(B)(t3)γc	7.2	0.750	5.40
Soil-1	1/2(a5)(a6)γs	3.51	0.433	1.52
Soil-2	1/2(a4)(a6)γs	3.51	0.867	3.04
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		20.94	0.925	19.37

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.32	1.05	2.43	Wind force
Total of active forces		4.52		2.93	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.52		0.75	

(3) Stability

Sliding,

V = 20.94 (kN/m)

H = 4.52 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.52 (kN/m)

SF =(V*f'+ HR_{max})/ H = 4.81 > 1.2 Safe !!

Overturning,

Mr_{max} = 20.90 (kN-m/m)

Mr_{act} = 20.12 (kN-m/m)

Mo = 2.93 (kN-m/m)

d = (Mr-Mo)/V = 0.82 (m)

SF =Mr_{max}/ M_o = 7.14 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.108 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k ys D Nq + 1/2 ys' βBe Nr)

where,

Be = B - 2 e = 1.357 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.071 (m)

α = 1.0

k = 1+0.3*D/B = 1.1

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H\text{-}HR_{act}$)/V = 0.000 minimum

= 212 (kN/m)

Qa = 106 (kN/m) > V = 20.94 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.679 m

q1 = V/B*(1-6e/B)= 17.942 (kN/m2)

q2 = V/B*(1+6e/B) = 9.978 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.880 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s I H		2.32	0.85	1.97	
Total		3.47		2.13	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.02	0.65	4.56	
Footing	γc(t3)(a5)	6.24	0.65	4.06	
Reaction	1/2(q2)(a5)	-6.486	0.867	-5.621	
	1/2(q3)(a5)	-10.97	0.433	-4.754	
Total		-4.20		-1.76	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	1.60	9.74	0.79	26.45	0.07
Footing	**Top bar**	5.41	3.25	2.66	89.40	0.02

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k=$\sqrt{(pn)^2}$+2pn	0.2112005			0.2112005	
j=1- k/3	0.9295998			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	26.45			89.40	
fc (concrete)	0.79			2.66	
v (shear)	0.07			0.02	
u (bond)	0.48			0.16	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.00~1.10

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	31.81	1.5	0.11	0.25	20.9	57
Normal-2	9.87	1.5	0.22	0.25	20.9	58
Flood-1	1.43	1	0.49	0.50	20.3	33
Flood-2	14.77	1	0.49	0.50	10.1	33
Seismic-1	3.91	1.2	0.21	0.50	20.9	79
Seismic-2	3.22	1.2	0.13	0.50	20.9	95
Wind-1	7.25	1.2	0.224	0.50	20.94	77
Wind-2	4.81	1.2	0.108	0.50	20.94	106

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079 √fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.31	-3.19	
Normal-2		0.16	1.16	0.19	-3.25	
Flood		4.50	9.74	5.41	2.46	
Seismic-1	*	0.73	1.28	0.75	-2.15	*: divided by 1.33
Seismic-2	*	0.81	1.79	-0.48	-2.75	*: divided by 1.33
Wind-1	*	1.50	1.93	0.96	-2.05	*: divided by 1.33
Wind-2	*	1.60	2.61	-1.32	-3.16	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	4.50	9.74	2.21	74.24	0.07
Footing	**Bot bar**	1.32	3.25	0.88	26.57	0.03

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k=$\sqrt{(pn)^2}$+2pn	0.2112005			0.2296026	
j=1- k/3	0.9295998			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	74.24			26.57	
fc (concrete)	2.21			0.88	
v (shear)	0.07			0.03	
u (bond)	0.48			0.20	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.10~1.20

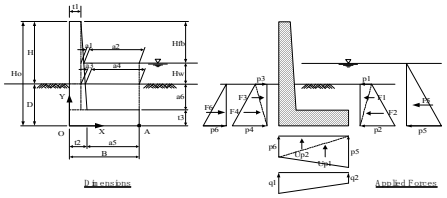
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.20	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	1.70	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	1.20	(m)		
Width of footing	B =	1.65	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	1.450	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	1.450	(m)
			a5=	1.450	(m)
			a6=	0.300	(m)



2. Case 1 : Normal condition-1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.92	0.825	6.53	
Soil-1	1/2(a5)(a6)γs	3.915	1.167	4.57	
Soil-2	1/2(a4)(a6)γs	3.92	0.683	2.68	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		22.95	0.632	14.50	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 22.95 (kN/m)
H = 0.68 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 0.68 (kN/m)
SF =(V*f'+ HR_{max})/ H = 33.58 > 1.5 Safe !!

Overturning,

Mr_{max} = 16.03 (kN-m/m)
Mr_{act} = 14.61 (kN-m/m)
Mo = 0.11 (kN-m/m)
SF =Mr_{max}/ M_o = 140.69 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.13 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 1.26 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.19
α = 1.0
k = 1+0.3*D/B = 1.0909091
β = 1.0
Nc = 20
Nq = 11
Nr = 7
tan θ= (H-HR_{act})/V = 0.000 minimum

= 192 (kN/m)
Qa = 64 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.632 m

q1 = V/B*(1+6e/B)= 23.688 (kN/m2)

q2 = V/B*(1-6e/B) = 4.131 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.317 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-2.995	0.967	-2.895	
	1/2(q3)(a5)	-15.45	0.483	-7.470	
Total		-3.66		0.36	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	1.550	11.16	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.450	0.00	
Footing	(B)(t3)γc	7.92	0.825	6.53	
Soil-1	1/2(a5)(a6)γs	3.915	0.483	1.89	
Soil-2	1/2(a4)(a6)γs	3.92	0.967	3.78	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		22.95	1.018	23.37	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 22.95 (kN/m)
H = 2.20 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 2.20 (kN/m)
SF =(V*f'+ HR_{max})/ H = 10.42 > 1.5 Safe !!

Overturning,

Mr_{max} = 24.90 (kN-m/m)
Mr_{act} = 23.74 (kN-m/m)
Mo = 0.49 (kN-m/m)
SF =Mr_{max}/ M_o = 50.44 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.24 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

Be = B - 2 e = 1.27 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.19 m

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 194 (kN/m)

Qa = 65 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.637 m

q1 = V/B*(1-6e/B)= 23.409 (kN/m2)

q2 = V/B*(1+6e/B) = 4.410 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.106 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-3.197	0.967	-3.090	
	1/2(q3)(a5)	-15.30	0.483	-7.396	
Total		-3.71		0.24	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.92	0.825	6.53	
Soil-1	1/2(a5)(a6)γsat	4.35	1.167	5.08	
Soil-2	1/2(a4)(a6)γsat	4.35	0.683	2.97	
Water-1	1/2(a4)(Hw)γw	8.53	1.167	9.95	
Water-2	1/2(a2)(Hw)γw	8.53	0.683	5.83	
Sub-Total		40.87	0.760	31.07	
Uplift-1	-1/2B(D+Hw)γw	-13.74	1.100	-15.12	
Uplift-2	-1/2B(D)γw	-4.04	0.550	-2.22	
Sub-Total		-17.79		-17.34	
Total		23.09		13.73	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	14.16	0.57	8.02	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		14.54		8.09	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 23.09 (kN/m)

H = 14.54 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.39 > 1.0 Safe !!

Overturning,

Mr_{max} = 32.13 (kN-m/m)

Mr = 32.13 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 25.43 (kN-m/m)

SF = Mr_{max}/M_o = 1.26 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.535 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.58 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.535 m

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.356

= 74 (kN/m)

Qa = 37.2 (kN/m) > V = 23.09 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.290 m

q1 = (2V)/3X = 53.037 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 40.852 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	11.03	0.50	5.51	Water pressure
Total		11.16		5.53	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	17.05	0.73	12.36	
Soil	γsat(a6)(a5)	8.70	0.73	6.31	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Uplift	-1/2(p5)(a5)	-12.08	0.97	-11.676	
	-1/2(p7)(a5)	-4.586	0.48	-2.217	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-13.696	0.224	-3.061	
Total		2.35		6.76	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	7.92	0.825	6.53	
Soil-1	1/2(a5)(a6)γsat	4.35	1.167	5.08	
Soil-2	1/2(a4)(a6)γsat	4.35	0.683	2.97	
Water-1	1/2(a4)(Hw)γw	2.13	1.167	2.49	
Water-2	1/2(a2)(Hw)γw	2.13	0.683	1.46	
Sub-Total		28.08	0.685	19.24	
Uplift-1	-1/2B(D+Hw)γw	-4.04	1.100	-4.45	
Uplift-2	-1/2B(D)γw	-13.74	0.550	-7.56	
Sub-Total		-17.79		-12.01	
Total		10.30		7.24	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.57	0.69	Active force
F6	1/2γw(D)^2	14.16	0.17	2.36	Resisting force
Total of active forces		1.60		0.76	
Total of maximum resisting forces		19.26		3.21	
Actual resisting forces		1.60		0.76	

(3) Stability

Sliding,

V = 10.30 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 19.26 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 15.85 > 1.0 Safe !!

Overturning,

Mr_{max} = 22.46 (kN-m/m)

Mr = 20.00 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 12.76 (kN-m/m)

SF = Mr_{max}/M_o = 1.76 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.535 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.58 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.535 m

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 74 (kN/m)

Qa = 37.2 (kN/m) > V = 10.30 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.290 m

q1 = (2V)/3X = 23.655 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 18.220 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		14.70	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	11.03	0.50	5.51	Water pressure
Total		11.16		5.53	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	17.05	0.73	12.36	
Soil	γsat(a6)(a5)	8.70	0.73	6.31	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Uplift	-1/2(p5)(a5)	-12.08	0.97	-11.676	
	-1/2(p7)(a5)	-4.586	0.48	-2.217	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.109	0.224	-1.365	
Total		9.94		8.46	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	0.950	6.84
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.700	0.00
Footing	(B)(t3)γc	7.92	0.825	6.53	0.100	0.79
Soil-1	1/2(a5)(a6)γs	3.915	1.167	4.57	0.300	1.17
Soil-2	1/2(a4)(a6)γs	3.92	0.683	2.68	0.400	1.57
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		22.95	0.632	14.50	0.452	10.37

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.59	0.45	2.07	Seismic force
Total of active forces		5.60		2.24	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		5.60		1.29	

(3) Stability

Sliding,

V = 22.95 (kN/m)

H = 5.60 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 5.60 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.85 > 1.2 Safe !!

Overturning,

Mr_{max} = 15.79 (kN-m/m)

Mr_{act} = 15.79 (kN-m/m)

Mo = 2.24 (kN-m/m)

d = (Mr-Mo)/V = 0.59 (m)

SF =M_{max}/ M_{act} = 7.04 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.23 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.18 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.23 m

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 176 (kN/m)

Qa = 88 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.590 m

q1 = V/B*(1+6e/B)= 25.781 (kN/m2)

q2 = V/B*(1-6e/B) = 2.037 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.903 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.50	0.00	Seismic force
Total		1.80		1.12	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-1.476872	0.9666667	-1.428	
	1/2(q3)(a5)	-16.605	0.483	-8.026	
Total		-3.29		1.27	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	1.550	11.16	0.950	6.84
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.450	0.00	0.700	0.00
Footing	(B)(t3)γc	7.92	0.825	6.53	0.100	0.79
Soil-1	1/2(a5)(a6)γs	3.915	0.483	1.89	0.300	1.17
Soil-2	1/2(a4)(a6)γs	3.92	0.967	3.78	0.400	1.57
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		22.95	1.018	23.37	0.452	10.37

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.59	0.45	2.07	Seismic force
Total of active forces		6.72		2.52	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		6.72		1.29	

(3) Stability

Sliding,

V = 22.95 (kN/m)

H = 6.72 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 6.72 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.21 > 1.2 Safe !!

Overturning,

Mr_{max} = 24.66 (kN-m/m)

Mr_{act} = 24.66 (kN-m/m)

Mo = 2.52 (kN-m/m)

d = (Mr-Mo)/V = 0.96 (m)

SF =Mr_{max}/ M_o = 9.78 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.140 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.370 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.140 m

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 214 (kN/m)

Qa = 107 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.825

q1 = V/B*(1-6e/B)= 20.978 (kN/m2)

q2 = V/B*(1+6e/B) = 6.841 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.264 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.50	0.00	Seismic force
Total		2.47		1.22	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-4.959	0.967	-4.794	
	1/2(q3)(a5)	-13.966	0.483	-6.750	
Total		-4.14		-0.82	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	7.92	0.825	6.53
Soil-1	1/2(a5)(a6)γs	3.915	1.167	4.57
Soil-2	1/2(a4)(a6)γs	3.92	0.683	2.68
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		22.95	0.632	14.50

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.53	1.10	2.78	Wind force
Total of active forces		3.21		2.89	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.21		1.53	

(3) Stability

Sliding,

V = 22.95 (kN/m)

H = 3.21 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.21 (kN/m)

SF =(V*f + HR_{max})/ H = 7.15 > 1.2 Safe !!

Overturning,

Mr_{max}= 16.03 (kN-m/m)

Mr_{act}= 16.03 (kN-m/m)

Mo = 2.89 (kN-m/m)

d = (Mr-Mo)/V = 0.57 (m)

SF =Mr_{max}/ M_o = 5.54 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.253 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.144 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.253 (m)

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 169 (kN/m)

Qa = 85 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.572 m

q1 = V/B*(1+6e/B)= 26.693 (kN/m2)

q2 = V/B*(1-6e/B) = 1.125 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.594 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		2.53	0.90	2.27	
Total		2.77		2.30	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-0.816	0.967	-0.789	
	1/2(q3)(a5)	-17.11	0.483	-8.268	
Total		-3.13		1.67	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.10~1.20

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	1.550	11.16
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.450	0.00
Footing	(B)(t3)γc	7.92	0.825	6.53
Soil-1	1/2(a5)(a6)γs	3.915	0.483	1.89
Soil-2	1/2(a4)(a6)γs	3.92	0.967	3.78
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		22.95	1.018	23.37

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.53	1.10	2.78	Wind force
Total of active forces		4.73		3.27	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.73		0.79	

(3) Stability

Sliding,

V = 22.95 (kN/m)

H = 4.73 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.73 (kN/m)

SF =(V*f + HR_{max})/ H = 4.85 > 1.2 Safe !!

Overturning,

Mr_{max} = 24.90 (kN-m/m)

Mr_{act} = 24.16 (kN-m/m)

Mo = 3.27 (kN-m/m)

d = (Mr-Mo)/V = 0.91 (m)

SF =Mr_{max}/ M_o = 7.61 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.117 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.480 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.085 (m)

α = 1.0

k = 1+0.3*D/B = 1.0909091

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 236 (kN/m)

Qa = 118 (kN/m) > V = 22.95 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.740 m

q1 = V/B*(1-6e/B)= 18.210 (kN/m2)

q2 = V/B*(1+6e/B) = 9.608 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 17.168 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		2.53	0.90	2.27	
Total		3.68		2.44	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	7.83	0.73	5.68	
Footing	γc(t3)(a5)	6.96	0.73	5.05	
Reaction	1/2(q2)(a5)	-6.966	0.967	-6.733	
	1/2(q3)(a5)	-12.45	0.483	-6.016	
Total		-4.62		-2.03	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	1.83	11.16	0.90	30.24	0.08
Footing	**Top bar**	6.76	3.71	3.32	111.67	0.03

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(pn)^2+2pn$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	30.24			111.67	
fc (concrete)	0.90			3.32	
v (shear)	0.08			0.03	
u (bond)	0.55			0.18	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.10~1.20

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	33.58	1.5	0.13	0.28	23.0	64
Normal-2	10.42	1.5	0.24	0.28	23.0	65
Flood-1	1.39	1	0.53	0.55	23.1	37
Flood-2	15.85	1	0.53	0.55	10.3	37
Seismic-1	3.85	1.2	0.23	0.55	23.0	88
Seismic-2	3.21	1.2	0.14	0.55	23.0	107
Wind-1	7.15	1.2	0.253	0.55	22.95	85
Wind-2	4.85	1.2	0.117	0.55	22.95	118

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.36	-3.66	
Normal-2		0.16	1.16	0.24	-3.71	
Flood		5.53	11.16	6.76	2.35	
Seismic-1	*	0.84	1.36	0.95	-2.47	*: divided by 1.33
Seismic-2	*	0.91	1.86	-0.62	-3.11	*: divided by 1.33
Wind-1	*	1.73	2.09	1.25	-2.35	*: divided by 1.33
Wind-2	*	1.83	2.77	-1.52	-3.48	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	5.53	11.16	2.71	91.25	0.08
Footing	**Bot bar**	1.52	3.71	1.01	30.65	0.03

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(pn)^2+2pn$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	91.25			30.65	
fc (concrete)	2.71			1.01	
v (shear)	0.08			0.03	
u (bond)	0.55			0.22	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.20~1.30

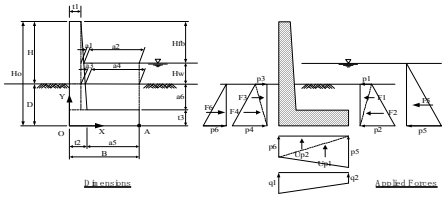
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.30	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	1.80	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	1.30	(m)		
Width of footing	B =	1.80	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	1.600	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	1.600	(m)
			a5=	1.600	(m)
			a6=	0.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.38 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.21

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 214 (kN/m)

Qa = 71 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.688 m

q1 = V/B*(1+6e/B)= 23.644 (kN/m2)

q2 = V/B*(1-6e/B) = 4.089 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.472 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-3.271	1.067	-3.489	
	1/2(q3)(a5)	-17.18	0.533	-9.161	
Total		-4.13		0.41	

2. Case 1 : Normal condition-1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	8.64	0.900	7.78	
Soil-1	1/2(a5)(a6)γs	4.32	1.267	5.47	
Soil-2	1/2(a4)(a6)γs	4.32	0.733	3.17	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		24.96	0.688	17.18	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 35.34 > 1.5 Safe !!

Overturning,

Mr_{max} = 18.71 (kN-m/m)

Mr_{act} = 17.30 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 164.28 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.15 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	1.700	13.06	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.600	0.00	
Footing	(B)(t3)γc	8.64	0.900	7.78	
Soil-1	1/2(a5)(a6)γs	4.32	0.533	2.30	
Soil-2	1/2(a4)(a6)γs	4.32	1.067	4.61	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		24.96	1.112	27.74	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 10.97 > 1.5 Safe !!

Overturning,

Mr_{max} = 29.27 (kN-m/m)

Mr_{act} = 28.11 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 59.30 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.25 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

Be = B - 2 e = 1.39 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.21 m

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 216 (kN/m)

Qa = 72 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.694 m

q1 = V/B*(1-6e/B)= 23.410 (kN/m2)

q2 = V/B*(1+6e/B) = 4.323 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.289 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-3.459	1.067	-3.689	
	1/2(q3)(a5)	-17.03	0.533	-9.083	
Total		-4.17		0.28	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	8.64	0.900	7.78	
Soil-1	1/2(a5)(a6)γsat	4.80	1.267	6.08	
Soil-2	1/2(a4)(a6)γsat	4.80	0.733	3.52	
Water-1	1/2(a4)(Hw)γw	10.19	1.267	12.91	
Water-2	1/2(a2)(Hw)γw	10.19	0.733	7.47	
Sub-Total		46.30	0.832	38.53	
Uplift-1	-1/2B(D+Hw)γw	-15.88	1.200	-19.05	
Uplift-2	-1/2B(D)γw	-4.41	0.600	-2.65	
Sub-Total		-20.29		-21.70	
Total		26.02		16.83	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	15.88	0.60	9.53	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		16.26		9.59	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 26.02 (kN/m)

H = 16.26 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.35 > 1.0 Safe !!

Overturning,

Mr_{max} = 39.58 (kN-m/m)

Mr = 39.58 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 31.29 (kN-m/m)

SF = Mr_{max}/M_o = 1.27 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.581 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.64 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.581 m

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.382

= 83 (kN/m)

Qa = 41.3 (kN/m) > V = 26.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.319 m

q1 = (2V)/3X = 54.398 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 43.024 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		15.68	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	12.54	0.53	6.69	Water pressure
Total		12.68		6.70	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	20.38	0.80	16.31	
Soil	γsat(a6)(a5)	9.60	0.80	7.68	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Uplift	-1/2(p5)(a5)	-14.11	1.07	-15.053	
	-1/2(p7)(a5)	-5.052	0.53	-2.695	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-16.276	0.252	-4.105	
Total		2.22		8.28	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	8.64	0.900	7.78	
Soil-1	1/2(a5)(a6)γsat	4.80	1.267	6.08	
Soil-2	1/2(a4)(a6)γsat	4.80	0.733	3.52	
Water-1	1/2(a4)(Hw)γw	2.35	1.267	2.98	
Water-2	1/2(a2)(Hw)γw	2.35	0.733	1.72	
Sub-Total		30.62	0.746	22.85	
Uplift-1	-1/2B(D+Hw)γw	-4.41	1.200	-5.29	
Uplift-2	-1/2B(D)γw	-15.88	0.600	-9.53	
Sub-Total		-20.29		-14.82	
Total		10.34		8.03	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.60	0.74	Active force
F6	1/2γw(D)^2	15.88	0.17	2.65	Resisting force
Total of active forces		1.60		0.80	
Total of maximum resisting forces		20.98		3.50	
Actual resisting forces		1.60		0.80	

(3) Stability

Sliding,

V = 10.34 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 20.98 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 16.94 > 1.0 Safe !!

Overturning,

Mr_{max} = 26.34 (kN-m/m)

Mr = 23.65 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 15.62 (kN-m/m)

SF = Mr_{max}/M_o = 1.69 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.581 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.64 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.581 m

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 83 (kN/m)

Qa = 41.3 (kN/m) > V = 10.34 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.319 m

q1 = (2V)/3X = 21.614 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 17.095 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		15.68	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	12.54	0.53	6.69	Water pressure
Total		12.68		6.70	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Water	γw(Hw)(a5)	20.38	0.80	16.31	
Soil	γsat(a6)(a5)	9.60	0.80	7.68	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Uplift	-1/2(p5)(a5)	-14.11	1.07	-15.053	
	-1/2(p7)(a5)	-5.052	0.53	-2.695	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.467	0.252	-1.631	
Total		12.03		10.75	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	1.000	7.68
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.733	0.00
Footing	(B)(t3)γc	8.64	0.900	7.78	0.100	0.86
Soil-1	1/2(a5)(a6)γs	4.32	1.267	5.47	0.300	1.30
Soil-2	1/2(a4)(a6)γs	4.32	0.733	3.17	0.400	1.73
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		24.96	0.688	17.18	0.463	11.57

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.99	0.46	2.31	Seismic force
Total of active forces		6.00		2.48	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		6.00		1.29	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 6.00 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 6.00 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.79 > 1.2 Safe !!

Overturning,

Mr_{max} = 18.48 (kN-m/m)

Mr_{act} = 18.48 (kN-m/m)

Mo = 2.48 (kN-m/m)

d = (Mr-Mo)/V = 0.64 (m)

SF =M_{max}/ M_{act} = 7.45 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.26 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.28 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.26 m

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 195 (kN/m)

Qa = 97 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.641 m

q1 = V/B*(1+6e/B)= 25.846 (kN/m2)

q2 = V/B*(1-6e/B) = 1.887 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.184 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.54	0.80	1.23	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.53	0.00	Seismic force
Total		1.90		1.27	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-1.509583	1.0666667	-1.610	
	1/2(q3)(a5)	-18.547	0.533	-9.892	
Total		-3.74		1.55	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	1.700	13.06	1.000	7.68
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.600	0.00	0.733	0.00
Footing	(B)(t3)γc	8.64	0.900	7.78	0.100	0.86
Soil-1	1/2(a5)(a6)γs	4.32	0.533	2.30	0.300	1.30
Soil-2	1/2(a4)(a6)γs	4.32	1.067	4.61	0.400	1.73
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		24.96	1.112	27.74	0.463	11.57

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.99	0.46	2.31	Seismic force
Total of active forces		7.12		2.76	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.12		1.29	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 7.12 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.12 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.19 > 1.2 Safe !!

Overturning,

Mr_{max} = 29.04 (kN-m/m)

Mr_{act} = 29.04 (kN-m/m)

Mo = 2.76 (kN-m/m)

d = (Mr-Mo)/V = 1.05 (m)

SF =Mr_{max}/ M_o = 10.52 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.153 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.495 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.153 m

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 238 (kN/m)

Qa = 119 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.900

q1 = V/B*(1-6e/B)= 20.925 (kN/m2)

q2 = V/B*(1+6e/B) = 6.809 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.356 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.54	0.80	1.23	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.53	0.00	Seismic force
Total		2.57		1.37	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-5.447	1.067	-5.810	
	1/2(q3)(a5)	-15.485	0.533	-8.259	
Total		-4.61		-1.01	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	8.64	0.900	7.78
Soil-1	1/2(a5)(a6)γs	4.32	1.267	5.47
Soil-2	1/2(a4)(a6)γs	4.32	0.733	3.17
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		24.96	0.688	17.18

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.74	1.15	3.15	Wind force
Total of active forces		3.42		3.26	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.42		1.53	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 3.42 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.42 (kN/m)

SF =(V*f + HR_{max})/ H = 7.06 > 1.2 Safe !!

Overturning,

Mr_{max}= 18.71 (kN-m/m)

Mr_{act}= 18.71 (kN-m/m)

Mo = 3.26 (kN-m/m)

d = (Mr-Mo)/V = 0.62 (m)

SF =Mr_{max}/ M_o = 5.74 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.281 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.238 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.281 (m)

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 186 (kN/m)

Qa = 93 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.619 m

q1 = V/B*(1+6e/B)= 26.852 (kN/m2)

q2 = V/B*(1-6e/B) = 0.881 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.967 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		2.74	0.95	2.60	
Total		2.98		2.63	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-0.705	1.067	-0.752	
	1/2(q3)(a5)	-19.17	0.533	-10.226	
Total		-3.56		2.08	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.20~1.30

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	1.700	13.06
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.600	0.00
Footing	(B)(t3)γc	8.64	0.900	7.78
Soil-1	1/2(a5)(a6)γs	4.32	0.533	2.30
Soil-2	1/2(a4)(a6)γs	4.32	1.067	4.61
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		24.96	1.112	27.74

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.74	1.15	3.15	Wind force
Total of active forces		4.94		3.64	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.94		0.82	

(3) Stability

Sliding,

V = 24.96 (kN/m)

H = 4.94 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.94 (kN/m)

SF =(V*f + HR_{max})/ H = 4.89 > 1.2 Safe !!

Overturning,

Mr_{max} = 29.27 (kN-m/m)

Mr_{act} = 28.57 (kN-m/m)

Mo = 3.64 (kN-m/m)

d = (Mr-Mo)/V = 1.00 (m)

SF =Mr_{max}/ M_o = 8.04 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.127 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.603 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.099 (m)

α = 1.0

k = 1+0.3*D/B = 1.0833333

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 262 (kN/m)

Qa = 131 (kN/m) > V = 24.96 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.801 m

q1 = V/B*(1-6e/B)= 18.425 (kN/m2)

q2 = V/B*(1+6e/B) = 9.309 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 17.412 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s I H		2.74	0.95	2.60	
Total		3.90		2.76	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.64	0.80	6.91	
Footing	γc(t3)(a5)	7.68	0.80	6.14	
Reaction	1/2(q2)(a5)	-7.447	1.067	-7.943	
	1/2(q3)(a5)	-13.93	0.533	-7.429	
Total		-5.06		-2.32	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.08	12.68	1.02	34.30	0.09
Footing	**Top bar**	8.28	4.17	4.07	136.71	0.03

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(pn)^2+2pn$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	34.30			136.71	
fc (concrete)	1.02			4.07	
v (shear)	0.09			0.03	
u (bond)	0.63			0.21	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.20~1.30

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	35.34	1.5	0.15	0.30	25.0	71
Normal-2	10.97	1.5	0.25	0.30	25.0	72
Flood-1	1.35	1	0.58	0.60	26.0	41
Flood-2	16.94	1	0.58	0.60	10.3	41
Seismic-1	3.79	1.2	0.26	0.60	25.0	97
Seismic-2	3.19	1.2	0.15	0.60	25.0	119
Wind-1	7.06	1.2	0.281	0.60	24.96	93
Wind-2	4.89	1.2	0.127	0.60	24.96	131

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.41	-4.13	
Normal-2		0.16	1.16	0.28	-4.17	
Flood		6.70	12.68	8.28	2.22	
Seismic-1	*	0.95	1.43	1.17	-2.81	*: divided by 1.33
Seismic-2	*	1.03	1.93	-0.76	-3.47	*: divided by 1.33
Wind-1	*	1.97	2.24	1.56	-2.68	*: divided by 1.33
Wind-2	*	2.08	2.93	-1.74	-3.80	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	6.70	12.68	3.29	110.70	0.09
Footing	**Bot bar**	1.74	4.17	1.16	35.03	0.04

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(pn)^2+2pn$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	110.70			35.03	
fc (concrete)	3.29			1.16	
v (shear)	0.09			0.04	
u (bond)	0.63			0.25	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.30~1.40

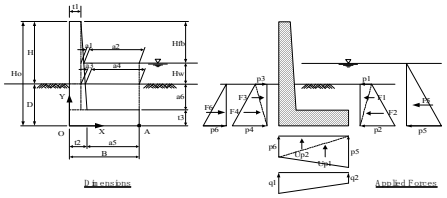
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.40	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	1.90	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	1.40	(m)		
Width of footing	B =	1.90	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	1.700	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	1.700	(m)
			a5=	1.700	(m)
			a6=	0.300	(m)



2. Case 1 : Normal condition-1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.16	0.100	0.82	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.12	0.950	8.66	
Soil-1	1/2(a5)(a6)γs	4.59	1.333	6.12	
Soil-2	1/2(a4)(a6)γs	4.59	0.767	3.52	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		26.46	0.723	19.12	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 26.46 (kN/m)
H = 0.68 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 0.68 (kN/m)
SF =(V*f'+ HR_{max})/ H = 36.66 > 1.5 Safe !!

Overturning,

Mr_{max} = 20.65 (kN-m/m)
Mr_{act} = 19.23 (kN-m/m)
Mo = 0.11 (kN-m/m)
SF =Mr_{max}/ M_o = 181.26 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.17 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 1.45 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.23
α = 1.0
k = 1+0.3*D/B = 1.0789474
β = 1.0
Nc = 20
Nq = 11
Nr = 7
tan θ= (H-HR_{act})/V = 0.000 minimum

= 227 (kN/m)
Qa = 76 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.723 m

q1 = V/B*(1+6e/B)= 23.929 (kN/m2)

q2 = V/B*(1-6e/B) = 3.924 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.823 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m)	Remarks
Weight					
Soil	γs(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-3.335	1.133	-3.780	
	1/2(q3)(a5)	-18.55	0.567	-10.511	
Total		-4.54		0.45	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.16	1.800	14.69	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.700	0.00	
Footing	(B)(t3)γc	9.12	0.950	8.66	
Soil-1	1/2(a5)(a6)γs	4.59	0.567	2.60	
Soil-2	1/2(a4)(a6)γs	4.59	1.133	5.20	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		26.46	1.177	31.16	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 26.46 (kN/m)
H = 2.20 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 2.20 (kN/m)
SF =(V*f'+ HR_{max})/ H = 11.38 > 1.5 Safe !!

Overturning,

Mr_{max} = 32.69 (kN-m/m)
Mr_{act} = 31.52 (kN-m/m)
Mo = 0.49 (kN-m/m)
SF =Mr_{max}/ M_o = 66.21 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.27 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

Be = B - 2 e = 1.45 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.22 m

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 229 (kN/m)

Qa = 76 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.727 m

q1 = V/B*(1-6e/B)= 23.718 (kN/m2)

q2 = V/B*(1+6e/B) = 4.134 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.657 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-3.514	1.133	-3.983	
	1/2(q3)(a5)	-18.41	0.567	-10.431	
Total		-4.58		0.32	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.16	0.100	0.82	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.12	0.950	8.66	
Soil-1	1/2(a5)(a6)γsat	5.10	1.333	6.80	
Soil-2	1/2(a4)(a6)γsat	5.10	0.767	3.91	
Water-1	1/2(a4)(Hw)γw	11.66	1.333	15.55	
Water-2	1/2(a2)(Hw)γw	11.66	0.767	8.94	
Sub-Total		50.80	0.879	44.68	
Uplift-1	-1/2B(D+Hw)γw	-17.69	1.267	-22.41	
Uplift-2	-1/2B(D)γw	-4.66	0.633	-2.95	
Sub-Total		-22.34		-25.35	
Total		28.46		19.33	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	17.69	0.63	11.20	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		18.07		11.27	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 28.46 (kN/m)

H = 18.07 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.30 > 1.0 Safe !!

Overturning,

Mr_{max} = 45.73 (kN-m/m)

Mr = 45.73 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 36.62 (kN-m/m)

SF = Mr_{max}/M_o = 1.25 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.630 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.64 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.630 m

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.413

= 83 (kN/m)

Qa = 41.4 (kN/m) > V = 28.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.320 m

q1 = (2V)/3X = 59.248 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 46.914 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		16.66	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	14.16	0.57	8.02	Water pressure
Total		14.30		8.04	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	23.32	0.85	19.83	
Soil	γsat(a6)(a5)	10.20	0.85	8.67	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Uplift	-1/2(p5)(a5)	-15.83	1.13	-17.937	
	-1/2(p7)(a5)	-5.393	0.57	-3.056	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-17.844	0.254	-4.525	
Total		2.62		9.91	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.16	0.100	0.82	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.12	0.950	8.66	
Soil-1	1/2(a5)(a6)γsat	5.10	1.333	6.80	
Soil-2	1/2(a4)(a6)γsat	5.10	0.767	3.91	
Water-1	1/2(a4)(Hw)γw	2.50	1.333	3.33	
Water-2	1/2(a2)(Hw)γw	2.50	0.767	1.92	
Sub-Total		32.48	0.783	25.44	
Uplift-1	-1/2B(D+Hw)γw	-4.66	1.267	-5.90	
Uplift-2	-1/2B(D)γw	-17.69	0.633	-11.20	
Sub-Total		-22.34		-17.10	
Total		10.13		8.34	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.63	0.78	Active force
F6	1/2γw(D)^2	17.69	0.17	2.95	Resisting force
Total of active forces		1.60		0.84	
Total of maximum resisting forces		22.79		3.80	
Actual resisting forces		1.60		0.84	

(3) Stability

Sliding,

V = 10.13 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 22.79 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 17.99 > 1.0 Safe !!

Overturning,

Mr_{max} = 29.24 (kN-m/m)

Mr = 26.28 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 17.94 (kN-m/m)

SF = Mr_{max}/M_o = 1.63 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.630 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.64 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.630 m

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 83 (kN/m)

Qa = 41.4 (kN/m) > V = 10.13 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.320 m

q1 = (2V)/3X = 21.097 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 16.705 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		16.66	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	14.16	0.57	8.02	Water pressure
Total		14.30		8.04	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	23.32	0.85	19.83	
Soil	γsat(a6)(a5)	10.20	0.85	8.67	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Uplift	-1/2(p5)(a5)	-15.83	1.13	-17.937	
	-1/2(p7)(a5)	-5.393	0.57	-3.056	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.354	0.254	-1.611	
Total		14.11		12.83	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.16	0.100	0.82	1.050	8.57
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.767	0.00
Footing	(B)(t3)γc	9.12	0.950	8.66	0.100	0.91
Soil-1	1/2(a5)(a6)γs	4.59	1.333	6.12	0.300	1.38
Soil-2	1/2(a4)(a6)γs	4.59	0.767	3.52	0.400	1.84
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		26.46	0.723	19.12	0.480	12.69

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.29	0.48	2.54	Seismic force
Total of active forces		6.30		2.71	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		6.30		1.29	

(3) Stability

Sliding,

V = 26.46 (kN/m)

H = 6.30 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 6.30 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.75 > 1.2 Safe !!

Overturning,

Mr_{max} = 20.41 (kN-m/m)

Mr_{act} = 20.41 (kN-m/m)

Mo = 2.71 (kN-m/m)

d = (Mr-Mo)/V = 0.67 (m)

SF =M_{max}/ M_{act} = 7.54 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.28 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.34 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.28 m

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 206 (kN/m)

Qa = 103 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.669 m

q1 = V/B*(1+6e/B)= 26.279 (kN/m2)

q2 = V/B*(1-6e/B) = 1.574 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.678 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.63	0.85	1.39	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.57	0.00	Seismic force
Total		1.99		1.42	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-1.337822	1.1333333	-1.516	
	1/2(q3)(a5)	-20.126	0.567	-11.405	
Total		-4.12		1.82	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.16	1.800	14.69	1.050	8.57
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.700	0.00	0.767	0.00
Footing	(B)(t3)γc	9.12	0.950	8.66	0.100	0.91
Soil-1	1/2(a5)(a6)γs	4.59	0.567	2.60	0.300	1.38
Soil-2	1/2(a4)(a6)γs	4.59	1.133	5.20	0.400	1.84
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		26.46	1.177	31.16	0.480	12.69

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.29	0.48	2.54	Seismic force
Total of active forces		7.42		2.99	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.42		1.29	

(3) Stability

Sliding,

V = 26.46 (kN/m)

H = 7.42 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.42 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.19 > 1.2 Safe !!

Overturning,

Mr_{max} = 32.45 (kN-m/m)

Mr_{act} = 32.45 (kN-m/m)

Mo = 2.99 (kN-m/m)

d = (Mr-Mo)/V = 1.11 (m)

SF =Mr_{max}/ M_o = 10.87 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.163 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.573 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.163 m

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 255 (kN/m)

Qa = 127 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.950

q1 = V/B*(1-6e/B)= 21.113 (kN/m2)

q2 = V/B*(1+6e/B) = 6.739 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.600 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.63	0.85	1.39	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.57	0.00	Seismic force
Total		2.67		1.52	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-5.728	1.133	-6.492	
	1/2(q3)(a5)	-16.660	0.567	-9.441	
Total		-5.05		-1.19	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.16	0.100	0.82
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	9.12	0.950	8.66
Soil-1	1/2(a5)(a6)γs	4.59	1.333	6.12
Soil-2	1/2(a4)(a6)γs	4.59	0.767	3.52
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		26.46	0.723	19.12

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	2.95	1.20	3.54	Wind force
Total of active forces		3.63		3.65	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.63		1.53	

(3) Stability

Sliding,

V = 26.46 (kN/m)

H = 3.63 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.63 (kN/m)

SF =(V*f + HR_{max})/ H = 6.90 > 1.2 Safe !!

Overturning,

Mr_{max}= 20.65 (kN-m/m)

Mr_{act}= 20.65 (kN-m/m)

Mo = 3.65 (kN-m/m)

d = (Mr-Mo)/V = 0.64 (m)

SF =Mr_{max}/ M_o = 5.65 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.308 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.285 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.308 (m)

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 195 (kN/m)

Qa = 98 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.642 m

q1 = V/B*(1+6e/B)= 27.455 (kN/m2)

q2 = V/B*(1-6e/B) = 0.397 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.607 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		2.95	1.00	2.95	
Total		3.19		2.97	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-0.338	1.133	-0.383	
	1/2(q3)(a5)	-20.92	0.567	-11.852	
Total		-3.91		2.50	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.30~1.40

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.16	1.800	14.69
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.700	0.00
Footing	(B)(t3)γc	9.12	0.950	8.66
Soil-1	1/2(a5)(a6)γs	4.59	0.567	2.60
Soil-2	1/2(a4)(a6)γs	4.59	1.133	5.20
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		26.46	1.177	31.16

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	2.95	1.20	3.54	Wind force
Total of active forces		5.15		4.03	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		5.15		0.86	

(3) Stability

Sliding,

V = 26.46 (kN/m)

H = 5.15 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 5.15 (kN/m)

SF =(V*f + HR_{max})/ H = 4.86 > 1.2 Safe !!

Overturning,

Mr_{max} = 32.69 (kN-m/m)

Mr_{act} = 32.01 (kN-m/m)

Mo = 4.03 (kN-m/m)

d = (Mr-Mo)/V = 1.06 (m)

SF =Mr_{max}/ M_o = 8.11 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.133 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.685 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.108 (m)

α = 1.0

k = 1+0.3*D/B = 1.0789474

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 279 (kN/m)

Qa = 140 (kN/m) > V = 26.46 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.842 m

q1 = V/B*(1-6e/B)= 18.654 (kN/m2)

q2 = V/B*(1+6e/B) = 9.198 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 17.659 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		2.95	1.00	2.95	
Total		4.11		3.11	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.18	0.85	7.80	
Footing	γc(t3)(a5)	8.16	0.85	6.94	
Reaction	1/2(q2)(a5)	-7.818	1.133	-8.861	
	1/2(q3)(a5)	-15.01	0.567	-8.506	
Total		-5.49		-2.63	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.142	16	250	804.25

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.34	14.30	1.15	38.61	0.10
Footing	**Top bar**	9.91	4.58	3.97	95.48	0.03

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	16	16
Spacing	250	565.49	565.49	250	1005.31
As/m	452.39	200.00	200.00	804.25	200.00
Circum.	150.7968			201.0624	
d'	0.056			0.058	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0056637	
k= $(pn)^2+2pn$	0.21120053			0.2723613	
j= 1- k/3	0.92959982			0.909213	
Actual Stresses, (Mpa)					
fs (steel)	38.61			95.48	
fc (concrete)	1.15			3.97	
v (shear)	0.10			0.03	
u (bond)	0.71			0.18	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.30~1.40

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	36.66	1.5	0.17	0.32	26.5	76
Normal-2	11.38	1.5	0.27	0.32	26.5	76
Flood-1	1.30	1	0.63	0.63	28.5	41
Flood-2	17.99	1	0.63	0.63	10.1	41
Seismic-1	3.75	1.2	0.28	0.63	26.5	103
Seismic-2	3.19	1.2	0.16	0.63	26.5	127
Wind-1	6.90	1.2	0.308	0.63	26.46	98
Wind-2	4.86	1.2	0.133	0.63	26.46	140

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.45	-4.54	
Normal-2		0.16	1.16	0.32	-4.58	
Flood		8.04	14.30	9.91	2.62	
Seismic-1	*	1.07	1.50	1.37	-3.10	*: divided by 1.33
Seismic-2	*	1.15	2.00	-0.90	-3.80	*: divided by 1.33
Wind-1	*	2.24	2.40	1.88	-2.94	*: divided by 1.33
Wind-2	*	2.34	3.09	-1.98	-4.13	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	8.04	14.30	3.95	132.74	0.10
Footing	**Bot bar**	1.98	4.58	1.32	39.74	0.04

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(pn)^2+2pn$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	132.74			39.74	
fc (concrete)	3.95			1.32	
v (shear)	0.10			0.04	
u (bond)	0.71			0.28	
Code Minimum reinforcements					
ratio (min.)	0.001	0.001		0.001	
As (min.) = ratio x b x h	200	200		200	

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.40~1.50

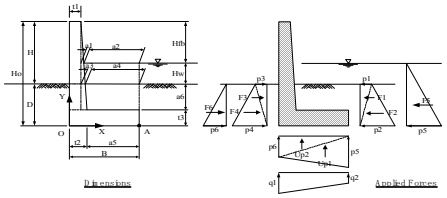
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.50 (m)		
Embedment of wall	D =	0.50 (m)		
Total height of wall	Ho=	2.00 (m)		
Freeboard	Hfb=	1.00 (m)		
Water depth under flood condition	Hw=	1.50 (m)		
Width of footing	B =	2.05 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.20 (m)		a2=	1.850 (m)
t3=	0.20 (m)		a3=	0.000 (m)
			a4=	1.850 (m)
			a5=	1.850 (m)
			a6=	0.300 (m)



2. Case 1 : Normal condition-1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	0.100	0.86	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.84	1.025	10.09	
Soil-1	1/2(a5)(a6)γs	4.995	1.433	7.16	
Soil-2	1/2(a4)(a6)γs	5.00	0.817	4.08	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		28.47	0.779	22.19	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 28.47 (kN/m)
H = 0.68 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 0.68 (kN/m)
SF =(V*f'+ HR_{max})/ H = 38.42 > 1.5 Safe !!

Overturning,

Mr_{max} = 23.72 (kN-m/m)
Mr_{act} = 22.30 (kN-m/m)
Mo = 0.11 (kN-m/m)
SF =Mr_{max}/ M_o = 208.21 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.20 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)
Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)
where,
Be = B - 2 e = 1.56 (m)
e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.25
α = 1.0
k = 1+0.3*D/B = 1.0731707
β = 1.0
Nc = 20
Nq = 11
Nr = 7
tan θ= (H-HR_{act})/V = 0.000 minimum

= 251 (kN/m)
Qa = 84 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.779 m

q1 = V/B*(1+6e/B)= 23.872 (kN/m2)

q2 = V/B*(1-6e/B) = 3.904 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.924 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-3.611	1.233	-4.454	
	1/2(q3)(a5)	-20.28	0.617	-12.506	
Total		-5.02		0.50	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	1.950	16.85	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.850	0.00	
Footing	(B)(t3)γc	9.84	1.025	10.09	
Soil-1	1/2(a5)(a6)γs	4.995	0.617	3.08	
Soil-2	1/2(a4)(a6)γs	5.00	1.233	6.16	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		28.47	1.271	36.17	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 28.47 (kN/m)
H = 2.20 (kN/m)
HR_{max} = 9.18 (kN/m)
HR_{act} = 2.20 (kN/m)
SF =(V*f'+ HR_{max})/ H = 11.92 > 1.5 Safe !!

Overturning,

Mr_{max} = 37.70 (kN-m/m)
Mr_{act} = 36.54 (kN-m/m)
Mo = 0.49 (kN-m/m)
SF =Mr_{max}/ M_o = 76.38 > 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V = 0.28 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.57 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.24 m

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 253 (kN/m)

Qa = 84 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.784 m

q1 = V/B*(1-6e/B)= 23.691 (kN/m2)

q2 = V/B*(1+6e/B) = 4.084 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.778 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-3.778	1.233	-4.660	
	1/2(q3)(a5)	-20.14	0.617	-12.423	
Total		-5.05		0.37	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	0.100	0.86	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.84	1.025	10.09	
Soil-1	1/2(a5)(a6)γsat	5.55	1.433	7.96	
Soil-2	1/2(a4)(a6)γsat	5.55	0.817	4.53	
Water-1	1/2(a4)(Hw)γw	13.60	1.433	19.49	
Water-2	1/2(a2)(Hw)γw	13.60	0.817	11.10	
Sub-Total		56.78	0.952	54.03	
Uplift-1	-1/2B(D+Hw)γw	-20.09	1.367	-27.46	
Uplift-2	-1/2B(D)γw	-5.02	0.683	-3.43	
Sub-Total		-25.11		-30.89	
Total		31.66		23.14	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	19.60	0.67	13.07	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		19.98		13.13	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 31.66 (kN/m)

H = 19.98 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.27 > 1.0 Safe !!

Overturning,

Mr_{max} = 55.09 (kN-m/m)

Mr = 55.09 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 44.02 (kN-m/m)

SF = Mr_{max}/M_o = 1.25 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.675 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.70 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.675 m

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.431

= 91 (kN/m)

Qa = 45.7 (kN/m) > V = 31.66 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.350 m

q1 = (2V)/3X = 60.386 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 48.870 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		17.64	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	15.88	0.60	9.53	Water pressure
Total		16.01		9.54	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	27.20	0.93	25.16	
Soil	γsat(a6)(a5)	11.10	0.93	10.27	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Uplift	-1/2(p5)(a5)	-18.13	1.23	-22.360	
	-1/2(p7)(a5)	-5.859	0.62	-3.613	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-20.737	0.283	-5.866	
Total		2.45		11.80	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	8.64	0.100	0.86	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	9.84	1.025	10.09	
Soil-1	1/2(a5)(a6)γsat	5.55	1.433	7.96	
Soil-2	1/2(a4)(a6)γsat	5.55	0.817	4.53	
Water-1	1/2(a4)(Hw)γw	2.72	1.433	3.90	
Water-2	1/2(a2)(Hw)γw	2.72	0.817	2.22	
Sub-Total		35.02	0.844	29.56	
Uplift-1	-1/2B(D+Hw)γw	-5.02	1.367	-6.86	
Uplift-2	-1/2B(D)γw	-20.09	0.683	-13.73	
Sub-Total		-25.11		-20.59	
Total		9.91		8.96	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.67	0.82	Active force
F6	1/2γw(D)^2	19.60	0.17	3.27	Resisting force
Total of active forces		1.60		0.88	
Total of maximum resisting forces		24.70		4.12	
Actual resisting forces		1.60		0.88	

(3) Stability

Sliding,

V = 9.91 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 24.70 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 19.10 > 1.0 Safe !!

Overturning,

Mr_{max} = 33.67 (kN-m/m)

Mr = 30.44 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 21.47 (kN-m/m)

SF = Mr_{max}/M_o = 1.57 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.675 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.70 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.675 m

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 91 (kN/m)

Qa = 45.7 (kN/m) > V = 9.91 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.350 m

q1 = (2V)/3X = 18.894 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 15.290 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		17.64	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	15.88	0.60	9.53	Water pressure
Total		16.01		9.54	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Water	γw(Hw)(a5)	27.20	0.93	25.16	
Soil	γsat(a6)(a5)	11.10	0.93	10.27	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Uplift	-1/2(p5)(a5)	-18.13	1.23	-22.360	
	-1/2(p7)(a5)	-5.859	0.62	-3.613	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.488	0.283	-1.835	
Total		16.70		15.83	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	0.100	0.86	1.100	9.50
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.800	0.00
Footing	(B)(t3)γc	9.84	1.025	10.09	0.100	0.98
Soil-1	1/2(a5)(a6)γs	4.995	1.433	7.16	0.300	1.50
Soil-2	1/2(a4)(a6)γs	5.00	0.817	4.08	0.400	2.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		28.47	0.779	22.19	0.491	13.98

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.69	0.49	2.80	Seismic force
Total of active forces		6.70		2.96	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		6.70		1.29	

(3) Stability

Sliding,

V = 28.47 (kN/m)

H = 6.70 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 6.70 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.71 > 1.2 Safe !!

Overturning,

Mr_{max} = 23.48 (kN-m/m)

Mr_{act} = 23.48 (kN-m/m)

Mo = 2.96 (kN-m/m)

d = (Mr-Mo)/V = 0.72 (m)

SF =M_{max}/ M_{act} = 7.92 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.30 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.44 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.30 m

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 226 (kN/m)

Qa = 113 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.721 m

q1 = V/B*(1+6e/B)= 26.259 (kN/m2)

q2 = V/B*(1-6e/B) = 1.516 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.845 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.73	0.90	1.56	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.60	0.00	Seismic force
Total		2.09		1.59	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-1.402414	1.2333333	-1.730	
	1/2(q3)(a5)	-22.057	0.617	-13.602	
Total		-4.59		2.12	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	1.950	16.85	1.100	9.50
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.850	0.00	0.800	0.00
Footing	(B)(t3)γc	9.84	1.025	10.09	0.100	0.98
Soil-1	1/2(a5)(a6)γs	4.995	0.617	3.08	0.300	1.50
Soil-2	1/2(a4)(a6)γs	5.00	1.233	6.16	0.400	2.00
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		28.47	1.271	36.17	0.491	13.98

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.69	0.49	2.80	Seismic force
Total of active forces		7.82		3.24	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 28.47 (kN/m)

H = 7.82 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.18 > 1.2 Safe !!

Overturning,

Mr_{max} = 37.47 (kN-m/m)

Mr_{act} = 37.47 (kN-m/m)

Mo = 3.24 (kN-m/m)

d = (Mr-Mo)/V = 1.20 (m)

SF =Mr_{max}/ M_o = 11.55 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.177 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.696 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.177 m

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.002

= 281 (kN/m)

Qa = 140 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.025

q1 = V/B*(1-6e/B)= 21.085 (kN/m2)

q2 = V/B*(1+6e/B) = 6.691 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.681 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.73	0.90	1.56	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.60	0.00	Seismic force
Total		2.76		1.69	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-6.189	1.233	-7.633	
	1/2(q3)(a5)	-18.205	0.617	-11.226	
Total		-5.52		-1.40	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	0.100	0.86
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	9.84	1.025	10.09
Soil-1	1/2(a5)(a6)γs	4.995	1.433	7.16
Soil-2	1/2(a4)(a6)γs	5.00	0.817	4.08
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		28.47	0.779	22.19

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.16	1.25	3.95	Wind force
Total of active forces		3.84		4.06	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		3.84		1.53	

(3) Stability

Sliding,

V = 28.47 (kN/m)

H = 3.84 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 3.84 (kN/m)

SF =(V*f + HR_{max})/ H = 6.83 > 1.2 Safe !!

Overturning,

Mr_{max}= 23.72 (kN-m/m)

Mr_{act}= 23.72 (kN-m/m)

Mo = 4.06 (kN-m/m)

d = (Mr-Mo)/V = 0.69 (m)

SF =Mr_{max}/ M_o = 5.84 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.335 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.381 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.335 (m)

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 213 (kN/m)

Qa = 107 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.690 m

q1 = V/B*(1+6e/B)= 27.488 (kN/m2)

q2 = V/B*(1-6e/B) = 0.288 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.834 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		3.16	1.05	3.32	
Total		3.41		3.34	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-0.266	1.233	-0.329	
	1/2(q3)(a5)	-22.97	0.617	-14.166	
Total		-4.37		2.96	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.40~1.50

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	8.64	1.950	16.85
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	1.850	0.00
Footing	(B)(t3)γc	9.84	1.025	10.09
Soil-1	1/2(a5)(a6)γs	4.995	0.617	3.08
Soil-2	1/2(a4)(a6)γs	5.00	1.233	6.16
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		28.47	1.271	36.17

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.16	1.25	3.95	Wind force
Total of active forces		5.36		4.44	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		5.36		0.89	

(3) Stability

Sliding,

V = 28.47 (kN/m)

H = 5.36 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 5.36 (kN/m)

SF =(V*f + HR_{max})/ H = 4.90 > 1.2 Safe !!

Overturning,

Mr_{max} = 37.70 (kN-m/m)

Mr_{act} = 37.07 (kN-m/m)

Mo = 4.44 (kN-m/m)

d = (Mr-Mo)/V = 1.15 (m)

SF =Mr_{max}/ M_o = 8.49 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.143 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.808 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.121 (m)

α = 1.0

k = 1+0.3*D/B = 1.0731707

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 307 (kN/m)

Qa = 153 (kN/m) > V = 28.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.904 m

q1 = V/B*(1-6e/B)= 18.805 (kN/m2)

q2 = V/B*(1+6e/B) = 8.970 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 17.846 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		3.16	1.05	3.32	
Total		4.32		3.48	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	9.99	0.93	9.24	
Footing	γc(t3)(a5)	8.88	0.93	8.21	
Reaction	1/2(q2)(a5)	-8.298	1.233	-10.234	
	1/2(q3)(a5)	-16.51	0.617	-10.179	
Total		-5.93		-2.96	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.142	16	250	804.25

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.62	16.01	1.28	43.19	0.11
Footing	**Top bar**	11.80	5.05	4.73	113.61	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	16	16
Spacing	250	565.49	565.49	250	1005.31
As/m	452.39	200.00	200.00	804.25	200.00
Circum.	150.7968			201.0624	
d'	0.056			0.058	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0056637	
k= $(pn)^2+2pn$	0.21120053			0.2723613	
j= 1- k/3	0.92959982			0.909213	
Actual Stresses, (Mpa)					
fs (steel)	43.19			113.61	
fc (concrete)	1.28			4.73	
v (shear)	0.11			0.04	
u (bond)	0.79			0.19	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.40~1.50

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	38.42	1.5	0.20	0.34	28.5	84
Normal-2	11.92	1.5	0.28	0.34	28.5	84
Flood-1	1.27	1	0.68	0.68	31.7	46
Flood-2	19.10	1	0.68	0.68	9.9	46
Seismic-1	3.71	1.2	0.30	0.68	28.5	113
Seismic-2	3.18	1.2	0.18	0.68	28.5	140
Wind-1	6.83	1.2	0.335	0.68	28.47	107
Wind-2	4.90	1.2	0.143	0.68	28.47	153

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.4fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{fc'}$	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.50	-5.02	
Normal-2		0.16	1.16	0.37	-5.05	
Flood		9.54	16.01	11.80	2.45	
Seismic-1	*	1.20	1.57	1.60	-3.45	*: divided by 1.33
Seismic-2	*	1.27	2.08	-1.06	-4.15	*: divided by 1.33
Wind-1	*	2.51	2.56	2.23	-3.28	*: divided by 1.33
Wind-2	*	2.62	3.25	-2.22	-4.46	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	9.54	16.01	3.82	91.87	0.11
Footing	**Bot bar**	2.22	5.05	1.48	44.74	0.04

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	250	1005.31	565.49	250	565.49
As/m	804.25	200.00	200.00	452.39	200.00
Circum.	201.0624			150.7968	
d'	0.058			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.00566373			0.0038016	
k= $(pn)^2+2pn$	0.2723613			0.2296026	
j= 1- k/3	0.9092129			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	91.87			44.74	
fc (concrete)	3.82			1.48	
v (shear)	0.11			0.04	
u (bond)	0.62			0.30	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.50~1.60

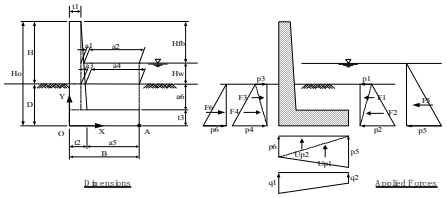
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.60	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	2.10	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	1.60	(m)		
Width of footing	B =	2.20	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	2.000	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	2.000	(m)
			a5=	2.000	(m)
			a6=	0.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.67 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.26

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 275 (kN/m)

Qa = 92 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.836 m

q1 = V/B*(1+6e/B)= 23.821 (kN/m2)

q2 = V/B*(1-6e/B) = 3.888 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.009 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-3.888	1.333	-5.183	
	1/2(q3)(a5)	-22.01	0.667	-14.673	
Total		-5.50		0.54	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.50~1.60

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.12	0.100	0.91	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	10.56	1.100	11.62	
Soil-1	1/2(a5)(a6)γs	5.4	1.533	8.28	
Soil-2	1/2(a4)(a6)γs	5.40	0.867	4.68	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		30.48	0.836	25.49	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 40.19 > 1.5 Safe !!

Overturning,

Mr_{max} = 27.02 (kN-m/m)

Mr_{act} = 25.60 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 237.17 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.22 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.50~1.60

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.12	2.100	19.15	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.000	0.00	
Footing	(B)(t3)γc	10.56	1.100	11.62	
Soil-1	1/2(a5)(a6)γs	5.4	0.667	3.60	
Soil-2	1/2(a4)(a6)γs	5.40	1.333	7.20	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		30.48	1.364	41.57	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 12.47 > 1.5 Safe !!

Overturning,

Mr_{max} = 43.10 (kN-m/m)

Mr_{act} = 41.94 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 87.31 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.30 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.68 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.26 m

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 277 (kN/m)

Qa = 92 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.840 m

q1 = V/B*(1-6e/B)= 23.665 (kN/m2)

q2 = V/B*(1+6e/B) = 4.045 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.881 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-4.045	1.333	-5.393	
	1/2(q3)(a5)	-21.88	0.667	-14.587	
Total		-5.53		0.42	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.12	0.100	0.91	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	10.56	1.100	11.62	
Soil-1	1/2(a5)(a6)γsat	6.00	1.533	9.20	
Soil-2	1/2(a4)(a6)γsat	6.00	0.867	5.20	
Water-1	1/2(a4)(Hw)γw	15.68	1.533	24.04	
Water-2	1/2(a2)(Hw)γw	15.68	0.867	13.59	
Sub-Total		63.04	1.024	64.56	
Uplift-1	-1/2B(D+Hw)γw	-22.64	1.467	-33.20	
Uplift-2	-1/2B(D)γw	-5.39	0.733	-3.95	
Sub-Total		-28.03		-37.16	
Total		35.01		27.40	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	21.61	0.70	15.13	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		21.99		15.19	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 35.01 (kN/m)

H = 21.99 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.24 > 1.0 Safe !!

Overturning,

Mr_{max} = 65.61 (kN-m/m)

Mr = 65.61 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 52.34 (kN-m/m)

SF = Mr_{max}/M_o = 1.25 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.721 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.76 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.721 m

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.447

= 100 (kN/m)

Qa = 50.1 (kN/m) > V = 35.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.379 m

q1 = (2V)/3X = 61.586 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 50.753 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		18.62	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	17.69	0.63	11.20	Water pressure
Total		17.83		11.22	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	31.36	1.00	31.36	
Soil	γsat(a6)(a5)	12.00	1.00	12.00	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Uplift	-1/2(p5)(a5)	-20.58	1.33	-27.440	
	-1/2(p7)(a5)	-6.325	0.67	-4.217	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-23.778	0.312	-7.427	
Total		2.28		13.88	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.12	0.100	0.91	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	10.56	1.100	11.62	
Soil-1	1/2(a5)(a6)γsat	6.00	1.533	9.20	
Soil-2	1/2(a4)(a6)γsat	6.00	0.867	5.20	
Water-1	1/2(a4)(Hw)γw	2.94	1.533	4.51	
Water-2	1/2(a2)(Hw)γw	2.94	0.867	2.55	
Sub-Total		37.56	0.905	33.98	
Uplift-1	-1/2B(D+Hw)γw	-5.39	1.467	-7.91	
Uplift-2	-1/2B(D)γw	-22.64	0.733	-16.60	
Sub-Total		-28.03		-24.51	
Total		9.53		9.48	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.70	0.86	Active force
F6	1/2γw(D)^2	21.61	0.17	3.60	Resisting force
Total of active forces		1.60		0.92	
Total of maximum resisting forces		26.71		4.45	
Actual resisting forces		1.60		0.92	

(3) Stability

Sliding,

V = 9.53 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 26.71 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 20.21 > 1.0 Safe !!

Overturning,

Mr_{max} = 38.44 (kN-m/m)

Mr = 34.90 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 25.43 (kN-m/m)

SF = Mr_{max}/M_o = 1.51 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.721 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.76 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.721 m

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 100 (kN/m)

Qa = 50.1 (kN/m) > V = 9.53 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.379 m

q1 = (2V)/3X = 16.767 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 13.818 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		18.62	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	17.69	0.63	11.20	Water pressure
Total		17.83		11.22	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	31.36	1.00	31.36	
Soil	γsat(a6)(a5)	12.00	1.00	12.00	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Uplift	-1/2(p5)(a5)	-20.58	1.33	-27.440	
	-1/2(p7)(a5)	-6.325	0.67	-4.217	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.474	0.312	-2.022	
Total		19.58		19.28	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.12	0.100	0.91	1.150	10.49
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.833	0.00
Footing	(B)(t3)γc	10.56	1.100	11.62	0.100	1.06
Soil-1	1/2(a5)(a6)γs	5.4	1.533	8.28	0.300	1.62
Soil-2	1/2(a4)(a6)γs	5.40	0.867	4.68	0.400	2.16
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		30.48	0.836	25.49	0.503	15.32

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{Kea}$	0.00	0.00	Active earth press.
p2	Kea(γh)-2c$\sqrt{Kea}$	0.50	4.03	Active earth press.
p3	Kep(γh)+2c$\sqrt{Kep}$	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c$\sqrt{Kep}$	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	$\sum$Wi*kh	6.10	0.50	3.06	Seismic force
Total of active forces		7.10		3.23	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.10		1.29	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 7.10 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.10 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.67 > 1.2 Safe !!

Overturning,

Mr_{max} = 26.78 (kN-m/m)

Mr_{act} = 26.78 (kN-m/m)

Mo = 3.23 (kN-m/m)

d = (Mr-Mo)/V = 0.77 (m)

SF =M_{max}/ M_{act} = 8.28 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.33 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.55 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.33 m

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 247 (kN/m)

Qa = 123 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.773 m

q1 = V/B*(1+6e/B)= 26.227 (kN/m2)

q2 = V/B*(1-6e/B) = 1.482 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.977 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{Kea}$	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c$\sqrt{Kea}$	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.82	0.95	1.73	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.63	0.00	Seismic force
Total		2.19		1.77	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-1.482357	1.3333333	-1.976	
	1/2(q3)(a5)	-23.977	0.667	-15.985	
Total		-5.06		2.44	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.12	2.100	19.15	1.150	10.49
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.000	0.00	0.833	0.00
Footing	(B)(t3)γc	10.56	1.100	11.62	0.100	1.06
Soil-1	1/2(a5)(a6)γs	5.4	0.667	3.60	0.300	1.62
Soil-2	1/2(a4)(a6)γs	5.40	1.333	7.20	0.400	2.16
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		30.48	1.364	41.57	0.503	15.32

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c$\sqrt{Kep}$	0.00	0.00	Passive press.
p2	Kep(γh)+2c$\sqrt{Kep}$	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c$\sqrt{Kea}$	0.00	2.24	Active press.
p4	Kea(γh+q')-2c$\sqrt{Kea}$	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	$\sum$Wi*kh	6.10	0.50	3.06	Seismic force
Total of active forces		8.22		3.51	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 8.22 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.17 > 1.2 Safe !!

Overturning,

Mr_{max} = 42.86 (kN-m/m)

Mr_{act} = 42.86 (kN-m/m)

Mo = 3.51 (kN-m/m)

d = (Mr-Mo)/V = 1.29 (m)

SF =Mr_{max}/ M_o = 12.20 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.191 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.818 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.191 m

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.015

= 308 (kN/m)

Qa = 154 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.100

q1 = V/B*(1-6e/B)= 21.070 (kN/m2)

q2 = V/B*(1+6e/B) = 6.640 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.758 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.82	0.95	1.73	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.63	0.00	Seismic force
Total		2.86		1.87	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-6.640	1.333	-8.853	
	1/2(q3)(a5)	-19.758	0.667	-13.172	
Total		-6.00		-1.62	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.12	0.100	0.91
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	10.56	1.100	11.62
Soil-1	1/2(a5)(a6)γs	5.4	1.533	8.28
Soil-2	1/2(a4)(a6)γs	5.40	0.867	4.68
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		30.48	0.836	25.49

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	3.37	1.30	4.38	Wind force
Total of active forces		4.05		4.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.05		1.53	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 4.05 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f + HR_{max})/ H = 6.78 > 1.2 Safe !!

Overturning,

Mr_{max}= 27.02 (kN-m/m)

Mr_{act}= 27.02 (kN-m/m)

Mo = 4.49 (kN-m/m)

d = (Mr-Mo)/V = 0.74 (m)

SF =Mr_{max}/ M_o = 6.01 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.361 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.478 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.361 (m)

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 233 (kN/m)

Qa = 116 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.739 m

q1 = V/B*(1+6e/B)= 27.496 (kN/m2)

q2 = V/B*(1-6e/B) = 0.213 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 25.016 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		3.37	1.10	3.71	
Total		3.62		3.73	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-0.213	1.333	-0.284	
	1/2(q3)(a5)	-25.02	0.667	-16.677	
Total		-4.83		3.44	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.50~1.60

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.12	2.100	19.15
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.000	0.00
Footing	(B)(t3)γc	10.56	1.100	11.62
Soil-1	1/2(a5)(a6)γs	5.4	0.667	3.60
Soil-2	1/2(a4)(a6)γs	5.40	1.333	7.20
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		30.48	1.364	41.57

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	3.37	1.30	4.38	Wind force
Total of active forces		5.57		4.87	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		5.57		0.93	

(3) Stability

Sliding,

V = 30.48 (kN/m)

H = 5.57 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 5.57 (kN/m)

SF =(V*f + HR_{max})/ H = 4.93 > 1.2 Safe !!

Overturning,

Mr_{max} = 43.10 (kN-m/m)

Mr_{act} = 42.50 (kN-m/m)

Mo = 4.87 (kN-m/m)

d = (Mr-Mo)/V = 1.23 (m)

SF =Mr_{max}/ M_o = 8.84 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.154 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.931 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.134 (m)

α = 1.0

k = 1+0.3*D/B = 1.0681818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 335 (kN/m)

Qa = 167 (kN/m) > V = 30.48 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.966 m

q1 = V/B*(1-6e/B)= 18.930 (kN/m2)

q2 = V/B*(1+6e/B) = 8.779 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.008 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		3.37	1.10	3.71	
Total		4.53		3.87	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.80	1.00	10.80	
Footing	γc(t3)(a5)	9.60	1.00	9.60	
Reaction	1/2(q2)(a5)	-8.779	1.333	-11.705	
	1/2(q3)(a5)	-18.01	0.667	-12.005	
Total		-6.39		-3.31	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.142	16	250	804.25

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.91	17.83	1.43	48.02	0.12
Footing	**Top bar**	13.88	5.53	5.56	133.64	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	16	16
Spacing	250	565.49	565.49	250	1005.31
As/m	452.39	200.00	200.00	804.25	200.00
Circum.	150.7968			201.0624	
d' $\sqrt{}$	0.056			0.058	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0056637	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2723613	
j= 1- k/3	0.92959982			0.909213	
Actual Stresses, (Mpa)					
fs (steel)	48.02			133.64	
fc (concrete)	1.43			5.56	
v (shear)	0.12			0.04	
u (bond)	0.88			0.21	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.50~1.60

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	40.19	1.5	0.22	0.37	30.5	92
Normal-2	12.47	1.5	0.30	0.37	30.5	92
Flood-1	1.24	1	0.72	0.73	35.0	50
Flood-2	20.21	1	0.72	0.73	9.5	50
Seismic-1	3.67	1.2	0.33	0.73	30.5	123
Seismic-2	3.17	1.2	0.19	0.73	30.5	154
Wind-1	6.78	1.2	0.361	0.73	30.48	116
Wind-2	4.93	1.2	0.154	0.73	30.48	167

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{}$fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.54	-5.50	
Normal-2		0.16	1.16	0.42	-5.53	
Flood		11.22	17.83	13.88	2.28	
Seismic-1	*	1.33	1.64	1.83	-3.80	*: divided by 1.33
Seismic-2	*	1.41	2.15	-1.22	-4.51	*: divided by 1.33
Wind-1	*	2.81	2.72	2.59	-3.63	*: divided by 1.33
Wind-2	*	2.91	3.40	-2.49	-4.80	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	11.22	17.83	4.49	108.02	0.13
Footing	**Bot bar**	2.49	5.53	1.66	50.06	0.05

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	250	1005.31	565.49	250	565.49
As/m	804.25	200.00	200.00	452.39	200.00
Circum.	201.0624			150.7968	
d' $\sqrt{}$	0.058			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.00566373			0.0038016	
k= $(p\,n)^2+2p\,n$	0.2723613			0.2296026	
j= 1- k/3	0.9092129			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	108.02			50.06	
fc (concrete)	4.49			1.66	
v (shear)	0.13			0.05	
u (bond)	0.69			0.33	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.60~1.70

1. Design Criteria

Unit weight :

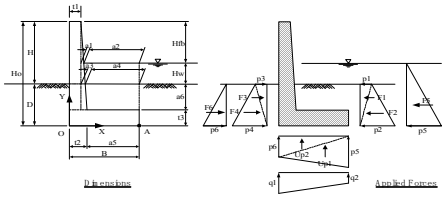
Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2

Coefficient of soil pressure :

Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.70 (m)		
Embedment of wall	D =	0.50 (m)		
Total height of wall	Ho=	2.20 (m)		
Freeboard	Hfb=	1.00 (m)		
Water depth under flood condition	Hw=	1.70 (m)		
Width of footing	B =	2.35 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.20 (m)		a2=	2.150 (m)
t3=	0.20 (m)		a3=	0.000 (m)
			a4=	2.150 (m)
			a5=	2.150 (m)
			a6=	0.300 (m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.79 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.28

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 300 (kN/m)

Qa = 100 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.893 m

q1 = V/B*(1+6e/B)= 23.776 (kN/m2)

q2 = V/B*(1-6e/B) = 3.875 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.083 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-4.165	1.433	-5.970	
	1/2(q3)(a5)	-23.74	0.717	-17.013	
Total		-5.97		0.59	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.60~1.70

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.6	0.100	0.96	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.28	1.175	13.25	
Soil-1	1/2(a5)(a6)γs	5.805	1.633	9.48	
Soil-2	1/2(a4)(a6)γs	5.81	0.917	5.32	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		32.49	0.893	29.02	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 41.95 > 1.5 Safe !!

Overturning,

Mr_{max} = 30.55 (kN-m/m)

Mr_{act} = 29.13 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 268.15 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.24 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.60~1.70

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.6	2.250	21.60	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.150	0.00	
Footing	(B)(t3)γc	11.28	1.175	13.25	
Soil-1	1/2(a5)(a6)γs	5.805	0.717	4.16	
Soil-2	1/2(a4)(a6)γs	5.81	1.433	8.32	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		32.49	1.457	47.33	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 13.02 > 1.5 Safe !!

Overturning,

Mr_{max} = 48.86 (kN-m/m)

Mr_{act} = 47.70 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 98.99 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.31 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.79 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.28 m

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 302 (kN/m)

Qa = 101 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.897 m

q1 = V/B*(1-6e/B)= 23.639 (kN/m2)

q2 = V/B*(1+6e/B) = 4.012 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.969 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-4.313	1.433	-6.182	
	1/2(q3)(a5)	-23.62	0.717	-16.925	
Total		-6.00		0.47	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.60~1.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.6	0.100	0.96	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.28	1.175	13.25	
Soil-1	1/2(a5)(a6)γsat	6.45	1.633	10.54	
Soil-2	1/2(a4)(a6)γsat	6.45	0.917	5.91	
Water-1	1/2(a4)(Hw)γw	17.91	1.633	29.25	
Water-2	1/2(a2)(Hw)γw	17.91	0.917	16.42	
Sub-Total		69.60	1.097	76.33	
Uplift-1	-1/2B(D+Hw)γw	-25.33	1.567	-39.69	
Uplift-2	-1/2B(D)γw	-5.76	0.783	-4.51	
Sub-Total		-31.09		-44.20	
Total		38.51		32.13	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	23.72	0.73	17.39	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		24.10		17.46	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 38.51 (kN/m)

H = 24.10 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.22 > 1.0 Safe !!

Overturning,

Mr_{max} = 77.38 (kN-m/m)

Mr = 77.38 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 61.65 (kN-m/m)

SF = Mr_{max}/M_o = 1.26 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.766 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.82 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.766 m

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.461

= 109 (kN/m)

Qa = 54.7 (kN/m) > V = 38.51 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.409 m

q1 = (2V)/3X = 62.842 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 52.587 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	19.60	0.67	13.07	Water pressure
Total		19.74		13.08	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	35.82	1.08	38.51	
Soil	γsat(a6)(a5)	12.90	1.08	13.87	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Uplift	-1/2(p5)(a5)	-23.18	1.43	-33.220	
	-1/2(p7)(a5)	-6.792	0.72	-4.867	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-26.966	0.342	-9.218	
Total		2.10		16.16	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.60~1.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	9.6	0.100	0.96	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.28	1.175	13.25	
Soil-1	1/2(a5)(a6)γsat	6.45	1.633	10.54	
Soil-2	1/2(a4)(a6)γsat	6.45	0.917	5.91	
Water-1	1/2(a4)(Hw)γw	3.16	1.633	5.16	
Water-2	1/2(a2)(Hw)γw	3.16	0.917	2.90	
Sub-Total		40.10	0.966	38.72	
Uplift-1	-1/2B(D+Hw)γw	-5.76	1.567	-9.02	
Uplift-2	-1/2B(D)γw	-25.33	0.783	-19.84	
Sub-Total		-31.09		-28.86	
Total		9.01		9.86	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.73	0.90	Active force
F6	1/2γw(D)^2	23.72	0.17	3.95	Resisting force
Total of active forces		1.60		0.96	
Total of maximum resisting forces		28.82		4.80	
Actual resisting forces		1.60		0.96	

(3) Stability

Sliding,

V = 9.01 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 28.82 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 21.33 > 1.0 Safe !!

Overturning,

Mr_{max} = 43.52 (kN-m/m)

Mr = 39.68 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 29.83 (kN-m/m)

SF = Mr_{max}/M_o = 1.46 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.766 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.82 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.766 m

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 109 (kN/m)

Qa = 54.7 (kN/m) > V = 9.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.409 m

q1 = (2V)/3X = 14.704 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 12.305 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	19.60	0.67	13.07	Water pressure
Total		19.74		13.08	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Water	γw(Hw)(a5)	35.82	1.08	38.51	
Soil	γsat(a6)(a5)	12.90	1.08	13.87	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Uplift	-1/2(p5)(a5)	-23.18	1.43	-33.220	
	-1/2(p7)(a5)	-6.792	0.72	-4.867	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-6.310	0.342	-2.157	
Total		22.76		23.22	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.60~1.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.6	0.100	0.96	1.200	11.52
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.867	0.00
Footing	(B)(t3)γc	11.28	1.175	13.25	0.100	1.13
Soil-1	1/2(a5)(a6)γs	5.805	1.633	9.48	0.300	1.74
Soil-2	1/2(a4)(a6)γs	5.81	0.917	5.32	0.400	2.32
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		32.49	0.893	29.02	0.514	16.71

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.50	0.51	3.34	Seismic force
Total of active forces		7.50		3.51	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.50		1.29	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 7.50 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.50 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.63 > 1.2 Safe !!

Overturning,

Mr_{max} = 30.31 (kN-m/m)

Mr_{act} = 30.31 (kN-m/m)

Mo = 3.51 (kN-m/m)

d = (Mr-Mo)/V = 0.82 (m)

SF =M_{max}/ M_{act} = 8.63 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.35 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.65 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.35 m

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 269 (kN/m)

Qa = 134 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.825 m

q1 = V/B*(1+6e/B)= 26.186 (kN/m2)

q2 = V/B*(1-6e/B) = 1.465 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.082 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.92	1.00	1.92	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.67	0.00	Seismic force
Total		2.28		1.96	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-1.575001	1.4333333	-2.258	
	1/2(q3)(a5)	-25.888	0.717	-18.553	
Total		-5.53		2.76	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.60~1.70

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.6	2.250	21.60	1.200	11.52
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.150	0.00	0.867	0.00
Footing	(B)(t3)γc	11.28	1.175	13.25	0.100	1.13
Soil-1	1/2(a5)(a6)γs	5.805	0.717	4.16	0.300	1.74
Soil-2	1/2(a4)(a6)γs	5.81	1.433	8.32	0.400	2.32
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		32.49	1.457	47.33	0.514	16.71

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.50	0.51	3.34	Seismic force
Total of active forces		8.62		3.79	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 8.62 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.16 > 1.2 Safe !!

Overturning,

Mr_{max} = 48.63 (kN-m/m)

Mr_{act} = 48.63 (kN-m/m)

Mo = 3.79 (kN-m/m)

d = (Mr-Mo)/V = 1.38 (m)

SF =Mr_{max}/ M_o = 12.83 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.205 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.940 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.205 m

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.027

= 336 (kN/m)

Qa = 168 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.175

q1 = V/B*(1-6e/B)= 21.063 (kN/m2)

q2 = V/B*(1+6e/B) = 6.588 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.831 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.92	1.00	1.92	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.67	0.00	Seismic force
Total		2.95		2.06	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-7.082	1.433	-10.151	
	1/2(q3)(a5)	-21.319	0.717	-15.278	
Total		-6.47		-1.85	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.60~1.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.6	0.100	0.96
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	11.28	1.175	13.25
Soil-1	1/2(a5)(a6)γs	5.805	1.633	9.48
Soil-2	1/2(a4)(a6)γs	5.81	0.917	5.32
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		32.49	0.893	29.02

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.58	1.35	4.83	Wind force
Total of active forces		4.26		4.95	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.26		1.53	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 4.26 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.26 (kN/m)

SF =(V*f + HR_{max})/ H = 6.73 > 1.2 Safe !!

Overturning,

Mr_{max}= 30.55 (kN-m/m)

Mr_{act}= 30.55 (kN-m/m)

Mo = 4.95 (kN-m/m)

d = (Mr-Mo)/V = 0.79 (m)

SF =Mr_{max}/ M_o = 6.17 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.387 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.576 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.387 (m)

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 253 (kN/m)

Qa = 126 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.788 m

q1 = V/B*(1+6e/B)= 27.489 (kN/m2)

q2 = V/B*(1-6e/B) = 0.162 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 25.163 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		3.58	1.15	4.12	
Total		3.83		4.14	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-0.174	1.433	-0.250	
	1/2(q3)(a5)	-27.05	0.717	-19.386	
Total		-5.29		3.94	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.60~1.70

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	9.6	2.250	21.60
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.150	0.00
Footing	(B)(t3)γc	11.28	1.175	13.25
Soil-1	1/2(a5)(a6)γs	5.805	0.717	4.16
Soil-2	1/2(a4)(a6)γs	5.81	1.433	8.32
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		32.49	1.457	47.33

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.58	1.35	4.83	Wind force
Total of active forces		5.78		5.33	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		5.78		0.96	

(3) Stability

Sliding,

V = 32.49 (kN/m)

H = 5.78 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 5.78 (kN/m)

SF =(V*f + HR_{max})/ H = 4.96 > 1.2 Safe !!

Overturning,

Mr_{max} = 48.86 (kN-m/m)

Mr_{act} = 48.30 (kN-m/m)

Mo = 5.33 (kN-m/m)

d = (Mr-Mo)/V = 1.32 (m)

SF =Mr_{max}/ M_o = 9.17 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.165 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.055 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.148 (m)

α = 1.0

k = 1+0.3*D/B = 1.0638298

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 364 (kN/m)

Qa = 182 (kN/m) > V = 32.49 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.027 m

q1 = V/B*(1-6e/B)= 19.036 (kN/m2)

q2 = V/B*(1+6e/B) = 8.615 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.149 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		3.58	1.15	4.12	
Total		4.74		4.28	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	11.61	1.08	12.48	
Footing	γc(t3)(a5)	10.32	1.08	11.09	
Reaction	1/2(q2)(a5)	-9.261	1.433	-13.274	
	1/2(q3)(a5)	-19.51	0.717	-13.982	
Total		-6.84		-3.68	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	125	904.78

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	3.22	19.74	1.58	53.12	0.14
Footing	**Top bar**	16.16	6.00	6.05	137.03	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	125	565.49
As/m	452.39	200.00	200.00	904.78	200.00
Circum.	150.7968			301.5936	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0062832	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2844723	
j= 1- k/3	0.92959982			0.905176	
Actual Stresses, (Mpa)					
fs (steel)	53.12			137.03	
fc (concrete)	1.58			6.05	
v (shear)	0.14			0.04	
u (bond)	0.98			0.15	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.60~1.70

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	41.95	1.5	0.24	0.39	32.5	100
Normal-2	13.02	1.5	0.31	0.39	32.5	101
Flood-1	1.22	1	0.77	0.78	38.5	55
Flood-2	21.33	1	0.77	0.78	9.0	55
Seismic-1	3.63	1.2	0.35	0.78	32.5	134
Seismic-2	3.16	1.2	0.21	0.78	32.5	168
Wind-1	6.73	1.2	0.387	0.78	32.49	126
Wind-2	4.96	1.2	0.165	0.78	32.49	182

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.59	-5.97	
Normal-2		0.16	1.16	0.47	-6.00	
Flood		13.08	19.74	16.16	2.10	
Seismic-1	*	1.47	1.72	2.08	-4.16	*: divided by 1.33
Seismic-2	*	1.55	2.22	-1.39	-4.87	*: divided by 1.33
Wind-1	*	3.11	2.88	2.96	-3.98	*: divided by 1.33
Wind-2	*	3.22	3.56	-2.77	-5.14	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	13.08	19.74	5.24	125.97	0.14
Footing	**Bot bar**	2.77	6.00	1.84	55.69	0.05

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	250	1005.31	565.49	250	565.49
As/m	804.25	200.00	200.00	452.39	200.00
Circum.	201.0624			150.7968	
d'	0.058			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.00566373			0.0038016	
k= $(p\,n)^2+2p\,n$	0.2723613			0.2296026	
j= 1- k/3	0.9092129			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	125.97			55.69	
fc (concrete)	5.24			1.84	
v (shear)	0.14			0.05	
u (bond)	0.76			0.36	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.70~1.80

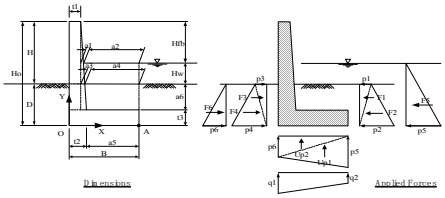
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.80	(m)
Embedment of wall	D =	0.50	(m)
Total height of wall	Ho=	2.30	(m)
Freeboard	Hfb=	1.00	(m)
Water depth under flood condition	Hw=	1.80	(m)
Width of footing	B =	2.45	(m)
Thickness of wall members :			
t1= 0.20 (m)		a1= 0.000	(m)
t2= 0.20 (m)		a2= 2.250	(m)
t3= 0.20 (m)		a3= 0.000	(m)
		a4= 2.250	(m)
		a5= 2.250	(m)
		a6= 0.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.85 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.30

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 315 (kN/m)

Qa = 105 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.927 m

q1 = V/B*(1+6e/B)= 23.994 (kN/m2)

q2 = V/B*(1-6e/B) = 3.753 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.342 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.15	1.13	13.67	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2(q2)(a5)	-4.222	1.500	-6.333	
	1/2(q3)(a5)	-25.13	0.750	-18.851	
Total		-6.41		0.64	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.70~1.80

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	0.100	1.01	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.76	1.225	14.41	
Soil-1	1/2(a5)(a6)γs	6.075	1.700	10.33	
Soil-2	1/2(a4)(a6)γs	6.08	0.950	5.77	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		33.99	0.927	31.51	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f + HR_{max})/ H = 43.27 > 1.5 Safe !!

Overturning,

Mr_{max} = 33.04 (kN-m/m)

Mr_{act} = 31.63 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 290.06 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.26 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.70~1.80

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	2.350	23.69	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.250	0.00	
Footing	(B)(t3)γc	11.76	1.225	14.41	
Soil-1	1/2(a5)(a6)γs	6.075	0.750	4.56	
Soil-2	1/2(a4)(a6)γs	6.08	1.500	9.11	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		33.99	1.523	51.76	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f + HR_{max})/ H = 13.43 > 1.5 Safe !!

Overturning,

Mr_{max} = 53.29 (kN-m/m)

Mr_{act} = 52.13 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 107.96 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.33 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.86 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.29 m

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 317 (kN/m)

Qa = 106 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.931 m

q1 = V/B*(1-6e/B)= 23.868 (kN/m2)

q2 = V/B*(1+6e/B) = 3.879 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.236 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.15	1.13	13.67	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2(q2)(a5)	-4.364	1.500	-6.546	
	1/2(q3)(a5)	-25.02	0.750	-18.762	
Total		-6.43		0.51	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.70~1.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	0.100	1.01	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.76	1.225	14.41	
Soil-1	1/2(a5)(a6)γsat	6.75	1.700	11.48	
Soil-2	1/2(a4)(a6)γsat	6.75	0.950	6.41	
Water-1	1/2(a4)(Hw)γw	19.85	1.700	33.74	
Water-2	1/2(a2)(Hw)γw	19.85	0.950	18.85	
Sub-Total		75.03	1.145	85.89	
Uplift-1	-1/2B(D+Hw)γw	-27.61	1.633	-45.10	
Uplift-2	-1/2B(D)γw	-6.00	0.817	-4.90	
Sub-Total		-33.61		-50.00	
Total		41.42		35.89	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	25.92	0.77	19.87	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		26.30		19.94	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 41.42 (kN/m)

H = 26.30 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f +HR_{max})/ H = 1.19 > 1.0 Safe !!

Overturning,

Mr_{max} = 86.94 (kN-m/m)

Mr = 86.94 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 69.94 (kN-m/m)

SF = Mr_{max}/M_o = 1.24 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.814 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.82 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.814 m

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.482

= 110 (kN/m)

Qa = 55.0 (kN/m) > V = 41.42 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.411 m

q1 = (2V)/3X = 67.234 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 56.319 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		20.58	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	21.61	0.70	15.13	Water pressure
Total		21.75		15.14	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	39.69	1.13	44.65	
Soil	γsat(a6)(a5)	13.50	1.13	15.19	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Uplift	-1/2(p5)(a5)	-25.36	1.50	-38.036	
	-1/2(p7)(a5)	-7.133	0.75	-5.349	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-29.061	0.344	-9.997	
Total		2.44		18.61	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.70~1.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.08	0.100	1.01	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	11.76	1.225	14.41	
Soil-1	1/2(a5)(a6)γsat	6.75	1.700	11.48	
Soil-2	1/2(a4)(a6)γsat	6.75	0.950	6.41	
Water-1	1/2(a4)(Hw)γw	3.31	1.700	5.62	
Water-2	1/2(a2)(Hw)γw	3.31	0.950	3.14	
Sub-Total		41.96	1.003	42.07	
Uplift-1	-1/2B(D+Hw)γw	-6.00	1.633	-9.80	
Uplift-2	-1/2B(D)γw	-27.61	0.817	-22.55	
Sub-Total		-33.61		-32.35	
Total		8.34		9.71	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.77	0.94	Active force
F6	1/2γw(D)^2	25.92	0.17	4.32	Resisting force
Total of active forces		1.60		1.00	
Total of maximum resisting forces		31.02		5.17	
Actual resisting forces		1.60		1.00	

(3) Stability

Sliding,

V = 8.34 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 31.02 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f +HR_{max})/ H = 22.45 > 1.0 Safe !!

Overturning,

Mr_{max} = 47.24 (kN-m/m)

Mr = 43.07 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 33.36 (kN-m/m)

SF = Mr_{max}/M_o = 1.42 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.814 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.82 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.814 m

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 110 (kN/m)

Qa = 55.0 (kN/m) > V = 8.34 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.411 m

q1 = (2V)/3X = 13.541 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 11.342 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		20.58	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	21.61	0.70	15.13	Water pressure
Total		21.75		15.14	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	39.69	1.13	44.65	
Soil	γsat(a6)(a5)	13.50	1.13	15.19	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Uplift	-1/2(p5)(a5)	-25.36	1.50	-38.036	
	-1/2(p7)(a5)	-7.133	0.75	-5.349	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.853	0.344	-2.013	
Total		25.65		26.59	

6. Case 5 : Seismic condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.70~1.80

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	0.100	1.01	1.250	12.60
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.900	0.00
Footing	(B)(t3)γc	11.76	1.225	14.41	0.100	1.18
Soil-1	1/2(a5)(a6)γs	6.075	1.700	10.33	0.300	1.82
Soil-2	1/2(a4)(a6)γs	6.08	0.950	5.77	0.400	2.43
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		33.99	0.927	31.51	0.530	18.03

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{Kea}$	0.00	0.00	Active earth press.
p2	Kea(γh)-2c$\sqrt{Kea}$	0.50	4.03	Active earth press.
p3	Kep(γh)+2c$\sqrt{Kep}$	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c$\sqrt{Kep}$	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.80	0.53	3.61	Seismic force
Total of active forces		7.80		3.77	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 7.80 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f + HR_{max})/ H = 3.61 > 1.2 Safe !!

Overturning,

Mr_{max} = 32.81 (kN-m/m)

Mr_{act} = 32.81 (kN-m/m)

Mo = 3.77 (kN-m/m)

d = (Mr-Mo)/V = 0.85 (m)

SF =M_{max}/ M_{act} = 8.69 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.37 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.71 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.37 m

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.001

= 282 (kN/m)

Qa = 141 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.854 m

q1 = V/B*(1+6e/B)= 26.474 (kN/m2)

q2 = V/B*(1-6e/B) = 1.273 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.417 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{Kea}$	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c$\sqrt{Kea}$	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.02	1.05	2.12	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.70	0.00	Seismic force
Total		2.38		2.15	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.15	1.13	13.67	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2(q2)(a5)	-1.431662	1.5	-2.147	
	1/2(q3)(a5)	-27.469	0.750	-20.602	
Total		-5.95		3.07	

7. Case 6 : Seismic condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.70~1.80

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	2.350	23.69	1.250	12.60
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.250	0.00	0.900	0.00
Footing	(B)(t3)γc	11.76	1.225	14.41	0.100	1.18
Soil-1	1/2(a5)(a6)γs	6.075	0.750	4.56	0.300	1.82
Soil-2	1/2(a4)(a6)γs	6.08	1.500	9.11	0.400	2.43
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		33.99	1.523	51.76	0.530	18.03

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c$\sqrt{Kep}$	0.00	0.00	Passive press.
p2	Kep(γh)+2c$\sqrt{Kep}$	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c$\sqrt{Kea}$	0.00	2.24	Active press.
p4	Kea(γh+q')-2c$\sqrt{Kea}$	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.80	0.53	3.61	Seismic force
Total of active forces		8.92		4.05	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 8.92 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f + HR_{max})/ H = 3.15 > 1.2 Safe !!

Overturning,

Mr_{max} = 53.06 (kN-m/m)

Mr_{act} = 53.06 (kN-m/m)

Mo = 4.05 (kN-m/m)

d = (Mr-Mo)/V = 1.44 (m)

SF =Mr_{max}/ M_o = 13.09 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.217 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 2.017 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.217 m

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.034

= 354 (kN/m)

Qa = 177 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.225

q1 = V/B*(1-6e/B)= 21.235 (kN/m2)

q2 = V/B*(1+6e/B) = 6.512 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.033 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c$\sqrt{}$Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.02	1.05	2.12	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.70	0.00	Seismic force
Total		3.05		2.25	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.15	1.13	13.67	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2(q2)(a5)	-7.326	1.500	-10.990	
	1/2(q3)(a5)	-22.537	0.750	-16.903	
Total		-6.91		-2.07	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.70~1.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	0.100	1.01
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	11.76	1.225	14.41
Soil-1	1/2(a5)(a6)γs	6.075	1.700	10.33
Soil-2	1/2(a4)(a6)γs	6.08	0.950	5.77
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		33.99	0.927	31.51

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c$\sqrt{}$Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	
p4	Kp(γh)+2c$\sqrt{}$Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.79	1.40	5.31	Wind force
Total of active forces		4.47		5.42	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.47		1.53	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 4.47 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.47 (kN/m)

SF =(V*f + HR_{max})/ H = 6.61 > 1.2 Safe !!

Overturning,

Mr_{max}= 33.04 (kN-m/m)

Mr_{act}= 33.04 (kN-m/m)

Mo = 5.42 (kN-m/m)

d = (Mr-Mo)/V = 0.81 (m)

SF =Mr_{max}/ M_o = 6.10 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.412 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 1.625 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.412 (m)

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 263 (kN/m)

Qa = 132 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.813 m

q1 = (2V)/3X = 27.884 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 25.597 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		3.79	1.20	4.55	
Total		4.04		4.57	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.15	1.13	13.67	
Footing	γc(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2*(q2)*(a5)	0.000	0.000	0.000	
	1/2(q3)(3X-t2)	-28.64	0.746	-21.366	
Total		-5.69		4.45	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.70~1.80

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.08	2.350	23.69
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.250	0.00
Footing	(B)(t3)γc	11.76	1.225	14.41
Soil-1	1/2(a5)(a6)γs	6.075	0.750	4.56
Soil-2	1/2(a4)(a6)γs	6.08	1.500	9.11
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		33.99	1.523	51.76

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{}$Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c$\sqrt{}$Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{}$Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	3.79	1.40	5.31	Wind force
Total of active forces		5.99		5.80	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		5.99		1.00	

(3) Stability

Sliding,

V = 33.99 (kN/m)

H = 5.99 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 5.99 (kN/m)

SF =(V*f + HR_{max})/ H = 4.93 > 1.2 Safe !!

Overturning,

Mr_{max} = 53.29 (kN-m/m)

Mr_{act} = 52.76 (kN-m/m)

Mo = 5.80 (kN-m/m)

d = (Mr-Mo)/V = 1.38 (m)

SF =Mr_{max}/ M_o = 9.19 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.172 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 2.137 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.157 (m)

α = 1.0

k = 1+0.3*D/B = 1.0612245

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 384 (kN/m)

Qa = 192 (kN/m) > V = 33.99 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.068 m

q1 = V/B*(1-6e/B)= 19.194 (kN/m2)

q2 = V/B*(1+6e/B) = 8.553 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.326 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		3.79	1.20	4.55	
Total		4.95		4.71	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	12.15	1.13	13.67	
Footing	γ_C(t3)(a5)	10.80	1.13	12.15	
Reaction	1/2(q2)(a5)	-9.622	1.500	-14.432	
	1/2(q3)(a5)	-20.62	0.750	-15.462	
Total		-7.29		-4.08	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.140	20	250	1256.64

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	3.54	21.75	1.74	58.48	0.15
Footing	**Top bar**	18.61	6.43	6.48	118.80	0.05

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	20	20
Spacing	250	565.49	565.49	250	1570.80
As/m	452.39	200.00	200.00	1256.64	200.00
Circum.	150.7968			251.328	
d'$\sqrt{}$	0.056			0.06	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.008976	
k= $(p\,n)^2+2p\,n$	0.21120053			0.3292087	
j= 1- k/3	0.92959982			0.890264	
Actual Stresses, (Mpa)					
fs (steel)	58.48			118.80	
fc (concrete)	1.74			6.48	
v (shear)	0.15			0.05	
u (bond)	1.08			0.21	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.70~1.80

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	43.27	1.5	0.26	0.41	34.0	105
Normal-2	13.43	1.5	0.33	0.41	34.0	106
Flood-1	1.19	1	0.81	0.82	41.4	55
Flood-2	22.45	1	0.81	0.82	8.3	55
Seismic-1	3.61	1.2	0.37	0.82	34.0	141
Seismic-2	3.15	1.2	0.22	0.82	34.0	177
Wind-1	6.61	1.2	0.412	0.82	33.99	132
Wind-2	4.93	1.2	0.172	0.82	33.99	192

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	$\overline{fy}$ =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{fc'}$	0.36 (MPa)
Tensile stress in reinforcement		140 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.64	-6.41	
Normal-2		0.16	1.16	0.51	-6.43	
Flood		15.14	21.75	18.61	2.44	
Seismic-1	*	1.62	1.79	2.31	-4.47	*: divided by 1.33
Seismic-2	*	1.69	2.29	-1.56	-5.20	*: divided by 1.33
Wind-1	*	3.44	3.04	3.35	-4.28	*: divided by 1.33
Wind-2	*	3.54	3.72	-3.06	-5.48	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	15.14	21.75	5.67	128.38	0.15
Footing	**Bot bar**	3.06	6.43	2.04	61.65	0.05

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	125	565.49	565.49	250	565.49
As/m	904.78	200.00	200.00	452.39	200.00
Circum.	301.5936			150.7968	
d'$\sqrt{}$	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0062832			0.0038016	
k= $(p\,n)^2+2p\,n$	0.28447227			0.2296026	
j= 1- k/3	0.90517591			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	128.38			61.65	
fc (concrete)	5.67			2.04	
v (shear)	0.15			0.05	
u (bond)	0.55			0.39	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.80~1.90

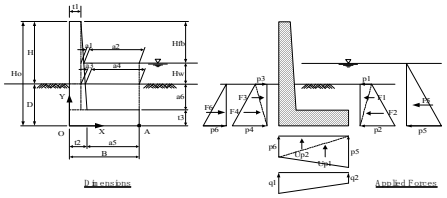
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.90	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	2.40	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	1.90	(m)		
Width of footing	B =	2.60	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	2.400	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	2.400	(m)
			a5=	2.400	(m)
			a6=	0.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.97 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.32

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 342 (kN/m)

Qa = 114 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.984 m

q1 = V/B*(1+6e/B)= 23.943 (kN/m2)

q2 = V/B*(1-6e/B) = 3.749 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.390 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2(q2)(a5)	-4.499	1.600	-7.198	
	1/2(q3)(a5)	-26.87	0.800	-21.494	
Total		-6.89		0.68	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.80~1.90

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.56	0.100	1.06	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	12.48	1.300	16.22	
Soil-1	1/2(a5)(a6)γs	6.48	1.800	11.66	
Soil-2	1/2(a4)(a6)γs	6.48	1.000	6.48	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		36.00	0.984	35.42	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f+ HR_{max})/ H = 45.03 > 1.5 Safe !!

Overturning,

Mr_{max} = 36.95 (kN-m/m)

Mr_{act} = 35.54 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 324.39 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.28 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.80~1.90

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.56	2.500	26.40	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.400	0.00	
Footing	(B)(t3)γc	12.48	1.300	16.22	
Soil-1	1/2(a5)(a6)γs	6.48	0.800	5.18	
Soil-2	1/2(a4)(a6)γs	6.48	1.600	10.37	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		36.00	1.616	58.18	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f+ HR_{max})/ H = 13.98 > 1.5 Safe !!

Overturning,

Mr_{max} = 59.71 (kN-m/m)

Mr_{act} = 58.54 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 120.95 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.34 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

Be = B - 2 e = 1.98 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.31 m

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 343 (kN/m)

Qa = 114 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.988 m

q1 = V/B*(1-6e/B)= 23.831 (kN/m2)

q2 = V/B*(1+6e/B) = 3.861 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.295 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2(q2)(a5)	-4.634	1.600	-7.414	
	1/2(q3)(a5)	-26.75	0.800	-21.403	
Total		-6.91		0.56	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.80~1.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.56	0.100	1.06	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	12.48	1.300	16.22	
Soil-1	1/2(a5)(a6)γsat	7.20	1.800	12.96	
Soil-2	1/2(a4)(a6)γsat	7.20	1.000	7.20	
Water-1	1/2(a4)(Hw)γw	22.34	1.800	40.22	
Water-2	1/2(a2)(Hw)γw	22.34	1.000	22.34	
Sub-Total		82.13	1.218	100.00	
Uplift-1	-1/2B(D+Hw)γw	-30.58	1.733	-53.00	
Uplift-2	-1/2B(D)γw	-6.37	0.867	-5.52	
Sub-Total		-36.95		-58.52	
Total		45.18		41.48	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	28.22	0.80	22.58	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		28.60		22.64	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 45.18 (kN/m)

H = 28.60 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.17 > 1.0 Safe !!

Overturning,

Mr_{max} = 101.06 (kN-m/m)

Mr = 101.06 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 81.16 (kN-m/m)

SF = Mr_{max}/M_o = 1.25 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.860 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.88 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.860 m

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.493

= 119 (kN/m)

Qa = 59.7 (kN/m) > V = 45.18 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.440 m

q1 = (2V)/3X = 68.403 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 58.047 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		21.56	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	23.72	0.73	17.39	Water pressure
Total		23.85		17.41	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	44.69	1.20	53.63	
Soil	γsat(a6)(a5)	14.40	1.20	17.28	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Uplift	-1/2(p5)(a5)	-28.22	1.60	-45.158	
	-1/2(p7)(a5)	-7.599	0.80	-6.079	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-32.537	0.374	-12.159	
Total		2.25		21.33	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.80~1.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	10.56	0.100	1.06	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	12.48	1.300	16.22	
Soil-1	1/2(a5)(a6)γsat	7.20	1.800	12.96	
Soil-2	1/2(a4)(a6)γsat	7.20	1.000	7.20	
Water-1	1/2(a4)(Hw)γw	3.53	1.800	6.35	
Water-2	1/2(a2)(Hw)γw	3.53	1.000	3.53	
Sub-Total		44.50	1.063	47.32	
Uplift-1	-1/2B(D+Hw)γw	-6.37	1.733	-11.04	
Uplift-2	-1/2B(D)γw	-30.58	0.867	-26.50	
Sub-Total		-36.95		-37.54	
Total		7.55		9.78	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γ'h)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.80	0.98	Active force
F6	1/2γw(D)^2	28.22	0.17	4.70	Resisting force
Total of active forces		1.60		1.04	
Total of maximum resisting forces		33.32		5.55	
Actual resisting forces		1.60		1.04	

(3) Stability

Sliding,

V = 7.55 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 33.32 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 23.59 > 1.0 Safe !!

Overturning,

Mr_{max} = 52.87 (kN-m/m)

Mr = 48.36 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 38.58 (kN-m/m)

SF = Mr_{max}/M_o = 1.37 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.860 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.88 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.860 m

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 119 (kN/m)

Qa = 59.7 (kN/m) > V = 7.55 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.440 m

q1 = (2V)/3X = 11.430 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 9.700 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		21.56	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	23.72	0.73	17.39	Water pressure
Total		23.85		17.41	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	44.69	1.20	53.63	
Soil	γsat(a6)(a5)	14.40	1.20	17.28	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Uplift	-1/2(p5)(a5)	-28.22	1.60	-45.158	
	-1/2(p7)(a5)	-7.599	0.80	-6.079	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.437	0.374	-2.032	
Total		29.35		31.46	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.80~1.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.56	0.100	1.06	1.300	13.73
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.933	0.00
Footing	(B)(t3)γc	12.48	1.300	16.22	0.100	1.25
Soil-1	1/2(a5)(a6)γs	6.48	1.800	11.66	0.300	1.94
Soil-2	1/2(a4)(a6)γs	6.48	1.000	6.48	0.400	2.59
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		36.00	0.984	35.42	0.542	19.51

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.20	0.54	3.90	Seismic force
Total of active forces		8.21		4.07	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 8.21 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.58 > 1.2 Safe !!

Overturning,

Mr_{max} = 36.72 (kN-m/m)

Mr_{act} = 36.72 (kN-m/m)

Mo = 4.07 (kN-m/m)

d = (Mr-Mo)/V = 0.91 (m)

SF =M_{max}/ M_{act} = 9.02 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.39 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.81 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.39 m

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.013

= 305 (kN/m)

Qa = 153 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.907 m

q1 = V/B*(1+6e/B)= 26.409 (kN/m2)

q2 = V/B*(1-6e/B) = 1.284 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.476 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.11	1.10	2.32	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.73	0.00	Seismic force
Total		2.47		2.36	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2(q2)(a5)	-1.540298	1.6	-2.464	
	1/2(q3)(a5)	-29.371	0.800	-23.497	
Total		-6.43		3.41	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.80~1.90

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.56	2.500	26.40	1.300	13.73
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.400	0.00	0.933	0.00
Footing	(B)(t3)γc	12.48	1.300	16.22	0.100	1.25
Soil-1	1/2(a5)(a6)γs	6.48	0.800	5.18	0.300	1.94
Soil-2	1/2(a4)(a6)γs	6.48	1.600	10.37	0.400	2.59
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		36.00	1.616	58.18	0.542	19.51

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.20	0.54	3.90	Seismic force
Total of active forces		9.33		4.35	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 9.33 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.15 > 1.2 Safe !!

Overturning,

Mr_{max} = 59.47 (kN-m/m)

Mr_{act} = 59.47 (kN-m/m)

Mo = 4.35 (kN-m/m)

d = (Mr-Mo)/V = 1.53 (m)

SF =Mr_{max}/ M_o = 13.67 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.231 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.138 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.231 m

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.044

= 384 (kN/m)

Qa = 192 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.300

q1 = V/B*(1-6e/B)= 21.229 (kN/m2)

q2 = V/B*(1+6e/B) = 6.463 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.094 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.11	1.10	2.32	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.73	0.00	Seismic force
Total		3.15		2.46	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2(q2)(a5)	-7.755	1.600	-12.409	
	1/2(q3)(a5)	-24.112	0.800	-19.290	
Total		-7.39		-2.32	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.80~1.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.56	0.100	1.06
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	12.48	1.300	16.22
Soil-1	1/2(a5)(a6)γs	6.48	1.800	11.66
Soil-2	1/2(a4)(a6)γs	6.48	1.000	6.48
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		36.00	0.984	35.42

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	4.00	1.45	5.80	Wind force
Total of active forces		4.68		5.92	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.68		1.53	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 4.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.68 (kN/m)

SF =(V*f + HR_{max})/ H = 6.57 > 1.2 Safe !!

Overturning,

Mr_{max}= 36.95 (kN-m/m)

Mr_{act}= 36.95 (kN-m/m)

Mo = 5.92 (kN-m/m)

d = (Mr-Mo)/V = 0.86 (m)

SF =Mr_{max}/ M_o = 6.25 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.438 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.724 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.438 (m)

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 285 (kN/m)

Qa = 142 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.862 m

q1 = (2V)/3X = 27.837 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 25.684 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		4.00	1.25	5.00	
Total		4.25		5.03	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2*(q2)*(a5)	0.000	0.000	0.000	
	1/2(q3)(3X-t2)	-30.65	0.796	-24.381	
Total		-6.17		5.00	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.80~1.90

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	10.56	2.500	26.40
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.400	0.00
Footing	(B)(t3)γc	12.48	1.300	16.22
Soil-1	1/2(a5)(a6)γs	6.48	0.800	5.18
Soil-2	1/2(a4)(a6)γs	6.48	1.600	10.37
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		36.00	1.616	58.18

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	4.00	1.45	5.80	Wind force
Total of active forces		6.20		6.30	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		6.20		1.03	

(3) Stability

Sliding,

V = 36.00 (kN/m)

H = 6.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 6.20 (kN/m)

SF =(V*f + HR_{max})/ H = 4.96 > 1.2 Safe !!

Overturning,

Mr_{max} = 59.71 (kN-m/m)

Mr_{act} = 59.21 (kN-m/m)

Mo = 6.30 (kN-m/m)

d = (Mr-Mo)/V = 1.47 (m)

SF =Mr_{max}/ M_o = 9.48 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.184 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.260 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.170 (m)

α = 1.0

k = 1+0.3*D/B = 1.0576923

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 415 (kN/m)

Qa = 208 (kN/m) > V = 36.00 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.130 m

q1 = V/B*(1-6e/B)= 19.273 (kN/m2)

q2 = V/B*(1+6e/B) = 8.419 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.438 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s l H		4.00	1.25	5.00	
Total		5.16		5.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	12.96	1.20	15.55	
Footing	γc(t3)(a5)	11.52	1.20	13.82	
Reaction	1/2(q2)(a5)	-10.103	1.600	-16.165	
	1/2(q3)(a5)	-22.13	0.800	-17.701	
Total		-7.75		-4.49	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.140	20	250	1256.64

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	3.88	23.85	1.91	64.10	0.17
Footing	**Top bar**	21.33	6.91	7.43	136.21	0.05

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	20	20
Spacing	250	565.49	565.49	250	1570.80
As/m	452.39	200.00	200.00	1256.64	200.00
Circum.	150.7968			251.328	
d'	0.056			0.06	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.008976	
k= $(pn)^2+2pn$	0.21120053			0.3292087	
j= 1- k/3	0.92959982			0.890264	
Actual Stresses, (Mpa)					
fs (steel)	64.10			136.21	
fc (concrete)	1.91			7.43	
v (shear)	0.17			0.05	
u (bond)	1.18			0.22	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.80~1.90

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	45.03	1.5	0.28	0.43	36.0	114
Normal-2	13.98	1.5	0.34	0.43	36.0	114
Flood-1	1.17	1	0.86	0.87	45.2	60
Flood-2	23.59	1	0.86	0.87	7.5	60
Seismic-1	3.58	1.2	0.39	0.87	36.0	153
Seismic-2	3.15	1.2	0.23	0.87	36.0	192
Wind-1	6.57	1.2	0.438	0.87	36.00	142
Wind-2	4.96	1.2	0.184	0.87	36.00	208

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.68	-6.89	
Normal-2		0.16	1.16	0.56	-6.91	
Flood		17.41	23.85	21.33	2.25	
Seismic-1	*	1.77	1.86	2.57	-4.84	*: divided by 1.33
Seismic-2	*	1.85	2.37	-1.75	-5.55	*: divided by 1.33
Wind-1	*	3.78	3.19	3.76	-4.64	*: divided by 1.33
Wind-2	*	3.88	3.88	-3.38	-5.83	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	17.41	23.85	6.06	111.13	0.17
Footing	**Bot bar**	3.38	6.91	2.25	67.90	0.06

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	250	1570.80	565.49	250	565.49
As/m	1256.64	200.00	200.00	452.39	200.00
Circum.	251.328			150.7968	
d'	0.06			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.008976			0.0038016	
k= $(pn)^2+2pn$	0.32920875			0.2296026	
j= 1- k/3	0.89026375			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	111.13			67.90	
fc (concrete)	6.06			2.25	
v (shear)	0.17			0.06	
u (bond)	0.76			0.42	
Code Minimum reinforcements					
ratio (min.)	0.001	0.001		0.001	
As (min.) = ratio x b x h	200	200		200	

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL

Height of Wall, H = 1.90~2.00

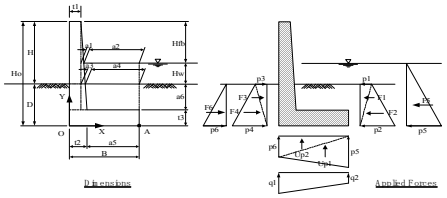
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	2.00	(m)		
Embedment of wall	D =	0.50	(m)		
Total height of wall	Ho=	2.50	(m)		
Freeboard	Hfb=	1.00	(m)		
Water depth under flood condition	Hw=	2.00	(m)		
Width of footing	B =	2.75	(m)		
Thickness of wall members :					
t1=	0.20	(m)		a1=	0.000 (m)
t2=	0.20	(m)		a2=	2.550 (m)
t3=	0.20	(m)		a3=	0.000 (m)
				a4=	2.550 (m)
				a5=	2.550 (m)
				a6=	0.300 (m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.08 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.33

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 369 (kN/m)

Qa = 123 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 1.041 m

q1 = V/B*(1+6e/B)= 23.897 (kN/m2)

q2 = V/B*(1-6e/B) = 3.747 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.432 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Total		0.25		0.02	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2(q2)(a5)	-4.777	1.700	-8.121	
	1/2(q3)(a5)	-28.60	0.850	-24.310	
Total		-7.37		0.73	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.90~2.00

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	11.04	0.100	1.10	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	13.2	1.375	18.15	
Soil-1	1/2(a5)(a6)γs	6.885	1.900	13.08	
Soil-2	1/2(a4)(a6)γs	6.89	1.050	7.23	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		38.01	1.041	39.56	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.50	36.72	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.68		0.11	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		0.68		0.11	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 0.68 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 0.68 (kN/m)

SF =(V*f'+ HR_{max})/ H = 46.80 > 1.5 Safe !!

Overturning,

Mr_{max} = 41.09 (kN-m/m)

Mr_{act} = 39.68 (kN-m/m)

Mo = 0.11 (kN-m/m)

SF =Mr_{max}/ M_o = 360.74 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.30 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.90~2.00

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	11.04	2.650	29.26	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.550	0.00	
Footing	(B)(t3)γc	13.2	1.375	18.15	
Soil-1	1/2(a5)(a6)γs	6.885	0.850	5.85	
Soil-2	1/2(a4)(a6)γs	6.89	1.700	11.70	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		38.01	1.709	64.96	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.20		0.49	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		2.20		0.37	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 2.20 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 2.20 (kN/m)

SF =(V*f'+ HR_{max})/ H = 14.52 > 1.5 Safe !!

Overturning,

Mr_{max} = 66.49 (kN-m/m)

Mr_{act} = 65.33 (kN-m/m)

Mo = 0.49 (kN-m/m)

SF =Mr_{max}/ M_o = 134.70 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.36 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

Be = B - 2 e = 2.09 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.33 m

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 371 (kN/m)

Qa = 124 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.044 m

q1 = V/B*(1-6e/B)= 23.797 (kN/m2)

q2 = V/B*(1+6e/B) = 3.847 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.346 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Total		1.16		0.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2(q2)(a5)	-4.905	1.700	-8.338	
	1/2(q3)(a5)	-28.49	0.850	-24.217	
Total		-7.39		0.61	

4. Case 3 : Flood condition-1

Height of wall, Hw= 1.90~2.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	11.04	0.100	1.10	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	13.2	1.375	18.15	
Soil-1	1/2(a5)(a6)γsat	7.65	1.900	14.54	
Soil-2	1/2(a4)(a6)γsat	7.65	1.050	8.03	
Water-1	1/2(a4)(Hw)γw	24.99	1.900	47.48	
Water-2	1/2(a2)(Hw)γw	24.99	1.050	26.24	
Sub-Total		89.52	1.291	115.54	
Uplift-1	-1/2B(D+Hw)γw	-33.69	1.833	-61.76	
Uplift-2	-1/2B(D)γw	-6.74	0.917	-6.18	
Sub-Total		-40.43		-67.94	
Total		49.10		47.61	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	30.63	0.83	25.52	Active force
F6	1/2γw(D)^2	1.23	0.17	0.20	Resisting force
Total of active forces		31.00		25.58	
Total of maximum resisting forces		6.33		1.05	
Actual resisting forces		6.33		1.05	

(3) Stability

Sliding,

V = 49.10 (kN/m)

H = 31.00 (kN/m)

HR_{max} = 6.33 (kN/m)

HR_{act} = 6.33 (kN/m)

SF =(V*f+HR_{max})/ H = 1.15 > 1.0 Safe !!

Overturning,

Mr_{max} = 116.60 (kN-m/m)

Mr = 116.60 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 93.52 (kN-m/m)

SF = Mr_{max}/M_o = 1.25 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.905 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.94 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.905 m

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.503

= 129 (kN/m)

Qa = 64.5 (kN/m) > V = 49.10 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.470 m

q1 = (2V)/3X = 69.635 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 59.758 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		22.54	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	25.92	0.77	19.87	Water pressure
Total		26.06		19.89	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	49.98	1.28	63.72	
Soil	γsat(a6)(a5)	15.30	1.28	19.51	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Uplift	-1/2(p5)(a5)	-31.24	1.70	-53.104	
	-1/2(p7)(a5)	-8.065	0.85	-6.855	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-36.156	0.403	-14.584	
Total		2.06		24.30	

5. Case 4 : Flood condition-2 (flooded in landside)

Height of wall, Hw= 1.90~2.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	11.04	0.100	1.10	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	13.2	1.375	18.15	
Soil-1	1/2(a5)(a6)γsat	7.65	1.900	14.54	
Soil-2	1/2(a4)(a6)γsat	7.65	1.050	8.03	
Water-1	1/2(a4)(Hw)γw	3.75	1.900	7.12	
Water-2	1/2(a2)(Hw)γw	3.75	1.050	3.94	
Sub-Total		47.04	1.124	52.88	
Uplift-1	-1/2B(D+Hw)γw	-6.74	1.833	-12.35	
Uplift-2	-1/2B(D)γw	-33.69	0.917	-30.88	
Sub-Total		-40.43		-43.23	
Total		6.61		9.65	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{Ka}$	0.50	1.52	Active earth press.
p3	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c$\sqrt{Kp}$	0.50	20.40	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.38	0.17	0.06	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	5.10	0.17	0.85	Resisting force
F5	1/2γw(D+Hw)^2	1.23	0.83	1.02	Active force
F6	1/2γw(D)^2	30.63	0.17	5.10	Resisting force
Total of active forces		1.60		1.08	
Total of maximum resisting forces		35.73		5.95	
Actual resisting forces		1.60		1.08	

(3) Stability

Sliding,

V = 6.61 (kN/m)

H = 1.60 (kN/m)

HR_{max} = 35.73 (kN/m)

HR_{act} = 1.60 (kN/m)

SF =(V*f+HR_{max})/ H = 24.73 > 1.0 Safe !!

Overturning,

Mr_{max} = 58.83 (kN-m/m)

Mr = 53.96 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 44.32 (kN-m/m)

SF = Mr_{max}/M_o = 1.33 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.905 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.94 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.905 m

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 129 (kN/m)

Qa = 64.5 (kN/m) > V = 6.61 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.470 m

q1 = (2V)/3X = 9.378 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 8.048 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	0.91	Active earth press.
p5'	γw(Hw+a6)		22.54	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.14	0.10	0.01	Active force
F5'	1/2(p5')(Hw+a6)	25.92	0.77	19.87	Water pressure
Total		26.06		19.89	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	49.98	1.28	63.72	
Soil	γsat(a6)(a5)	15.30	1.28	19.51	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Uplift	-1/2(p5)(a5)	-31.24	1.70	-53.104	
	-1/2(p7)(a5)	-8.065	0.85	-6.855	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-4.869	0.403	-1.964	
Total		33.35		36.91	

6. Case 5 : Seismic condition-1

Height of wall, Hw= 1.90~2.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	11.04	0.100	1.10	1.350	14.90
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.967	0.00
Footing	(B)(t3)γc	13.2	1.375	18.15	0.100	1.32
Soil-1	1/2(a5)(a6)γs	6.885	1.900	13.08	0.300	2.07
Soil-2	1/2(a4)(a6)γs	6.89	1.050	7.23	0.400	2.75
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		38.01	1.041	39.56	0.554	21.04

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.50	4.03	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.50	31.02	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	1.01	0.17	0.17	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	7.75	0.17	1.29	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.60	0.55	4.21	Seismic force
Total of active forces		8.61		4.38	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 8.61 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.55 > 1.2 Safe !!

Overturning,

Mr_{max} = 40.86 (kN-m/m)

Mr_{act} = 40.86 (kN-m/m)

Mo = 4.38 (kN-m/m)

d = (Mr-Mo)/V = 0.96 (m)

SF =M_{max}/ M_{act} = 9.34 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.42 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.92 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.42 m

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.022

= 329 (kN/m)

Qa = 165 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.960 m

q1 = V/B*(1+6e/B)= 26.344 (kN/m2)

q2 = V/B*(1-6e/B) = 1.300 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.523 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.30	2.42	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.36	0.10	0.04	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.21	1.15	2.54	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.77	0.00	Seismic force
Total		2.57		2.58	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2(q2)(a5)	-1.657072	1.7	-2.817	
	1/2(q3)(a5)	-31.266	0.850	-26.576	
Total		-6.91		3.77	

7. Case 6 : Seismic condition-2

Height of wall, Hw= 1.90~2.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	11.04	2.650	29.26	1.350	14.90
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.550	0.00	0.967	0.00
Footing	(B)(t3)γc	13.2	1.375	18.15	0.100	1.32
Soil-1	1/2(a5)(a6)γs	6.885	0.850	5.85	0.300	2.07
Soil-2	1/2(a4)(a6)γs	6.89	1.700	11.70	0.400	2.75
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		38.01	1.709	64.96	0.554	21.04

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.50	31.02	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.50	6.27	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	7.75	0.17	1.29	Resisting force
F3	1/2(p3)h	0.56	0.33	0.19	Active force
F4	1/2(p4)h	1.57	0.17	0.26	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.60	0.55	4.21	Seismic force
Total of active forces		9.73		4.66	
Total of maximum resisting forces		7.75		1.29	
Actual resisting forces		7.75		1.29	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 9.73 (kN/m)

HR_{max} = 7.75 (kN/m)

HR_{act} = 7.75 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.14 > 1.2 Safe !!

Overturning,

Mr_{max} = 66.26 (kN-m/m)

Mr_{act} = 66.26 (kN-m/m)

Mo = 4.66 (kN-m/m)

d = (Mr-Mo)/V = 1.62 (m)

SF =Mr_{max}/ M_o = 14.23 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.246 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.259 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.246 m

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.052

= 414 (kN/m)

Qa = 207 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.375

q1 = V/B*(1-6e/B)= 21.228 (kN/m2)

q2 = V/B*(1+6e/B) = 6.415 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 20.151 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.30	4.65	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.34	0.20	0.07	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
Wall-1	γc(t1)(Ho-t3)kh	2.21	1.15	2.54	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.77	0.00	Seismic force
Total		3.24		2.68	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2(q2)(a5)	-8.180	1.700	-13.905	
	1/2(q3)(a5)	-25.692	0.850	-21.839	
Total		-7.86		-2.58	

8. Case 7 : Wind condition 1

Height of wall, Hw= 1.90~2.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	11.04	0.100	1.10
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	13.2	1.375	18.15
Soil-1	1/2(a5)(a6)γs	6.885	1.900	13.08
Soil-2	1/2(a4)(a6)γs	6.89	1.050	7.23
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		38.01	1.041	39.56

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.50	2.73	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.50	36.72	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Active force
F2	1/2(p2)h	0.68	0.17	0.11	Active force
F3	1/2(p3)h	0.00	0.33	0.00	Resisting force
F4	1/2(p4)h	9.18	0.17	1.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	4.21	1.50	6.32	Wind force
Total of active forces		4.90		6.43	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		4.90		1.53	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 4.90 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 4.90 (kN/m)

SF =(V*f + HR_{max})/ H = 6.53 > 1.2 Safe !!

Overturning,

Mr_{max}= 41.09 (kN-m/m)

Mr_{act}= 41.09 (kN-m/m)

Mo = 6.43 (kN-m/m)

d = (Mr-Mo)/V = 0.91 (m)

SF =Mr_{max}/ M_o = 6.39 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.463 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.824 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.463 (m)

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 307 (kN/m)

Qa = 153 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.912 m

q1 = (2V)/3X = 27.787 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 25.755 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	1.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.20	0.00	Active force
F2'	1/2(p2')(a6)	0.25	0.10	0.02	Active force
Wind Load		4.21	1.30	5.48	
Total		4.46		5.50	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2*(q2)*(a5)	0.000	0.000	0.000	
	1/2(q3)(3X-t2)	-32.66	0.845	-27.603	
Total		-6.65		5.56	

9. Case 8 : Wind condition 2

Height of wall, Hw= 1.90~2.00

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	11.04	2.650	29.26
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	2.550	0.00
Footing	(B)(t3)γc	13.2	1.375	18.15
Soil-1	1/2(a5)(a6)γs	6.885	0.850	5.85
Soil-2	1/2(a4)(a6)γs	6.89	1.700	11.70
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		38.01	1.709	64.96

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.50	36.72	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.50	5.77	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.33	0.00	Resisting force
F2	1/2(p2)h	9.18	0.17	1.53	Resisting force
F3	1/2(p3)h	0.76	0.33	0.25	Active force
F4	1/2(p4)h	1.44	0.17	0.24	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	4.21	1.50	6.32	Wind force
Total of active forces		6.41		6.81	
Total of maximum resisting forces		9.18		1.53	
Actual resisting forces		6.41		1.07	

(3) Stability

Sliding,

V = 38.01 (kN/m)

H = 6.41 (kN/m)

HR_{max} = 9.18 (kN/m)

HR_{act} = 6.41 (kN/m)

SF =(V*f + HR_{max})/ H = 4.99 > 1.2 Safe !!

Overturning,

Mr_{max} = 66.49 (kN-m/m)

Mr_{act} = 66.03 (kN-m/m)

Mo = 6.81 (kN-m/m)

d = (Mr-Mo)/V = 1.56 (m)

SF =Mr_{max}/ M_o = 9.76 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.195 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 2.384 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.183 (m)

α = 1.0

k = 1+0.3*D/B = 1.0545455

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 448 (kN/m)

Qa = 224 (kN/m) > V = 38.01 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 1.192 m

q1 = V/B*(1-6e/B)= 19.341 (kN/m2)

q2 = V/B*(1+6e/B) = 8.303 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.538 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.30	4.68	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.46	0.20	0.09	Active force
F2'	1/2(p2')(a6)	0.70	0.10	0.07	Active force
C_eC_q q_s I H		4.21	1.30	5.48	
Total		5.37		5.64	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	13.77	1.28	17.56	
Footing	γc(t3)(a5)	12.24	1.28	15.61	
Reaction	1/2(q2)(a5)	-10.586	1.700	-17.996	
	1/2(q3)(a5)	-23.64	0.850	-20.091	
Total		-8.21		-4.92	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.142	16	125	1608.50

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	4.24	26.06	2.08	69.99	0.18
Footing	**Top bar**	24.30	7.39	7.59	120.92	0.05

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	16	16
Spacing	250	565.49	565.49	125	1005.31
As/m	452.39	200.00	200.00	1608.50	200.00
Circum.	150.7968			402.1248	
d'	0.056			0.058	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0113275	
k= $(pn)^2+2pn$	0.21120053			0.3609648	
j= 1- k/3	0.92959982			0.879678	
Actual Stresses, (Mpa)					
fs (steel)	69.99			120.92	
fc (concrete)	2.08			7.59	
v (shear)	0.18			0.05	
u (bond)	1.29			0.15	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

10. Summary of stability analysis

Height of wall, Hw= 1.90~2.00

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	46.80	1.5	0.30	0.46	38.0	123
Normal-2	14.52	1.5	0.36	0.46	38.0	124
Flood-1	1.15	1	0.90	0.92	49.1	65
Flood-2	24.73	1	0.90	0.92	6.6	65
Seismic-1	3.55	1.2	0.42	0.92	38.0	165
Seismic-2	3.14	1.2	0.25	0.92	38.0	207
Wind-1	6.53	1.2	0.463	0.92	38.01	153
Wind-2	4.99	1.2	0.195	0.92	38.01	224

11. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement		140.0 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.02	0.25	0.73	-7.37	
Normal-2		0.16	1.16	0.61	-7.39	
Flood		19.89	26.06	24.30	2.06	
Seismic-1	*	1.94	1.93	2.83	-5.20	*: divided by 1.33
Seismic-2	*	2.01	2.44	-1.94	-5.91	*: divided by 1.33
Wind-1	*	4.14	3.35	4.18	-5.00	*: divided by 1.33
Wind-2	*	4.24	4.04	-3.70	-6.17	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	19.89	26.06	6.92	126.97	0.19
Footing	**Bot bar**	3.70	7.39	2.47	74.47	0.06

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	250	1570.80	565.49	250	565.49
As/m	1256.64	200.00	200.00	452.39	200.00
Circum.	251.328			150.7968	
d'	0.06			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.008976			0.0038016	
k= $(pn)^2+2pn$	0.32920875			0.2296026	
j= 1- k/3	0.89026375			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	126.97			74.47	
fc (concrete)	6.92			2.47	
v (shear)	0.19			0.06	
u (bond)	0.83			0.45	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

3.5 L-type Parapet Wall with Soil Embankment

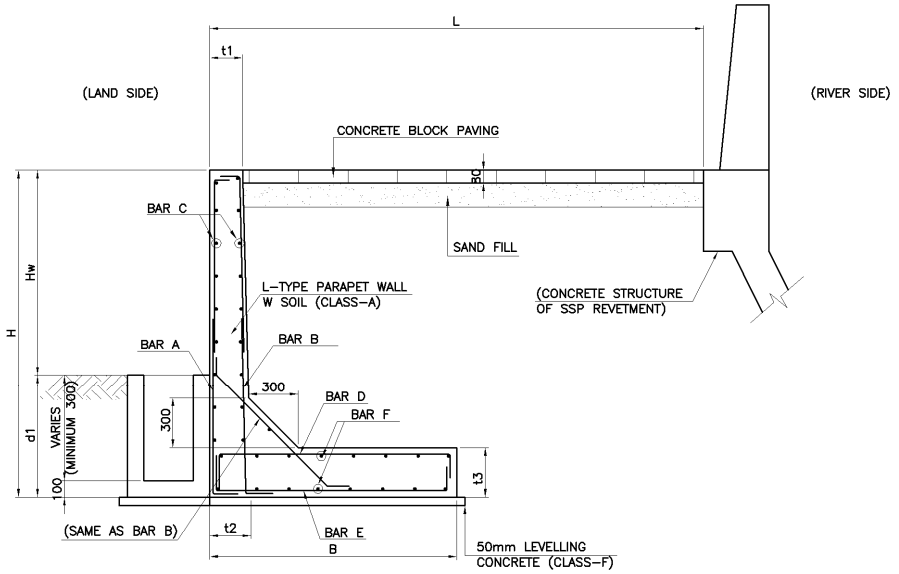


Figure 3.5.1 Typical Cross Section of L-type Parapet Wall-SE

Table 3.5.1 Standard Dimensions of L-Type Parapet Wall-SE

Hw Range (m)	B. base (m)	d1, Embankment (m)	t1 (m)	t2 (m)	t3 (m)	Reinforcement											
						BAR A		BAR B		BAR C		BAR D		BAR E		BAR F	
						Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)	Dia (mm)	Spacing (mm)
0.00 ~ 0.50	0.50	0.40	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
0.50 ~ 0.60	0.50	0.40	0.20	0.20	0.20	12	250	12	250	12	300	12	250	12	250	12	300
0.60 ~ 0.70	0.55	0.40	0.20	0.20	0.20	12	250	16	250	12	300	16	250	12	250	12	300
0.70 ~ 0.80	0.65	0.40	0.20	0.20	0.20	12	250	16	250	12	300	16	250	12	250	12	300
0.80 ~ 0.90	0.75	0.40	0.20	0.20	0.20	12	250	20	250	12	300	20	250	12	250	12	300
0.90 ~ 1.00	0.85	0.40	0.20	0.20	0.20	12	250	16	125	12	300	16	125	12	250	12	300
1.00 ~ 1.10	0.95	0.40	0.20	0.20	0.20	12	250	25	250	12	300	25	250	12	250	12	300
1.10 ~ 1.20	1.00	0.40	0.20	0.30	0.30	12	250	20	250	12	300	20	250	12	250	12	300
1.20 ~ 1.30	1.15	0.40	0.20	0.30	0.30	12	250	16	125	12	300	16	125	12	250	12	300
1.30 ~ 1.40	1.25	0.40	0.20	0.30	0.30	12	250	25	250	12	300	25	250	12	250	12	300
1.40 ~ 1.50	1.35	0.40	0.20	0.30	0.30	12	250	20	125	12	250	20	125	12	250	12	250
1.50 ~ 1.60	1.45	0.40	0.20	0.35	0.35	16	250	20	125	12	250	20	125	16	250	12	250

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.0~0.50

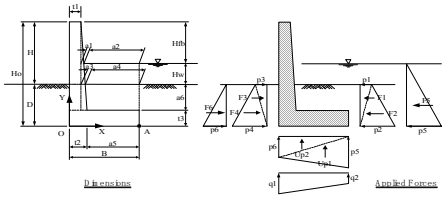
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	0.50	(m)		
Embedment of wall	D =	0.40	(m)		
Total height of wall	Ho=	0.90	(m)		
Freeboard	Hfb=	0.00	(m)		
Water depth under flood condition	Hw=	0.50	(m)		
Width of footing	B =	0.50	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	0.300	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	0.300	(m)
			a5=	0.300	(m)
			a6=	0.700	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.47 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.01

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 54 (kN/m)

Qa = 18 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.237 m

q1 = V/B*(1+6e/B)= 22.104 (kN/m2)

q2 = V/B*(1-6e/B) = 16.056 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.685 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.70	3.83	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.47	0.00	Active force
F2'	1/2(p2')(a6)	1.34	0.23	0.31	Active force
Total		1.34		0.31	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.408	0.200	-0.482	
	1/2(q3)(a5)	-2.95	0.100	-0.295	
Total		-0.14		0.01	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.0~0.50

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.36	0.100	0.34	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γs	1.89	0.400	0.76	
Soil-2	1/2(a4)(a6)γs	1.89	0.300	0.57	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		9.54	0.237	2.26	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	0.90	4.92	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.98	0.13	0.13	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		0.98		0.13	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		0.98		0.13	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 0.98 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 0.98 (kN/m)

SF =(V*f+ HR_{max})/ H = 11.79 > 1.5 Safe !!

Overturning,

Mr_{max} = 3.04 (kN-m/m)

Mr_{act} = 2.39 (kN-m/m)

Mo = 0.13 (kN-m/m)

SF =Mr_{max}/ M_o = 23.18 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.06 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 0.0~0.50

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.36	0.400	1.34	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γs	1.89	0.100	0.19	
Soil-2	1/2(a4)(a6)γs	1.89	0.200	0.38	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		9.54	0.263	2.51	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	0.90	66.10	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	13.22	0.13	1.76	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		13.22		1.76	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 13.22 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 11.46 > 1.5 Safe !!

Overturning,

Mr_{max} = 4.27 (kN-m/m)

Mr_{act} = 2.73 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 14.18 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.17 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.49 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = 0.00 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 57 (kN/m)

Qa = 19 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.245 m

q1 = V/B*(1-6e/B)= 20.160 (kN/m2)

q2 = V/B*(1+6e/B) = 18.000 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.296 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.70	6.87	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.06	0.47	0.50	Active force
F2'	1/2(p2')(a6)	2.40	0.23	0.56	Active force
Total		3.47		1.06	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.700	0.200	-0.540	
	1/2(q3)(a5)	-2.89	0.100	-0.289	
Total		-0.37		-0.05	

4. Case 3 : Flood condition

Height of wall, Hw= 0.0~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.36	0.100	0.34	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γsat	2.10	0.400	0.84	
Soil-2	1/2(a4)(a6)γsat	2.10	0.300	0.63	
Water-1	1/2(a4)(Hw)γw	0.74	0.400	0.29	
Water-2	1/2(a2)(Hw)γw	0.74	0.300	0.22	
Sub-Total		11.43	0.256	2.92	
Uplift-1	-1/2B(D+Hw)γw	-2.21	0.333	-0.74	
Uplift-2	-1/2B(D)γw	-0.98	0.167	-0.16	
Sub-Total		-3.19		-0.90	
Total		8.25		2.02	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	0.90	2.73	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.55	0.13	0.07	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	3.97	0.30	1.19	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		4.52		1.26	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 8.25 (kN/m)

H = 4.52 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.99 > 1.0 Safe !!

Overturning,

Mr_{max} = 3.46 (kN-m/m)

Mr = 3.46 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 2.16 (kN-m/m)

SF = Mr_{max}/M_o = 1.60 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.093 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.31 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.093 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.057

= 34 (kN/m)

Qa = 17.2 (kN/m) > V = 8.25 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.157 m

q1 = (2V)/3X = 34.906 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 20.128 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.70	2.13	Active earth press.
p5'	γw(Hw+a6)		11.76	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.47	0.00	Active force
F2'	1/2(p2')(a6)	0.74	0.23	0.17	Active force
F5'	1/2(p5')(Hw+a6)	7.06	0.40	2.82	Water pressure
Total		7.80		3.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	1.47	0.15	0.22	
Soil	γsat(a6)(a5)	4.20	0.15	0.63	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Uplift	-1/2(p5)(a5)	-1.32	0.20	-0.265	
	-1/2(p7)(a5)	-0.882	0.10	-0.088	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-2.742	0.091	-0.249	
Total		2.16		0.46	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.0~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.36	0.100	0.34	0.550	1.85
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.433	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60	0.100	0.24
Soil-1	1/2(a5)(a6)γs	1.89	0.400	0.76	0.433	0.82
Soil-2	1/2(a4)(a6)γs	1.89	0.300	0.57	0.667	1.26
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		9.54	0.237	2.26	0.437	4.17

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	0.90	7.25	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.45	0.13	0.19	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	1.91	0.44	0.83	Seismic force
Total of active forces		3.36		1.03	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		3.36		0.66	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 3.36 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 3.36 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.18 > 1.2 Safe !!

Overturning,

Mr_{max} = 2.92 (kN-m/m)

Mr_{act} = 2.92 (kN-m/m)

Mo = 1.03 (kN-m/m)

d = (Mr-Mo)/V = 0.20 (m)

SF =M_{max}/ M_{act} = 2.84 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.05 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.40 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.05 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 45 (kN/m)

Qa = 22 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.199 m

q1 = V/B*(1+6e/B)= 30.865 (kN/m2)

q2 = V/B*(1-6e/B) = 7.295 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.437 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.70	5.64	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.47	0.00	Active force
F2'	1/2(p2')(a6)	1.97	0.23	0.46	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.67	0.35	0.24	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.23	0.00	Seismic force
Total		2.65		0.70	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-1.094309	0.2	-0.219	
	1/2(q3)(a5)	-3.216	0.100	-0.322	
Total		0.91		0.24	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.0~0.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.36	0.400	1.34	0.550	1.85
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00	0.433	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60	0.100	0.24
Soil-1	1/2(a5)(a6)γs	1.89	0.100	0.19	0.433	0.82
Soil-2	1/2(a4)(a6)γs	1.89	0.200	0.38	0.667	1.26
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		9.54	0.263	2.51	0.437	4.17

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	0.90	55.83	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	11.17	0.13	1.49	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	1.91	0.44	0.83	Seismic force
Total of active forces		3.45		1.10	
Total of maximum resisting forces		11.17		1.49	
Actual resisting forces		3.45		1.10	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 3.45 (kN/m)

HR_{max} = 11.17 (kN/m)

HR_{act} = 3.45 (kN/m)

SF =(V*f + HR_{max})/ H = 4.90 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.00 (kN-m/m)

Mr_{act} = 3.61 (kN-m/m)

Mo = 1.10 (kN-m/m)

d = (Mr-Mo)/V = 0.26 (m)

SF =Mr_{max}/ M_o = 3.64 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.054 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.474 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.013 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 54 (kN/m)

Qa = 27 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.250

q1 = V/B*(1-6e/B)= 22.104 (kN/m2)

q2 = V/B*(1+6e/B) = 16.056 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.685 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.70	7.88	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.78	0.47	0.37	Active force
F2'	1/2(p2')(a6)	2.76	0.23	0.64	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.67	0.35	0.24	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.23	0.00	Seismic force
Total		4.21		1.24	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.408	0.200	-0.482	
	1/2(q3)(a5)	-2.953	0.100	-0.295	
Total		-0.14		0.01	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.0~0.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.36	0.100	0.34
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60
Soil-1	1/2(a5)(a6)γs	1.89	0.400	0.76
Soil-2	1/2(a4)(a6)γs	1.89	0.300	0.57
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		9.54	0.237	2.26

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	0.90	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	66.10	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	13.22	0.13	1.76	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	1.05	0.65	0.68	Wind force
Total of active forces		1.49		0.74	
Total of maximum resisting forces		13.22		1.76	
Actual resisting forces		1.49		0.74	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 1.49 (kN/m)

HR_{max} = 13.22 (kN/m)

HR_{act} = 1.49 (kN/m)

SF =(V*f + HR_{max})/ H = 12.71 > 1.2 Safe !!

Overturning,

Mr_{max}= 4.02 (kN-m/m)

Mr_{act}= 3.00 (kN-m/m)

Mo = 0.74 (kN-m/m)

d = (Mr-Mo)/V = 0.24 (m)

SF =Mr_{max}/ M_o = 5.41 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.094 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.474 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.013 (m)

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 54 (kN/m)

Qa = 27 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.237 m

q1 = V/B*(1+6e/B)= 22.104 (kN/m2)

q2 = V/B*(1-6e/B) = 16.056 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.685 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.70	3.83	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.47	0.00	Active force
F2'	1/2(p2')(a6)	1.34	0.23	0.31	Active force
Wind Load		1.05	0.95	1.00	
Total		2.39		1.31	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.408	0.200	-0.482	
	1/2(q3)(a5)	-2.95	0.100	-0.295	
Total		-0.14		0.01	

8. Case 7 : Wind condition 2

Height of wall, Hw= 0.0~0.50

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.36	0.400	1.34
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60
Soil-1	1/2(a5)(a6)γs	1.89	0.100	0.19
Soil-2	1/2(a4)(a6)γs	1.89	0.200	0.38
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		9.54	0.263	2.51

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	0.90	66.10	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	13.22	0.13	1.76	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	1.05	0.65	0.68	Wind force
Total of active forces		2.71		0.99	
Total of maximum resisting forces		13.22		1.76	
Actual resisting forces		2.71		0.36	

(3) Stability

Sliding,

V = 9.54 (kN/m)

H = 2.71 (kN/m)

HR_{max} = 13.22 (kN/m)

HR_{act} = 2.71 (kN/m)

SF =(V*f + HR_{max})/ H = 7.00 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.27 (kN-m/m)

Mr_{act} = 2.87 (kN-m/m)

Mo = 0.99 (kN-m/m)

d = (Mr-Mo)/V = 0.20 (m)

SF =Mr_{max}/ M_o = 4.34 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.095 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.395 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.052 (m)

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 44 (kN/m)

Qa = 22 (kN/m) > V = 9.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.198 m

q1 = V/B*(1-6e/B)= 7.103 (kN/m2)

q2 = V/B*(1+6e/B) = 31.057 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 16.685 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.70	6.87	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.06	0.47	0.50	Active force
F2'	1/2(p2')(a6)	2.40	0.23	0.56	Active force
$C_e C_q q_s$ l H		1.05	0.95	1.00	
Total		4.52		2.06	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	3.78	0.15	0.57	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-4.659	0.200	-0.932	
	1/2(q3)(a5)	-2.50	0.100	-0.250	
Total		-1.94		-0.40	

9. Summary of stability analysis

Height of wall, Hw= 0.0~0.50

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-1	11.79	1.50	(0.06)	0.08	9.54	18.12
Normal-2	11.46	1.50	(0.17)	0.08	9.54	18.87
Flood	1.99	1.00	0.09	0.17	8.25	8.25
Seismic-1	3.18	1.20	0.05	0.17	9.54	22.26
Seismic-2	4.90	1.20	(0.05)	0.17	9.54	27.18
Wind-1	12.71	1.20	(0.09)	0.17	9.54	27.18
Wind-2	7.00	1.20	(0.09)	0.17	9.54	22.15

10. Design of RC members

(1) Design Criteria

Concrete strength fc' = 20.7 (MPa)

Steel strength fy = 275 (MPa)

Modular ratio n=Es/Ec= 9

Allowable stress :

Fiber stress in flexural compress. 0.40fc' 8.28 (MPa)

Shear stress 0.079$\sqrt{fc'}$ 0.36 (MPa)

Tensile stress in reinforcement 0.40fy 110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall		Footing		Remarks
		B.M (kN-m/m)	Shear (kN/m)	B.M (kN-m/m)	Shear (kN/m)	
Normal-1		0.31	1.34	0.01	-0.14	
Normal-2		1.06	3.47	-0.05	-0.37	
Flood		3.00	7.80	0.46	2.16	
Seismic-1	*	0.52	1.99	0.18	0.68	*: divided by 1.33
Seismic-2	*	0.94	3.17	0.00	-0.11	*: divided by 1.33
Wind-1	*	0.99	1.80	0.00	-0.11	*: divided by 1.33
Wind-2	*	1.55	3.40	-0.30	-1.46	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	1.55	7.80	0.76	25.54	0.05
Footing	**Top bar**	0.46	2.16	0.23	7.67	0.02

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	25.54			7.67	
fc (concrete)	0.76			0.23	
v (shear)	0.05			0.02	
u (bond)	0.39			0.11	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	3.00	7.80	1.47	49.47	0.05
Footing	**Bot bar**	0.30	2.16	0.20	6.03	0.02

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	49.47			6.03	
fc (concrete)	1.47			0.20	
v (shear)	0.05			0.02	
u (bond)	0.39			0.13	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.50~0.60

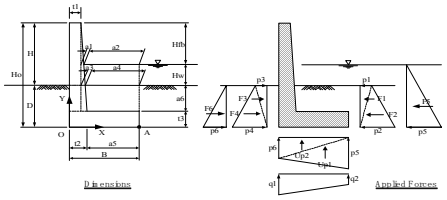
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.60 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	1.00 (m)		
Freeboard	Hfb=	0.00 (m)		
Water depth under flood condition	Hw=	0.60 (m)		
Width of footing	B =	0.50 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.20 (m)		a2=	0.300 (m)
t3=	0.20 (m)		a3=	0.000 (m)
			a4=	0.300 (m)
			a5=	0.300 (m)
			a6=	0.800 (m)



2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.50~0.60

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γs	2.16	0.400	0.86	
Soil-2	1/2(a4)(a6)γs	2.16	0.300	0.65	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		10.56	0.236	2.50	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.00	5.47	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.09	0.13	0.15	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.09		0.15	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.09		0.15	

(3) Stability

Sliding,

V =	10.56 (kN/m)	
H =	1.09 (kN/m)	
HR_{max} =	5.88 (kN/m)	
HR_{act} =	1.09 (kN/m)	
SF =(V*f + HR_{max})/ H =	11.17	> 1.5 Safe !!

Overturning,

Mr_{max} =	3.28 (kN-m/m)	
Mr_{act} =	2.64 (kN-m/m)	
Mo =	0.15 (kN-m/m)	
SF =Mr_{max}/ M_o =	22.49	> 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V =	-0.05 (m)	< B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.47 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.01

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 54 (kN/m)

Qa = 18 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.236 m

q1 = V/B*(1+6e/B)= 24.576 (kN/m2)

q2 = V/B*(1-6e/B) = 17.664 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.811 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.80	4.37	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.53	0.00	Active force
F2'	1/2(p2')(a6)	1.75	0.27	0.47	Active force
Total		1.75		0.47	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.650	0.200	-0.530	
	1/2(q3)(a5)	-3.27	0.100	-0.327	
Total		-0.16		0.01	

3. Case 2 : Normal condition-2

Height of wall, Hw= 0.50~0.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.400	1.54	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γs	2.16	0.100	0.22	
Soil-2	1/2(a4)(a6)γs	2.16	0.200	0.43	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		10.56	0.264	2.78	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.00	73.45	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	14.69	0.13	1.96	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		14.69		1.96	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 10.56 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 14.69 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 12.72 > 1.5 Safe !!

Overturning,

Mr_{max} = 4.74 (kN-m/m)

Mr_{act} = 3.00 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max})/ M_o = 15.74 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.17 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.49 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 56 (kN/m)

Qa = 19 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.244 m

q1 = V/B*(1-6e/B)= 22.632 (kN/m2)

q2 = V/B*(1+6e/B) = 19.608 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.422 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.80	7.41	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.22	0.53	0.65	Active force
F2'	1/2(p2')(a6)	2.96	0.27	0.79	Active force
Total		4.18		1.44	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.941	0.200	-0.588	
	1/2(q3)(a5)	-3.21	0.100	-0.321	
Total		-0.39		-0.05	

4. Case 3 : Flood condition

Height of wall, Hw= 0.50~0.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.4	0.250	0.60	
Soil-1	1/2(a5)(a6)γsat	2.40	0.400	0.96	
Soil-2	1/2(a4)(a6)γsat	2.40	0.300	0.72	
Water-1	1/2(a4)(Hw)γw	0.88	0.400	0.35	
Water-2	1/2(a2)(Hw)γw	0.88	0.300	0.26	
Sub-Total		12.80	0.256	3.28	
Uplift-1	-1/2B(D+Hw)γw	-2.45	0.333	-0.82	
Uplift-2	-1/2B(D)γw	-0.98	0.167	-0.16	
Sub-Total		-3.43		-0.98	
Total		9.37		2.30	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.00	3.04	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.61	0.13	0.08	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	4.90	0.33	1.63	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		5.51		1.71	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 9.37 (kN/m)

H = 5.51 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.76 > 1.0 Safe !!

Overturning,

Mr_{max} = 3.82 (kN-m/m)

Mr = 3.82 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 2.69 (kN-m/m)

SF = Mr_{max}/M_o = 1.42 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.130 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.24 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.130 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.156

= 26 (kN/m)

Qa = 12.8 (kN/m) > V = 9.37 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.120 m

q1 = (2V)/3X = 51.988 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 23.156 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.80	2.43	Active earth press.
p5'	γw(Hw+a6)		13.72	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.53	0.00	Active force
F2'	1/2(p2')(a6)	0.97	0.27	0.26	Active force
F5'	1/2(p5')(Hw+a6)	9.60	0.47	4.48	Water pressure
Total		10.58		4.74	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	1.76	0.15	0.26	
Soil	γsat(a6)(a5)	4.80	0.15	0.72	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Uplift	-1/2(p5)(a5)	-1.47	0.20	-0.294	
	-1/2(p7)(a5)	-0.941	0.10	-0.094	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-1.860	0.054	-0.100	
Total		3.73		0.71	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.50~0.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38	0.600	2.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.467	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60	0.100	0.24
Soil-1	1/2(a5)(a6)γs	2.16	0.400	0.86	0.467	1.01
Soil-2	1/2(a4)(a6)γs	2.16	0.300	0.65	0.733	1.58
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		10.56	0.236	2.50	0.486	5.14

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.00	8.06	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.61	0.13	0.21	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.11	0.49	1.03	Seismic force
Total of active forces		3.72		1.24	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		3.72		0.66	

(3) Stability

Sliding,

V = 10.56 (kN/m)

H = 3.72 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 3.72 (kN/m)

SF =(V*f+ HR_{max})/ H = 3.03 > 1.2 Safe !!

Overturning,

Mr_{max} = 3.16 (kN-m/m)

Mr_{act} = 3.16 (kN-m/m)

Mo = 1.24 (kN-m/m)

d = (Mr-Mo)/V = 0.18 (m)

SF =M_{max}/ M_{act} = 2.54 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.07 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.36 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.07 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 40 (kN/m)

Qa = 20 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.181 m

q1 = V/B*(1+6e/B)= 38.503 (kN/m2)

q2 = V/B*(1-6e/B) = 3.737 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.597 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.80	6.44	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.53	0.00	Active force
F2'	1/2(p2')(a6)	2.58	0.27	0.69	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.77	0.40	0.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.27	0.00	Seismic force
Total		3.35		0.99	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-0.560498	0.2	-0.112	
	1/2(q3)(a5)	-3.690	0.100	-0.369	
Total		1.51		0.38	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.50~0.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.400	1.54	0.600	2.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00	0.467	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60	0.100	0.24
Soil-1	1/2(a5)(a6)γs	2.16	0.100	0.22	0.467	1.01
Soil-2	1/2(a4)(a6)γs	2.16	0.200	0.43	0.733	1.58
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		10.56	0.264	2.78	0.486	5.14

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.00	62.03	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	12.41	0.13	1.65	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.11	0.49	1.03	Seismic force
Total of active forces		3.65		1.29	
Total of maximum resisting forces		12.41		1.65	
Actual resisting forces		3.65		1.29	

(3) Stability

Sliding,

V = 10.56 (kN/m)

H = 3.65 (kN/m)

HR_{max} = 12.41 (kN/m)

HR_{act} = 3.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 5.13 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.44 (kN-m/m)

Mr_{act} = 4.08 (kN-m/m)

Mo = 1.29 (kN-m/m)

d = (Mr-Mo)/V = 0.26 (m)

SF =Mr_{max}/ M_o = 3.43 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.048 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.473 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.014 m

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 54 (kN/m)

Qa = 27 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.250

q1 = V/B*(1-6e/B)= 24.576 (kN/m2)

q2 = V/B*(1+6e/B) = 17.664 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.811 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.80	8.68	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.90	0.53	0.48	Active force
F2'	1/2(p2')(a6)	3.47	0.27	0.93	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.77	0.40	0.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.27	0.00	Seismic force
Total		5.14		1.71	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.650	0.200	-0.530	
	1/2(q3)(a5)	-3.272	0.100	-0.327	
Total		-0.16		0.01	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.50~0.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.100	0.38
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60
Soil-1	1/2(a5)(a6)γs	2.16	0.400	0.86
Soil-2	1/2(a4)(a6)γs	2.16	0.300	0.65
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		10.56	0.236	2.50

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.00	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	73.45	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	14.69	0.13	1.96	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.26	0.70	0.88	Wind force
Total of active forces		1.70		0.94	
Total of maximum resisting forces		14.69		1.96	
Actual resisting forces		1.70		0.94	

(3) Stability

Sliding,

V = 10.56 (kN/m)

H = 1.70 (kN/m)

HR_{max} = 14.69 (kN/m)

HR_{act} = 1.70 (kN/m)

SF =(V*f + HR_{max})/ H = 12.36 > 1.2 Safe !!

Overturning,

Mr_{max}= 4.45 (kN-m/m)

Mr_{act}= 3.44 (kN-m/m)

Mo = 0.94 (kN-m/m)

d = (Mr-Mo)/V = 0.24 (m)

SF =Mr_{max}/ M_o = 4.72 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.083 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.473 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.014 (m)

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 54 (kN/m)

Qa = 27 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.236 m

q1 = V/B*(1+6e/B)= 24.576 (kN/m2)

q2 = V/B*(1-6e/B) = 17.664 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.811 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.80	4.37	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.53	0.00	Active force
F2'	1/2(p2')(a6)	1.75	0.27	0.47	Active force
Wind Load		1.26	1.10	1.39	
Total		3.01		1.86	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-2.650	0.200	-0.530	
	1/2(q3)(a5)	-3.27	0.100	-0.327	
Total		-0.16		0.01	

8. Case 7 : Wind condition 2

Height of wall, Hw= 0.50~0.60

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	3.84	0.400	1.54
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.300	0.00
Footing	(B)(t3)γc	2.4	0.250	0.60
Soil-1	1/2(a5)(a6)γs	2.16	0.100	0.22
Soil-2	1/2(a4)(a6)γs	2.16	0.200	0.43
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		10.56	0.264	2.78

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.00	73.45	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	14.69	0.13	1.96	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.26	0.70	0.88	Wind force
Total of active forces		2.92		1.19	
Total of maximum resisting forces		14.69		1.96	
Actual resisting forces		2.92		0.39	

(3) Stability

Sliding,

V = 10.56 (kN/m)

H = 2.92 (kN/m)

HR_{max} = 14.69 (kN/m)

HR_{act} = 2.92 (kN/m)

SF =(V*f + HR_{max})/ H = 7.21 > 1.2 Safe !!

Overturning,

Mr_{max} = 4.74 (kN-m/m)

Mr_{act} = 3.17 (kN-m/m)

Mo = 1.19 (kN-m/m)

d = (Mr-Mo)/V = 0.19 (m)

SF =Mr_{max}/ M_o = 4.00 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.087 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.376 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.062 (m)

α = 1.0

k = 1+0.3*D/B = 1.24

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 42 (kN/m)

Qa = 21 (kN/m) > V = 10.56 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.188 m

q1 = V/B*(1-6e/B)= 5.447 (kN/m2)

q2 = V/B*(1+6e/B) = 36.793 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 17.985 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.80	7.41	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.22	0.53	0.65	Active force
F2'	1/2(p2')(a6)	2.96	0.27	0.79	Active force
C_eC_q q_s l H		1.26	1.10	1.39	
Total		5.44		2.83	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	4.32	0.15	0.65	
Footing	γc(t3)(a5)	1.44	0.15	0.22	
Reaction	1/2(q2)(a5)	-5.519	0.200	-1.104	
	1/2(q3)(a5)	-2.70	0.100	-0.270	
Total		-2.46		-0.51	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.13	10.58	1.04	35.12	0.07
Footing	**Top bar**	0.71	3.73	0.35	11.77	0.03

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d' / d	0.056 / 0.144			0.056 / 0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	35.12			11.77	
fc (concrete)	1.04			0.35	
v (shear)	0.07			0.03	
u (bond)	0.52			0.18	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 0.50~0.60

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	11.17	1.50	(0.05)	0.08	10.56	18.08
Normal-2	12.72	1.50	(0.17)	0.08	10.56	18.76
Flood	1.76	1.00	0.13	0.17	9.37	12.82
Seismic-1	3.03	1.20	0.07	0.17	10.56	20.12
Seismic-2	5.13	1.20	(0.05)	0.17	10.56	27.12
Wind-1	12.36	1.20	(0.08)	0.17	10.56	27.12
Wind-2	7.21	1.20	(0.09)	0.17	10.56	20.96

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.47	1.75	0.01	-0.16	
Normal-2		1.44	4.18	-0.05	-0.39	
Flood		4.74	10.58	0.71	3.73	
Seismic-1	*	0.75	2.52	0.29	1.14	*: divided by 1.33
Seismic-2	*	1.29	3.86	0.01	-0.12	*: divided by 1.33
Wind-1	*	1.40	2.27	0.01	-0.12	*: divided by 1.33
Wind-2	*	2.13	4.09	-0.38	-1.85	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	4.74	10.58	2.33	78.29	0.07
Footing	**Bot bar**	0.38	3.73	0.26	7.71	0.03

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d' / d	0.056 / 0.14			0.081 / 0.12	
Coefficients					
p = As/bd	0.0031416			0.0038016	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2296026	
j= 1- k/3	0.92959982			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	78.29			7.71	
fc (concrete)	2.33			0.26	
v (shear)	0.07			0.03	
u (bond)	0.52			0.23	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.60~0.70

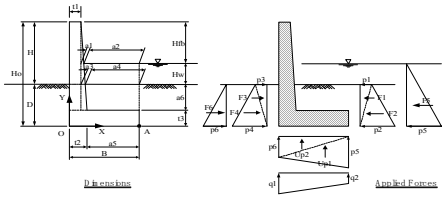
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	0.70	(m)		
Embedment of wall	D =	0.40	(m)		
Total height of wall	Ho=	1.10	(m)		
Freeboard	Hfb=	0.00	(m)		
Water depth under flood condition	Hw=	0.70	(m)		
Width of footing	B =	0.55	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	0.350	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	0.350	(m)
			a5=	0.350	(m)
			a6=	0.900	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.52 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.01

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 60 (kN/m)

Qa = 20 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.260 m

q1 = V/B*(1+6e/B)= 26.712 (kN/m2)

q2 = V/B*(1-6e/B) = 19.215 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.986 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.90	4.92	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.60	0.00	Active force
F2'	1/2(p2')(a6)	2.21	0.30	0.66	Active force
Total		2.21		0.66	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-3.363	0.233	-0.785	
	1/2(q3)(a5)	-4.20	0.117	-0.490	
Total		-0.21		0.01	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.60~0.70

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.100	0.43	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.64	0.275	0.73	
Soil-1	1/2(a5)(a6)γs	2.835	0.433	1.23	
Soil-2	1/2(a4)(a6)γs	2.84	0.317	0.90	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		12.63	0.260	3.28	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.10	6.01	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.20	0.13	0.16	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.20		0.16	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.20		0.16	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 1.20 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 1.20 (kN/m)

SF =(V*f+ HR_{max})/ H = 11.18 > 1.5 Safe !!

Overturning,

Mr_{max} = 4.07 (kN-m/m)

Mr_{act} = 3.44 (kN-m/m)

Mo = 0.16 (kN-m/m)

SF =Mr_{max}/ M_o = 25.36 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.03 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 0.60~0.70

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.450	1.94	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.350	0.00	
Footing	(B)(t3)γc	2.64	0.275	0.73	
Soil-1	1/2(a5)(a6)γs	2.835	0.117	0.33	
Soil-2	1/2(a4)(a6)γs	2.84	0.233	0.66	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		12.63	0.290	3.66	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.10	80.79	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	16.16	0.13	2.15	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		16.16		2.15	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 16.16 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 14.36 > 1.5 Safe !!

Overturning,

Mr_{max} = 5.82 (kN-m/m)

Mr_{act} = 3.88 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 19.30 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.16 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.53 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 61 (kN/m)

Qa = 20 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.266 m

q1 = V/B*(1-6e/B)= 25.106 (kN/m2)

q2 = V/B*(1+6e/B) = 20.822 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.548 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	0.90	7.96	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.37	0.60	0.82	Active force
F2'	1/2(p2')(a6)	3.58	0.30	1.07	Active force
Total		4.95		1.89	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-3.644	0.233	-0.850	
	1/2(q3)(a5)	-4.12	0.117	-0.481	
Total		-0.41		-0.04	

4. Case 3 : Flood condition

Height of wall, Hw= 0.60~0.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.32	0.100	0.43	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	2.64	0.275	0.73	
Soil-1	1/2(a5)(a6)γsat	3.15	0.433	1.37	
Soil-2	1/2(a4)(a6)γsat	3.15	0.317	1.00	
Water-1	1/2(a4)(Hw)γw	1.20	0.433	0.52	
Water-2	1/2(a2)(Hw)γw	1.20	0.317	0.38	
Sub-Total		15.66	0.282	4.42	
Uplift-1	-1/2B(D+Hw)γw	-2.96	0.367	-1.09	
Uplift-2	-1/2B(D)γw	-1.08	0.183	-0.20	
Sub-Total		-4.04		-1.28	
Total		11.62		3.14	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	1.10	3.34	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.67	0.13	0.09	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	5.93	0.37	2.17	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		6.60		2.26	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 11.62 (kN/m)

H = 6.60 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f +HR_{max})/ H = 1.67 > 1.0 Safe !!

Overturning,

Mr_{max} = 4.96 (kN-m/m)

Mr = 4.96 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 3.55 (kN-m/m)

SF = Mr_{max}/M_o = 1.40 <1.5 Fails!!!

e = B/2 - (Mr_{max}-Mo) / V = 0.153 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.24 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.153 m

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.219

= 26 (kN/m)

Qa = 12.8 (kN/m) > V = 11.62 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.122 m

q1 = (2V)/3X = 63.691 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 28.776 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	0.90	2.73	Active earth press.
p5'	γw(Hw+a6)		15.68	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.60	0.00	Active force
F2'	1/2(p2')(a6)	1.23	0.30	0.37	Active force
F5'	1/2(p5')(Hw+a6)	12.54	0.53	6.69	Water pressure
Total		13.77		7.06	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	2.40	0.18	0.42	
Soil	γsat(a6)(a5)	6.30	0.18	1.10	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Uplift	-1/2(p5)(a5)	-1.89	0.23	-0.440	
	-1/2(p7)(a5)	-1.123	0.12	-0.131	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-2.372	0.055	-0.130	
Total		5.00		1.12	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.60~0.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.100	0.43	0.650	2.81
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.500	0.00
Footing	(B)(t3)γc	2.64	0.275	0.73	0.100	0.26
Soil-1	1/2(a5)(a6)γs	2.835	0.433	1.23	0.500	1.42
Soil-2	1/2(a4)(a6)γs	2.84	0.317	0.90	0.800	2.27
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		12.63	0.260	3.28	0.535	6.76

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.10	8.86	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.77	0.13	0.24	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.53	0.54	1.35	Seismic force
Total of active forces		4.30		1.59	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.30		0.66	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 4.30 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.30 (kN/m)

SF =(V*f + HR_{max})/ H = 2.92 > 1.2 Safe !!

Overturning,

Mr_{max} = 3.95 (kN-m/m)

Mr_{act} = 3.95 (kN-m/m)

Mo = 1.59 (kN-m/m)

d = (Mr-Mo)/V = 0.19 (m)

SF =M_{max}/ M_{act} = 2.49 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.09 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.37 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.09 m

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 41 (kN/m)

Qa = 20 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.187 m

q1 = V/B*(1+6e/B)= 45.081 (kN/m2)

q2 = V/B*(1-6e/B) = 0.846 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 28.996 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	0.90	7.25	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.60	0.00	Active force
F2'	1/2(p2')(a6)	3.26	0.30	0.98	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.86	0.45	0.39	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.30	0.00	Seismic force
Total		4.13		1.37	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-0.148086	0.2333333	-0.035	
	1/2(q3)(a5)	-5.074	0.117	-0.592	
Total		2.13		0.66	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.60~0.70

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.450	1.94	0.650	2.81
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.350	0.00	0.500	0.00
Footing	(B)(t3)γc	2.64	0.275	0.73	0.100	0.26
Soil-1	1/2(a5)(a6)γs	2.835	0.117	0.33	0.500	1.42
Soil-2	1/2(a4)(a6)γs	2.84	0.233	0.66	0.800	2.27
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		12.63	0.290	3.66	0.535	6.76

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.10	68.24	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	13.65	0.13	1.82	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	2.53	0.54	1.35	Seismic force
Total of active forces		4.07		1.62	
Total of maximum resisting forces		13.65		1.82	
Actual resisting forces		4.07		1.62	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 4.07 (kN/m)

HR_{max} = 13.65 (kN/m)

HR_{act} = 4.07 (kN/m)

SF =(V*f + HR_{max})/ H = 5.22 > 1.2 Safe !!

Overturning,

Mr_{max} = 5.48 (kN-m/m)

Mr_{act} = 5.28 (kN-m/m)

Mo = 1.62 (kN-m/m)

d = (Mr-Mo)/V = 0.29 (m)

SF =Mr_{max}/ M_o = 3.39 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.031 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.520 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.015 m

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 60 (kN/m)

Qa = 30 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.275

q1 = V/B*(1-6e/B)= 26.712 (kN/m2)

q2 = V/B*(1+6e/B) = 19.215 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.986 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	0.90	9.49	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.01	0.60	0.60	Active force
F2'	1/2(p2')(a6)	4.27	0.30	1.28	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.86	0.45	0.39	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.30	0.00	Seismic force
Total		6.14		2.27	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-3.363	0.233	-0.785	
	1/2(q3)(a5)	-4.198	0.117	-0.490	
Total		-0.21		0.01	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.60~0.70

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.100	0.43
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	2.64	0.275	0.73
Soil-1	1/2(a5)(a6)γs	2.835	0.433	1.23
Soil-2	1/2(a4)(a6)γs	2.84	0.317	0.90
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		12.63	0.260	3.28

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.10	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	80.79	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	16.16	0.13	2.15	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	1.47	0.75	1.11	Wind force
Total of active forces		1.91		1.16	
Total of maximum resisting forces		16.16		2.15	
Actual resisting forces		1.91		1.16	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 1.91 (kN/m)

HR_{max} = 16.16 (kN/m)

HR_{act} = 1.91 (kN/m)

SF =(V*f + HR_{max})/ H = 12.42 > 1.2 Safe !!

Overturning,

Mr_{max}= 5.44 (kN-m/m)

Mr_{act}= 4.45 (kN-m/m)

Mo = 1.16 (kN-m/m)

d = (Mr-Mo)/V = 0.26 (m)

SF =Mr_{max}/ M_o = 4.67 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.063 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.520 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.015 (m)

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 60 (kN/m)

Qa = 30 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.260 m

q1 = V/B*(1+6e/B)= 26.712 (kN/m2)

q2 = V/B*(1-6e/B) = 19.215 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 23.986 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.90	4.92	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.60	0.00	Active force
F2'	1/2(p2')(a6)	2.21	0.30	0.66	Active force
Wind Load		1.47	1.25	1.84	
Total		3.69		2.51	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-3.363	0.233	-0.785	
	1/2(q3)(a5)	-4.20	0.117	-0.490	
Total		-0.21		0.01	

8. Case 7 : Wind condition 2

Height of wall, Hw= 0.60~0.70

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.32	0.450	1.94
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.350	0.00
Footing	(B)(t3)γc	2.64	0.275	0.73
Soil-1	1/2(a5)(a6)γs	2.835	0.117	0.33
Soil-2	1/2(a4)(a6)γs	2.84	0.233	0.66
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		12.63	0.290	3.66

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	1.10	80.79	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	16.16	0.13	2.15	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	1.47	0.75	1.11	Wind force
Total of active forces		3.13		1.41	
Total of maximum resisting forces		16.16		2.15	
Actual resisting forces		3.13		0.42	

(3) Stability

Sliding,

V = 12.63 (kN/m)

H = 3.13 (kN/m)

HR_{max} = 16.16 (kN/m)

HR_{act} = 3.13 (kN/m)

SF =(V*f + HR_{max})/ H = 7.59 > 1.2 Safe !!

Overturning,

Mr_{max} = 5.82 (kN-m/m)

Mr_{act} = 4.08 (kN-m/m)

Mo = 1.41 (kN-m/m)

d = (Mr-Mo)/V = 0.21 (m)

SF =Mr_{max}/ M_o = 4.13 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.074 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.423 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.063 (m)

α = 1.0

k = 1+0.3*D/B = 1.2181818

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 47 (kN/m)

Qa = 24 (kN/m) > V = 12.63 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.212 m

q1 = V/B*(1-6e/B)= 7.074 (kN/m2)

q2 = V/B*(1+6e/B) = 38.853 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 18.630 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	0.90	7.96	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.37	0.60	0.82	Active force
F2'	1/2(p2')(a6)	3.58	0.30	1.07	Active force
$C_e C_q q_s$ l H		1.47	1.25	1.84	
Total		6.42		3.74	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	5.67	0.18	0.99	
Footing	γc(t3)(a5)	1.68	0.18	0.29	
Reaction	1/2(q2)(a5)	-6.799	0.233	-1.587	
	1/2(q3)(a5)	-3.26	0.117	-0.380	
Total		-2.71		-0.68	

9. Summary of stability analysis

Height of wall, Hw= 0.60~0.70

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	11.18	1.50	(0.03)	0.09	12.63	19.88
Normal-2	14.36	1.50	(0.16)	0.09	12.63	20.45
Flood	1.67	1.00	0.15	0.18	11.62	12.77
Seismic-1	2.92	1.20	0.09	0.18	12.63	20.45
Seismic-2	5.22	1.20	(0.03)	0.18	12.63	29.82
Wind-1	12.42	1.20	(0.06)	0.18	12.63	29.82
Wind-2	7.59	1.20	(0.07)	0.18	12.63	23.55

10. Design of RC members

(1) Design Criteria

Concrete strength fc' = 20.7 (MPa)

Steel strength fy = 275 (MPa)

Modular ratio n=Es/Ec= 9

Allowable stress :

Fiber stress in flexural compress. 0.40fc' 8.28 (MPa)

Shear stress 0.079$\sqrt{fc'}$ 0.36 (MPa)

Tensile stress in reinforcement 0.40fy 110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.66	2.21	0.01	-0.21	
Normal-2		1.89	4.95	-0.04	-0.41	
Flood		7.06	13.77	1.12	5.00	
Seismic-1	*	1.03	3.10	0.50	1.60	*: divided by 1.33
Seismic-2	*	1.71	4.62	0.01	-0.16	*: divided by 1.33
Wind-1	*	1.89	2.77	0.01	-0.16	*: divided by 1.33
Wind-2	*	2.81	4.83	-0.51	-2.04	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (mm)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	2.81	13.77	1.38	46.40	0.10
Footing	**Top bar**	1.12	5.00	0.55	18.42	0.03

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	46.40			18.42	
fc (concrete)	1.38			0.55	
v (shear)	0.10			0.03	
u (bond)	0.68			0.25	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	7.06	13.77	2.83	67.98	0.10
Footing	**Bot bar**	0.51	5.00	0.34	10.29	0.04

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	250	1005.31	565.49	250	565.49
As/m	804.25	200.00	200.00	452.39	200.00
Circum.	201.0624			150.7968	
d'	0.058			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.00566373			0.0038016	
k= $(p\,n)^2+2p\,n$	0.2723613			0.2296026	
j= 1- k/3	0.9092129			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	67.98			10.29	
fc (concrete)	2.83			0.34	
v (shear)	0.10			0.04	
u (bond)	0.53			0.30	
Code Minimum reinforcements					
ratio (min.)	0.001		0.001		0.001
As (min.) = ratio x b x h	200		200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.70~0.80

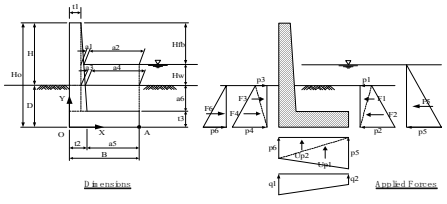
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	0.80 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	1.20 (m)		
Freeboard	Hfb=	0.00 (m)		
Water depth under flood condition	Hw=	0.80 (m)		
Width of footing	B =	0.65 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.20 (m)		a2=	0.450 (m)
t3=	0.20 (m)		a3=	0.000 (m)
			a4=	0.450 (m)
			a5=	0.450 (m)
			a6=	1.000 (m)



Dimensions Applied Forces

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.70~0.80

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.8	0.100	0.48	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	3.12	0.325	1.01	
Soil-1	1/2(a5)(a6)γs	4.05	0.500	2.03	
Soil-2	1/2(a4)(a6)γs	4.05	0.350	1.42	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		16.02	0.308	4.94	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.20	6.56	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.31	0.13	0.17	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.31		0.17	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.31		0.17	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 1.31 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 1.31 (kN/m)

SF =(V*f + HR_{max})/ H = 11.80 > 1.5 Safe !!

Overturning,

Mr_{max} = 5.72 (kN-m/m)

Mr_{act} = 5.11 (kN-m/m)

Mo = 0.17 (kN-m/m)

SF =Mr_{max}/ M_o = 32.69 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.02 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.62 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 71 (kN/m)

Qa = 24 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.308 m

q1 = V/B*(1+6e/B)= 28.480 (kN/m2)

q2 = V/B*(1-6e/B) = 20.812 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 26.121 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.00	5.47	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Active force
F2'	1/2(p2')(a6)	2.73	0.33	0.91	Active force
Total		2.73		0.91	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-4.683	0.300	-1.405	
	1/2(q3)(a5)	-5.88	0.150	-0.882	
Total		-0.30		0.02	

3. Case 2 : Normal condition-2

Height of wall, Hw= 0.70~0.80

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.8	0.550	2.64	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.450	0.00	
Footing	(B)(t3)γc	3.12	0.325	1.01	
Soil-1	1/2(a5)(a6)γs	4.05	0.150	0.61	
Soil-2	1/2(a4)(a6)γs	4.05	0.300	1.22	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		16.02	0.342	5.48	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.20	88.14	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	17.63	0.13	2.35	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		17.63		2.35	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 17.63 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 16.48 > 1.5 Safe !!

Overturning,

Mr_{max} = 7.83 (kN-m/m)

Mr_{act} = 5.70 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max})/ M_o = 25.97 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.14 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.63 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 73 (kN/m)

Qa = 24 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.313 m

q1 = V/B*(1-6e/B)= 27.330 (kN/m2)

q2 = V/B*(1+6e/B) = 21.962 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 25.678 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(a6)	4.25	0.33	1.42	Active force
Total		5.77		2.43	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-4.942	0.300	-1.482	
	1/2(q3)(a5)	-5.78	0.150	-0.867	
Total		-0.46		-0.04	

4. Case 3 : Flood condition

Height of wall, Hw= 0.70~0.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	4.8	0.100	0.48	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	3.12	0.325	1.01	
Soil-1	1/2(a5)(a6)γsat	4.50	0.500	2.25	
Soil-2	1/2(a4)(a6)γsat	4.50	0.350	1.58	
Water-1	1/2(a4)(Hw)γw	1.76	0.500	0.88	
Water-2	1/2(a2)(Hw)γw	1.76	0.350	0.62	
Sub-Total		20.45	0.333	6.82	
Uplift-1	-1/2B(D+Hw)γw	-3.82	0.433	-1.66	
Uplift-2	-1/2B(D)γw	-1.27	0.217	-0.28	
Sub-Total		-5.10		-1.93	
Total		15.35		4.89	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.20	3.65	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.73	0.13	0.10	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	7.06	0.40	2.82	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		7.79		2.92	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 15.35 (kN/m)

H = 7.79 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.70 > 1.0 Safe !!

Overturning,

Mr_{max} = 7.36 (kN-m/m)

Mr = 7.36 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 4.85 (kN-m/m)

SF = Mr_{max}/M_o = 1.52 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.162 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.33 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.162 m

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.243

= 34 (kN/m)

Qa = 17.2 (kN/m) > V = 15.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.163 m

q1 = (2V)/3X = 62.690 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 37.091 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.00	3.04	Active earth press.
p5'	γw(Hw+a6)		17.64	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Active force
F2'	1/2(p2')(a6)	1.52	0.33	0.51	Active force
F5'	1/2(p5')(Hw+a6)	15.88	0.60	9.53	Water pressure
Total		17.39		10.03	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	3.53	0.23	0.79	
Soil	γsat(a6)(a5)	9.00	0.23	2.03	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Uplift	-1/2(p5)(a5)	-2.65	0.30	-0.794	
	-1/2(p7)(a5)	-1.425	0.15	-0.214	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-5.374	0.097	-0.519	
Total		5.24		1.78	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.70~0.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.8	0.100	0.48	0.700	3.36
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.533	0.00
Footing	(B)(t3)γc	3.12	0.325	1.01	0.100	0.31
Soil-1	1/2(a5)(a6)γs	4.05	0.500	2.03	0.533	2.16
Soil-2	1/2(a4)(a6)γs	4.05	0.350	1.42	0.867	3.51
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		16.02	0.308	4.94	0.583	9.34

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.20	9.67	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.93	0.13	0.26	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.20	0.58	1.87	Seismic force
Total of active forces		5.14		2.13	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 5.14 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.84 > 1.2 Safe !!

Overturning,

Mr_{max} = 5.60 (kN-m/m)

Mr_{act} = 5.60 (kN-m/m)

Mo = 2.13 (kN-m/m)

d = (Mr-Mo)/V = 0.22 (m)

SF =M_{max}/ M_{act} = 2.63 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.11 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.43 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.11 m

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.011

= 47 (kN/m)

Qa = 24 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.217 m

q1 = V/B*(1+6e/B)= 49.278 (kN/m2)

q2 = V/B*(1-6e/B) = 0.015 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 34.120 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.00	8.06	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Active force
F2'	1/2(p2')(a6)	4.03	0.33	1.34	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.96	0.50	0.48	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.33	0.00	Seismic force
Total		4.99		1.82	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-0.003298	0.3	-0.001	
	1/2(q3)(a5)	-7.677	0.150	-1.152	
Total		2.58		1.16	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.70~0.80

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.8	0.550	2.64	0.700	3.36
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.450	0.00	0.533	0.00
Footing	(B)(t3)γc	3.12	0.325	1.01	0.100	0.31
Soil-1	1/2(a5)(a6)γs	4.05	0.150	0.61	0.533	2.16
Soil-2	1/2(a4)(a6)γs	4.05	0.300	1.22	0.867	3.51
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		16.02	0.342	5.48	0.583	9.34

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.20	74.44	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	14.89	0.13	1.99	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.20	0.58	1.87	Seismic force
Total of active forces		4.74		2.13	
Total of maximum resisting forces		14.89		1.99	
Actual resisting forces		4.74		1.99	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 4.74 (kN/m)

HR_{max} = 14.89 (kN/m)

HR_{act} = 4.74 (kN/m)

SF =(V*f+ HR_{max})/ H = 5.17 > 1.2 Safe !!

Overturning,

Mr_{max} = 7.46 (kN-m/m)

Mr_{act} = 7.46 (kN-m/m)

Mo = 2.13 (kN-m/m)

d = (Mr-Mo)/V = 0.33 (m)

SF =Mr_{max}/ M_o = 3.50 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.008 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.635 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = -0.008 m

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 74 (kN/m)

Qa = 37 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.325

q1 = V/B*(1-6e/B)= 26.376 (kN/m2)

q2 = V/B*(1+6e/B) = 22.917 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 25.311 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.00	10.29	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.12	0.67	0.75	Active force
F2'	1/2(p2')(a6)	5.15	0.33	1.72	Active force
Wall-1	γc(t1)(Ho-t3)kh	0.96	0.50	0.48	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.33	0.00	Seismic force
Total		7.23		2.94	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-5.156	0.300	-1.547	
	1/2(q3)(a5)	-5.695	0.150	-0.854	
Total		-0.59		-0.09	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.70~0.80

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.8	0.100	0.48
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	3.12	0.325	1.01
Soil-1	1/2(a5)(a6)γs	4.05	0.500	2.03
Soil-2	1/2(a4)(a6)γs	4.05	0.350	1.42
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		16.02	0.308	4.94

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.20	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	88.14	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	17.63	0.13	2.35	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.68	0.80	1.35	Wind force
Total of active forces		2.12		1.41	
Total of maximum resisting forces		17.63		2.35	
Actual resisting forces		2.12		1.41	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 2.12 (kN/m)

HR_{max} = 17.63 (kN/m)

HR_{act} = 2.12 (kN/m)

SF =(V*f + HR_{max})/ H = 12.84 > 1.2 Safe !!

Overturning,

Mr_{max}= 7.29 (kN-m/m)

Mr_{act}= 6.34 (kN-m/m)

Mo = 1.41 (kN-m/m)

d = (Mr-Mo)/V = 0.31 (m)

SF =Mr_{max}/ M_o = 5.18 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.042 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.616 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.017 (m)

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 71 (kN/m)

Qa = 36 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.308 m

q1 = V/B*(1+6e/B)= 28.480 (kN/m2)

q2 = V/B*(1-6e/B) = 20.812 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 26.121 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.00	5.47	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.67	0.00	Active force
F2'	1/2(p2')(a6)	2.73	0.33	0.91	Active force
Wind Load		1.68	1.40	2.36	
Total		4.42		3.27	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-4.683	0.300	-1.405	
	1/2(q3)(a5)	-5.88	0.150	-0.882	
Total		-0.30		0.02	

8. Case 7 : Wind condition 2

Height of wall, Hw= 0.70~0.80

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	4.8	0.550	2.64
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.450	0.00
Footing	(B)(t3)γc	3.12	0.325	1.01
Soil-1	1/2(a5)(a6)γs	4.05	0.150	0.61
Soil-2	1/2(a4)(a6)γs	4.05	0.300	1.22
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		16.02	0.342	5.48

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.20	88.14	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	17.63	0.13	2.35	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	1.68	0.80	1.35	Wind force
Total of active forces		3.34		1.65	
Total of maximum resisting forces		17.63		2.35	
Actual resisting forces		3.34		0.44	

(3) Stability

Sliding,

V = 16.02 (kN/m)

H = 3.34 (kN/m)

HR_{max} = 17.63 (kN/m)

HR_{act} = 3.34 (kN/m)

SF =(V*f + HR_{max})/ H = 8.16 > 1.2 Safe !!

Overturning,

Mr_{max} = 7.83 (kN-m/m)

Mr_{act} = 5.92 (kN-m/m)

Mo = 1.65 (kN-m/m)

d = (Mr-Mo)/V = 0.27 (m)

SF =Mr_{max}/ M_o = 4.75 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.061 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.533 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.058 (m)

α = 1.0

k = 1+0.3*D/B = 1.1846154

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 60 (kN/m)

Qa = 30 (kN/m) > V = 16.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.267 m

q1 = V/B*(1-6e/B)= 11.379 (kN/m2)

q2 = V/B*(1+6e/B) = 37.913 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 19.544 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.00	8.51	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.52	0.67	1.01	Active force
F2'	1/2(p2')(a6)	4.25	0.33	1.42	Active force
C_eC_q q_s l H		1.68	1.40	2.36	
Total		7.46		4.79	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	8.10	0.23	1.82	
Footing	γc(t3)(a5)	2.16	0.23	0.49	
Reaction	1/2(q2)(a5)	-8.530	0.300	-2.559	
	1/2(q3)(a5)	-4.40	0.150	-0.660	
Total		-2.67		-0.91	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	3.60	17.39	1.77	59.46	0.12
Footing	**Top bar**	1.78	5.24	0.87	29.36	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	59.46			29.36	
fc (concrete)	1.77			0.87	
v (shear)	0.12			0.04	
u (bond)	0.86			0.26	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 0.70~0.80

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	11.80	1.50	(0.02)	0.11	16.02	23.71
Normal-2	16.48	1.50	(0.14)	0.11	16.02	24.17
Flood	1.70	1.00	0.16	0.22	15.35	17.18
Seismic-1	2.84	1.20	0.11	0.22	16.02	23.62
Seismic-2	5.17	1.20	(0.01)	0.22	16.02	36.83
Wind-1	12.84	1.20	(0.04)	0.22	16.02	35.56
Wind-2	8.16	1.20	(0.06)	0.22	16.02	30.00

10. Design of RC members

(1) Design Criteria

Concrete strength		fc' =	20.7 (MPa)
Steel strength		fy =	275 (MPa)
Modular ratio		n=Es/Ec=	9
Allowable stress :			
Fiber stress in flexural compress.	0.40fc'		8.28 (MPa)
Shear stress	0.079√fc'		0.36 (MPa)
Tensile stress in reinforcement	0.40fy		110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		0.91	2.73	0.02	-0.30	
Normal-2		2.43	5.77	-0.04	-0.46	
Flood		10.03	17.39	1.78	5.24	
Seismic-1	*	1.37	3.75	0.87	1.94	*: divided by 1.33
Seismic-2	*	2.21	5.43	-0.07	-0.44	*: divided by 1.33
Wind-1	*	2.46	3.32	0.02	-0.23	*: divided by 1.33
Wind-2	*	3.60	5.61	-0.68	-2.01	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	10.03	17.39	4.02	96.61	0.12
Footing	**Bot bar**	0.68	5.24	0.46	13.77	0.04

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	250	1005.31	565.49	250	565.49
As/m	804.25	200.00	200.00	452.39	200.00
Circum.	201.0624			150.7968	
d'	0.058			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.00566373			0.0038016	
k= $(p\,n)^2+2p\,n$	0.2723613			0.2296026	
j= 1- k/3	0.9092129			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	96.61			13.77	
fc (concrete)	4.02			0.46	
v (shear)	0.12			0.04	
u (bond)	0.67			0.32	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.80~0.90

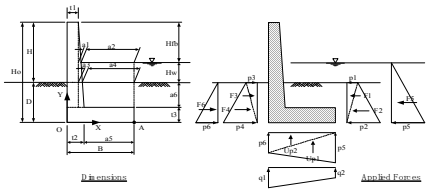
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	0.90	(m)	
Embedment of wall	D =	0.40	(m)	
Total height of wall	Ho=	1.30	(m)	
Freeboard	Hfb=	0.00	(m)	
Water depth under flood condition	Hw=	0.90	(m)	
Width of footing	B =	0.75	(m)	
Thickness of wall members :				
t1=	0.20 (m)	a1=	0.000	(m)
t2=	0.20 (m)	a2=	0.550	(m)
t3=	0.20 (m)	a3=	0.000	(m)
		a4=	0.550	(m)
		a5=	0.550	(m)
		a6=	1.100	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.71 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 83 (kN/m)

Qa = 28 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.357 m

q1 = V/B*(1+6e/B)= 30.232 (kN/m2)

q2 = V/B*(1-6e/B) = 22.488 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 28.167 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.10	6.01	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.73	0.00	Active force
F2'	1/2(p2')(a6)	3.31	0.37	1.21	Active force
Total		3.31		1.21	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2)(a5)	-6.184	0.367	-2.268	
	1/2(q3)(a5)	-7.75	0.183	-1.420	
Total		-0.40		0.03	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.80~0.90

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.28	0.100	0.53	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	3.6	0.375	1.35	
Soil-1	1/2(a5)(a6)γs	5.445	0.567	3.09	
Soil-2	1/2(a4)(a6)γs	5.45	0.383	2.09	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		19.77	0.357	7.05	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.30	7.11	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.42	0.13	0.19	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.42		0.19	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.42		0.19	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 1.42 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 1.42 (kN/m)

SF =(V*f + HR_{max})/ H = 12.48 > 1.5 Safe !!

Overturning,

Mr_{max} = 7.83 (kN-m/m)

Mr_{act} = 7.24 (kN-m/m)

Mo = 0.19 (kN-m/m)

SF =Mr_{max}/ M_o = 41.33 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.01 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 0.80~0.90

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.28	0.650	3.43	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.550	0.00	
Footing	(B)(t3)γc	3.6	0.375	1.35	
Soil-1	1/2(a5)(a6)γs	5.445	0.183	1.00	
Soil-2	1/2(a4)(a6)γs	5.45	0.367	2.00	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		19.77	0.393	7.78	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.30	95.48	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	19.10	0.13	2.55	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		19.10		2.55	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 19.10 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f + HR_{max})/ H = 18.73 > 1.5 Safe !!

Overturning,

Mr_{max} = 10.32 (kN-m/m)

Mr_{act} = 8.00 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max})/ M_o = 34.26 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.13 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.72 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 85 (kN/m)

Qa = 28 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.361 m

q1 = V/B*(1-6e/B)= 29.368 (kN/m2)

q2 = V/B*(1+6e/B) = 23.352 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 27.764 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	1.10	9.05	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1')(a6)	1.67	0.73	1.23	Active force
F2'	1/2(p2')(a6)	4.98	0.37	1.83	Active force
Total		6.65		3.05	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2')(a5)	-6.422	0.367	-2.355	
	1/2(q3')(a5)	-7.64	0.183	-1.400	
Total		-0.53		-0.03	

4. Case 3 : Flood condition

Height of wall, Hw= 0.80~0.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1')(Ho-t3')γc	5.28	0.100	0.53	
Wall-2	1/2(t2-t1')(Ho-t3')γc	0	0.200	0.00	
Footing	(B)(t3')γc	3.6	0.375	1.35	
Soil-1	1/2(a5)(a6)γsat	6.05	0.567	3.43	
Soil-2	1/2(a4)(a6)γsat	6.05	0.383	2.32	
Water-1	1/2(a4)(Hw)γw	2.43	0.567	1.37	
Water-2	1/2(a2)(Hw)γw	2.43	0.383	0.93	
Sub-Total		25.83	0.384	9.93	
Uplift-1	-1/2B(D+Hw)γw	-4.78	0.500	-2.39	
Uplift-2	-1/2B(D)γw	-1.47	0.250	-0.37	
Sub-Total		-6.25		-2.76	
Total		19.58		7.17	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c$\sqrt{}$Ka	1.30	3.95	Active earth press.
p3	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c$\sqrt{}$Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.79	0.13	0.11	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	8.28	0.43	3.59	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		9.07		3.69	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 19.58 (kN/m)

H = 9.07 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f +HR_{max})/ H = 1.74 > 1.0 Safe !!

Overturning,

Mr_{max} = 10.47 (kN-m/m)

Mr = 10.47 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 6.45 (kN-m/m)

SF = Mr_{max}/M_o = 1.62 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.170 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.41 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.170 m

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.256

= 44 (kN/m)

Qa = 21.8 (kN/m) > V = 19.58 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.205 m

q1 = (2V)/3X = 63.609 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 42.948 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{}$Ka	1.10	3.34	Active earth press.
p5'	γw(Hw+a6)		19.60	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1')(a6)	0.00	0.73	0.00	Active force
F2'	1/2(p2')(a6)	1.84	0.37	0.67	Active force
F5'	1/2(p5')(Hw+a6)	19.60	0.67	13.07	Water pressure
Total		21.44		13.74	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	4.85	0.28	1.33	
Soil	γsat(a6)(a5)	12.10	0.28	3.33	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Uplift	-1/2(p5)(a5)	-3.50	0.37	-1.285	
	-1/2(p7)(a5)	-1.725	0.18	-0.316	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-8.928	0.139	-1.237	
Total		5.43		2.55	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.80~0.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1')(Ho-t3')γc	5.28	0.100	0.53	0.750	3.96
Wall-2	1/2(t2-t1')(Ho-t3')γc	0	0.200	0.00	0.567	0.00
Footing	(B)(t3')γc	3.6	0.375	1.35	0.100	0.36
Soil-1	1/2(a5)(a6)γs	5.445	0.567	3.09	0.567	3.09
Soil-2	1/2(a4)(a6)γs	5.45	0.383	2.09	0.933	5.08
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		19.77	0.357	7.05	0.632	12.49

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{}$Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c$\sqrt{}$Kea	1.30	10.47	Active earth press.
p3	Kep(γh)+2c$\sqrt{}$Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c$\sqrt{}$Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.09	0.13	0.28	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.95	0.63	2.50	Seismic force
Total of active forces		6.05		2.78	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 6.05 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f + HR_{max})/ H = 2.78 > 1.2 Safe !!

Overturning,

Mr_{max} = 7.71 (kN-m/m)

Mr_{act} = 7.71 (kN-m/m)

Mo = 2.78 (kN-m/m)

d = (Mr-Mo)/V = 0.25 (m)

SF = M_{max}/ M_{act} = 2.78 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.13 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.50 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.13 m

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.055

= 55 (kN/m)

Qa = 27 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.250 m

q1 = (2V)/3X = 52.793 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 38.695 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{}$Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c$\sqrt{}$Kea	1.10	8.86	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.73	0.00	Active force
F2'	1/2(p2')(a6)	4.87	0.37	1.79	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.06	0.55	0.58	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.37	0.00	Seismic force
Total		5.93		2.37	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2)(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-10.621	0.183	-1.944	
Total		2.91		1.78	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.80~0.90

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.28	0.650	3.43	0.750	3.96
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.550	0.00	0.567	0.00
Footing	(B)(t3)γc	3.6	0.375	1.35	0.100	0.36
Soil-1	1/2(a5)(a6)γs	5.445	0.183	1.00	0.567	3.09
Soil-2	1/2(a4)(a6)γs	5.45	0.367	2.00	0.933	5.08
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		19.77	0.393	7.78	0.632	12.49

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c$\sqrt{}$Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c$\sqrt{}$Kep	1.30	80.64	Passive press.
p3	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c$\sqrt{}$Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	16.13	0.13	2.15	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	3.95	0.63	2.50	Seismic force
Total of active forces		5.49		2.76	
Total of maximum resisting forces		16.13		2.15	
Actual resisting forces		5.49		2.15	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 5.49 (kN/m)

HR_{max} = 16.13 (kN/m)

HR_{act} = 5.49 (kN/m)

SF =(V*f + HR_{max})/ H = 5.10 > 1.2 Safe !!

Overturning,

Mr_{max} = 9.93 (kN-m/m)

Mr_{act} = 9.93 (kN-m/m)

Mo = 2.76 (kN-m/m)

d = (Mr-Mo)/V = 0.36 (m)

SF =Mr_{max}/ M_o = 3.59 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.013 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.725 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.013 m

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 85 (kN/m)

Qa = 42 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.375

q1 = V/B*(1-6e/B)= 23.705 (kN/m2)

q2 = V/B*(1+6e/B) = 29.015 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 25.121 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c$\sqrt{}$Kea	1.10	11.10	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.23	0.73	0.90	Active force
F2'	1/2(p2')(a6)	6.10	0.37	2.24	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.06	0.55	0.58	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.37	0.00	Seismic force
Total		8.39		3.72	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2)(a5)	-7.979	0.367	-2.926	
	1/2(q3)(a5)	-6.908	0.183	-1.267	
Total		-1.36		-0.47	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.80~0.90

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.28	0.100	0.53
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	3.6	0.375	1.35
Soil-1	1/2(a5)(a6)γs	5.445	0.567	3.09
Soil-2	1/2(a4)(a6)γs	5.45	0.383	2.09
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		19.77	0.357	7.05

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c$\sqrt{}$Ka	1.30	2.19	Active press.
p3	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	
p4	Kp(γh)+2c$\sqrt{}$Kp	0.40	95.48	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	19.10	0.13	2.55	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	1.90	0.85	1.61	Wind force
Total of active forces		2.33		1.67	
Total of maximum resisting forces		19.10		2.55	
Actual resisting forces		2.33		1.67	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 2.33 (kN/m)

HR_{max} = 19.10 (kN/m)

HR_{act} = 2.33 (kN/m)

SF =(V*f + HR_{max})/ H = 13.27 > 1.2 Safe !!

Overturning,

Mr_{max}= 9.60 (kN-m/m)

Mr_{act}= 8.72 (kN-m/m)

Mo = 1.67 (kN-m/m)

d = (Mr-Mo)/V = 0.36 (m)

SF =Mr_{max})/ M_o = 5.75 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.026 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.713 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.018 (m)

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 83 (kN/m)

Qa = 42 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.357 m

q1 = V/B*(1+6e/B)= 30.232 (kN/m2)

q2 = V/B*(1-6e/B) = 22.488 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 28.167 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.10	6.01	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.73	0.00	Active force
F2'	1/2(p2')(a6)	3.31	0.37	1.21	Active force
Wind Load		1.90	1.55	2.94	
Total		5.20		4.15	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2)(a5)	-6.184	0.367	-2.268	
	1/2(q3)(a5)	-7.75	0.183	-1.420	
Total		-0.40		0.03	

8. Case 7 : Wind condition 2

Wind from the land side

Height of wall, Hw= 0.80~0.90

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.28	0.650	3.43
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.550	0.00
Footing	(B)(t3)γc	3.6	0.375	1.35
Soil-1	1/2(a5)(a6)γs	5.445	0.183	1.00
Soil-2	1/2(a4)(a6)γs	5.45	0.367	2.00
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		19.77	0.393	7.78

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	1.30	95.48	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	19.10	0.13	2.55	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s I H	1.90	0.85	1.61	Wind force
Total of active forces		3.55		1.91	
Total of maximum resisting forces		19.10		2.55	
Actual resisting forces		3.55		0.47	

(3) Stability

Sliding,

V = 19.77 (kN/m)

H = 3.55 (kN/m)

HR_{max} = 19.10 (kN/m)

HR_{act} = 3.55 (kN/m)

SF =(V*f + HR_{max})/ H = 8.73 > 1.2 Safe !!

Overturning,

Mr_{max} = 10.32 (kN-m/m)

Mr_{act} = 8.25 (kN-m/m)

Mo = 1.91 (kN-m/m)

d = (Mr-Mo)/V = 0.32 (m)

SF =Mr_{max})/ M_o = 5.40 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.050 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.641 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.054 (m)

α = 1.0

k = 1+0.3*D/B = 1.16

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 73 (kN/m)

Qa = 37 (kN/m) > V = 19.77 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.321 m

q1 = V/B*(1-6e/B)= 14.879 (kN/m2)

q2 = V/B*(1+6e/B) = 37.841 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 21.002 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.10	9.05	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.67	0.73	1.23	Active force
F2'	1/2(p2')(a6)	4.98	0.37	1.83	Active force
C_eC_q q_s I H		1.90	1.55	2.94	
Total		8.55		5.99	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	10.89	0.28	2.99	
Footing	γc(t3)(a5)	2.64	0.28	0.73	
Reaction	1/2(q2)(a5)	-10.406	0.367	-3.816	
	1/2(q3)(a5)	-5.78	0.183	-1.059	
Total		-2.65		-1.15	

9. Summary of stability analysis

Height of wall, Hw= 0.80~0.90

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding		Overturning		Bearing capacity	
	SF	min.SF	e (m)	max. e (m)	V (kN/m)	Qa (kN/m)
Normal-1	12.48	1.50	(0.01)	0.13	19.77	27.78
Normal-2	18.73	1.50	(0.13)	0.13	19.77	28.17
Flood	1.74	1.00	0.17	0.25	19.58	21.81
Seismic-1	2.78	1.20	0.13	0.25	19.77	27.30
Seismic-2	5.10	1.20	0.01	0.25	19.77	42.49
Wind-1	13.27	1.20	(0.03)	0.25	19.77	41.67
Wind-2	8.73	1.20	(0.05)	0.25	19.77	36.64

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{fc'}$	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		1.21	3.31	0.03	-0.40	
Normal-2		3.05	6.65	-0.03	-0.53	
Flood		13.74	21.44	2.55	5.43	
Seismic-1	*	1.78	4.46	1.34	2.19	*: divided by 1.33
Seismic-2	*	2.80	6.31	-0.35	-1.02	*: divided by 1.33
Wind-1	*	3.12	3.91	0.02	-0.30	*: divided by 1.33
Wind-2	*	4.50	6.42	-0.87	-1.99	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	4.50	21.44	2.21	74.36	0.15
Footing	**Top bar**	2.55	5.43	1.25	42.10	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.2112005			0.2112005	
j= 1- k/3	0.9295998			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	74.36			42.10	
fc (concrete)	2.21			1.25	
v (shear)	0.15			0.04	
u (bond)	1.06			0.27	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	13.74	21.44	4.78	87.73	0.15
Footing	**Bot bar**	0.87	5.43	0.58	17.45	0.05

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	250	1570.80	565.49	250	565.49
As/m	1256.64	200.00	200.00	452.39	200.00
Circum.	251.328			150.7968	
d'	0.06			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.008976			0.0038016	
k= $(p\,n)^2+2p\,n$	0.3292087			0.2296026	
j= 1- k/3	0.8902638			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	87.73			17.45	
fc (concrete)	4.78			0.58	
v (shear)	0.15			0.05	
u (bond)	0.68			0.33	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 0.90~1.00

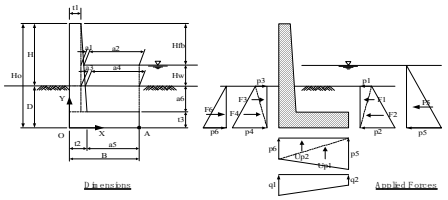
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.00 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	1.40 (m)		
Freeboard	Hfb=	0.00 (m)		
Width of footing	B =	0.85 (m)		
Thickness of wall members :				
t1= 0.20 (m)			a1=	0.000 (m)
t2= 0.20 (m)			a2=	0.650 (m)
t3= 0.20 (m)			a3=	0.000 (m)
			a4=	0.650 (m)
			a5=	0.650 (m)
			a6=	1.200 (m)



2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 0.90~1.00

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.100	0.58	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.08	0.425	1.73	
Soil-1	1/2(a5)(a6)γs	7.02	0.633	4.45	
Soil-2	1/2(a4)(a6)γs	7.02	0.417	2.93	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		23.88	0.405	9.68	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.40	7.66	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.53	0.13	0.20	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.53		0.20	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.53		0.20	

(3) Stability

Sliding,

V =	23.88 (kN/m)		
H =	1.53 (kN/m)		
HR_{max} =	5.88 (kN/m)		
HR_{act} =	1.53 (kN/m)		
SF =(V*f+ HR_{max})/ H =		13.20 > 1.5	Safe !!

Overturning,

Mr_{max} =	10.46 (kN-m/m)		
Mr_{act} =	9.89 (kN-m/m)		
Mo =	0.20 (kN-m/m)		
SF =Mr_{max}/ M_o =		51.26 > 2.0	Safe !!
e = B/2 - (Mr_{max}-Mo) / V =		0.00 (m)	< B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.81 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 96 (kN/m)

Qa = 32 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.405 m

q1 = V/B*(1+6e/B)= 31.981 (kN/m2)

q2 = V/B*(1-6e/B) = 24.208 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 30.152 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.20	6.56	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.80	0.00	Active force
F2'	1/2(p2')(a6)	3.94	0.40	1.57	Active force
Total		3.94		1.57	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-7.867	0.433	-3.409	
	1/2(q3)(a5)	-9.80	0.217	-2.123	
Total		-0.51		0.04	

3. Case 2 : Normal condition-2

Height of wall, Hw= 0.90~1.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.750	4.32	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.650	0.00	
Footing	(B)(t3)γc	4.08	0.425	1.73	
Soil-1	1/2(a5)(a6)γs	7.02	0.217	1.52	
Soil-2	1/2(a4)(a6)γs	7.02	0.433	3.04	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		23.88	0.445	10.62	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.40	102.82	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	20.56	0.13	2.74	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		20.56		2.74	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 23.88 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 20.56 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 21.11 > 1.5 Safe !!

Overturning,

Mr_{max} = 13.36 (kN-m/m)

Mr_{act} = 10.84 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 44.33 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.12 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.82 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.02 m

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 97 (kN/m)

Qa = 32 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.409 m

q1 = V/B*(1-6e/B)= 31.308 (kN/m2)

q2 = V/B*(1+6e/B) = 24.880 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 29.796 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.20	9.60	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.82	0.80	1.46	Active force
F2'	1/2(p2')(a6)	5.76	0.40	2.30	Active force
Total		7.58		3.76	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-8.086	0.433	-3.504	
	1/2(q3)(a5)	-9.68	0.217	-2.098	
Total		-0.61		-0.03	

4. Case 3 : Flood condition

Height of wall, Hw= 0.90~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	5.76	0.100	0.58	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.08	0.425	1.73	
Soil-1	1/2(a5)(a6)γsat	7.80	0.633	4.94	
Soil-2	1/2(a4)(a6)γsat	7.80	0.417	3.25	
Water-1	1/2(a4)(Hw)γw	3.19	0.633	2.02	
Water-2	1/2(a2)(Hw)γw	3.19	0.417	1.33	
Sub-Total		31.81	0.435	13.84	
Uplift-1	-1/2B(D+Hw)γw	-5.83	0.567	-3.30	
Uplift-2	-1/2B(D)γw	-1.67	0.283	-0.47	
Sub-Total		-7.50		-3.78	
Total		24.31		10.07	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.40	4.25	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.85	0.13	0.11	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	9.60	0.47	4.48	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		10.45		4.60	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 24.31 (kN/m)

H = 10.45 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.78 > 1.0 Safe !!

Overturning,

Mr_{max} = 14.38 (kN-m/m)

Mr = 14.38 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 8.37 (kN-m/m)

SF = Mr_{max}/M_o = 1.72 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.178 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.49 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.178 m

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.263

= 53 (kN/m)

Qa = 26.6 (kN/m) > V = 24.31 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.247 m

q1 = (2V)/3X = 65.544 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 47.874 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.20	3.65	Active earth press.
p5'	γw(Hw+a6)		21.56	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.80	0.00	Active force
F2'	1/2(p2')(a6)	2.19	0.40	0.87	Active force
F5'	1/2(p5')(Hw+a6)	23.72	0.73	17.39	Water pressure
Total		25.90		18.27	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	6.37	0.33	2.07	
Soil	γsat(a6)(a5)	15.60	0.33	5.07	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Uplift	-1/2(p5)(a5)	-4.46	0.43	-1.932	
	-1/2(p7)(a5)	-2.023	0.22	-0.438	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-12.971	0.181	-2.343	
Total		5.64		3.44	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 0.90~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.100	0.58	0.800	4.61
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.600	0.00
Footing	(B)(t3)γc	4.08	0.425	1.73	0.100	0.41
Soil-1	1/2(a5)(a6)γs	7.02	0.633	4.45	0.600	4.21
Soil-2	1/2(a4)(a6)γs	7.02	0.417	2.93	1.000	7.02
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		23.88	0.405	9.68	0.680	16.25

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.40	11.28	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.26	0.13	0.30	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.78	0.68	3.25	Seismic force
Total of active forces		7.03		3.55	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 23.88 (kN/m)

H = 7.03 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.74 > 1.2 Safe !!

Overturning,

Mr_{max} = 10.34 (kN-m/m)

Mr_{act} = 10.34 (kN-m/m)

Mo = 3.55 (kN-m/m)

d = (Mr-Mo)/V = 0.28 (m)

SF =M_{max}/ M_{act} = 2.91 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.14 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.57 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.14 m

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.087

= 63 (kN/m)

Qa = 31 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.284 m

q1 = V/B*(1+6e/B)= 55.969 (kN/m2)

q2 = V/B*(1-6e/B) = 0.219 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 42.852 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.20	9.67	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.80	0.00	Active force
F2'	1/2(p2')(a6)	5.80	0.40	2.32	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.15	0.60	0.69	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.40	0.00	Seismic force
Total		6.95		3.01	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-0.071172	0.4333333	-0.031	
	1/2(q3)(a5)	-13.927	0.217	-3.017	
Total		3.16		2.53	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 0.90~1.00

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.750	4.32	0.800	4.61
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.650	0.00	0.600	0.00
Footing	(B)(t3)γc	4.08	0.425	1.73	0.100	0.41
Soil-1	1/2(a5)(a6)γs	7.02	0.217	1.52	0.600	4.21
Soil-2	1/2(a4)(a6)γs	7.02	0.433	3.04	1.000	7.02
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		23.88	0.445	10.62	0.680	16.25

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.40	86.85	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	17.37	0.13	2.32	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	4.78	0.68	3.25	Seismic force
Total of active forces		6.32		3.51	
Total of maximum resisting forces		17.37		2.32	
Actual resisting forces		6.32		2.32	

(3) Stability

Sliding,

V = 23.88 (kN/m)

H = 6.32 (kN/m)

HR_{max} = 17.37 (kN/m)

HR_{act} = 6.32 (kN/m)

SF =(V*f+ HR_{max})/ H = 5.02 > 1.2 Safe !!

Overturning,

Mr_{max} = 12.93 (kN-m/m)

Mr_{act} = 12.93 (kN-m/m)

Mo = 3.51 (kN-m/m)

d = (Mr-Mo)/V = 0.39 (m)

SF =Mr_{max}/ M_o = 3.68 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.031 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.789 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.031 m

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 93 (kN/m)

Qa = 47 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.425

q1 = V/B*(1-6e/B)= 22.027 (kN/m2)

q2 = V/B*(1+6e/B) = 34.161 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.882 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.20	11.90	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.34	0.80	1.07	Active force
F2'	1/2(p2')(a6)	7.14	0.40	2.86	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.15	0.60	0.69	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.40	0.00	Seismic force
Total		9.64		4.62	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-11.102	0.433	-4.811	
	1/2(q3)(a5)	-8.087	0.217	-1.752	
Total		-2.03		-0.99	

7. Case 6 : Wind condition 1

Height of wall, Hw= 0.90~1.00

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.100	0.58
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	4.08	0.425	1.73
Soil-1	1/2(a5)(a6)γs	7.02	0.633	4.45
Soil-2	1/2(a4)(a6)γs	7.02	0.417	2.93
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		23.88	0.405	9.68

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.40	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	102.82	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	20.56	0.13	2.74	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.11	0.90	1.90	Wind force
Total of active forces		2.54		1.95	
Total of maximum resisting forces		20.56		2.74	
Actual resisting forces		2.54		1.95	

(3) Stability

Sliding,

V = 23.88 (kN/m)

H = 2.54 (kN/m)

HR_{max} = 20.56 (kN/m)

HR_{act} = 2.54 (kN/m)

SF =(V*f + HR_{max})/ H = 13.72 > 1.2 Safe !!

Overturning,

Mr_{max}= 12.42 (kN-m/m)

Mr_{act}= 11.63 (kN-m/m)

Mo = 1.95 (kN-m/m)

d = (Mr-Mo)/V = 0.41 (m)

SF =Mr_{max}/ M_o = 6.36 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.013 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.811 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.020 (m)

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 96 (kN/m)

Qa = 48 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.405 m

q1 = V/B*(1+6e/B)= 31.981 (kN/m2)

q2 = V/B*(1-6e/B) = 24.208 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 30.152 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.20	6.56	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.80	0.00	Active force
F2'	1/2(p2')(a6)	3.94	0.40	1.57	Active force
Wind Load		2.11	1.70	3.58	
Total		6.04		5.15	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-7.867	0.433	-3.409	
	1/2(q3)(a5)	-9.80	0.217	-2.123	
Total		-0.51		0.04	

8. Case 7 : Wind condition 2

Height of wall, Hw= 0.90~1.00

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	5.76	0.750	4.32
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.650	0.00
Footing	(B)(t3)γc	4.08	0.425	1.73
Soil-1	1/2(a5)(a6)γs	7.02	0.217	1.52
Soil-2	1/2(a4)(a6)γs	7.02	0.433	3.04
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		23.88	0.445	10.62

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.40	102.82	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	20.56	0.13	2.74	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.11	0.90	1.90	Wind force
Total of active forces		3.76		2.20	
Total of maximum resisting forces		20.56		2.74	
Actual resisting forces		3.76		0.50	

(3) Stability

Sliding,

V = 23.88 (kN/m)

H = 3.76 (kN/m)

HR_{max} = 20.56 (kN/m)

HR_{act} = 3.76 (kN/m)

SF =(V*f + HR_{max})/ H = 9.28 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.36 (kN-m/m)

Mr_{act} = 11.12 (kN-m/m)

Mo = 2.20 (kN-m/m)

d = (Mr-Mo)/V = 0.37 (m)

SF =Mr_{max}/ M_o = 6.08 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.042 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.747 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.051 (m)

α = 1.0

k = 1+0.3*D/B = 1.1411765

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 87 (kN/m)

Qa = 44 (kN/m) > V = 23.88 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.374 m

q1 = V/B*(1-6e/B)= 17.899 (kN/m2)

q2 = V/B*(1+6e/B) = 38.289 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 22.697 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.20	9.60	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.82	0.80	1.46	Active force
F2'	1/2(p2')(a6)	5.76	0.40	2.30	Active force
C_eC_q q_s l H		2.11	1.70	3.58	
Total		9.69		7.34	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	14.04	0.33	4.56	
Footing	γc(t3)(a5)	3.12	0.33	1.01	
Reaction	1/2(q2)(a5)	-12.444	0.433	-5.392	
	1/2(q3)(a5)	-7.38	0.217	-1.598	
Total		-2.66		-1.41	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	5.52	25.90	2.71	91.16	0.18
Footing	**Top bar**	3.44	5.64	1.69	56.82	0.04

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'/d	0.056 / 0.144			0.056 / 0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	91.16			56.82	
fc (concrete)	2.71			1.69	
v (shear)	0.18			0.04	
u (bond)	1.28			0.28	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 0.90~1.00

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	13.20	1.50	(0.00)	0.14	23.88	32.10
Normal-2	21.11	1.50	(0.12)	0.14	23.88	32.43
Flood	1.78	1.00	0.18	0.28	24.31	26.63
Seismic-1	2.74	1.20	0.14	0.28	23.88	31.37
Seismic-2	5.02	1.20	0.03	0.28	23.88	46.54
Wind-1	13.72	1.20	(0.01)	0.28	23.88	48.15
Wind-2	9.28	1.20	(0.04)	0.28	23.88	43.54

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		1.57	3.94	0.04	-0.51	
Normal-2		3.76	7.58	-0.03	-0.61	
Flood		18.27	25.90	3.44	5.64	
Seismic-1	*	2.26	5.23	1.90	2.38	*: divided by 1.33
Seismic-2	*	3.48	7.25	-0.74	-1.53	*: divided by 1.33
Wind-1	*	3.88	4.54	0.03	-0.38	*: divided by 1.33
Wind-2	*	5.52	7.28	-1.06	-2.00	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	18.27	25.90	5.71	90.91	0.18
Footing	**Bot bar**	1.06	5.64	0.71	21.38	0.05

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	125	1005.31	565.49	250	565.49
As/m	1608.50	200.00	200.00	452.39	200.00
Circum.	402.1248			150.7968	
d'/d	0.058 / 0.14			0.081 / 0.12	
Coefficients					
p = As/bd	0.01132746			0.0038016	
k= $(p\,n)^2+2p\,n$	0.36096483			0.2296026	
j= 1- k/3	0.87967839			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	90.91			21.38	
fc (concrete)	5.71			0.71	
v (shear)	0.18			0.05	
u (bond)	0.52			0.34	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.00~1.10

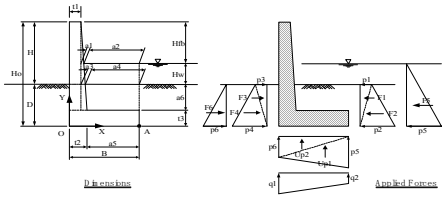
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.10	(m)		
Embedment of wall	D =	0.40	(m)		
Total height of wall	Ho=	1.50	(m)		
Freeboard	Hfb=	0.00	(m)		
Water depth under flood condition	Hw=	1.10	(m)		
Width of footing	B =	0.95	(m)		
Thickness of wall members :					
t1=	0.20	(m)	a1=	0.000	(m)
t2=	0.20	(m)	a2=	0.750	(m)
t3=	0.20	(m)	a3=	0.000	(m)
			a4=	0.750	(m)
			a5=	0.750	(m)
			a6=	1.300	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.91 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 110 (kN/m)

Qa = 37 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.454 m

q1 = V/B*(1+6e/B)= 33.731 (kN/m2)

q2 = V/B*(1-6e/B) = 25.953 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 32.094 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	7.11	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	4.62	0.43	2.00	Active force
Total		4.62		2.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	17.55	0.38	6.58	
Footing	γc(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-9.732	0.500	-4.866	
	1/2(q3)(a5)	-12.04	0.250	-3.009	
Total		-0.62		0.06	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.00~1.10

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.56	0.475	2.17	
Soil-1	1/2(a5)(a6)γs	8.775	0.700	6.14	
Soil-2	1/2(a4)(a6)γs	8.78	0.450	3.95	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		28.35	0.454	12.88	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.50	8.20	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.64	0.13	0.22	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.64		0.22	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.64		0.22	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 1.64 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 1.64 (kN/m)

SF =(V*f+ HR_{max})/ H = 13.95 > 1.5 Safe !!

Overturning,

Mr_{max} = 13.66 (kN-m/m)

Mr_{act} = 13.10 (kN-m/m)

Mo = 0.22 (kN-m/m)

SF =Mr_{max}/ M_o = 62.48 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.00 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.00~1.10

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.850	5.30	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.750	0.00	
Footing	(B)(t3)γc	4.56	0.475	2.17	
Soil-1	1/2(a5)(a6)γs	8.775	0.250	2.19	
Soil-2	1/2(a4)(a6)γs	8.78	0.500	4.39	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		28.35	0.496	14.05	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.50	110.17	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	22.03	0.13	2.94	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		22.03		2.94	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 22.03 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 23.63 > 1.5 Safe !!

Overturning,

Mr_{max} = 16.99 (kN-m/m)

Mr_{act} = 14.27 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 56.38 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.11 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.91 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.02 m

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 111 (kN/m)

Qa = 37 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.457 m

q1 = V/B*(1-6e/B)= 33.193 (kN/m2)

q2 = V/B*(1+6e/B) = 26.491 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 31.782 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	10.15	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.97	0.87	1.71	Active force
F2'	1/2(p2')(a6)	6.60	0.43	2.86	Active force
Total		8.57		4.57	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	17.55	0.38	6.58	
Footing	γc(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-9.934	0.500	-4.967	
	1/2(q3)(a5)	-11.92	0.250	-2.980	
Total		-0.70		-0.02	

4. Case 3 : Flood condition

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	
Footing	(B)(t3)γc	4.56	0.475	2.17	
Soil-1	1/2(a5)(a6)γsat	9.75	0.700	6.83	
Soil-2	1/2(a4)(a6)γsat	9.75	0.450	4.39	
Water-1	1/2(a4)(Hw)γw	4.04	0.700	2.83	
Water-2	1/2(a2)(Hw)γw	4.04	0.450	1.82	
Sub-Total		38.39	0.486	18.65	
Uplift-1	-1/2B(D+Hw)γw	-6.98	0.633	-4.42	
Uplift-2	-1/2B(D)γw	-1.86	0.317	-0.59	
Sub-Total		-8.84		-5.01	
Total		29.54		13.64	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	1.50	4.56	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.91	0.13	0.12	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	11.03	0.50	5.51	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		11.94		5.63	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 29.54 (kN/m)

H = 11.94 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f +HR_{max})/ H = 1.82 > 1.0 Safe !!

Overturning,

Mr_{max} = 19.19 (kN-m/m)

Mr = 19.19 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 10.65 (kN-m/m)

SF = Mr_{max}/M_o = 1.80 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.186 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.58 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.186 m

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.267

= 63 (kN/m)

Qa = 31.7 (kN/m) > V = 29.54 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.289 m

q1 = (2V)/3X = 68.080 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 52.390 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	3.95	Active earth press.
p5'	γw(Hw+a6)		23.52	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	2.57	0.43	1.11	Active force
F5'	1/2(p5')(Hw+a6)	28.22	0.80	22.58	Water pressure
Total		30.79		23.69	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	8.09	0.38	3.03	
Soil	γsat(a6)(a5)	19.50	0.38	7.31	
Footing	γc(t3)(a5)	3.60	0.38	1.35	
Uplift	-1/2(p5)(a5)	-5.51	0.50	-2.756	
	-1/2(p7)(a5)	-2.321	0.25	-0.580	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-17.493	0.223	-3.894	
Total		5.86		4.46	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	0.850	5.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00	0.633	0.00
Footing	(B)(t3)γc	4.56	0.475	2.17	0.100	0.46
Soil-1	1/2(a5)(a6)γs	8.775	0.700	6.14	0.633	5.56
Soil-2	1/2(a4)(a6)γs	8.78	0.450	3.95	1.067	9.36
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		28.35	0.454	12.88	0.729	20.68

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.50	12.08	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.42	0.13	0.32	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.67	0.73	4.14	Seismic force
Total of active forces		8.09		4.46	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 8.09 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f + HR_{max})/ H = 2.72 > 1.2 Safe !!

Overturning,

Mr_{max} = 13.54 (kN-m/m)

Mr_{act} = 13.54 (kN-m/m)

Mo = 4.46 (kN-m/m)

d = (Mr-Mo)/V = 0.32 (m)

SF =M_{max}/ M_{act} = 3.04 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.15 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.64 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.15 m

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.110

= 72 (kN/m)

Qa = 36 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.320 m

q1 = V/B*(1+6e/B)= 58.968 (kN/m2)

q2 = V/B*(1-6e/B) = 0.716 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 46.704 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.30	10.47	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	6.81	0.43	2.95	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.43	0.00	Seismic force
Total		8.05		3.76	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	17.55	0.38	6.58	
Footing	γc(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-0.268602	0.5	-0.134	
	1/2(q3)(a5)	-17.514	0.250	-4.379	
Total		3.37		3.42	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.850	5.30	0.850	5.30
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.750	0.00	0.633	0.00
Footing	(B)(t3)γc	4.56	0.475	2.17	0.100	0.46
Soil-1	1/2(a5)(a6)γs	8.775	0.250	2.19	0.633	5.56
Soil-2	1/2(a4)(a6)γs	8.78	0.500	4.39	1.067	9.36
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		28.35	0.496	14.05	0.729	20.68

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.50	93.05	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	18.61	0.13	2.48	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	5.67	0.73	4.14	Seismic force
Total of active forces		7.21		4.40	
Total of maximum resisting forces		18.61		2.48	
Actual resisting forces		7.21		2.48	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 7.21 (kN/m)

HR_{max} = 18.61 (kN/m)

HR_{act} = 7.21 (kN/m)

SF =(V*f + HR_{max})/ H = 4.94 > 1.2 Safe !!

Overturning,

Mr_{max} = 16.53 (kN-m/m)

Mr_{act} = 16.53 (kN-m/m)

Mo = 4.40 (kN-m/m)

d = (Mr-Mo)/V = 0.43 (m)

SF =Mr_{max}/ M_o = 3.76 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.047 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.856 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.047 m

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 102 (kN/m)

Qa = 51 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.475

q1 = V/B*(1-6e/B)= 20.973 (kN/m2)

q2 = V/B*(1+6e/B) = 38.711 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.707 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.30	12.71	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.45	0.87	1.26	Active force
F2'	1/2(p2')(a6)	8.26	0.43	3.58	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.00	0.43	0.00	Seismic force
Total		10.96		5.65	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	17.55	0.38	6.58	
Footing	γc(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-14.517	0.500	-7.258	
	1/2(q3)(a5)	-9.265	0.250	-2.316	
Total		-2.63		-1.64	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.00~1.10

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	0	0.200	0.00
Footing	(B)(t3)γc	4.56	0.475	2.17
Soil-1	1/2(a5)(a6)γs	8.775	0.700	6.14
Soil-2	1/2(a4)(a6)γs	8.78	0.450	3.95
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		28.35	0.454	12.88

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.50	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	110.17	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	22.03	0.13	2.94	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.32	0.95	2.20	Wind force
Total of active forces		2.75		2.26	
Total of maximum resisting forces		22.03		2.94	
Actual resisting forces		2.75		2.26	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 2.75 (kN/m)

HR_{max} = 22.03 (kN/m)

HR_{act} = 2.75 (kN/m)

SF =(V*f + HR_{max})/ H = 14.18 > 1.2 Safe !!

Overturning,

Mr_{max}= 15.82 (kN-m/m)

Mr_{act}= 15.14 (kN-m/m)

Mo = 2.26 (kN-m/m)

d = (Mr-Mo)/V = 0.45 (m)

SF =Mr_{max}/ M_o = 7.00 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.003 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.909 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.021 (m)

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 110 (kN/m)

Qa = 55 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.454 m

q1 = V/B*(1+6e/B)= 33.731 (kN/m2)

q2 = V/B*(1-6e/B) = 25.953 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 32.094 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.30	7.11	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	4.62	0.43	2.00	Active force
Wind Load		2.32	1.85	4.29	
Total		6.94		6.29	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	17.55	0.38	6.58	
Footing	γ_C(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-9.732	0.500	-4.866	
	1/2(q3)(a5)	-12.04	0.250	-3.009	
Total		-0.62		0.06	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.00~1.10

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γ_C	6.24	0.850	5.30
Wall-2	1/2(t2-t1)(Ho-t3)γ_C	0	0.750	0.00
Footing	(B)(t3)γ_C	4.56	0.475	2.17
Soil-1	1/2(a5)(a6)γ_S	8.775	0.250	2.19
Soil-2	1/2(a4)(a6)γ_S	8.78	0.500	4.39
Water-1	1/2(a4)(Hw)γ_W	-	-	0
Water-2	1/2(a2)(Hw)γ_W	-	-	0
Total		28.35	0.496	14.05

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	1.50	110.17	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	22.03	0.13	2.94	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γ_W(D+Hw)^2	-	-		
F6	1/2γ_W(D)^2	-	-		
F8	$C_e C_q$ q_s l H	2.32	0.95	2.20	Wind force
Total of active forces		3.97		2.50	
Total of maximum resisting forces		22.03		2.94	
Actual resisting forces		3.97		0.53	

(3) Stability

Sliding,

V = 28.35 (kN/m)

H = 3.97 (kN/m)

HR_{max} = 22.03 (kN/m)

HR_{act} = 3.97 (kN/m)

SF =(V*f + HR_{max})/ H = 9.84 > 1.2 Safe !!

Overturning,

Mr_{max} = 16.99 (kN-m/m)

Mr_{act} = 14.58 (kN-m/m)

Mo = 2.50 (kN-m/m)

d = (Mr-Mo)/V = 0.43 (m)

SF =Mr_{max}/ M_o = 6.79 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.036 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 0.852 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.049 (m)

α = 1.0

k = 1+0.3*D/B = 1.1263158

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 101 (kN/m)

Qa = 51 (kN/m) > V = 28.35 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.426 m

q1 = V/B*(1-6e/B)= 20.615 (kN/m2)

q2 = V/B*(1+6e/B) = 39.069 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 24.500 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.30	10.15	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.97	0.87	1.71	Active force
F2'	1/2(p2')(a6)	6.60	0.43	2.86	Active force
$C_e C_q$ q_s l H		2.32	1.85	4.29	
Total		10.89		8.85	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	17.55	0.38	6.58	
Footing	γ_C(t3)(a5)	3.60	0.38	1.35	
Reaction	1/2(q2)(a5)	-14.651	0.500	-7.325	
	1/2(q3)(a5)	-9.19	0.250	-2.297	
Total		-2.69		-1.69	

9. Summary of stability analysis

Height of wall, Hw= 1.00~1.10

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	13.95	1.50	0.00	0.16	28.35	36.66
Normal-2	23.63	1.50	(0.11)	0.16	28.35	36.95
Flood	1.82	1.00	0.19	0.32	29.54	31.66
Seismic-1	2.72	1.20	0.15	0.32	28.35	35.78
Seismic-2	4.94	1.20	0.05	0.32	28.35	50.99
Wind-1	14.18	1.20	(0.00)	0.32	28.35	54.98
Wind-2	9.84	1.20	(0.04)	0.32	28.35	50.71

10. Design of RC members

(1) Design Criteria

Concrete strength fc' = 20.7 (MPa)

Steel strength fy = 275 (MPa)

Modular ratio n=Es/Ec= 9

Allowable stress :

Fiber stress in flexural compress. 0.40fc' 8.28 (MPa)

Shear stress 0.079$\sqrt{fc'}$ 0.36 (MPa)

Tensile stress in reinforcement 0.40fy 110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		2.00	4.62	0.06	-0.62	
Normal-2		4.57	8.57	-0.02	-0.70	
Flood		23.69	30.79	4.46	5.86	
Seismic-1	*	2.83	6.06	2.57	2.53	*: divided by 1.33
Seismic-2	*	4.25	8.24	-1.24	-1.98	*: divided by 1.33
Wind-1	*	4.73	5.22	0.04	-0.46	*: divided by 1.33
Wind-2	*	6.66	8.19	-1.27	-2.02	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.20	0.144	12	250	452.39
Footing	1	0.20	0.144	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	6.66	30.79	3.27	109.94	0.21
Footing	**Top bar**	4.46	5.86	2.19	73.71	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	565.49	565.49	250	565.49
As/m	452.39	200.00	200.00	452.39	200.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.144			0.14	
Coefficients					
p = As/bd	0.0031416			0.0031416	
k= $(p\,n)^2+2p\,n$	0.21120053			0.2112005	
j= 1- k/3	0.92959982			0.929600	
Actual Stresses, (Mpa)					
fs (steel)	109.94			73.71	
fc (concrete)	3.27			2.19	
v (shear)	0.21			0.04	
u (bond)	1.53			0.29	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		200	200		200

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	23.69	30.79	7.31	101.04	0.22
Footing	**Bot bar**	1.27	5.86	0.85	25.58	0.05

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	25	25	12	12	12
Spacing	250	2454.37	565.49	250	565.49
As/m	1963.50	200.00	200.00	452.39	200.00
Circum.	314.16			150.7968	
d'	0.0625			0.081	
d	0.14			0.12	
Coefficients					
p = As/bd	0.01428			0.0038016	
k= $(p\,n)^2+2p\,n$	0.39450714			0.2296026	
j= 1- k/3	0.86849762			0.923466	
Actual Stresses, (Mpa)					
fs (steel)	101.04			25.58	
fc (concrete)	7.31			0.85	
v (shear)	0.22			0.05	
u (bond)	0.82			0.35	
Code Minimum reinforcements					
ratio (min.)	0.001		0.001		0.001
As (min.) = ratio x b x h	200		200		200

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.10~1.20

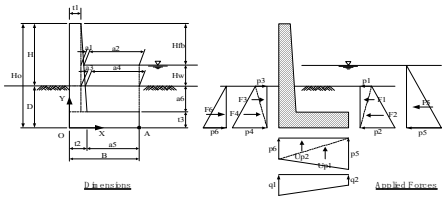
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.20 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	1.60 (m)		
Freeboard	Hfb=	0.00 (m)		
Width of footing	B =	1.00 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.30 (m)		a2=	0.800 (m)
t3=	0.30 (m)		a3=	0.092 (m)
			a4=	0.708 (m)
			a5=	0.700 (m)
			a6=	1.300 (m)



Height of wall, Hw= 1.10~1.20

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.233	0.36	
Footing	(B)(t3)γc	7.2	0.500	3.60	
Soil-1	1/2(a5)(a6)γs	8.19	0.767	6.28	
Soil-2	1/2(a4)(a6)γs	8.28	0.528	4.37	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		31.47	0.484	15.24	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.60	8.75	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.75	0.13	0.23	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.75		0.23	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.75		0.23	

(3) Stability

Sliding,

V =	31.47 (kN/m)	
H =	1.75 (kN/m)	
HR_{max} =	5.88 (kN/m)	
HR_{act} =	1.75 (kN/m)	
SF =(V*f + HR_{max})/ H =	14.15	> 1.5 Safe !!

Overturning,

Mr_{max} =	16.02 (kN-m/m)	
Mr_{act} =	15.47 (kN-m/m)	
Mo =	0.23 (kN-m/m)	
SF =Mr_{max}/ M_o =	68.68	> 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V =	0.00 (m)	< B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.97 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 119 (kN/m)

Qa = 40 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.484 m

q1 = V/B*(1+6e/B)= 34.437 (kN/m2)

q2 = V/B*(1-6e/B) = 28.503 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 32.657 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	7.11	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	4.62	0.43	2.00	Active force
Total		4.62		2.00	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-9.976	0.467	-4.656	
	1/2(q3)(a5)	-11.43	0.233	-2.667	
Total		0.01		0.17	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.900	5.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.767	1.20	
Footing	(B)(t3)γc	7.2	0.500	3.60	
Soil-1	1/2(a5)(a6)γs	8.19	0.233	1.91	
Soil-2	1/2(a4)(a6)γs	8.28	0.472	3.91	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		31.47	0.516	16.23	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.60	117.51	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	23.50	0.13	3.13	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		23.50		3.13	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 31.47 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 23.50 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 25.65 > 1.5 Safe !!

Overturning,

Mr_{max} = 19.36 (kN-m/m)

Mr_{act} = 16.45 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 64.25 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.11 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 0.97 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 120 (kN/m)

Qa = 40 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.487 m

q1 = V/B*(1-6e/B)= 33.951 (kN/m2)

q2 = V/B*(1+6e/B) = 28.989 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 32.462 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	10.15	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.97	0.87	1.71	Active force
F2'	1/2(p2')(a6)	6.60	0.43	2.86	Active force
Total		8.57		4.57	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-10.146	0.467	-4.735	
	1/2(q3)(a5)	-11.36	0.233	-2.651	
Total		-0.09		0.11	

4. Case 3 : Flood condition

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.233	0.36	
Footing	(B)(t3)γc	7.2	0.500	3.60	
Soil-1	1/2(a5)(a6)γsat	9.10	0.767	6.98	
Soil-2	1/2(a4)(a6)γsat	9.20	0.528	4.86	
Water-1	1/2(a4)(Hw)γw	4.16	0.764	3.18	
Water-2	1/2(a2)(Hw)γw	4.70	0.467	2.20	
Sub-Total		42.17	0.517	21.80	
Uplift-1	-1/2B(D+Hw)γw	-7.84	0.667	-5.23	
Uplift-2	-1/2B(D)γw	-1.96	0.333	-0.65	
Sub-Total		-9.80		-5.88	
Total		32.37		15.92	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	1.60	4.86	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.97	0.13	0.13	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	12.54	0.53	6.69	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		13.52		6.82	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 32.37 (kN/m)

H = 13.52 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.74 > 1.0 Safe !!

Overturning,

Mr_{max} = 22.34 (kN-m/m)

Mr = 22.34 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 12.70 (kN-m/m)

SF = Mr_{max}/M_o = 1.76 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.202 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.60 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.202 m

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.293

= 65 (kN/m)

Qa = 32.6 (kN/m) > V = 32.37 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.298 m

q1 = (2V)/3X = 72.449 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 48.123 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	3.95	Active earth press.
p5'	γw(Hw+a6)		24.50	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	2.57	0.43	1.11	Active force
F5'	1/2(p5')(Hw+a6)	30.63	0.83	25.52	Water pressure
Total		33.19		26.63	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	8.23	0.35	2.88	
Soil	γsat(a6)(a5)	18.20	0.35	6.37	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Uplift	-1/2(p5)(a5)	-5.49	0.47	-2.561	
	-1/2(p7)(a5)	-2.607	0.23	-0.608	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-14.279	0.198	-2.825	
Total		9.10		5.02	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62	0.950	5.93
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.233	0.36	0.733	1.14
Footing	(B)(t3)γc	7.2	0.500	3.60	0.150	1.08
Soil-1	1/2(a5)(a6)γs	8.19	0.767	6.28	0.733	6.01
Soil-2	1/2(a4)(a6)γs	8.28	0.528	4.37	1.167	9.66
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		31.47	0.484	15.24	0.757	23.82

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.60	12.89	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.58	0.13	0.34	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.29	0.76	4.76	Seismic force
Total of active forces		8.87		5.11	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 31.47 (kN/m)

H = 8.87 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.69 > 1.2 Safe !!

Overturning,

Mr_{max} = 15.90 (kN-m/m)

Mr_{act} = 15.90 (kN-m/m)

Mo = 5.11 (kN-m/m)

d = (Mr-Mo)/V = 0.34 (m)

SF =M_{max}/ M_{act} = 3.11 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.16 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.69 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.16 m

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.124

= 77 (kN/m)

Qa = 39 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.343 m

q1 = V/B*(1+6e/B)= 61.110 (kN/m2)

q2 = V/B*(1-6e/B) = 1.830 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 43.326 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.30	10.47	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	6.81	0.43	2.95	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.31	0.43	0.14	Seismic force
Total		8.37		3.90	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-0.640389	0.4666667	-0.299	
	1/2(q3)(a5)	-15.164	0.233	-3.538	
Total		5.62		3.66	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.900	5.62	0.950	5.93
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.767	1.20	0.733	1.14
Footing	(B)(t3)γc	7.2	0.500	3.60	0.150	1.08
Soil-1	1/2(a5)(a6)γs	8.19	0.233	1.91	0.733	6.01
Soil-2	1/2(a4)(a6)γs	8.28	0.472	3.91	1.167	9.66
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		31.47	0.516	16.23	0.757	23.82

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.60	99.26	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	19.85	0.13	2.65	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	6.29	0.76	4.76	Seismic force
Total of active forces		7.83		5.03	
Total of maximum resisting forces		19.85		2.65	
Actual resisting forces		7.83		2.65	

(3) Stability

Sliding,

V = 31.47 (kN/m)

H = 7.83 (kN/m)

HR_{max} = 19.85 (kN/m)

HR_{act} = 7.83 (kN/m)

SF =(V*f+ HR_{max})/ H = 4.94 > 1.2 Safe !!

Overturning,

Mr_{max} = 18.88 (kN-m/m)

Mr_{act} = 18.88 (kN-m/m)

Mo = 5.03 (kN-m/m)

d = (Mr-Mo)/V = 0.44 (m)

SF =Mr_{max}/ M_o = 3.75 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.060 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.880 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.060 m

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 105 (kN/m)

Qa = 53 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.500

q1 = V/B*(1-6e/B)= 20.146 (kN/m2)

q2 = V/B*(1+6e/B) = 42.794 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 26.941 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.30	12.71	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.45	0.87	1.26	Active force
F2'	1/2(p2')(a6)	8.26	0.43	3.58	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.25	0.65	0.81	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.31	0.43	0.14	Seismic force
Total		11.28		5.79	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-14.978	0.467	-6.990	
	1/2(q3)(a5)	-9.429	0.233	-2.200	
Total		-2.99		-1.69	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.10~1.20

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.100	0.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.233	0.36
Footing	(B)(t3)γc	7.2	0.500	3.60
Soil-1	1/2(a5)(a6)γs	8.19	0.667	5.46
Soil-2	1/2(a4)(a6)γs	8.28	0.436	3.61
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		31.47	0.434	13.66

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.60	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	117.51	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	23.50	0.13	3.13	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.53	1.00	2.53	Wind force
Total of active forces		2.96		2.59	
Total of maximum resisting forces		23.50		3.13	
Actual resisting forces		2.96		2.59	

(3) Stability

Sliding,

V = 31.47 (kN/m)

H = 2.96 (kN/m)

HR_{max} = 23.50 (kN/m)

HR_{act} = 2.96 (kN/m)

SF =(V*f + HR_{max})/ H = 14.30 > 1.2 Safe !!

Overturning,

Mr_{max}= 16.79 (kN-m/m)

Mr_{act}= 16.24 (kN-m/m)

Mo = 2.59 (kN-m/m)

d = (Mr-Mo)/V = 0.43 (m)

SF =Mr_{max}/ M_o = 6.49 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.049 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.868 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.066 (m)

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 103 (kN/m)

Qa = 52 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.434 m

q1 = V/B*(1+6e/B)= 43.937 (kN/m2)

q2 = V/B*(1-6e/B) = 19.003 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 36.457 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	7.11	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.87	0.00	Active force
F2'	1/2(p2')(a6)	4.62	0.43	2.00	Active force
Wind Load		2.53	1.90	4.80	
Total		7.15		6.80	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-6.651	0.467	-3.104	
	1/2(q3)(a5)	-12.76	0.233	-2.977	
Total		2.01		1.42	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.10~1.20

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.24	0.900	5.62
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.56	0.767	1.20
Footing	(B)(t3)γc	7.2	0.500	3.60
Soil-1	1/2(a5)(a6)γs	8.19	0.233	1.91
Soil-2	1/2(a4)(a6)γs	8.28	0.472	3.91
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		31.47	0.516	16.23

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.60	117.51	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	23.50	0.13	3.13	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.53	1.00	2.53	Wind force
Total of active forces		4.18		2.83	
Total of maximum resisting forces		23.50		3.13	
Actual resisting forces		4.18		0.56	

(3) Stability

Sliding,

V = 31.47 (kN/m)

H = 4.18 (kN/m)

HR_{max} = 23.50 (kN/m)

HR_{act} = 4.18 (kN/m)

SF =(V*f + HR_{max})/ H = 10.14 > 1.2 Safe !!

Overturning,

Mr_{max} = 19.36 (kN-m/m)

Mr_{act} = 16.79 (kN-m/m)

Mo = 2.83 (kN-m/m)

d = (Mr-Mo)/V = 0.44 (m)

SF =Mr_{max}/ M_o = 6.85 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.025 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.887 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.056 (m)

α = 1.0

k = 1+0.3*D/B = 1.12

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 106 (kN/m)

Qa = 53 (kN/m) > V = 31.47 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.444 m

q1 = V/B*(1-6e/B)= 20.809 (kN/m2)

q2 = V/B*(1+6e/B) = 42.131 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 27.206 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.30	10.15	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.97	0.87	1.71	Active force
F2'	1/2(p2')(a6)	6.60	0.43	2.86	Active force
C_eC_q q_s l H		2.53	1.90	4.80	
Total		11.10		9.37	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	16.38	0.35	5.73	
Footing	γc(t3)(a5)	5.04	0.35	1.76	
Reaction	1/2(q2)(a5)	-14.746	0.467	-6.881	
	1/2(q3)(a5)	-9.52	0.233	-2.222	
Total		-2.85		-1.61	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.30	0.244	12	250	452.39
Footing	1	0.30	0.244	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	7.05	33.19	1.50	67.59	0.14
Footing	**Top bar**	5.02	9.10	1.07	48.17	0.04

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	376.99	376.99	250	376.99
As/m	452.39	300.00	300.00	452.39	300.00
Circum.	150.7968			150.7968	
d' / d	0.056 / 0.244			0.056 / 0.24	
Coefficients					
p = As/bd	0.00185406			0.0018541	
k= $(pn)^2+2pn$	0.16675693			0.1667569	
j= 1- k/3	0.94441436			0.944414	
Actual Stresses, (Mpa)					
fs (steel)	67.59			48.17	
fc (concrete)	1.50			1.07	
v (shear)	0.14			0.04	
u (bond)	0.96			0.26	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 1.10~1.20

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	14.15	1.50	(0.00)	0.17	31.47	39.58
Normal-2	25.65	1.50	(0.11)	0.17	31.47	39.85
Flood	1.74	1.00	0.20	0.33	32.37	32.63
Seismic-1	2.69	1.20	0.16	0.33	31.47	38.66
Seismic-2	4.94	1.20	0.06	0.33	31.47	52.59
Wind-1	14.30	1.20	0.05	0.33	31.47	51.68
Wind-2	10.14	1.20	(0.03)	0.33	31.47	53.11

10. Design of RC members

(1) Design Criteria

Concrete strength		fc' =	20.7 (MPa)
Steel strength		fy =	275 (MPa)
Modular ratio		n=Es/Ec=	9
Allowable stress :			
Fiber stress in flexural compress.	0.40fc'		8.28 (MPa)
Shear stress	0.079√fc'		0.36 (MPa)
Tensile stress in reinforcement	0.40fy		110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		2.00	4.62	0.17	0.01	
Normal-2		4.57	8.57	0.11	-0.09	
Flood		26.63	33.19	5.02	9.10	
Seismic-1	*	2.93	6.29	2.75	4.22	*: divided by 1.33
Seismic-2	*	4.35	8.48	-1.27	-2.25	*: divided by 1.33
Wind-1	*	5.12	5.37	1.06	1.51	*: divided by 1.33
Wind-2	*	7.05	8.34	-1.21	-2.14	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	26.63	33.19	3.85	96.81	0.14
Footing	**Bot bar**	1.27	9.10	0.32	13.64	0.04

	Wall		Footing		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	250	1047.20	376.99	250	376.99
As/m	1256.64	300.00	300.00	452.39	300.00
Circum.	251.328			150.7968	
d' / d	0.06 / 0.24			0.081 / 0.22	
Coefficients					
p = As/bd	0.005236			0.0020657	
k= $(pn)^2+2pn$	0.26347006			0.1751311	
j= 1- k/3	0.91217665			0.941623	
Actual Stresses, (Mpa)					
fs (steel)	96.81			13.64	
fc (concrete)	3.85			0.32	
v (shear)	0.14			0.04	
u (bond)	0.60			0.29	
Code Minimum reinforcements					
ratio (min.)	0.001	0.001		0.001	
As (min.) = ratio x b x h	300	300		300	

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.20~1.30

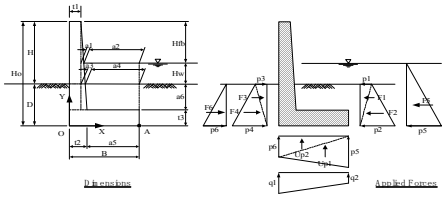
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.30 (m)	
Embedment of wall	D =	0.40 (m)	
Total height of wall	Ho=	1.70 (m)	
Freeboard	Hfb=	0.00 (m)	
Width of footing	B =	1.15 (m)	
Thickness of wall members :			
t1= 0.20 (m)		a1= 0.000 (m)	
t2= 0.30 (m)		a2= 0.950 (m)	
t3= 0.30 (m)		a3= 0.093 (m)	
		a4= 0.857 (m)	
		a5= 0.850 (m)	
		a6= 1.400 (m)	



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.12 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 142 (kN/m)

Qa = 47 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.559 m

q1 = V/B*(1+6e/B)= 35.948 (kN/m2)

q2 = V/B*(1-6e/B) = 30.470 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 34.519 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.40	7.66	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.93	0.00	Active force
F2'	1/2(p2')(a6)	5.36	0.47	2.50	Active force
Total		5.36		2.50	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-12.950	0.567	-7.338	
	1/2(q3)(a5)	-14.67	0.283	-4.157	
Total		-0.08		0.21	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.20~1.30

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.233	0.39	
Footing	(B)(t3)γc	8.28	0.575	4.76	
Soil-1	1/2(a5)(a6)γs	10.71	0.867	9.28	
Soil-2	1/2(a4)(a6)γs	10.80	0.579	6.25	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		38.19	0.559	21.36	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.70	9.30	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.86	0.13	0.25	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.86		0.25	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.86		0.25	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 1.86 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 1.86 (kN/m)

SF =(V*f'+ HR_{max})/ H = 15.49 > 1.5 Safe !!

Overturning,

Mr_{max} = 22.14 (kN-m/m)

Mr_{act} = 21.60 (kN-m/m)

Mo = 0.25 (kN-m/m)

SF =Mr_{max}/ M_o = 89.31 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.00 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.20~1.30

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	1.050	7.06	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.917	1.54	
Footing	(B)(t3)γc	8.28	0.575	4.76	
Soil-1	1/2(a5)(a6)γs	10.71	0.283	3.03	
Soil-2	1/2(a4)(a6)γs	10.80	0.571	6.17	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		38.19	0.591	22.56	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.70	124.86	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	24.97	0.13	3.33	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		24.97		3.33	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 24.97 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f'+ HR_{max})/ H = 28.98 > 1.5 Safe !!

Overturning,

Mr_{max} = 25.89 (kN-m/m)

Mr_{act} = 22.78 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 85.92 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.10 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.12 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 142 (kN/m)

Qa = 47 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.561 m

q1 = V/B*(1-6e/B)= 35.580 (kN/m2)

q2 = V/B*(1+6e/B) = 30.837 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 34.343 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.40	10.69	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.13	0.93	1.98	Active force
F2'	1/2(p2')(a6)	7.49	0.47	3.49	Active force
Total		9.61		5.48	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-13.106	0.567	-7.427	
	1/2(q3)(a5)	-14.60	0.283	-4.135	
Total		-0.16		0.14	

4. Case 3 : Flood condition

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.233	0.39	
Footing	(B)(t3)γc	8.28	0.575	4.76	
Soil-1	1/2(a5)(a6)γsat	11.90	0.867	10.31	
Soil-2	1/2(a4)(a6)γsat	12.00	0.579	6.94	
Water-1	1/2(a4)(Hw)γw	5.46	0.864	4.72	
Water-2	1/2(a2)(Hw)γw	6.05	0.517	3.13	
Sub-Total		52.09	0.594	30.93	
Uplift-1	-1/2B(D+Hw)γw	-9.58	0.767	-7.34	
Uplift-2	-1/2B(D)γw	-2.25	0.383	-0.86	
Sub-Total		-11.83		-8.21	
Total		40.26		22.72	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γ'h)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γ'h)-2c√Ka	1.70	5.16	Active earth press.
p3	Kp(γ'h)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γ'h)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.03	0.13	0.14	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	14.16	0.57	8.02	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		15.19		8.16	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 40.26 (kN/m)

H = 15.19 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.86 > 1.0 Safe !!

Overturning,

Mr_{max} = 31.47 (kN-m/m)

Mr = 31.47 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 16.37 (kN-m/m)

SF = Mr_{max}/M_o = 1.92 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.200 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.75 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.200 m

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.277

= 85 (kN/m)

Qa = 42.6 (kN/m) > V = 40.26 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.375 m

q1 = (2V)/3X = 71.573 (kN/m2)

q2 = 0.000 (kN/m2)

q3 = q1(3X-t2)/(3X) = 52.486 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.40	4.25	Active earth press.
p5'	γw(Hw+a6)		26.46	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.93	0.00	Active force
F2'	1/2(p2')(a6)	2.98	0.47	1.39	Active force
F5'	1/2(p5')(Hw+a6)	35.72	0.90	32.15	Water pressure
Total		38.70		33.54	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	10.83	0.43	4.60	
Soil	γsat(a6)(a5)	23.80	0.43	10.12	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Uplift	-1/2(p5)(a5)	-7.08	0.57	-4.012	
	-1/2(p7)(a5)	-3.078	0.28	-0.872	
Reaction	1/2*(q2)*(a5)	0	0	0.000	
	1/2(q3)(3X-t2)	-21.649	0.275	-5.953	
Total		8.94		6.48	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67	1.000	6.72
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.233	0.39	0.767	1.29
Footing	(B)(t3)γc	8.28	0.575	4.76	0.150	1.24
Soil-1	1/2(a5)(a6)γs	10.71	0.867	9.28	0.767	8.21
Soil-2	1/2(a4)(a6)γs	10.80	0.579	6.25	1.233	13.32
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		38.19	0.559	21.36	0.806	30.78

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.70	13.69	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.74	0.13	0.37	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.64	0.81	6.16	Seismic force
Total of active forces		10.38		6.52	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 10.38 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.69 > 1.2 Safe !!

Overturning,

Mr_{max} = 22.02 (kN-m/m)

Mr_{act} = 22.02 (kN-m/m)

Mo = 6.52 (kN-m/m)

d = (Mr-Mo)/V = 0.41 (m)

SF =M_{max}/ M_{act} = 3.38 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.17 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.81 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.17 m

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.142

= 94 (kN/m)

Qa = 47 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.406 m

q1 = V/B*(1+6e/B)= 62.532 (kN/m2)

q2 = V/B*(1-6e/B) = 3.885 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 47.233 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c$\sqrt{}$Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c$\sqrt{}$Kea	1.40	11.28	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.93	0.00	Active force
F2'	1/2(p2')(a6)	7.89	0.47	3.68	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.34	0.70	0.94	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.34	0.47	0.16	Seismic force
Total		9.57		4.78	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-1.65128	0.5666667	-0.936	
	1/2(q3)(a5)	-20.074	0.283	-5.688	
Total		5.81		5.08	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	1.050	7.06	1.000	6.72
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.917	1.54	0.767	1.29
Footing	(B)(t3)γc	8.28	0.575	4.76	0.150	1.24
Soil-1	1/2(a5)(a6)γs	10.71	0.283	3.03	0.767	8.21
Soil-2	1/2(a4)(a6)γs	10.80	0.571	6.17	1.233	13.32
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		38.19	0.591	22.56	0.806	30.78

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c$\sqrt{}$Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c$\sqrt{}$Kep	1.70	105.46	Passive press.
p3	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c$\sqrt{}$Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	21.09	0.13	2.81	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	7.64	0.81	6.16	Seismic force
Total of active forces		9.18		6.42	
Total of maximum resisting forces		21.09		2.81	
Actual resisting forces		9.18		2.81	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 9.18 (kN/m)

HR_{max} = 21.09 (kN/m)

HR_{act} = 9.18 (kN/m)

SF =(V*f + HR_{max})/ H = 4.79 > 1.2 Safe !!

Overturning,

Mr_{max} = 25.38 (kN-m/m)

Mr_{act} = 25.38 (kN-m/m)

Mo = 6.42 (kN-m/m)

d = (Mr-Mo)/V = 0.50 (m)

SF =Mr_{max}/ M_o = 3.95 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.079 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.993 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.079 m

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 121 (kN/m)

Qa = 61 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.575

q1 = V/B*(1-6e/B)= 19.574 (kN/m2)

q2 = V/B*(1+6e/B) = 46.843 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 26.688 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c$\sqrt{}$Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c$\sqrt{}$Kea	1.40	13.52	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.57	0.93	1.46	Active force
F2'	1/2(p2')(a6)	9.46	0.47	4.41	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.34	0.70	0.94	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.34	0.47	0.16	Seismic force
Total		12.71		6.97	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-19.908	0.567	-11.281	
	1/2(q3)(a5)	-11.342	0.283	-3.214	
Total		-3.71		-2.79	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.20~1.30

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	0.100	0.67
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.233	0.39
Footing	(B)(t3)γc	8.28	0.575	4.76
Soil-1	1/2(a5)(a6)γs	10.71	0.767	8.21
Soil-2	1/2(a4)(a6)γs	10.80	0.486	5.25
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		38.19	0.505	19.28

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{}$Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c$\sqrt{}$Ka	1.70	2.19	Active press.
p3	Kp(γh)+2c$\sqrt{}$Kp	0.00	0.00	
p4	Kp(γh)+2c$\sqrt{}$Kp	0.40	124.86	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	24.97	0.13	3.33	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	2.74	1.05	2.87	Wind force
Total of active forces		3.18		2.93	
Total of maximum resisting forces		24.97		3.33	
Actual resisting forces		3.18		2.93	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 3.18 (kN/m)

HR_{max} = 24.97 (kN/m)

HR_{act} = 3.18 (kN/m)

SF =(V*f + HR_{max})/ H = 15.08 > 1.2 Safe !!

Overturning,

Mr_{max}= 22.61 (kN-m/m)

Mr_{act}= 22.21 (kN-m/m)

Mo = 2.93 (kN-m/m)

d = (Mr-Mo)/V = 0.50 (m)

SF =Mr_{max}/ M_o = 7.71 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.060 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.010 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.070 (m)

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 124 (kN/m)

Qa = 62 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.505 m

q1 = V/B*(1+6e/B)= 45.356 (kN/m2)

q2 = V/B*(1-6e/B) = 21.061 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 39.018 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.40	7.66	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	0.93	0.00	Active force
F2'	1/2(p2')(a6)	5.36	0.47	2.50	Active force
Wind Load		2.74	2.05	5.61	
Total		8.10		8.11	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-8.951	0.567	-5.072	
	1/2(q3)(a5)	-16.58	0.283	-4.698	
Total		2.01		1.93	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.20~1.30

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	6.72	1.050	7.06
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.68	0.917	1.54
Footing	(B)(t3)γc	8.28	0.575	4.76
Soil-1	1/2(a5)(a6)γs	10.71	0.283	3.03
Soil-2	1/2(a4)(a6)γs	10.80	0.571	6.17
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		38.19	0.591	22.56

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	1.70	124.86	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	24.97	0.13	3.33	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.74	1.05	2.87	Wind force
Total of active forces		4.39		3.18	
Total of maximum resisting forces		24.97		3.33	
Actual resisting forces		4.39		0.59	

(3) Stability

Sliding,

V = 38.19 (kN/m)

H = 4.39 (kN/m)

HR_{max} = 24.97 (kN/m)

HR_{act} = 4.39 (kN/m)

SF =(V*f + HR_{max})/ H = 10.91 > 1.2 Safe !!

Overturning,

Mr_{max} = 25.89 (kN-m/m)

Mr_{act} = 23.15 (kN-m/m)

Mo = 3.18 (kN-m/m)

d = (Mr-Mo)/V = 0.52 (m)

SF =Mr_{max}/ M_o = 8.15 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.020 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.046 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.052 (m)

α = 1.0

k = 1+0.3*D/B = 1.1043478

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 130 (kN/m)

Qa = 65 (kN/m) > V = 38.19 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.523 m

q1 = V/B*(1-6e/B)= 24.194 (kN/m2)

q2 = V/B*(1+6e/B) = 42.223 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 28.897 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.40	10.69	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.13	0.93	1.98	Active force
F2'	1/2(p2')(a6)	7.49	0.47	3.49	Active force
$C_e C_q q_s$ l H		2.74	2.05	5.61	
Total		12.35		11.09	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	21.42	0.43	9.10	
Footing	γc(t3)(a5)	6.12	0.43	2.60	
Reaction	1/2(q2)(a5)	-17.945	0.567	-10.169	
	1/2(q3)(a5)	-12.28	0.283	-3.480	
Total		-2.69		-1.94	

9. Summary of stability analysis

Height of wall, Hw= 1.20~1.30

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	15.49	1.50	0.00	0.19	38.19	47.20
Normal-2	28.98	1.50	(0.10)	0.19	38.19	47.43
Flood	1.86	1.00	0.20	0.38	38.19	42.64
Seismic-1	2.69	1.20	0.17	0.38	38.19	47.01
Seismic-2	4.79	1.20	0.08	0.38	38.19	60.65
Wind-1	15.08	1.20	0.06	0.38	38.19	62.00
Wind-2	10.91	1.20	(0.02)	0.38	38.19	64.89

10. Design of RC members

(1) Design Criteria

Concrete strength fc' = 20.7 (MPa)

Steel strength fy = 275 (MPa)

Modular ratio n=Es/Ec= 9

Allowable stress :

Fiber stress in flexural compress. 0.40fc' 8.28 (MPa)

Shear stress 0.079$\sqrt{fc'}$ 0.36 (MPa)

Tensile stress in reinforcement 0.40fy 110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		2.50	5.36	0.21	-0.08	
Normal-2		5.48	9.61	0.14	-0.16	
Flood		33.54	38.70	6.48	8.94	
Seismic-1	*	3.60	7.20	3.82	4.37	*: divided by 1.33
Seismic-2	*	5.24	9.55	-2.10	-2.79	*: divided by 1.33
Wind-1	*	6.10	6.09	1.45	1.51	*: divided by 1.33
Wind-2	*	8.34	9.29	-1.46	-2.02	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.30	0.244	12	250	452.39
Footing	1	0.30	0.244	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	8.34	38.70	1.78	79.99	0.16
Footing	**Top bar**	6.48	8.94	1.38	62.17	0.04

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	376.99	376.99	250	376.99
As/m	452.39	300.00	300.00	452.39	300.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.244			0.24	
Coefficients					
p = As/bd	0.00185406			0.0018541	
k= $(p\,n)^2+2p\,n$	0.16675693			0.1667569	
j= 1- k/3	0.94441436			0.944414	
Actual Stresses, (Mpa)					
fs (steel)	79.99			62.17	
fc (concrete)	1.78			1.38	
v (shear)	0.16			0.04	
u (bond)	1.11			0.26	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	33.54	38.70	4.36	95.42	0.16
Footing	**Bot bar**	2.10	8.94	0.53	22.49	0.04

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	12	12
Spacing	125	670.21	376.99	250	376.99
As/m	1608.50	300.00	300.00	452.39	300.00
Circum.	402.1248			150.7968	
d'	0.058			0.081	
d	0.24			0.22	
Coefficients					
p = As/bd	0.00664669			0.0020657	
k= $(p\,n)^2+2p\,n$	0.29120527			0.1751311	
j= 1- k/3	0.90293158			0.941623	
Actual Stresses, (Mpa)					
fs (steel)	95.42			22.49	
fc (concrete)	4.36			0.53	
v (shear)	0.16			0.04	
u (bond)	0.44			0.29	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.30~1.40

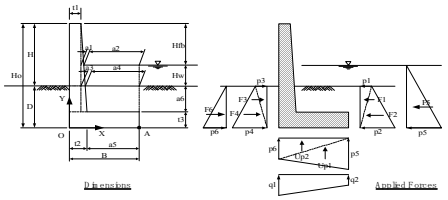
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.40 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	1.80 (m)		
Freeboard	Hfb=	0.00 (m)		
Width of footing	B =	1.25 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.30 (m)		a2=	1.050 (m)
t3=	0.30 (m)		a3=	0.093 (m)
			a4=	0.957 (m)
			a5=	0.950 (m)
			a6=	1.500 (m)



2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.30~1.40

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	0.233	0.42	
Footing	(B)(t3)γc	9	0.625	5.63	
Soil-1	1/2(a5)(a6)γs	12.825	0.933	11.97	
Soil-2	1/2(a4)(a6)γs	12.92	0.612	7.91	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		43.74	0.609	26.64	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.80	9.84	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.97	0.13	0.26	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.97		0.26	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		1.97		0.26	

(3) Stability

Sliding,

V =	43.74 (kN/m)	
H =	1.97 (kN/m)	
HR_{max} =	5.88 (kN/m)	
HR_{act} =	1.97 (kN/m)	
SF =(V*f + HR_{max})/ H =	16.32	> 1.5 Safe !!

Overturning,

Mr_{max} =	27.43 (kN-m/m)	
Mr_{act} =	26.90 (kN-m/m)	
Mo =	0.26 (kN-m/m)	
SF =Mr_{max}/ M_o =	104.49	> 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V =	0.00 (m)	< B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.22 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 158 (kN/m)

Qa = 53 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.609 m

q1 = V/B*(1+6e/B)= 37.663 (kN/m2)

q2 = V/B*(1-6e/B) = 32.321 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 36.381 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.50	8.20	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Active force
F2'	1/2(p2')(a6)	6.15	0.50	3.08	Active force
Total		6.15		3.08	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-15.352	0.633	-9.723	
	1/2(q3)(a5)	-17.28	0.317	-5.472	
Total		-0.14		0.24	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	1.150	8.28	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	1.017	1.83	
Footing	(B)(t3)γc	9	0.625	5.63	
Soil-1	1/2(a5)(a6)γs	12.825	0.317	4.06	
Soil-2	1/2(a4)(a6)γs	12.92	0.638	8.24	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		43.74	0.641	28.03	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.80	132.20	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	26.44	0.13	3.53	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		26.44		3.53	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 43.74 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 26.44 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 31.88 > 1.5 Safe !!

Overturning,

Mr_{max} = 31.56 (kN-m/m)

Mr_{act} = 28.25 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 104.72 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.09 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.22 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 158 (kN/m)

Qa = 53 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.611 m

q1 = V/B*(1-6e/B)= 37.352 (kN/m2)

q2 = V/B*(1+6e/B) = 32.632 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 36.219 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(a6)	8.43	0.50	4.21	Active force
Total		10.71		6.49	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-15.500	0.633	-9.817	
	1/2(q3)(a5)	-17.20	0.317	-5.448	
Total		-0.21		0.17	

4. Case 3 : Flood condition

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	0.233	0.42	
Footing	(B)(t3)γc	9	0.625	5.63	
Soil-1	1/2(a5)(a6)γsat	14.25	0.933	13.30	
Soil-2	1/2(a4)(a6)γsat	14.35	0.612	8.79	
Water-1	1/2(a4)(Hw)γw	6.56	0.931	6.11	
Water-2	1/2(a2)(Hw)γw	7.20	0.550	3.96	
Sub-Total		60.37	0.645	38.92	
Uplift-1	-1/2B(D+Hw)γw	-11.03	0.833	-9.19	
Uplift-2	-1/2B(D)γw	-2.45	0.417	-1.02	
Sub-Total		-13.48		-10.21	
Total		46.89		28.71	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.80	5.47	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.09	0.13	0.15	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	15.88	0.60	9.53	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		16.97		9.67	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 46.89 (kN/m)

H = 16.97 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.90 > 1.0 Safe !!

Overturning,

Mr_{max} = 39.46 (kN-m/m)

Mr = 39.46 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 19.88 (kN-m/m)

SF = Mr_{max}/M_o = 1.99 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.207 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.84 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.207 m

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.276

= 97 (kN/m)

Qa = 48.5 (kN/m) > V = 46.89 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.418 m

q1 = V/B*(1+6e/B)= 74.853 (kN/m2)

q2 = V/B*(1-6e/B) = 0.172 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 56.929 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.50	4.56	Active earth press.
p5'	γw(Hw+a6)		28.42	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Active force
F2'	1/2(p2')(a6)	3.42	0.50	1.71	Active force
F5'	1/2(p5')(Hw+a6)	41.21	0.97	39.84	Water pressure
Total		44.63		41.54	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	13.03	0.48	6.19	
Soil	γsat(a6)(a5)	28.50	0.48	13.54	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Uplift	-1/2(p5)(a5)	-8.38	0.63	-5.307	
	-1/2(p7)(a5)	-3.426	0.32	-1.085	
Reaction	1/2(q2)(a5)	0.081881	0.6333333	0.052	
	1/2(q3)(a5)	-27.042	0.317	-8.563	
Total		9.61		8.07	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72	1.050	7.56
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	0.233	0.42	0.800	1.44
Footing	(B)(t3)γc	9	0.625	5.63	0.150	1.35
Soil-1	1/2(a5)(a6)γs	12.825	0.933	11.97	0.800	10.26
Soil-2	1/2(a4)(a6)γs	12.92	0.612	7.91	1.300	16.79
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		43.74	0.609	26.64	0.855	37.40

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.80	14.50	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.90	0.13	0.39	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	8.75	0.86	7.48	Seismic force
Total of active forces		11.65		7.87	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 43.74 (kN/m)

H = 11.65 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.68 > 1.2 Safe !!

Overturning,

Mr_{max} = 27.30 (kN-m/m)

Mr_{act} = 27.30 (kN-m/m)

Mo = 7.87 (kN-m/m)

d = (Mr-Mo)/V = 0.44 (m)

SF =M_{max}/ M_{act} = 3.47 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.18 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.89 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.18 m

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.153

= 105 (kN/m)

Qa = 52 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.444 m

q1 = V/B*(1+6e/B)= 65.330 (kN/m2)

q2 = V/B*(1-6e/B) = 4.654 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 50.768 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.50	12.08	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Active force
F2'	1/2(p2')(a6)	9.06	0.50	4.53	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.36	0.50	0.18	Seismic force
Total		10.86		5.79	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-2.210682	0.6333333	-1.400	
	1/2(q3)(a5)	-24.115	0.317	-7.636	
Total		6.16		6.40	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	1.150	8.28	1.050	7.56
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	1.017	1.83	0.800	1.44
Footing	(B)(t3)γc	9	0.625	5.63	0.150	1.35
Soil-1	1/2(a5)(a6)γs	12.825	0.317	4.06	0.800	10.26
Soil-2	1/2(a4)(a6)γs	12.92	0.638	8.24	1.300	16.79
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		43.74	0.641	28.03	0.855	37.40

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.80	111.66	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	22.33	0.13	2.98	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	8.75	0.86	7.48	Seismic force
Total of active forces		10.29		7.74	
Total of maximum resisting forces		22.33		2.98	
Actual resisting forces		10.29		2.98	

(3) Stability

Sliding,

V = 43.74 (kN/m)

H = 10.29 (kN/m)

HR_{max} = 22.33 (kN/m)

HR_{act} = 10.29 (kN/m)

SF =(V*f+ HR_{max})/ H = 4.72 > 1.2 Safe !!

Overturning,

Mr_{max} = 31.01 (kN-m/m)

Mr_{act} = 31.01 (kN-m/m)

Mo = 7.74 (kN-m/m)

d = (Mr-Mo)/V = 0.53 (m)

SF =Mr_{max}/ M_o = 4.00 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.093 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.064 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.093 m

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 132 (kN/m)

Qa = 66 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.625

q1 = V/B*(1-6e/B)= 19.357 (kN/m2)

q2 = V/B*(1+6e/B) = 50.627 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 26.862 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.50	14.32	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.68	1.00	1.68	Active force
F2'	1/2(p2')(a6)	10.74	0.50	5.37	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.44	0.75	1.08	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.36	0.50	0.18	Seismic force
Total		14.22		8.31	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-24.048	0.633	-15.230	
	1/2(q3)(a5)	-12.759	0.317	-4.040	
Total		-4.32		-3.84	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.30~1.40

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	0.100	0.72
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	0.233	0.42
Footing	(B)(t3)γc	9	0.625	5.63
Soil-1	1/2(a5)(a6)γs	12.825	0.833	10.69
Soil-2	1/2(a4)(a6)γs	12.92	0.519	6.70
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		43.74	0.552	24.15

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.80	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	132.20	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	26.44	0.13	3.53	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.95	1.10	3.24	Wind force
Total of active forces		3.39		3.30	
Total of maximum resisting forces		26.44		3.53	
Actual resisting forces		3.39		3.30	

(3) Stability

Sliding,

V = 43.74 (kN/m)

H = 3.39 (kN/m)

HR_{max} = 26.44 (kN/m)

HR_{act} = 3.39 (kN/m)

SF =(V*f + HR_{max})/ H = 15.56 > 1.2 Safe !!

Overturning,

Mr_{max}= 27.68 (kN-m/m)

Mr_{act}= 27.46 (kN-m/m)

Mo = 3.30 (kN-m/m)

d = (Mr-Mo)/V = 0.55 (m)

SF =Mr_{max}/ M_o = 8.38 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.068 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.104 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.073 (m)

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 139 (kN/m)

Qa = 69 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.552 m

q1 = V/B*(1+6e/B)= 47.217 (kN/m2)

q2 = V/B*(1-6e/B) = 22.767 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 41.349 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.50	8.20	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.00	0.00	Active force
F2'	1/2(p2')(a6)	6.15	0.50	3.08	Active force
Wind Load		2.95	2.20	6.49	
Total		9.10		9.56	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-10.814	0.633	-6.849	
	1/2(q3)(a5)	-19.64	0.317	-6.220	
Total		2.03		2.36	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.30~1.40

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.2	1.150	8.28
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.8	1.017	1.83
Footing	(B)(t3)γc	9	0.625	5.63
Soil-1	1/2(a5)(a6)γs	12.825	0.317	4.06
Soil-2	1/2(a4)(a6)γs	12.92	0.638	8.24
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		43.74	0.641	28.03

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.80	132.20	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	26.44	0.13	3.53	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ l H	2.95	1.10	3.24	Wind force
Total of active forces		4.60		3.54	
Total of maximum resisting forces		26.44		3.53	
Actual resisting forces		4.60		0.61	

(3) Stability

Sliding,

V = 43.74 (kN/m)

H = 4.60 (kN/m)

HR_{max} = 26.44 (kN/m)

HR_{act} = 4.60 (kN/m)

SF =(V*f + HR_{max})/ H = 11.45 > 1.2 Safe !!

Overturning,

Mr_{max} = 31.56 (kN-m/m)

Mr_{act} = 28.65 (kN-m/m)

Mo = 3.54 (kN-m/m)

d = (Mr-Mo)/V = 0.57 (m)

SF =Mr_{max}/ M_o = 8.90 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.015 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.148 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.051 (m)

α = 1.0

k = 1+0.3*D/B = 1.096

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 146 (kN/m)

Qa = 73 (kN/m) > V = 43.74 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.574 m

q1 = V/B*(1-6e/B)= 26.408 (kN/m2)

q2 = V/B*(1+6e/B) = 43.576 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 30.528 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.50	11.24	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.28	1.00	2.28	Active force
F2'	1/2(p2')(a6)	8.43	0.50	4.21	Active force
C_eC_q q_s l H		2.95	2.20	6.49	
Total		13.66		12.98	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	25.65	0.48	12.18	
Footing	γc(t3)(a5)	6.84	0.48	3.25	
Reaction	1/2(q2)(a5)	-20.699	0.633	-13.109	
	1/2(q3)(a5)	-14.50	0.317	-4.592	
Total		-2.71		-2.27	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.30	0.244	12	250	452.39
Footing	1	0.30	0.244	12	250	452.39

Member stresses

Member	Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face** 9.76	44.63	2.08	93.62	0.18
Footing	**Top bar** 8.07	9.61	1.72	77.46	0.04

Calculation of required reinforcements

	Wall			Footing	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	376.99	376.99	250	376.99
As/m	452.39	300.00	300.00	452.39	300.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.244			0.24	
Coefficients					
p = As/bd	0.00185406			0.0018541	
k= $(p\,n)^2+2p\,n$	0.16675693			0.1667569	
j= 1- k/3	0.94441436			0.944414	
Actual Stresses, (Mpa)					
fs (steel)	93.62			77.46	
fc (concrete)	2.08			1.72	
v (shear)	0.18			0.04	
u (bond)	1.28			0.28	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 1.30~1.40

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	16.32	1.50	0.00	0.21	43.74	52.56
Normal-2	31.88	1.50	(0.09)	0.21	43.74	52.77
Flood	1.90	1.00	0.21	0.42	46.89	48.46
Seismic-1	2.68	1.20	0.18	0.42	43.74	52.40
Seismic-2	4.72	1.20	0.09	0.42	43.74	65.98
Wind-1	15.56	1.20	0.07	0.42	43.74	69.28
Wind-2	11.45	1.20	(0.02)	0.42	43.74	72.87

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		3.08	6.15	0.24	-0.14	
Normal-2		6.49	10.71	0.17	-0.21	
Flood		41.54	44.63	8.07	9.61	
Seismic-1	*	4.35	8.17	4.81	4.64	*: divided by 1.33
Seismic-2	*	6.25	10.69	-2.89	-3.25	*: divided by 1.33
Wind-1	*	7.19	6.84	1.78	1.53	*: divided by 1.33
Wind-2	*	9.76	10.27	-1.71	-2.04	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member	B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face** 41.54	44.63	5.17	99.67	0.19
Footing	**Bot bar** 2.89	9.61	0.73	30.93	0.04

	Wall		Footing		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	25	25	12	12	12
Spacing	250	1636.25	376.99	250	376.99
As/m	1963.50	300.00	300.00	452.39	300.00
Circum.	314.16			150.7968	
d'	0.0625			0.081	
d	0.24			0.22	
Coefficients					
p = As/bd	0.00826737			0.0020657	
k= $(p\,n)^2+2p\,n$	0.31846635			0.1751311	
j= 1- k/3	0.89384455			0.941623	
Actual Stresses, (Mpa)					
fs (steel)	99.67			30.93	
fc (concrete)	5.17			0.73	
v (shear)	0.19			0.04	
u (bond)	0.67			0.31	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.40~1.50

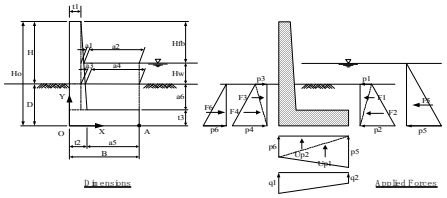
1. Design Criteria

Unit weight :

Concrete	γc=	24	(kN/m3)
Water	γw=	9.8	(kN/m3)
Soil(wet)	γs =	18	(kN/m3)
Soil(saturated)	γsat=	20	(kN/m3)
Soil(submerged)	γs'=	10	(kN/m3)
Surcharge (normal)	q =	10	(kN/m2)
Surcharge (seismic)	q'=	5	(kN/m2)
Internal friction angle of soil	ϕ =	30	(deg.)
Friction angle btwn. soil/wall	δ =	10.0	(deg.)
Cohesion of soil	c =	0	(kN/m2)
Friction factor for sliding	f =	0.6	
Seismic coefficient (horizontal)	kh=	0.2	
Coefficient of soil pressure :			
Active (normal,flood)	Ka=	0.304	
Passive (normal,flood)	Kp=	4.080	
Active (seismic)	Kea=	0.448	
Passive (seismic)	Kep=	3.446	

Dimensions of wall and water depth :

Height of wall	H =	1.50	(m)	
Embedment of wall	D =	0.40	(m)	
Total height of wall	Ho=	1.90	(m)	
Freeboard	Hfb=	0.00	(m)	
Width of footing	B =	1.35	(m)	
Thickness of wall members :				
t1=	0.20 (m)	a1=	0.000	(m)
t2=	0.30 (m)	a2=	1.150	(m)
t3=	0.30 (m)	a3=	0.094	(m)
		a4=	1.056	(m)
		a5=	1.050	(m)
		a6=	1.600	(m)



Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.32 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.02

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 174 (kN/m)

Qa = 58 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.659 m

q1 = V/B*(1+6e/B)= 39.391 (kN/m2)

q2 = V/B*(1-6e/B) = 34.165 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 38.229 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.60	8.75	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.07	0.00	Active force
F2'	1/2(p2')(a6)	7.00	0.53	3.73	Active force
Total		7.00		3.73	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	30.24	0.53	15.88	
Footing	γc(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-17.937	0.700	-12.556	
	1/2(q3)(a5)	-20.07	0.350	-7.025	
Total		-0.21		0.26	

2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.40~1.50

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	0.233	0.45	
Footing	(B)(t3)γc	9.72	0.675	6.56	
Soil-1	1/2(a5)(a6)γs	15.12	1.000	15.12	
Soil-2	1/2(a4)(a6)γs	15.21	0.646	9.82	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		49.65	0.659	32.72	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.90	10.39	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.08	0.13	0.28	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.08		0.28	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		2.08		0.28	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 2.08 (kN/m)

HR_{max} = 5.88 (kN/m)

HR_{act} = 2.08 (kN/m)

SF =(V*f+ HR_{max})/ H = 17.16 > 1.5 Safe !!

Overturning,

Mr_{max} = 33.50 (kN-m/m)

Mr_{act} = 33.00 (kN-m/m)

Mo = 0.28 (kN-m/m)

SF =Mr_{max}/ M_o = 120.93 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = 0.01 (m) < B/6 Safe !!

3. Case 2 : Normal condition-2

(Direction of forces : Active forces are applied from land side)

Height of wall, Hw= 1.40~1.50

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	1.250	9.60	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	1.117	2.14	
Footing	(B)(t3)γc	9.72	0.675	6.56	
Soil-1	1/2(a5)(a6)γs	15.12	0.350	5.29	
Soil-2	1/2(a4)(a6)γs	15.21	0.704	10.71	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		49.65	0.691	34.31	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	1.90	139.55	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	27.91	0.13	3.72	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		27.91		3.72	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 27.91 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 34.92 > 1.5 Safe !!

Overturning,

Mr_{max} = 38.03 (kN-m/m)

Mr_{act} = 34.53 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 126.19 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.08 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.32 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 175 (kN/m)

Qa = 58 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.661 m

q1 = V/B*(1-6e/B)= 39.124 (kN/m2)

q2 = V/B*(1+6e/B) = 34.432 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 38.081 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.60	11.79	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.43	1.07	2.59	Active force
F2'	1/2(p2')(a6)	9.43	0.53	5.03	Active force
Total		11.86		7.62	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	30.24	0.53	15.88	
Footing	γc(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-18.077	0.700	-12.654	
	1/2(q3)(a5)	-19.99	0.350	-6.997	
Total		-0.27		0.19	

4. Case 3 : Flood condition

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	0.233	0.45	
Footing	(B)(t3)γc	9.72	0.675	6.56	
Soil-1	1/2(a5)(a6)γsat	16.80	1.000	16.80	
Soil-2	1/2(a4)(a6)γsat	16.90	0.646	10.91	
Water-1	1/2(a4)(Hw)γw	7.76	0.998	7.75	
Water-2	1/2(a2)(Hw)γw	8.45	0.583	4.93	
Sub-Total		69.24	0.696	48.17	
Uplift-1	-1/2B(D+Hw)γw	-12.57	0.900	-11.31	
Uplift-2	-1/2B(D)γw	-2.65	0.450	-1.19	
Sub-Total		-15.21		-12.50	
Total		54.02		35.67	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	1.90	5.77	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.15	0.13	0.15	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	17.69	0.63	11.20	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		18.84		11.36	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 54.02 (kN/m)

H = 18.84 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.93 > 1.0 Safe !!

Overturning,

Mr_{max} = 48.71 (kN-m/m)

Mr = 48.71 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 23.86 (kN-m/m)

SF = Mr_{max}/M_o = 2.04 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.215 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.92 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.215 m

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.274

= 109 (kN/m)

Qa = 54.5 (kN/m) > V = 54.02 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.460 m

q1 = V/B*(1+6e/B)= 78.253 (kN/m2)

q2 = V/B*(1-6e/B) = 1.779 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 61.259 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.60	4.86	Active earth press.
p5'	γw(Hw+a6)		30.38	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.07	0.00	Active force
F2'	1/2(p2')(a6)	3.89	0.53	2.07	Active force
F5'	1/2(p5')(Hw+a6)	47.09	1.03	48.66	Water pressure
Total		50.98		50.73	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	15.44	0.53	8.10	
Soil	γsat(a6)(a5)	33.60	0.53	17.64	
Footing	γc(t3)(a5)	7.56	0.53	3.97	
Uplift	-1/2(p5)(a5)	-9.78	0.70	-6.843	
	-1/2(p7)(a5)	-3.773	0.35	-1.321	
Reaction	1/2(q2)(a5)	0.933848	0.7	0.654	
	1/2(q3)(a5)	-32.161	0.350	-11.256	
Total		11.82		10.95	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77	1.100	8.45
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	0.233	0.45	0.833	1.60
Footing	(B)(t3)γc	9.72	0.675	6.56	0.150	1.46
Soil-1	1/2(a5)(a6)γs	15.12	1.000	15.12	0.833	12.60
Soil-2	1/2(a4)(a6)γs	15.21	0.646	9.82	1.367	20.79
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		49.65	0.659	32.72	0.904	44.89

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	1.90	15.31	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	3.06	0.13	0.41	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	9.93	0.90	8.98	Seismic force
Total of active forces		12.99		9.39	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 12.99 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.68 > 1.2 Safe !!

Overturning,

Mr_{max} = 33.38 (kN-m/m)

Mr_{act} = 33.38 (kN-m/m)

Mo = 9.39 (kN-m/m)

d = (Mr-Mo)/V = 0.48 (m)

SF =M_{max}/ M_{act} = 3.56 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.19 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 0.97 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.19 m

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.162

= 116 (kN/m)

Qa = 58 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.483 m

q1 = V/B*(1+6e/B)= 68.115 (kN/m2)

q2 = V/B*(1-6e/B) = 5.441 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 54.187 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.60	12.89	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.07	0.00	Active force
F2'	1/2(p2')(a6)	10.31	0.53	5.50	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.54	0.80	1.23	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.38	0.53	0.20	Seismic force
Total		12.23		6.93	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	30.24	0.53	15.88	
Footing	γc(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-2.85633	0.7	-1.999	
	1/2(q3)(a5)	-28.448	0.350	-9.957	
Total		6.50		7.89	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	1.250	9.60	1.100	8.45
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	1.117	2.14	0.833	1.60
Footing	(B)(t3)γc	9.72	0.675	6.56	0.150	1.46
Soil-1	1/2(a5)(a6)γs	15.12	0.350	5.29	0.833	12.60
Soil-2	1/2(a4)(a6)γs	15.21	0.704	10.71	1.367	20.79
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		49.65	0.691	34.31	0.904	44.89

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	1.90	117.87	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	23.57	0.13	3.14	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	9.93	0.90	8.98	Seismic force
Total of active forces		11.47		9.24	
Total of maximum resisting forces		23.57		3.14	
Actual resisting forces		11.47		3.14	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 11.47 (kN/m)

HR_{max} = 23.57 (kN/m)

HR_{act} = 11.47 (kN/m)

SF =(V*f + HR_{max})/ H = 4.65 > 1.2 Safe !!

Overturning,

Mr_{max} = 37.45 (kN-m/m)

Mr_{act} = 37.45 (kN-m/m)

Mo = 9.24 (kN-m/m)

d = (Mr-Mo)/V = 0.57 (m)

SF =Mr_{max}/ M_o = 4.05 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.107 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.136 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.107 m

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 143 (kN/m)

Qa = 72 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.675

q1 = V/B*(1-6e/B)= 19.307 (kN/m2)

q2 = V/B*(1+6e/B) = 54.249 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 27.072 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.60	15.13	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.79	1.07	1.91	Active force
F2'	1/2(p2')(a6)	12.10	0.53	6.45	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.54	0.80	1.23	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.38	0.53	0.20	Seismic force
Total		15.81		9.80	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	30.24	0.53	15.88	
Footing	γc(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-28.481	0.700	-19.936	
	1/2(q3)(a5)	-14.213	0.350	-4.974	
Total		-4.89		-5.07	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.40~1.50

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.68	0.100	0.77
Wall-2	1/2(t2-t1)(Ho-t3)γc	1.92	0.233	0.45
Footing	(B)(t3)γc	9.72	0.675	6.56
Soil-1	1/2(a5)(a6)γs	15.12	0.900	13.61
Soil-2	1/2(a4)(a6)γs	15.21	0.552	8.40
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		49.65	0.600	29.78

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	1.90	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	139.55	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	27.91	0.13	3.72	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	$C_e C_q q_s$ I H	3.16	1.15	3.63	Wind force
Total of active forces		3.60		3.69	
Total of maximum resisting forces		27.91		3.72	
Actual resisting forces		3.60		3.69	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 3.60 (kN/m)

HR_{max} = 27.91 (kN/m)

HR_{act} = 3.60 (kN/m)

SF =(V*f + HR_{max})/ H = 16.04 > 1.2 Safe !!

Overturning,

Mr_{max}= 33.50 (kN-m/m)

Mr_{act}= 33.47 (kN-m/m)

Mo = 3.69 (kN-m/m)

d = (Mr-Mo)/V = 0.60 (m)

SF =Mr_{max}/ M_o = 9.08 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.075 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 1.200 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.075 (m)

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 154 (kN/m)

Qa = 77 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.600 m

q1 = V/B*(1+6e/B)= 49.063 (kN/m2)

q2 = V/B*(1-6e/B) = 24.493 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 43.603 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.60	8.75	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.07	0.00	Active force
F2'	1/2(p2')(a6)	7.00	0.53	3.73	Active force
Wind Load		3.16	2.35	7.42	
Total		10.16		11.16	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	30.24	0.53	15.88	
Footing	γ_C(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-12.859	0.700	-9.001	
	1/2(q3)(a5)	-22.89	0.350	-8.012	
Total		2.05		2.83	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.40~1.50

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γ_C	7.68	1.250	9.60
Wall-2	1/2(t2-t1)(Ho-t3)γ_C	1.92	1.117	2.14
Footing	(B)(t3)γ_C	9.72	0.675	6.56
Soil-1	1/2(a5)(a6)γ_S	15.12	0.350	5.29
Soil-2	1/2(a4)(a6)γ_S	15.21	0.704	10.71
Water-1	1/2(a4)(Hw)γ_W	-	-	0
Water-2	1/2(a2)(Hw)γ_W	-	-	0
Total		49.65	0.691	34.31

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c$\sqrt{Kp}$	0.00	0.00	Passive press.
p2	Kp(γh)+2c$\sqrt{Kp}$	1.90	139.55	Passive press.
p3	Ka(γh+q')-2c$\sqrt{Ka}$	0.00	3.04	Active press.
p4	Ka(γh+q')-2c$\sqrt{Ka}$	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	27.91	0.13	3.72	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γ_W(D+Hw)^2	-	-		
F6	1/2γ_W(D)^2	-	-		
F8	$C_e C_q q_s$ l H	3.16	1.15	3.63	Wind force
Total of active forces		4.81		3.93	
Total of maximum resisting forces		27.91		3.72	
Actual resisting forces		4.81		0.64	

(3) Stability

Sliding,

V = 49.65 (kN/m)

H = 4.81 (kN/m)

HR_{max} = 27.91 (kN/m)

HR_{act} = 4.81 (kN/m)

SF =(V*f + HR_{max})/ H = 11.99 > 1.2 Safe !!

Overturning,

Mr_{max} = 38.03 (kN-m/m)

Mr_{act} = 34.95 (kN-m/m)

Mo = 3.93 (kN-m/m)

d = (Mr-Mo)/V = 0.62 (m)

SF =Mr_{max}/ M_o = 9.67 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.012 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γ_S D Nq + 1/2 γ_S' βBe Nr)

where,

Be = B - 2 e = 1.249 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.050 (m)

α = 1.0

k = 1+0.3*D/B = 1.0888889

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 162 (kN/m)

Qa = 81 (kN/m) > V = 49.65 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.625 m

q1 = V/B*(1-6e/B)= 28.551 (kN/m2)

q2 = V/B*(1+6e/B) = 45.005 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 32.207 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c$\sqrt{Ka}$	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c$\sqrt{Ka}$	1.60	11.79	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.43	1.07	2.59	Active force
F2'	1/2(p2')(a6)	9.43	0.53	5.03	Active force
$C_e C_q q_s$ l H		3.16	2.35	7.42	
Total		15.02		15.04	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γ_S(a6)(a5)	30.24	0.53	15.88	
Footing	γ_C(t3)(a5)	7.56	0.53	3.97	
Reaction	1/2(q2)(a5)	-23.628	0.700	-16.539	
	1/2(q3)(a5)	-16.91	0.350	-5.918	
Total		-2.74		-2.61	

9. Summary of stability analysis

Height of wall, Hw= 1.40~1.50

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	17.16	1.50	0.01	0.23	49.65	58.16
Normal-2	34.92	1.50	(0.08)	0.23	49.65	58.35
Flood	1.93	1.00	0.21	0.45	54.02	54.48
Seismic-1	2.68	1.20	0.19	0.45	49.65	58.03
Seismic-2	4.65	1.20	0.11	0.45	49.65	71.59
Wind-1	16.04	1.20	0.07	0.45	49.65	76.92
Wind-2	11.99	1.20	(0.01)	0.45	49.65	81.19

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079$\sqrt{fc'}$	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		3.73	7.00	0.26	-0.21	
Normal-2		7.62	11.86	0.19	-0.27	
Flood		50.73	50.98	10.95	11.82	
Seismic-1	*	5.21	9.20	5.93	4.88	*: divided by 1.33
Seismic-2	*	7.37	11.89	-3.81	-3.68	*: divided by 1.33
Wind-1	*	8.39	7.64	2.13	1.54	*: divided by 1.33
Wind-2	*	11.31	11.29	-1.96	-2.06	*: divided by 1.33

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.30	0.244	12	250	452.39
Footing	1	0.30	0.244	12	250	452.39

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	11.31	50.98	2.41	108.51	0.21
Footing	**Top bar**	10.95	11.82	2.33	105.00	0.05

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	12	12	12	12	12
Spacing	250	376.99	376.99	250	376.99
As/m	452.39	300.00	300.00	452.39	300.00
Circum.	150.7968			150.7968	
d'	0.056			0.056	
d	0.244			0.24	
Coefficients					
p = As/bd	0.00185406			0.0018541	
k= $(p\,n)^2+2p\,n$	0.16675693			0.1667569	
j= 1- k/3	0.94441436			0.944414	
Actual Stresses, (Mpa)					
fs (steel)	108.51			105.00	
fc (concrete)	2.41			2.33	
v (shear)	0.21			0.05	
u (bond)	1.47			0.34	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		300	300		300

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	50.73	50.98	5.70	95.22	0.21
Footing	**Bot bar**	3.81	11.82	0.96	40.83	0.05

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	125	1047.20	376.99	250	376.99
As/m	2513.28	300.00	300.00	452.39	300.00
Circum.	502.656			150.7968	
d'	0.06			0.081	
d	0.24			0.22	
Coefficients					
p = As/bd	0.010472			0.0020657	
k= $(p\,n)^2+2p\,n$	0.35002521			0.1751311	
j= 1- k/3	0.88332493			0.941623	
Actual Stresses, (Mpa)					
fs (steel)	95.22			40.83	
fc (concrete)	5.70			0.96	
v (shear)	0.21			0.05	
u (bond)	0.48			0.38	
Code Minimum reinforcements					
ratio (min.)	0.001		0.001		0.001
As (min.) = ratio x b x h	300		300		300

ANALYSIS AND DESIGN OF L-SHAPED PARAPET WALL WITH SOIL EMBANKMENT

Height of Wall, H = 1.50~1.60

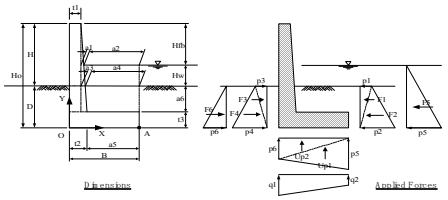
1. Design Criteria

Unit weight :

Concrete	γc=	24 (kN/m3)
Water	γw=	9.8 (kN/m3)
Soil(wet)	γs =	18 (kN/m3)
Soil(saturated)	γsat=	20 (kN/m3)
Soil(submerged)	γs'=	10 (kN/m3)
Surcharge (normal)	q =	10 (kN/m2)
Surcharge (seismic)	q'=	5 (kN/m2)
Internal friction angle of soil	ϕ =	30 (deg.)
Friction angle btwn. soil/wall	δ =	10.0 (deg.)
Cohesion of soil	c =	0 (kN/m2)
Friction factor for sliding	f =	0.6
Seismic coefficient (horizontal)	kh=	0.2
Coefficient of soil pressure :		
Active (normal,flood)	Ka=	0.304
Passive (normal,flood)	Kp=	4.080
Active (seismic)	Kea=	0.448
Passive (seismic)	Kep=	3.446

Dimensions of wall and water depth :

Height of wall	H =	1.60 (m)		
Embedment of wall	D =	0.40 (m)		
Total height of wall	Ho=	2.00 (m)		
Freeboard	Hfb=	0.00 (m)		
Width of footing	B =	1.45 (m)		
Thickness of wall members :				
t1=	0.20 (m)		a1=	0.000 (m)
t2=	0.35 (m)		a2=	1.250 (m)
t3=	0.35 (m)		a3=	0.145 (m)
			a4=	1.105 (m)
			a5=	1.100 (m)
			a6=	1.650 (m)



2. Case 1 : Normal condition-1

(Direction of forces : Active forces are applied from river side)

Height of wall, Hw= 1.50~1.60

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.92	0.100	0.79	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	0.250	0.74	
Footing	(B)(t3)γc	12.18	0.725	8.83	
Soil-1	1/2(a5)(a6)γs	16.335	1.083	17.70	
Soil-2	1/2(a4)(a6)γs	16.40	0.714	11.71	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		55.81	0.713	39.77	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	2.00	10.94	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	29.38	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	2.19	0.13	0.29	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	5.88	0.13	0.78	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		2.19		0.29	
Total of maximum resisting forces		5.88		0.78	
Actual resisting forces		2.19		0.29	

(3) Stability

Sliding,

V =	55.81 (kN/m)	
H =	2.19 (kN/m)	
HR_{max} =	5.88 (kN/m)	
HR_{act} =	2.19 (kN/m)	
SF =(V*f + HR_{max})/ H =	18.00	> 1.5 Safe !!

Overturning,

Mr_{max} =	40.55 (kN-m/m)	
Mr_{act} =	40.06 (kN-m/m)	
Mo =	0.29 (kN-m/m)	
SF =Mr_{max}/ M_o =	139.05	> 2.0 Safe !!
e = B/2 - (Mr_{max}-Mo) / V =	0.00 (m)	< B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.43 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.01

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 193 (kN/m)

Qa = 64 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.713 m

q1 = V/B*(1+6e/B)= 40.468 (kN/m2)

q2 = V/B*(1-6e/B) = 36.508 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 39.512 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.65	9.02	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.10	0.00	Active force
F2'	1/2(p2')(a6)	7.44	0.55	4.09	Active force
Total		7.44		4.09	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-20.079	0.733	-14.725	
	1/2(q3)(a5)	-21.73	0.367	-7.968	
Total		0.10		0.36	

3. Case 2 : Normal condition-2

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, consider moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.92	1.350	10.69	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	1.200	3.56	
Footing	(B)(t3)γc	12.18	0.725	8.83	
Soil-1	1/2(a5)(a6)γs	16.335	0.367	5.99	
Soil-2	1/2(a4)(a6)γs	16.40	0.736	12.08	
Water-1	1/2(a4)(Hw)γw	-	-	0	
Water-2	1/2(a2)(Hw)γw	-	-	0	
Total		55.81	0.737	41.15	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	2.00	146.89	Passive press.
p3	Ka(γh+q)-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q)-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	29.38	0.13	3.92	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
Total of active forces		1.65		0.30	
Total of maximum resisting forces		29.38		3.92	
Actual resisting forces		1.65		0.22	

(3) Stability

Sliding,

V = 55.81 (kN/m)

H = 1.65 (kN/m)

HR_{max} = 29.38 (kN/m)

HR_{act} = 1.65 (kN/m)

SF =(V*f+ HR_{max})/ H = 38.04 > 1.5 Safe !!

Overturning,

Mr_{max} = 45.07 (kN-m/m)

Mr_{act} = 41.37 (kN-m/m)

Mo = 0.30 (kN-m/m)

SF =Mr_{max}/ M_o = 149.57 > 2.0 Safe !!

e = B/2 - (Mr_{max}-Mo) / V = -0.08 (m) < B/6 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 3 : under normal condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

Be = B - 2 e = 1.43 (m)

where,

e =actual eccen. = B/2 - (Mr_{act}-Mo) / V = -0.01 m

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 194 (kN/m)

Qa = 65 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.714 m

q1 = V/B*(1-6e/B)= 40.237 (kN/m2)

q2 = V/B*(1+6e/B) = 36.739 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 39.392 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.65	12.06	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.51	1.10	2.76	Active force
F2'	1/2(p2')(a6)	9.95	0.55	5.47	Active force
Total		12.46		8.23	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-20.207	0.733	-14.818	
	1/2(q3)(a5)	-21.67	0.367	-7.944	
Total		0.04		0.29	

4. Case 3 : Flood condition

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	Remarks
Wall-1	(t1)(Ho-t3)γc	7.92	0.100	0.79	
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	0.250	0.74	
Footing	(B)(t3)γc	12.18	0.725	8.83	
Soil-1	1/2(a5)(a6)γsat	18.15	1.083	19.66	
Soil-2	1/2(a4)(a6)γsat	18.23	0.714	13.01	
Water-1	1/2(a4)(Hw)γw	8.66	1.082	9.37	
Water-2	1/2(a2)(Hw)γw	9.80	0.617	6.04	
Sub-Total		77.90	0.750	58.45	
Uplift-1	-1/2B(D+Hw)γw	-14.21	0.967	-13.74	
Uplift-2	-1/2B(D)γw	-2.84	0.483	-1.37	
Sub-Total		-17.05		-15.11	
Total		60.85		43.34	

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2	Ka(γh)-2c√Ka	2.00	6.08	Active earth press.
p3	Kp(γh)+2c√Kp	0.00	0.00	Passive earth press.
p4	Kp(γh)+2c√Kp	0.40	16.32	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	1.22	0.13	0.16	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	3.26	0.13	0.44	Resisting force
F5	1/2γw(D+Hw)^2	19.60	0.67	13.07	Active force
F6	1/2γw(D)^2	0.78	0.13	0.10	Resisting force
Total of active forces		20.82		13.23	
Total of maximum resisting forces		4.05		0.54	
Actual resisting forces		4.05		0.54	

(3) Stability

Sliding,

V = 60.85 (kN/m)

H = 20.82 (kN/m)

HR_{max} = 4.05 (kN/m)

HR_{act} = 4.05 (kN/m)

SF =(V*f+HR_{max})/ H = 1.95 > 1.0 Safe !!

Overturning,

Mr_{max} = 58.98 (kN-m/m)

Mr = 58.98 (kN-m/m) (=ΣW*x + ΣFR*y)

Mo = 28.34 (kN-m/m)

SF = Mr_{max}/M_o = 2.08 >1.5 Safe

e = B/2 - (Mr_{max}-Mo) / V = 0.221 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under flood condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.01 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.221 m

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.276

= 122 (kN/m)

Qa = 60.9 (kN/m) > V = 60.85 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.504 m

q1 = V/B*(1+6e/B)= 80.413 (kN/m2)

q2 = V/B*(1-6e/B) = 3.522 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 61.853 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.65	5.01	Active earth press.
p5'	γw(Hw+a6)		31.85	Water pressure

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.10	0.00	Active force
F2'	1/2(p2')(a6)	4.14	0.55	2.27	Active force
F5'	1/2(p5')(Hw+a6)	51.76	1.08	56.07	Water pressure
Total		55.89		58.34	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Water	γw(Hw)(a5)	17.25	0.55	9.49	
Soil	γsat(a6)(a5)	36.30	0.55	19.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Uplift	-1/2(p5)(a5)	-10.78	0.73	-7.905	
	-1/2(p7)(a5)	-4.238	0.37	-1.554	
Reaction	1/2(q2)(a5)	1.936872	0.7333333	1.420	
	1/2(q3)(a5)	-34.019	0.367	-12.474	
Total		15.69		14.02	

5. Case 4 : Seismic condition-1

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.92	0.100	0.79	1.175	9.31
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	0.250	0.74	0.900	2.67
Footing	(B)(t3)γc	12.18	0.725	8.83	0.175	2.13
Soil-1	1/2(a5)(a6)γs	16.335	1.083	17.70	0.900	14.70
Soil-2	1/2(a4)(a6)γs	16.40	0.714	11.71	1.450	23.78
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		55.81	0.713	39.77	0.942	52.60

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2	Kea(γh)-2c√Kea	2.00	16.11	Active earth press.
p3	Kep(γh)+2c√Kep	0.00	0.00	Passive earth press.
p4	Kep(γh)+2c√Kep	0.40	24.81	Passive earth press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	3.22	0.13	0.43	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	4.96	0.13	0.66	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	11.16	0.94	10.52	Seismic force
Total of active forces		14.38		10.95	
Total of maximum resisting forces		4.96		0.66	
Actual resisting forces		4.96		0.66	

(3) Stability

Sliding,

V = 55.81 (kN/m)

H = 14.38 (kN/m)

HR_{max} = 4.96 (kN/m)

HR_{act} = 4.96 (kN/m)

SF =(V*f+ HR_{max})/ H = 2.67 > 1.2 Safe !!

Overturning,

Mr_{max} = 40.43 (kN-m/m)

Mr_{act} = 40.43 (kN-m/m)

Mo = 10.95 (kN-m/m)

d = (Mr-Mo)/V = 0.53 (m)

SF =M_{max}/ M_{act} = 3.69 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.20 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.06 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.20 m

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.169

= 130 (kN/m)

Qa = 65 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.528 m

q1 = V/B*(1+6e/B)= 69.824 (kN/m2)

q2 = V/B*(1-6e/B) = 7.152 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 54.696 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh)-2c√Kea	0.00	0.00	Active earth press.
p2'	Kea(γh)-2c√Kea	1.65	13.29	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.10	0.00	Active force
F2'	1/2(p2')(a6)	10.97	0.55	6.03	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.58	0.83	1.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.59	0.55	0.33	Seismic force
Total		13.14		7.66	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN-m/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-3.933326	0.7333333	-2.884	
	1/2(q3)(a5)	-30.083	0.367	-11.030	
Total		7.89		9.14	

6. Case 5 : Seismic condition-2

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from land side)

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	B-xi (m)	Wi*(B-xi) (kN-m/m)	yi (m)	Wi*yi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.92	1.350	10.69	1.175	9.31
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	1.200	3.56	0.900	2.67
Footing	(B)(t3)γc	12.18	0.725	8.83	0.175	2.13
Soil-1	1/2(a5)(a6)γs	16.335	0.367	5.99	0.900	14.70
Soil-2	1/2(a4)(a6)γs	16.40	0.736	12.08	1.450	23.78
Water-1	1/2(a4)(Hw)γw	-	-	0		0
Water-2	1/2(a2)(Hw)γw	-	-	0		0
Total		55.81	0.737	41.15	0.942	52.60

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kep(γh)+2c√Kep	0.00	0.00	Passive press.
p2	Kep(γh)+2c√Kep	2.00	124.07	Passive press.
p3	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p4	Kea(γh+q')-2c√Kea	0.40	5.46	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	24.81	0.13	3.31	Resisting force
F3	1/2(p3)h	0.45	0.27	0.12	Active force
F4	1/2(p4)h	1.09	0.13	0.15	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F7	ΣWi*kh	11.16	0.94	10.52	Seismic force
Total of active forces		12.70		10.78	
Total of maximum resisting forces		24.81		3.31	
Actual resisting forces		12.70		3.31	

(3) Stability

Sliding,

V = 55.81 (kN/m)

H = 12.70 (kN/m)

HR_{max} = 24.81 (kN/m)

HR_{act} = 12.70 (kN/m)

SF =(V*f+ HR_{max})/ H = 4.59 > 1.2 Safe !!

Overturning,

Mr_{max} = 44.46 (kN-m/m)

Mr_{act} = 44.46 (kN-m/m)

Mo = 10.78 (kN-m/m)

d = (Mr-Mo)/V = 0.60 (m)

SF =Mr_{max}/ M_o = 4.12 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.122 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under seismic condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.207 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.122 m

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{act})/V = 0.000 minimum

= 154 (kN/m)

Qa = 77 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.725

q1 = V/B*(1-6e/B)= 19.134 (kN/m2)

q2 = V/B*(1+6e/B) = 57.841 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 28.478 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kea(γh+q')-2c√Kea	0.00	2.24	Active press.
p2'	Kea(γh+q')-2c√Kea	1.65	15.53	Active press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	1.85	1.10	2.03	Active force
F2'	1/2(p2')(a6)	12.81	0.55	7.05	Active force
Wall-1	γc(t1)(Ho-t3)kh	1.58	0.83	1.31	Seismic force
Wall-2	γc(t2-t1)(Ho-t3)kh/2	0.59	0.55	0.33	Seismic force
Total		16.84		10.71	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-31.813	0.733	-23.329	
	1/2(q3)(a5)	-15.663	0.367	-5.743	
Total		-5.57		-6.02	

7. Case 6 : Wind condition 1

Height of wall, Hw= 1.50~1.60

(Direction of forces : Active forces are applied from river side)

(1) Weight of wall (including soil and water, considering moment about point O)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.92	0.100	0.79
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	0.250	0.74
Footing	(B)(t3)γc	12.18	0.725	8.83
Soil-1	1/2(a5)(a6)γs	16.335	0.933	15.25
Soil-2	1/2(a4)(a6)γs	16.40	0.568	9.32
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		55.81	0.626	34.93

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active press.
p2	Ka(γh)-2c√Ka	2.00	2.19	Active press.
p3	Kp(γh)+2c√Kp	0.00	0.00	
p4	Kp(γh)+2c√Kp	0.40	146.89	

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Active force
F2	1/2(p2)h	0.44	0.13	0.06	Active force
F3	1/2(p3)h	0.00	0.27	0.00	Resisting force
F4	1/2(p4)h	29.38	0.13	3.92	Resisting force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	3.37	1.20	4.04	Wind force
Total of active forces		3.81		4.10	
Total of maximum resisting forces		29.38		3.92	
Actual resisting forces		3.81		3.92	

(3) Stability

Sliding,

V = 55.81 (kN/m)

H = 3.81 (kN/m)

HR_{max} = 29.38 (kN/m)

HR_{act} = 3.81 (kN/m)

SF =(V*f + HR_{max})/ H = 16.51 > 1.2 Safe !!

Overturning,

Mr_{max}= 38.85 (kN-m/m)

Mr_{act}= 38.85 (kN-m/m)

Mo = 4.10 (kN-m/m)

d = (Mr-Mo)/V = 0.62 (m)

SF =Mr_{max}/ M_o = 9.47 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = 0.102 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.245 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.102 (m)

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= (H-HR_{max})/V = 0.000

= 161 (kN/m)

Qa = 81 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 - abs(e) = 0.623 m

q1 = V/B*(1+6e/B)= 54.796 (kN/m2)

q2 = V/B*(1-6e/B) = 22.180 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 46.923 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	0.00	Active earth press.
p2'	Ka(γh)-2c√Ka	1.65	9.02	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	0.00	1.10	0.00	Active force
F2'	1/2(p2')(a6)	7.44	0.55	4.09	Active force
Wind Load		3.37	2.45	8.26	
Total		10.81		12.35	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-12.199	0.733	-8.946	
	1/2(q3)(a5)	-25.81	0.367	-9.463	
Total		3.90		4.64	

8. Case 7 : Wind condition 2

Height of wall, Hw= 1.50~1.60

Wind from the land side

(1) Weight of wall (including soil and water, considering moment about point A)

Item	Formula	Wi (kN/m)	xi (m)	Wi*xi (kN-m/m)
Wall-1	(t1)(Ho-t3)γc	7.92	1.350	10.69
Wall-2	1/2(t2-t1)(Ho-t3)γc	2.97	1.200	3.56
Footing	(B)(t3)γc	12.18	0.725	8.83
Soil-1	1/2(a5)(a6)γs	16.335	0.367	5.99
Soil-2	1/2(a4)(a6)γs	16.40	0.736	12.08
Water-1	1/2(a4)(Hw)γw	-	-	0
Water-2	1/2(a2)(Hw)γw	-	-	0
Total		55.81	0.737	41.15

(2) Horizontal forces

Earth pressure and surcharge

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Kp(γh)+2c√Kp	0.00	0.00	Passive press.
p2	Kp(γh)+2c√Kp	2.00	146.89	Passive press.
p3	Ka(γh+q')-2c√Ka	0.00	3.04	Active press.
p4	Ka(γh+q')-2c√Ka	0.40	5.23	Active press.

Horizontal forces

Item	Formula	Fi (kN/m)	yi (m)	Fi*yi (kN-m/m)	Remarks
F1	1/2(p1)h	0.00	0.27	0.00	Resisting force
F2	1/2(p2)h	29.38	0.13	3.92	Resisting force
F3	1/2(p3)h	0.61	0.27	0.16	Active force
F4	1/2(p4)h	1.05	0.13	0.14	Active force
F5	1/2γw(D+Hw)^2	-	-		
F6	1/2γw(D)^2	-	-		
F8	C_eC_q q_s l H	3.37	1.20	4.04	Wind force
Total of active forces		5.02		4.34	
Total of maximum resisting forces		29.38		3.92	
Actual resisting forces		5.02		0.67	

(3) Stability

Sliding,

V = 55.81 (kN/m)

H = 5.02 (kN/m)

HR_{max} = 29.38 (kN/m)

HR_{act} = 5.02 (kN/m)

SF =(V*f + HR_{max})/ H = 12.52 > 1.2 Safe !!

Overturning,

Mr_{max} = 45.07 (kN-m/m)

Mr_{act} = 41.82 (kN-m/m)

Mo = 4.34 (kN-m/m)

d = (Mr-Mo)/V = 0.67 (m)

SF =Mr_{max}/ M_o = 10.37 > 1.5 Safe !!

e = B/2-(Mr_{max}-Mo)/V = B/2-d = -0.005 (m) < B/3 Safe !!

Bearing capacity,

Qa = Qu / SF (SF = 2 : under wind condition)

Qu = Be (α k c Nc + k γs D Nq + 1/2 γs' βBe Nr)

where,

Be = B - 2 e = 1.343 (m)

e =actual e = B/2 - (Mr_{act}-Mo) / V = 0.053 (m)

α = 1.0

k = 1+0.3*D/B = 1.0827586

β = 1.0

Nc = 20

Nq = 11

Nr = 7

tan θ= ($H-HR_{act}$)/V = 0.000 minimum

= 178 (kN/m)

Qa = 89 (kN/m) > V = 55.81 (kN/m) Safe !!

Reaction on foundation,

x = B/2 -abs(e)= 0.672 m

q1 = V/B*(1-6e/B)= 29.980 (kN/m2)

q2 = V/B*(1+6e/B) = 46.996 (kN/m2)

q3 = q2+(q1-q2)(B-t2)/B = 34.087 (kN/m2)

(4) Sectional forces

Applied load for wall

Item	Formula	h (m)	pi (kN/m2)	Remarks
p1	Ka(γh)-2c√Ka	0.00	3.04	Active earth press.
p2'	Ka(γh)-2c√Ka	1.65	12.06	Active earth press.

Maximum sectional forces of wall

Item	Formula	Fi (kN/m)	yi (m)	Mi=Fi*yi (kN-m/m)	Remarks
F1'	1/2(p1)(a6)	2.51	1.10	2.76	Active force
F2'	1/2(p2')(a6)	9.95	0.55	5.47	Active force
C_eC_q q_s l H		3.37	2.45	8.26	
Total		15.83		16.48	

Maximum sectional forces of footing

Item	Formula	Fi (kN/m)	xi (m)	Mi=Fi*xi (kN/m2)	Remarks
Weight					
Soil	γs(a6)(a5)	32.67	0.55	17.97	
Footing	γc(t3)(a5)	9.24	0.55	5.08	
Reaction	1/2(q2)(a5)	-25.848	0.733	-18.955	
	1/2(q3)(a5)	-18.75	0.367	-6.874	
Total		-2.69		-2.78	

(3) Computation of stresses

Main bar arrangement for the maximum bending moment

Member	b (m)	Thick., h (m)	d (m)	Dia. (mm)	Spacing (mm)	Area (mm2)
Wall	1	0.35	0.292	16	250	804.25
Footing	1	0.35	0.292	16	250	804.25

Member stresses

Member		Max.B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Landside Face**	12.39	55.89	1.56	56.53	0.19
Footing	**Top bar**	14.02	15.69	1.77	63.95	0.05

Calculation of required reinforcements

	Wall			**Footing**	
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	16	16	12	16	16
Spacing	250	574.46	323.14	250	574.46
As/m	804.25	350.00	350.00	804.25	350.00
Circum.	201.0624			201.0624	
d'	0.058			0.058	
d	0.292			0.29	
Coefficients					
p = As/bd	0.00275428			0.0027543	
k= $(pn)^2+2pn$	0.19924608			0.1992461	
j= 1- k/3	0.93358464			0.933585	
Actual Stresses, (Mpa)					
fs (steel)	56.53			63.95	
fc (concrete)	1.56			1.77	
v (shear)	0.19			0.05	
u (bond)	1.02			0.29	
Code Requirements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		350	350		350

Spacing (wall), MAX. = 3t or 450

450

S<Smax,ok

9. Summary of stability analysis

Height of wall, Hw= 1.50~1.60

Results of stability analysis for each load conditions are tabulated as follow:

Load conditions	Sliding SF	Sliding min.SF	Overturning e (m)	Overturning max. e (m)	Bearing capacity V (kN/m)	Bearing capacity Qa (kN/m)
Normal-1	18.00	1.50	0.00	0.24	55.81	64.43
Normal-2	38.04	1.50	(0.08)	0.24	55.81	64.61
Flood	1.95	1.00	0.22	0.48	60.85	60.94
Seismic-1	2.67	1.20	0.20	0.48	55.81	64.83
Seismic-2	4.59	1.20	0.12	0.48	55.81	77.24
Wind-1	16.51	1.20	0.10	0.48	55.81	80.53
Wind-2	12.52	1.20	(0.00)	0.48	55.81	89.16

10. Design of RC members

(1) Design Criteria

Concrete strength	fc' =	20.7 (MPa)
Steel strength	fy =	275 (MPa)
Modular ratio	n=Es/Ec=	9
Allowable stress :		
Fiber stress in flexural compress.	0.40fc'	8.28 (MPa)
Shear stress	0.079√fc'	0.36 (MPa)
Tensile stress in reinforcement	0.40fy	110 (MPa)

(2) Sectional forces for each load conditions are tabulated as below:

Load conditions		Wall B.M (kN-m/m)	Wall Shear (kN/m)	Footing B.M (kN-m/m)	Footing Shear (kN/m)	Remarks
Normal-1		4.09	7.44	0.36	0.10	
Normal-2		8.23	12.46	0.29	0.04	
Flood		58.34	55.89	14.02	15.69	
Seismic-1	*	5.76	9.88	6.87	5.94	*: divided by 1.33
Seismic-2	*	8.05	12.66	-4.53	-4.18	*: divided by 1.33
Wind-1	*	9.29	8.13	3.49	2.93	*: divided by 1.33
Wind-2	*	12.39	11.90	-2.09	-2.02	*: divided by 1.33

REINFORCEMENT IN THE OPPOSITE FACE

Member stresses (opposite Moment sign)

Member		B.M (kN-m/m)	Max.V (kN/m)	fc (MPa)	fs (MPa)	v (MPa)
Wall	**Riverside Face**	58.34	55.89	4.79	89.76	0.19
Footing	**Bot bar**	4.53	15.69	0.83	39.30	0.06

	Wall		**Footing**		
	Main Vertical Bar		Horizontal Bar	Main Bar	
Parameters	Required	Minimum	Minimum	Required	Minimum
Diameter	20	20	12	12	12
Spacing	125	897.60	323.14	250	323.14
As/m	2513.28	350.00	350.00	452.39	350.00
Circum.	502.656			150.7968	
d'	0.06			0.081	
d	0.29			0.27	
Coefficients					
p = As/bd	0.00866648			0.0016817	
k= $(pn)^2+2pn$	0.3245938			0.1595084	
j= 1- k/3	0.89180207			0.946831	
Actual Stresses, (Mpa)					
fs (steel)	89.76			39.30	
fc (concrete)	4.79			0.83	
v (shear)	0.19			0.06	
u (bond)	0.43			0.41	
Code Minimum reinforcements					
ratio (min.)		0.001	0.001		0.001
As (min.) = ratio x b x h		350	350		350

3.6 Slope Stability of Riprap

Table 3.6.1 Slope Stability Result of Riprap

No.	Bank	Station	Case-1: Riprap Slope 1.0		Case-2: Riprap Slope 1.5		Portion of the Slope 1.5
			Factor of Safety	Judgment	Factor of Safety	Judgment	
1	Left	2+600	1.133	NG	1.239	Safe	2+419-2+694
2		2+931	0.914	NG	1.215	Safe	2+854-3+072
3		3+050	1.102	NG	1.346	Safe	
4		14+200	1.184	NG	1.386	Safe	14+150-14+272
5		15+236	1.203	Safe	-	-	-
6		15+300	1.229	Safe	-	-	-
7		15+350	1.352	Safe	-	-	-
8		16+042	1.174	NG	1.457	Safe	16+000-16+100
9	Right	5+100	1.531	Safe	-	-	-
10		6+415	1.016	NG	1.215	Safe	6+337-6+510
11		6+471	0.955	NG	1.215	Safe	
12		8+600	1.085	NG	1.622	Safe	8+550-8+700
13		9+000	1.201	Safe	-	-	-
14		9+100	1.419	Safe	-	-	-
15		9+750	1.168	NG	1.510	Safe	9+723-9+792
16		13+700	1.524	Safe	-	-	-
17		13+914.5	1.049	NG	1.416	Safe	13+804-13+952
18		16+667	1.468	Safe	-		-

Note: Allowable Factor of Safety > 1.20

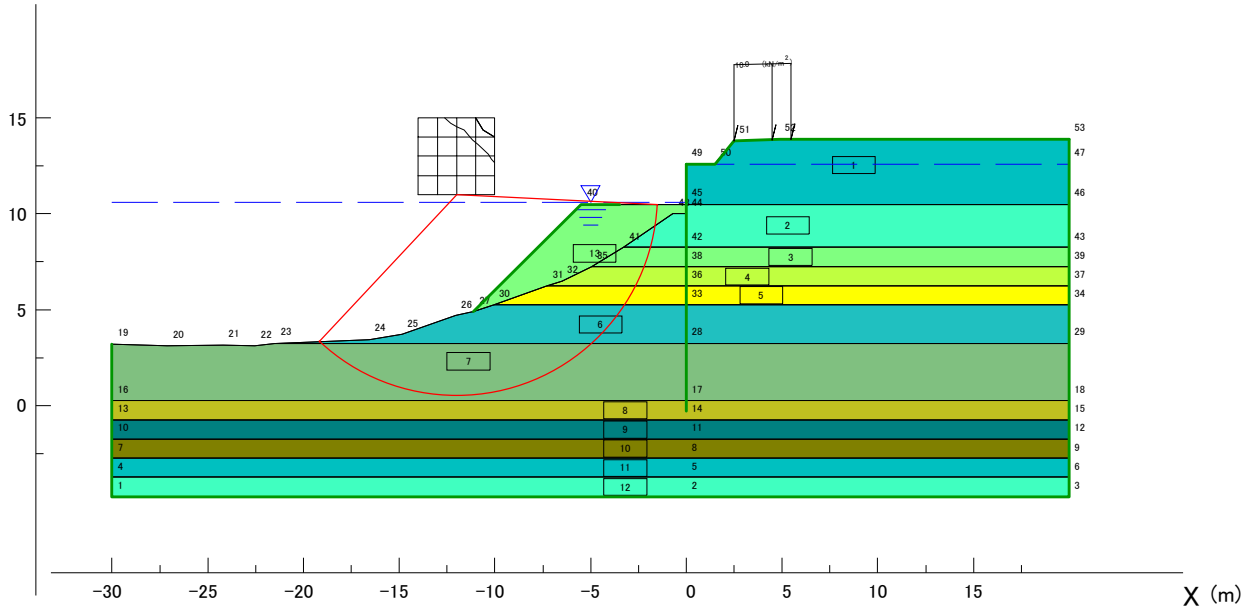
Riprap Stability Right Sta.5+100

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.531	
Center of arc	X	=	−12.00	(m)
	Y	=	11.00	(m)
Radius	R	=	10.50	(m)
Resisting moment	M_R	=	3260.2	(kNm)
Sliding moment	M_D	=	2130.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	18.00	0.00	0.000	0.000
3	18.00	18.00	28.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	16.00	16.00	0.00	24.00	0.00	0.000	0.000
6	16.00	16.00	0.00	25.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	100.00	0.00	0.000	0.000
10	18.00	18.00	34.00	1.00	0.00	0.000	0.000
11	18.00	18.00	31.00	1.00	0.00	0.000	0.000
12	18.00	18.00	32.00	1.00	0.00	0.000	0.000
13	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

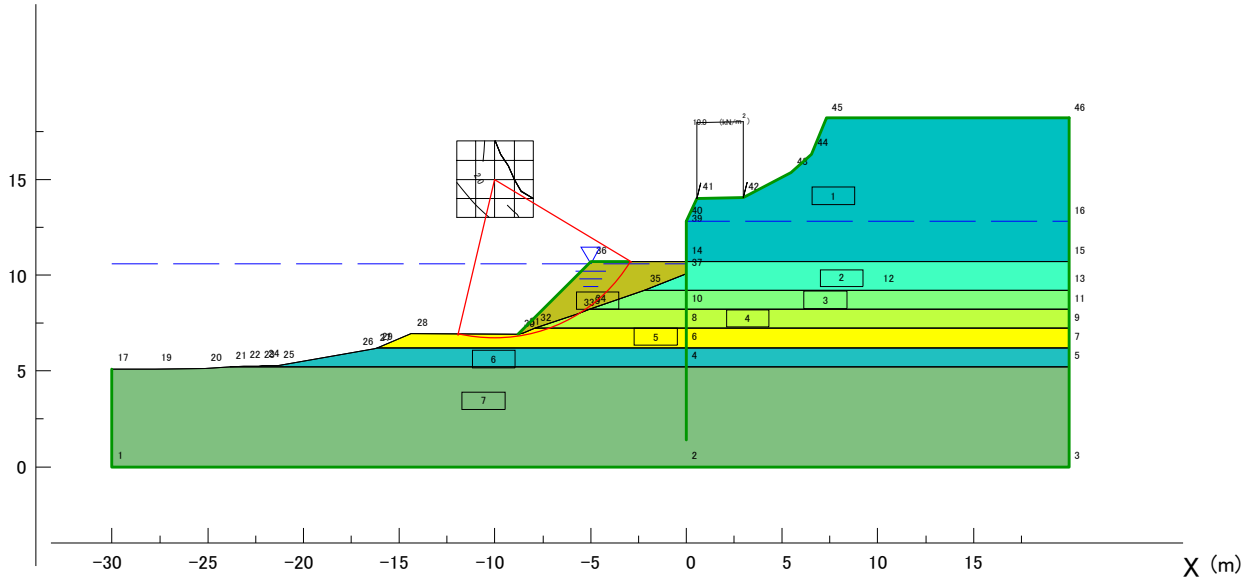
Riprap Stability Right Sta.16+667

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.468	
Center of arc	X	=	−10.00	(m)
	Y	=	15.00	(m)
Radius	R	=	8.30	(m)
Resisting moment	M_R	=	487.1	(kNm)
Sliding moment	M_D	=	331.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	35.00	1.00	0.00	0.000	0.000
5	18.00	18.00	39.00	1.00	0.00	0.000	0.000
6	18.00	18.00	45.00	1.00	0.00	0.000	0.000
7	18.00	18.00	45.00	1.00	0.00	0.000	0.000
8	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

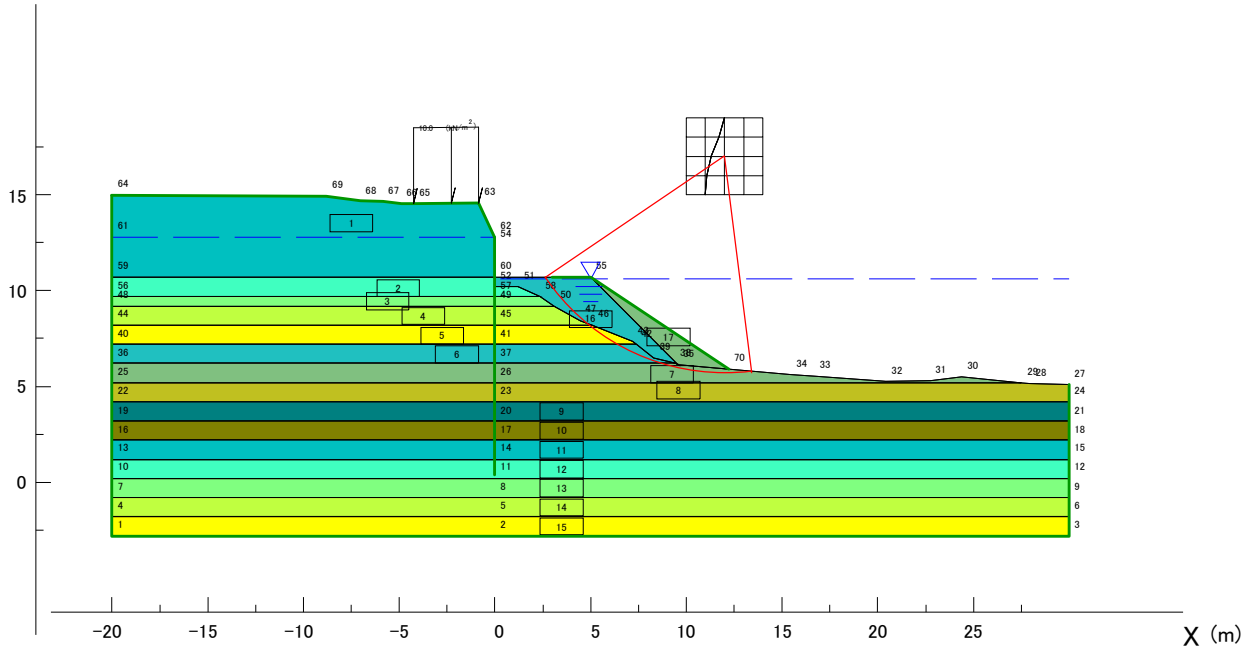
Riprap Stability Left Sta.16+042 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.457	
Center of arc	X	=	12.00	(m)
	Y	=	17.00	(m)
Radius	R	=	11.30	(m)
Resisting moment	M_R	=	1118.7	(kNm)
Sliding moment	M_D	=	767.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	6.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	33.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	38.00	1.00	0.00	0.000	0.000
8	18.00	18.00	32.00	1.00	0.00	0.000	0.000
9	18.00	18.00	37.00	1.00	0.00	0.000	0.000
10	18.00	18.00	38.00	1.00	0.00	0.000	0.000
11	18.00	18.00	39.00	1.00	0.00	0.000	0.000
12	18.00	18.00	39.00	1.00	0.00	0.000	0.000
13	18.00	18.00	40.00	1.00	0.00	0.000	0.000
14	18.00	18.00	40.00	1.00	0.00	0.000	0.000
15	18.00	18.00	40.00	1.00	0.00	0.000	0.000
16	19.00	19.00	40.00	0.00	0.00	0.000	0.000
17	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

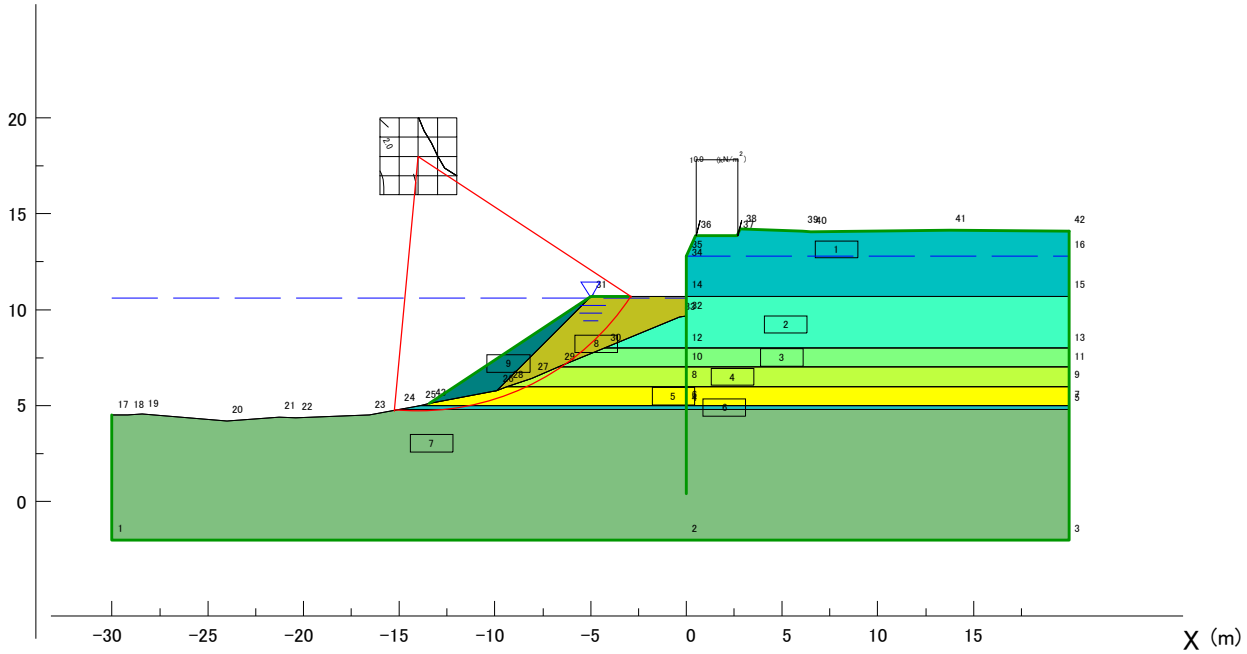
Riprap Stability Right Sta.13+914.5 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.416	
Center of arc	X	=	−14.00	(m)
	Y	=	18.00	(m)
Radius	R	=	13.30	(m)
Resisting moment	M_R	=	1610.2	(kNm)
Sliding moment	M_D	=	1137.2	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	30.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	30.00	1.00	0.00	0.000	0.000
6	20.00	20.00	45.00	1.00	0.00	0.000	0.000
7	20.00	20.00	45.00	1.00	0.00	0.000	0.000
8	19.00	19.00	40.00	0.00	0.00	0.000	0.000
9	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

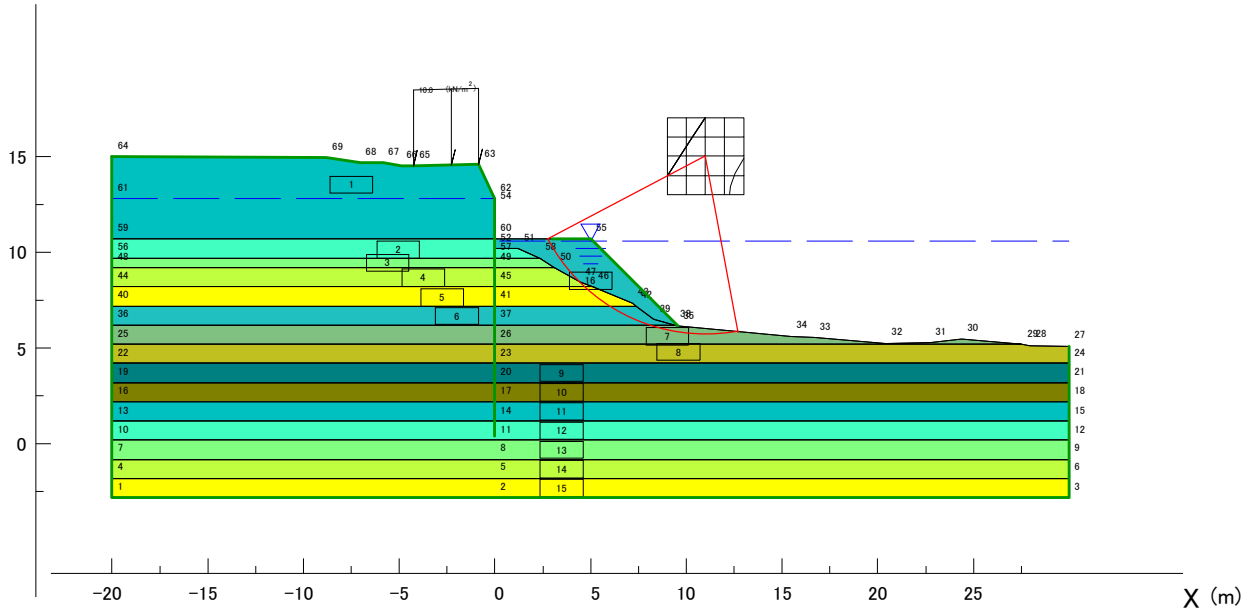
Riprap Stability Left Sta.16+042

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.174	
Center of arc	X	=	11.00	(m)
	Y	=	15.00	(m)
Radius	R	=	9.30	(m)
Resisting moment	M_R	=	649.8	(kNm)
Sliding moment	M_D	=	553.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	6.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	33.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	38.00	1.00	0.00	0.000	0.000
8	18.00	18.00	32.00	1.00	0.00	0.000	0.000
9	18.00	18.00	37.00	1.00	0.00	0.000	0.000
10	18.00	18.00	38.00	1.00	0.00	0.000	0.000
11	18.00	18.00	39.00	1.00	0.00	0.000	0.000
12	18.00	18.00	39.00	1.00	0.00	0.000	0.000
13	18.00	18.00	40.00	1.00	0.00	0.000	0.000
14	18.00	18.00	40.00	1.00	0.00	0.000	0.000
15	18.00	18.00	40.00	1.00	0.00	0.000	0.000
16	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

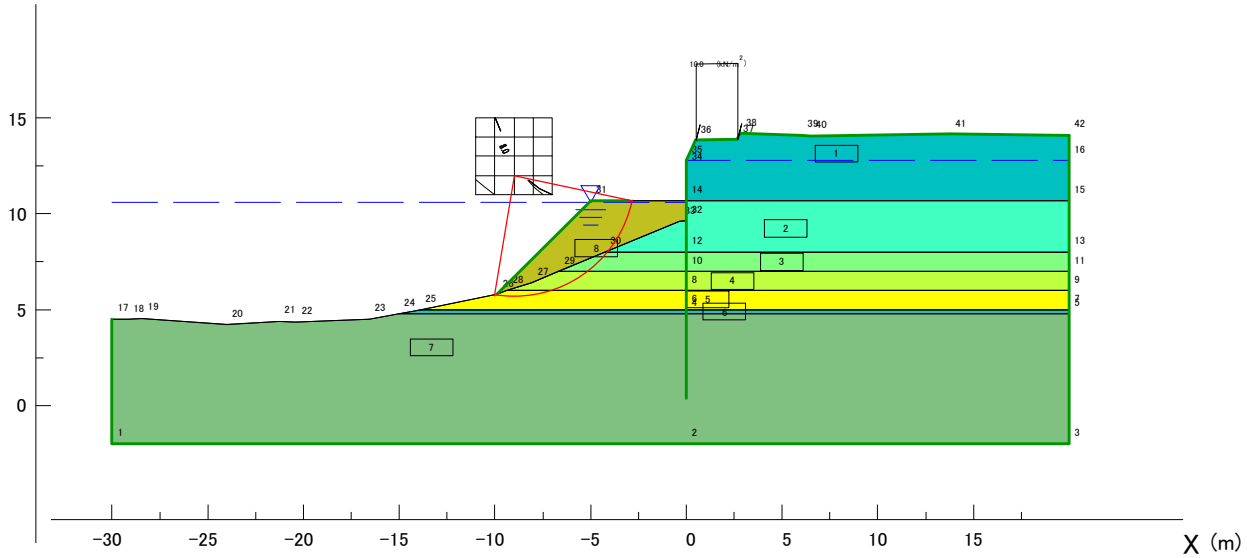
Riprap Stability Right Sta.13+914.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.049	
Center of arc	X	=	−9.00	(m)
	Y	=	12.00	(m)
Radius	R	=	6.30	(m)
Resisting moment	M_R	=	458.1	(kNm)
Sliding moment	M_D	=	436.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	30.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	30.00	1.00	0.00	0.000	0.000
6	20.00	20.00	45.00	1.00	0.00	0.000	0.000
7	20.00	20.00	45.00	1.00	0.00	0.000	0.000
8	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

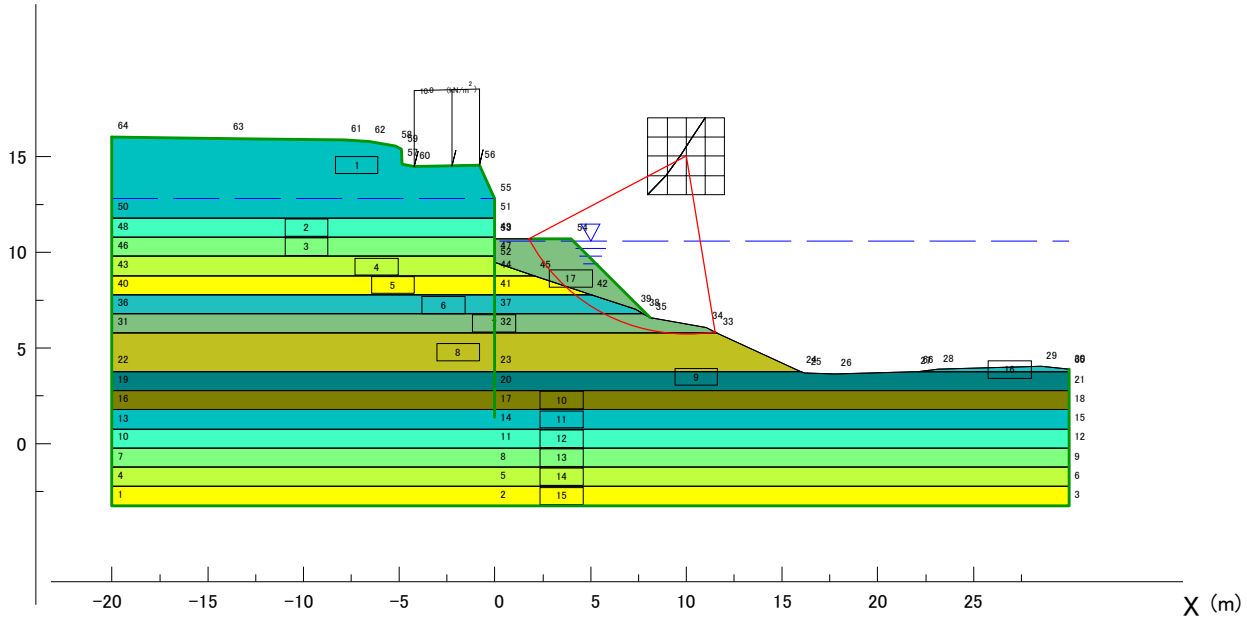
Riprap Stability Left Sta.15+350

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.352	
Center of arc	X	=	10.00	(m)
	Y	=	15.00	(m)
Radius	R	=	9.30	(m)
Resisting moment	M_R	=	750.5	(kNm)
Sliding moment	M_D	=	555.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	18.00	18.00	29.00	1.00	0.00	0.000	0.000
3	18.00	18.00	31.00	1.00	0.00	0.000	0.000
4	18.00	18.00	32.00	1.00	0.00	0.000	0.000
5	18.00	18.00	35.00	1.00	0.00	0.000	0.000
6	18.00	18.00	30.00	1.00	0.00	0.000	0.000
7	18.00	18.00	39.00	1.00	0.00	0.000	0.000
8	18.00	18.00	33.00	1.00	0.00	0.000	0.000
9	18.00	18.00	34.00	1.00	0.00	0.000	0.000
10	18.00	18.00	35.00	1.00	0.00	0.000	0.000
11	18.00	18.00	33.00	1.00	0.00	0.000	0.000
12	18.00	18.00	39.00	1.00	0.00	0.000	0.000
13	18.00	18.00	29.00	1.00	0.00	0.000	0.000
14	18.00	18.00	27.00	1.00	0.00	0.000	0.000
15	18.00	18.00	31.00	1.00	0.00	0.000	0.000
16	18.00	18.00	33.00	1.00	0.00	0.000	0.000
17	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

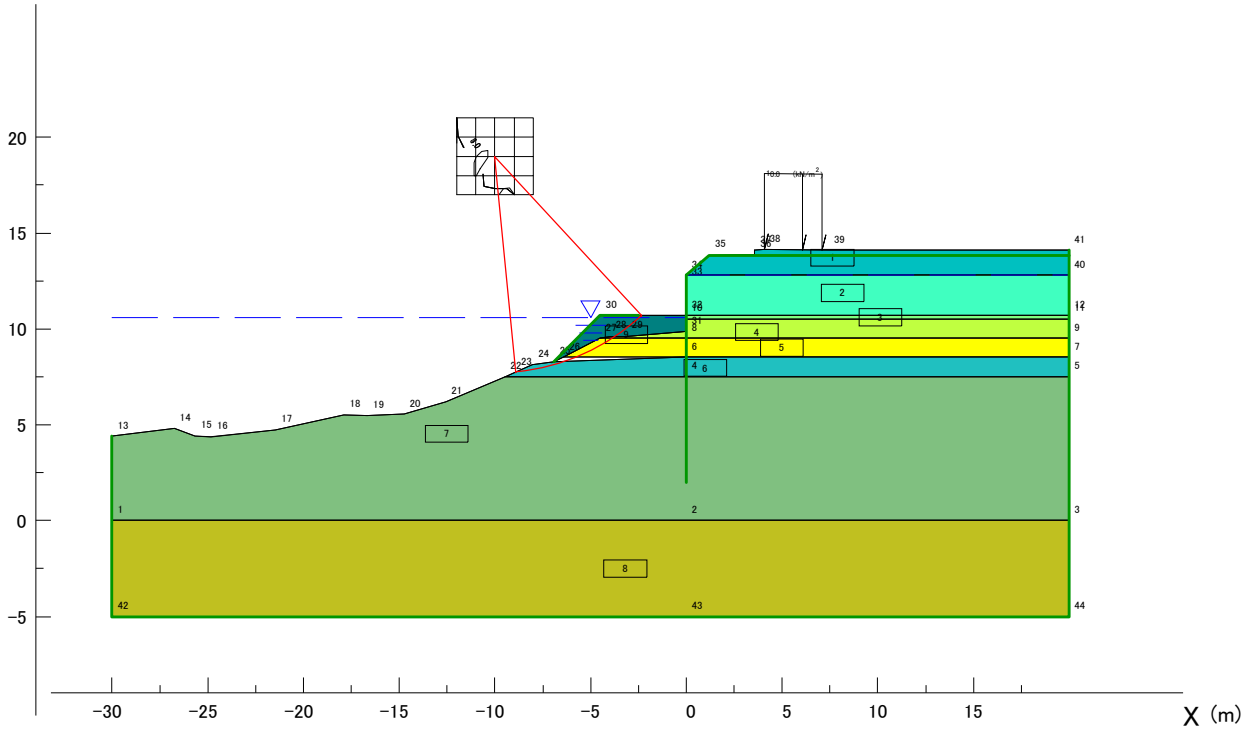
Riprap Stability Right Sta.13+700

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.524	
Center of arc	X	=	−10.00	(m)
	Y	=	19.00	(m)
Radius	R	=	11.30	(m)
Resisting moment	M_R	=	328.3	(kNm)
Sliding moment	M_D	=	215.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	30.00	1.00	0.00	0.000	0.000
3	16.00	16.00	0.00	100.00	0.00	0.000	0.000
4	16.00	16.00	0.00	12.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	18.00	18.00	40.00	1.00	0.00	0.000	0.000
7	20.00	20.00	45.00	1.00	0.00	0.000	0.000
8	20.00	20.00	45.00	1.00	0.00	0.000	0.000
9	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

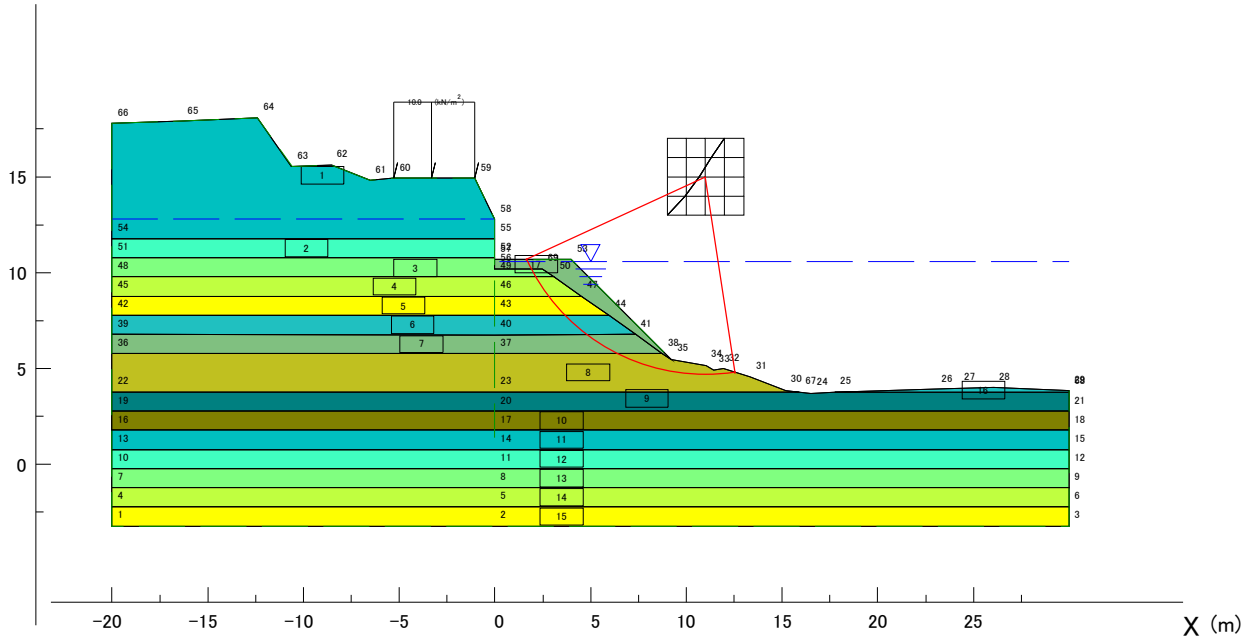
Riprap Stability Left Sta.15+300

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.229	
Center of arc	X	=	11.00	(m)
	Y	=	15.00	(m)
Radius	R	=	10.30	(m)
Resisting moment	M_R	=	1002.7	(kNm)
Sliding moment	M_D	=	816.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	18.00	18.00	29.00	1.00	0.00	0.000	0.000
3	18.00	18.00	31.00	1.00	0.00	0.000	0.000
4	18.00	18.00	32.00	1.00	0.00	0.000	0.000
5	18.00	18.00	35.00	1.00	0.00	0.000	0.000
6	18.00	18.00	30.00	1.00	0.00	0.000	0.000
7	18.00	18.00	39.00	1.00	0.00	0.000	0.000
8	18.00	18.00	33.00	1.00	0.00	0.000	0.000
9	18.00	18.00	34.00	1.00	0.00	0.000	0.000
10	18.00	18.00	35.00	1.00	0.00	0.000	0.000
11	18.00	18.00	33.00	1.00	0.00	0.000	0.000
12	18.00	18.00	39.00	1.00	0.00	0.000	0.000
13	18.00	18.00	29.00	1.00	0.00	0.000	0.000
14	18.00	18.00	27.00	1.00	0.00	0.000	0.000
15	18.00	18.00	31.00	1.00	0.00	0.000	0.000
16	18.00	18.00	33.00	1.00	0.00	0.000	0.000
17	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

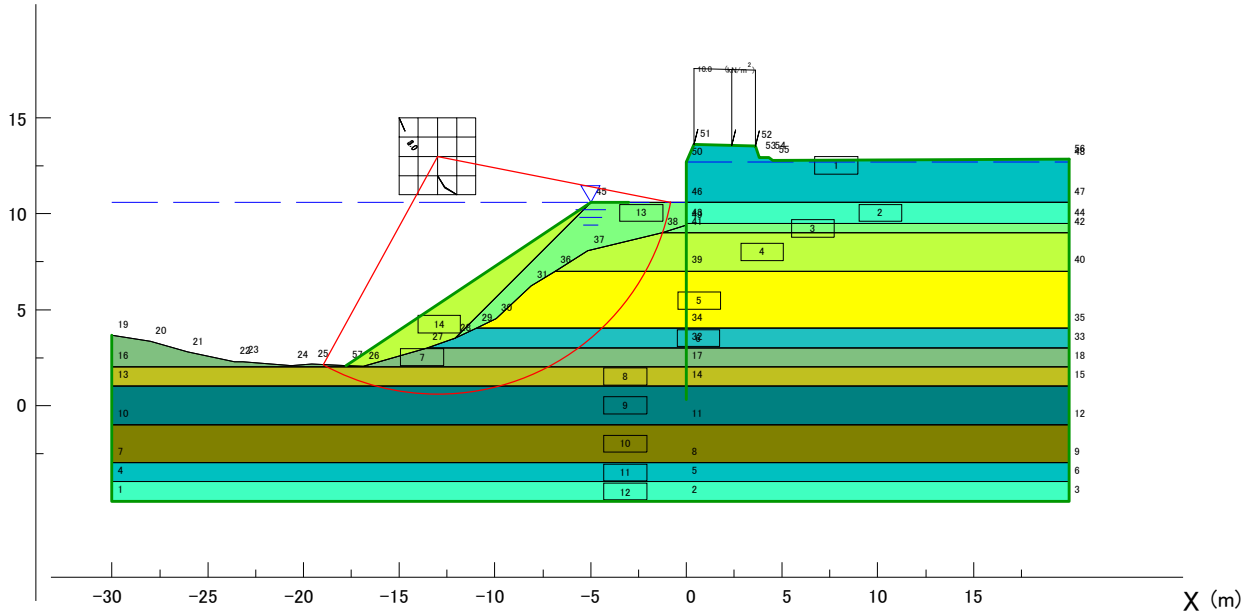
Riprap Stability Right Sta.9+750 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.510	
Center of arc	X	=	−13.00	(m)
	Y	=	13.00	(m)
Radius	R	=	12.40	(m)
Resisting moment	M_R	=	4667.3	(kNm)
Sliding moment	M_D	=	3091.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	12.00	0.00	0.000	0.000
3	18.00	18.00	29.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	31.00	1.00	0.00	0.000	0.000
6	16.00	16.00	0.00	12.00	0.00	0.000	0.000
7	16.00	16.00	0.00	25.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	24.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	16.00	16.00	0.00	18.00	0.00	0.000	0.000
12	16.00	16.00	0.00	24.00	0.00	0.000	0.000
13	19.00	19.00	40.00	0.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

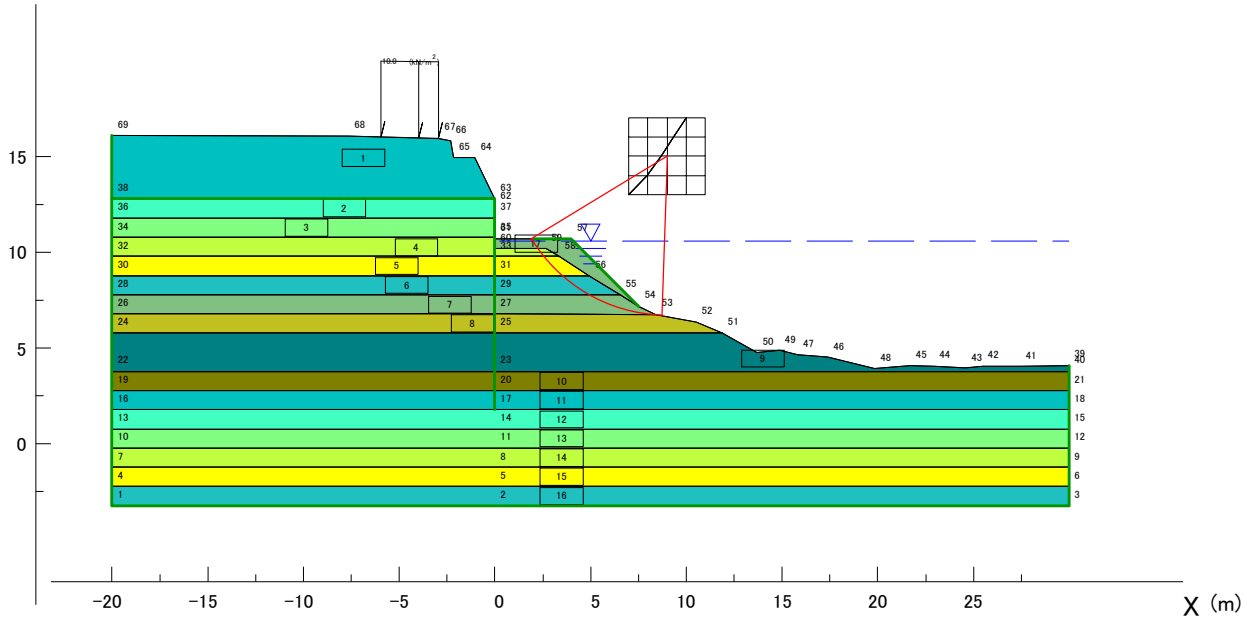
Riprap Stability Left Sta.15+236

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.203	
Center of arc	X	=	9.00	(m)
	Y	=	15.00	(m)
Radius	R	=	8.30	(m)
Resisting moment	M_R	=	383.1	(kNm)
Sliding moment	M_D	=	318.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	18.00	18.00	28.00	1.00	0.00	0.000	0.000
3	18.00	18.00	29.00	1.00	0.00	0.000	0.000
4	18.00	18.00	31.00	1.00	0.00	0.000	0.000
5	18.00	18.00	32.00	1.00	0.00	0.000	0.000
6	18.00	18.00	35.00	1.00	0.00	0.000	0.000
7	18.00	18.00	30.00	1.00	0.00	0.000	0.000
8	18.00	18.00	39.00	1.00	0.00	0.000	0.000
9	18.00	18.00	33.00	1.00	0.00	0.000	0.000
10	18.00	18.00	34.00	1.00	0.00	0.000	0.000
11	18.00	18.00	35.00	1.00	0.00	0.000	0.000
12	18.00	18.00	33.00	1.00	0.00	0.000	0.000
13	18.00	18.00	39.00	1.00	0.00	0.000	0.000
14	18.00	18.00	29.00	1.00	0.00	0.000	0.000
15	18.00	18.00	27.00	1.00	0.00	0.000	0.000
16	18.00	18.00	31.00	1.00	0.00	0.000	0.000
17	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

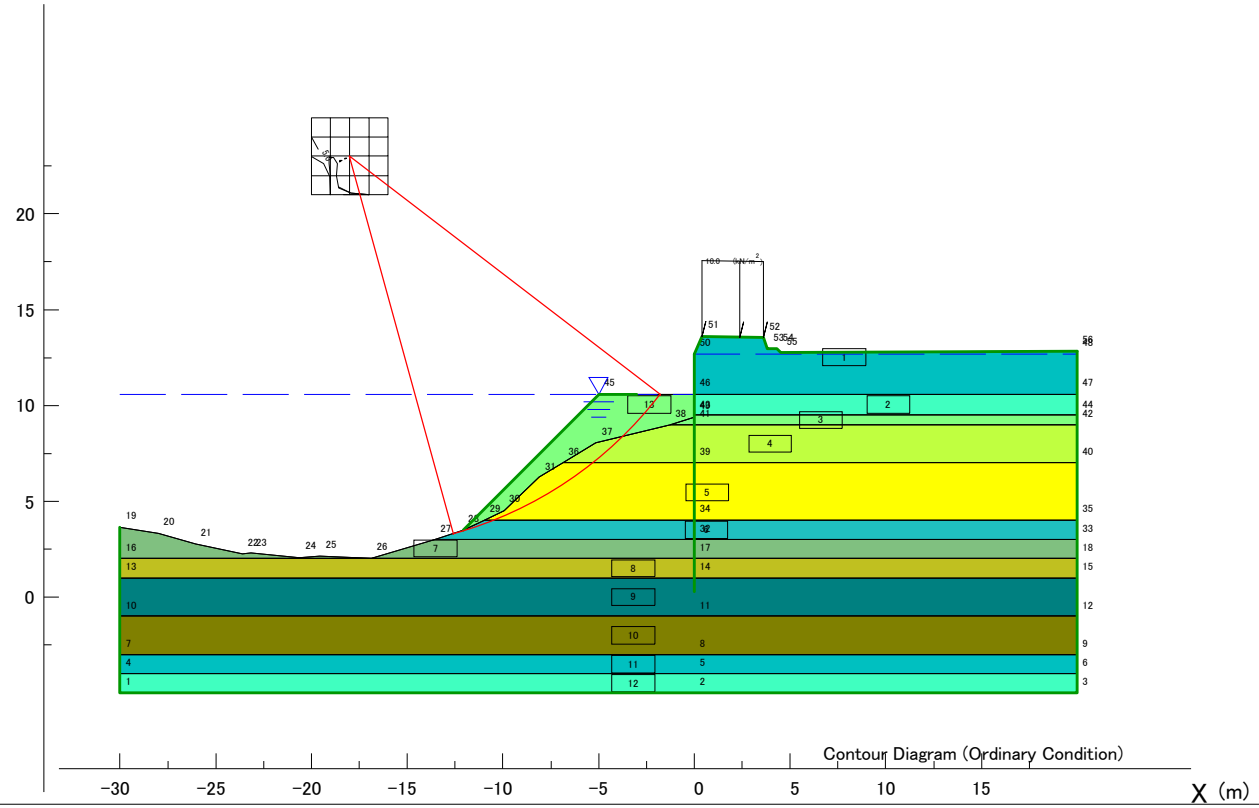
Riprap Stability Right Sta.9+750

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.168	
Center of arc	X	=	−18.00	(m)
	Y	=	23.00	(m)
Radius	R	=	20.40	(m)
Resisting moment	M_R	=	2365.6	(kNm)
Sliding moment	M_D	=	2025.5	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	12.00	0.00	0.000	0.000
3	18.00	18.00	29.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	31.00	1.00	0.00	0.000	0.000
6	16.00	16.00	0.00	12.00	0.00	0.000	0.000
7	16.00	16.00	0.00	25.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	24.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	16.00	16.00	0.00	18.00	0.00	0.000	0.000
12	16.00	16.00	0.00	24.00	0.00	0.000	0.000
13	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

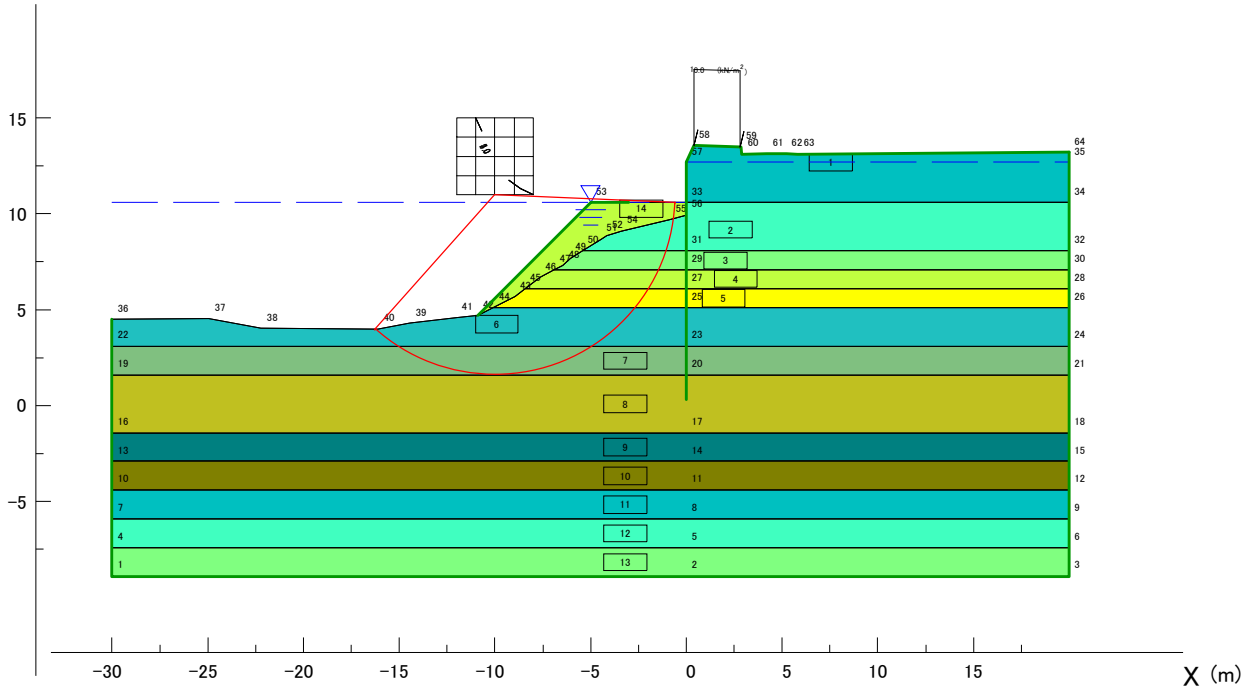
Riprap Stability Right Sta.9+100

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.419	
Center of arc	X	=	−10.00	(m)
	Y	=	11.00	(m)
Radius	R	=	9.40	(m)
Resisting moment	M_R	=	2367.2	(kNm)
Sliding moment	M_D	=	1668.5	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	28.00	1.00	0.00	0.000	0.000
5	16.00	16.00	0.00	25.00	0.00	0.000	0.000
6	16.00	16.00	0.00	18.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	24.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	18.00	18.00	27.00	1.00	0.00	0.000	0.000
12	18.00	18.00	36.00	1.00	0.00	0.000	0.000
13	18.00	18.00	40.00	1.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

3.200

SLOPE STABILITY OF RIPRAP

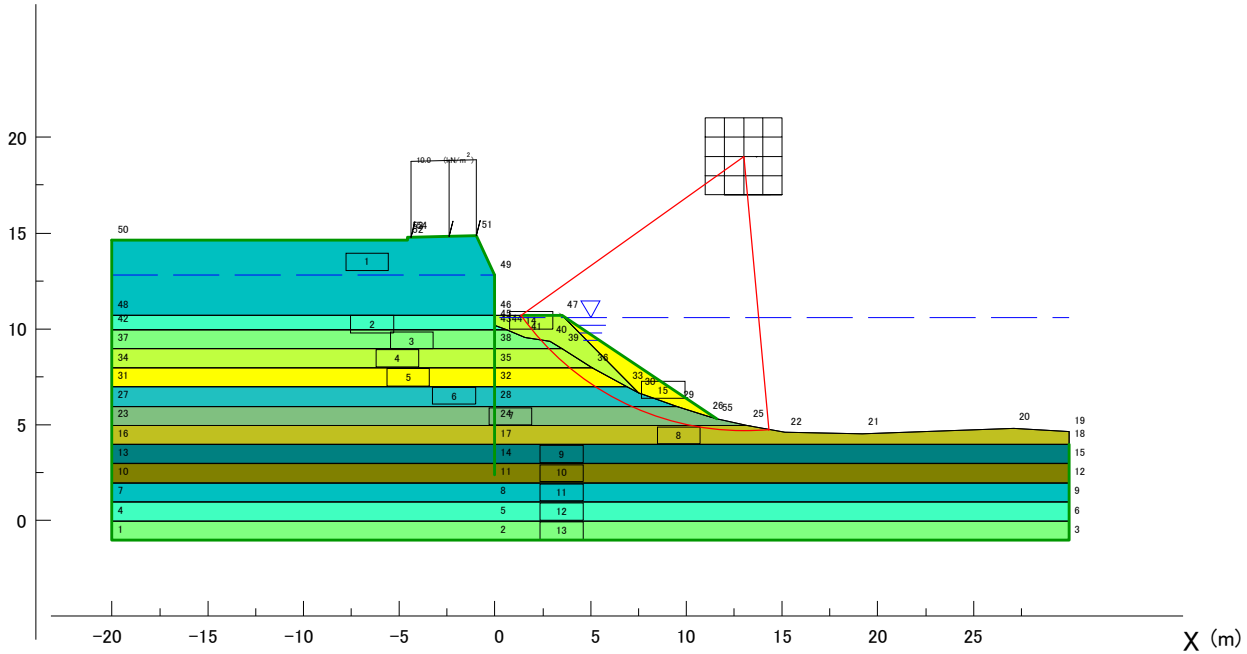
Riprap Stability Left Sta.14+200 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.386	
Center of arc	X	=	13.00	(m)
	Y	=	19.00	(m)
Radius	R	=	14.30	(m)
Resisting moment	M_R	=	1580.3	(kNm)
Sliding moment	M_D	=	1140.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	28.00	1.00	0.00	0.000	0.000
4	18.00	18.00	31.00	1.00	0.00	0.000	0.000
5	18.00	18.00	33.00	1.00	0.00	0.000	0.000
6	18.00	18.00	33.00	1.00	0.00	0.000	0.000
7	18.00	18.00	33.00	1.00	0.00	0.000	0.000
8	18.00	18.00	34.00	1.00	0.00	0.000	0.000
9	18.00	18.00	34.00	1.00	0.00	0.000	0.000
10	18.00	18.00	32.00	1.00	0.00	0.000	0.000
11	18.00	18.00	33.00	1.00	0.00	0.000	0.000
12	18.00	18.00	30.00	1.00	0.00	0.000	0.000
13	18.00	18.00	32.00	1.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000
15	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

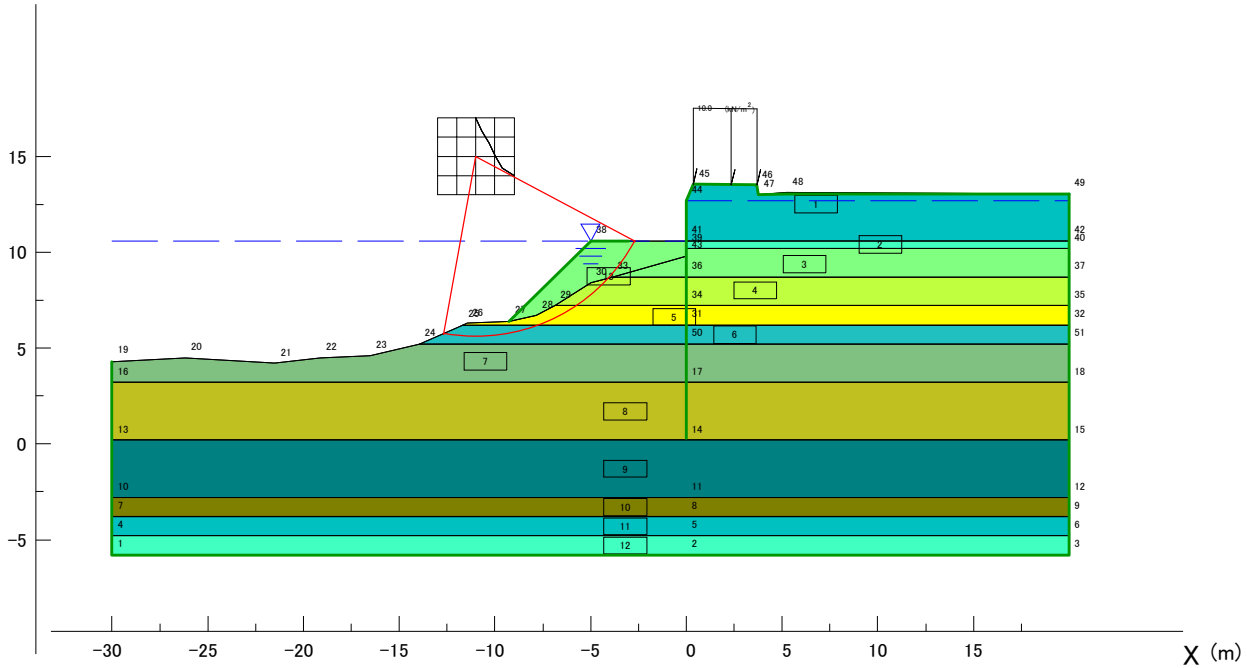
Riprap Stability Right Sta.9+000

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.201	
Center of arc	X	=	−11.00	(m)
	Y	=	15.00	(m)
Radius	R	=	9.40	(m)
Resisting moment	M_R	=	662.7	(kNm)
Sliding moment	M_D	=	551.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	18.00	0.00	0.000	0.000
3	16.00	16.00	0.00	12.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	30.00	1.00	0.00	0.000	0.000
6	18.00	18.00	31.00	1.00	0.00	0.000	0.000
7	18.00	18.00	29.00	1.00	0.00	0.000	0.000
8	16.00	16.00	0.00	12.00	0.00	0.000	0.000
9	16.00	16.00	0.00	18.00	0.00	0.000	0.000
10	16.00	16.00	0.00	18.00	0.00	0.000	0.000
11	16.00	16.00	0.00	24.00	0.00	0.000	0.000
12	16.00	16.00	0.00	12.00	0.00	0.000	0.000
13	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

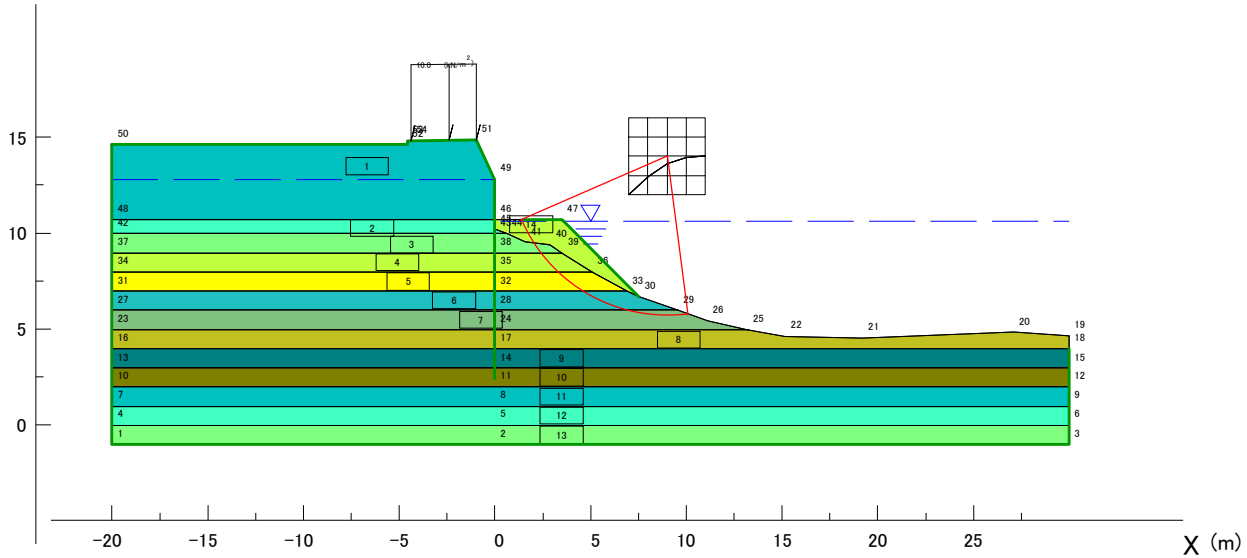
Riprap Stability Left Sta.14+200

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.184	
Center of arc	X	=	9.00	(m)
	Y	=	14.00	(m)
Radius	R	=	8.30	(m)
Resisting moment	M_R	=	590.7	(kNm)
Sliding moment	M_D	=	498.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	28.00	1.00	0.00	0.000	0.000
4	18.00	18.00	31.00	1.00	0.00	0.000	0.000
5	18.00	18.00	33.00	1.00	0.00	0.000	0.000
6	18.00	18.00	33.00	1.00	0.00	0.000	0.000
7	18.00	18.00	33.00	1.00	0.00	0.000	0.000
8	18.00	18.00	34.00	1.00	0.00	0.000	0.000
9	18.00	18.00	34.00	1.00	0.00	0.000	0.000
10	18.00	18.00	32.00	1.00	0.00	0.000	0.000
11	18.00	18.00	33.00	1.00	0.00	0.000	0.000
12	18.00	18.00	30.00	1.00	0.00	0.000	0.000
13	18.00	18.00	32.00	1.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

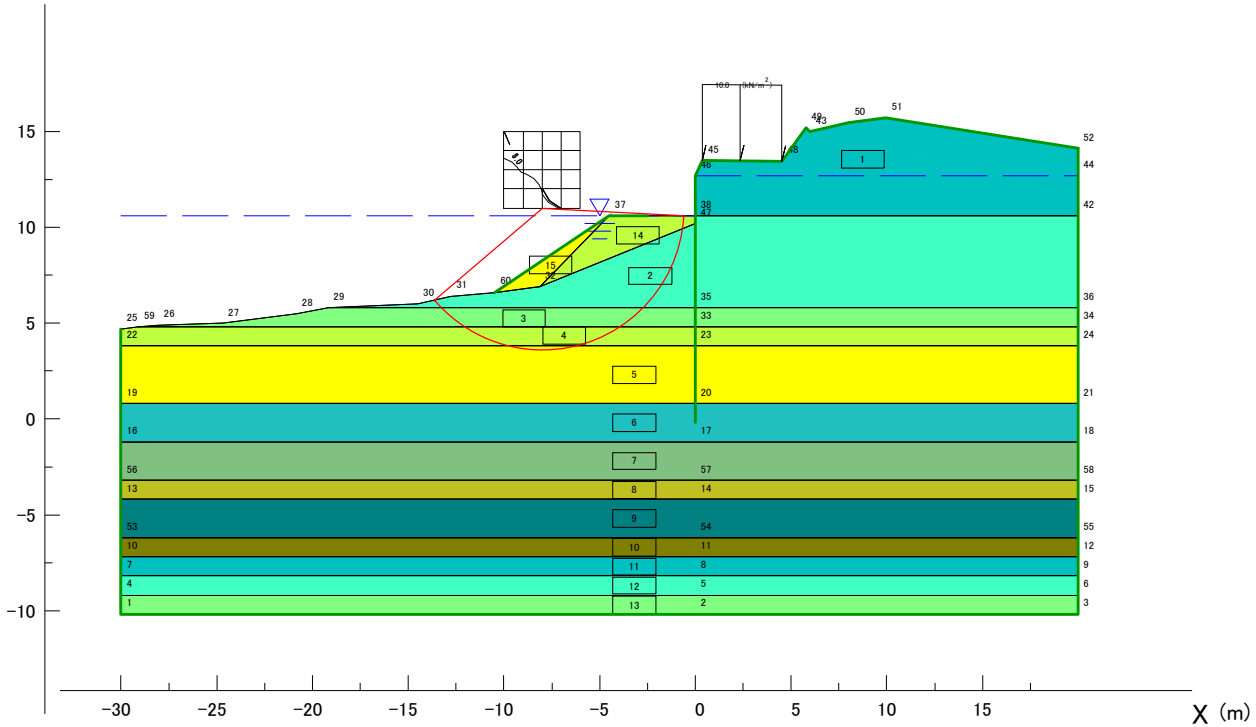
Riprap Stability Right Sta.8+600 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.622	
Center of arc	X	=	−8.00	(m)
	Y	=	11.00	(m)
Radius	R	=	7.40	(m)
Resisting moment	M_R	=	1278.1	(kNm)
Sliding moment	M_D	=	788.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	16.00	16.00	0.00	6.00	0.00	0.000	0.000
5	16.00	16.00	0.00	12.00	0.00	0.000	0.000
6	16.00	16.00	0.00	24.00	0.00	0.000	0.000
7	16.00	16.00	0.00	30.00	0.00	0.000	0.000
8	16.00	16.00	0.00	24.00	0.00	0.000	0.000
9	16.00	16.00	0.00	25.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	16.00	16.00	0.00	50.00	0.00	0.000	0.000
12	16.00	16.00	0.00	100.00	0.00	0.000	0.000
13	16.00	16.00	0.00	50.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000
15	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

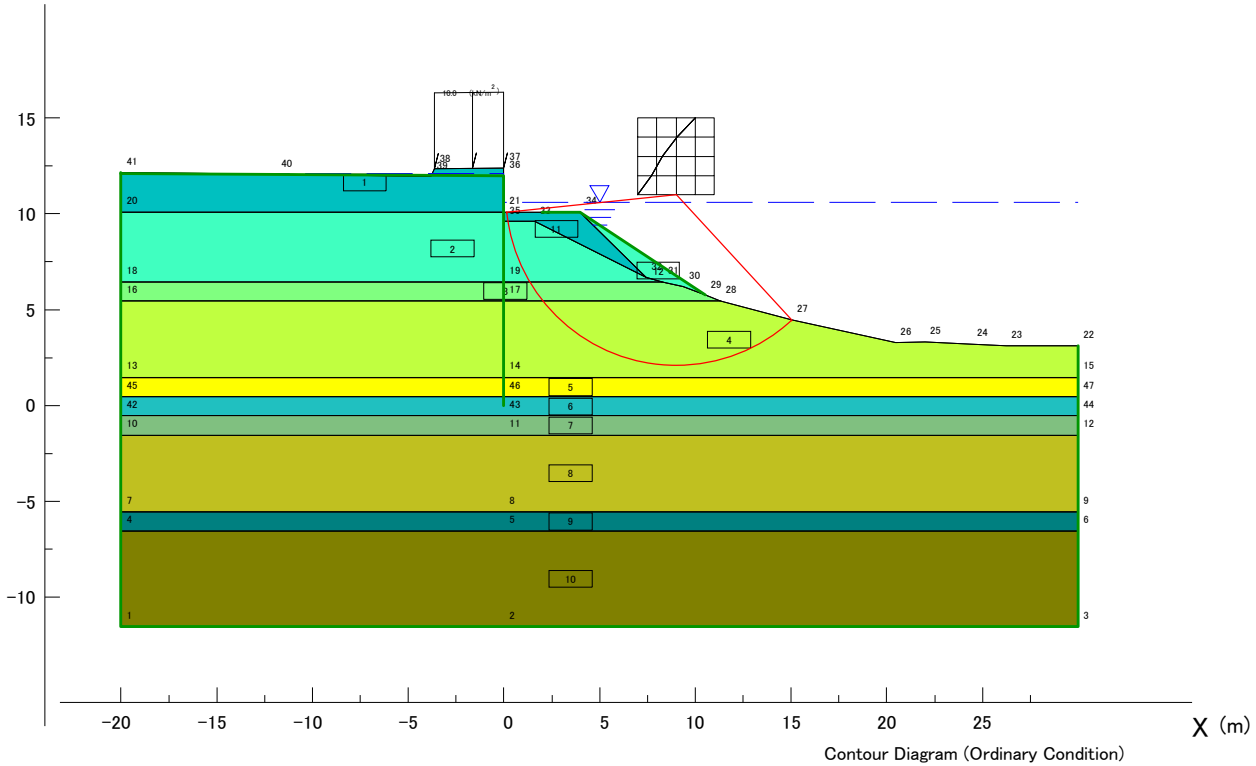
Riprap Stability Left Sta.3+050 Slope1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.346	
Center of arc	X	=	9.00	(m)
	Y	=	11.00	(m)
Radius	R	=	8.90	(m)
Resisting moment	M_R	=	1706.0	(kNm)
Sliding moment	M_D	=	1267.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	16.00	16.00	0.00	12.00	0.00	0.000	0.000
5	16.00	16.00	0.00	24.00	0.00	0.000	0.000
6	16.00	16.00	0.00	25.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	24.00	0.00	0.000	0.000
9	16.00	16.00	0.00	18.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000
12	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

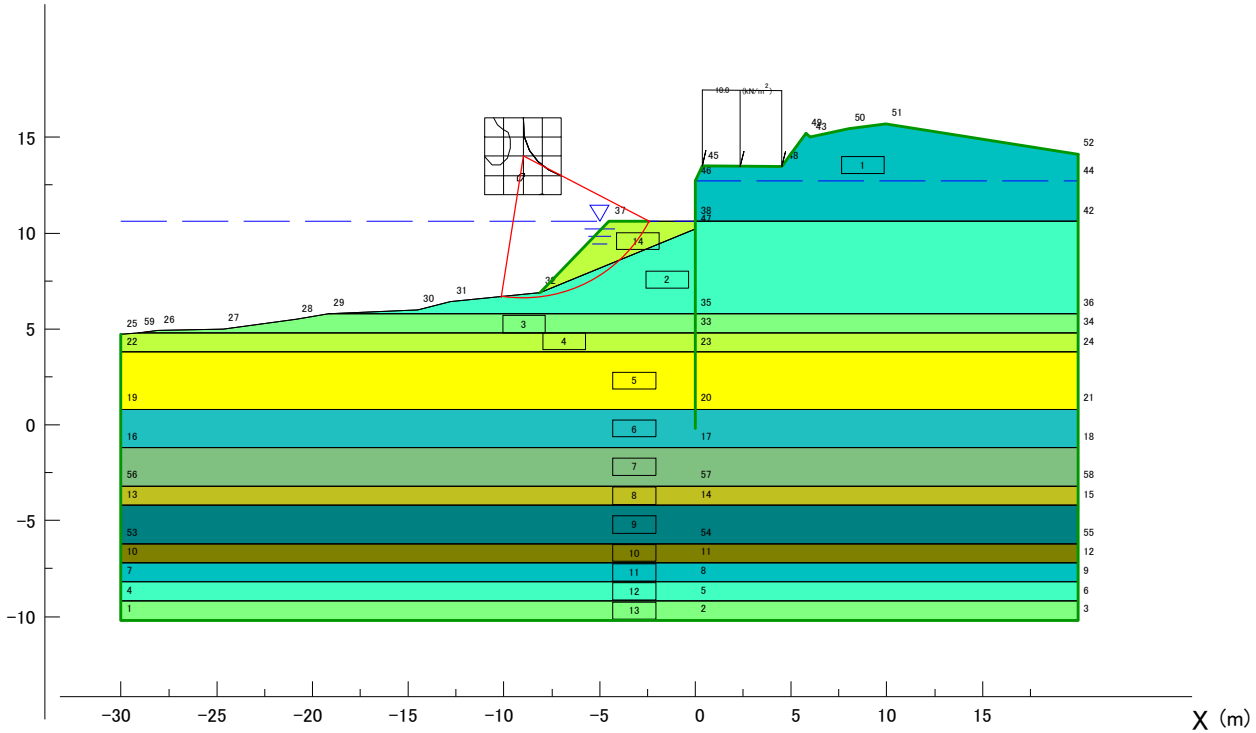
Riprap Stability Right Sta.8+600

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.085	
Center of arc	X	=	-9.00	(m)
	Y	=	14.00	(m)
Radius	R	=	7.40	(m)
Resisting moment	M_R	=	325.2	(kNm)
Sliding moment	M_D	=	299.6	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	16.00	16.00	0.00	6.00	0.00	0.000	0.000
5	16.00	16.00	0.00	12.00	0.00	0.000	0.000
6	16.00	16.00	0.00	24.00	0.00	0.000	0.000
7	16.00	16.00	0.00	30.00	0.00	0.000	0.000
8	16.00	16.00	0.00	24.00	0.00	0.000	0.000
9	16.00	16.00	0.00	25.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	16.00	16.00	0.00	50.00	0.00	0.000	0.000
12	16.00	16.00	0.00	100.00	0.00	0.000	0.000
13	16.00	16.00	0.00	50.00	0.00	0.000	0.000
14	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

SLOPE STABILITY OF RIPRAP

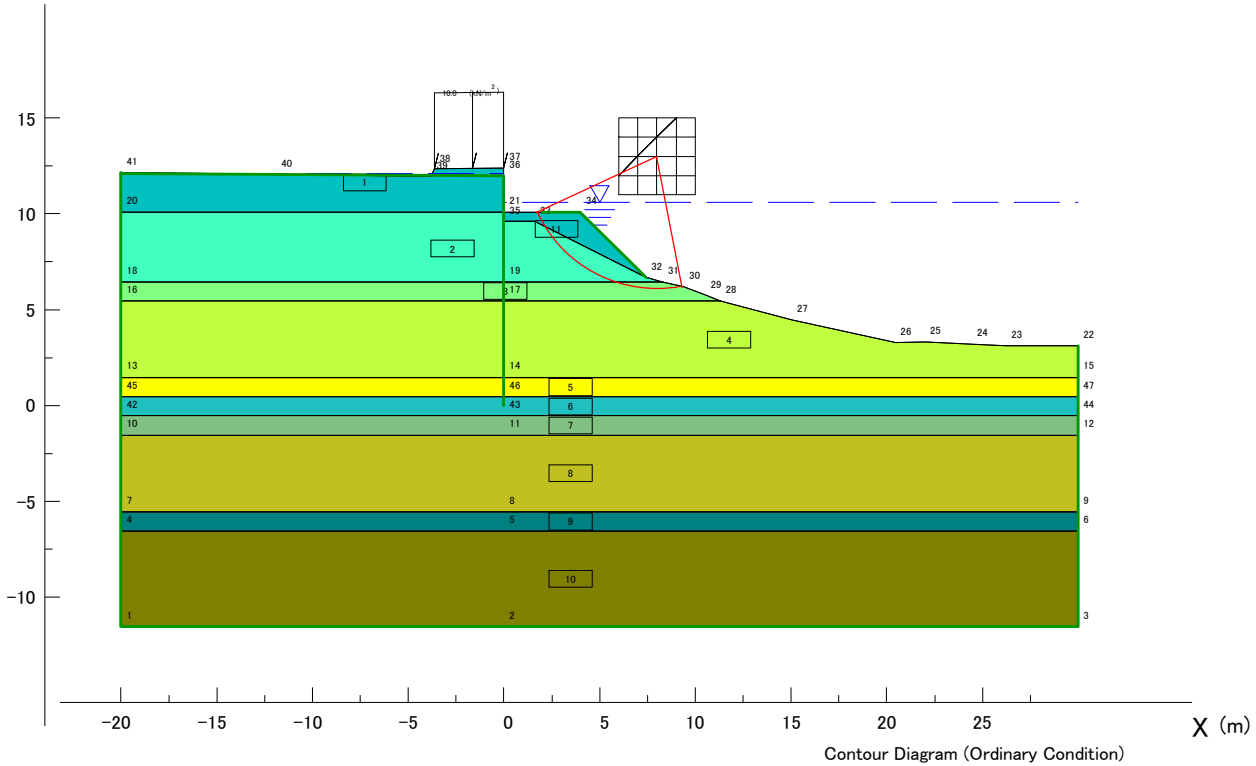
Riprap Stability Left Sta.3+050

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.102	
Center of arc	X	=	8.00	(m)
	Y	=	13.00	(m)
Radius	R	=	6.90	(m)
Resisting moment	M_R	=	327.4	(kNm)
Sliding moment	M_D	=	297.0	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	30.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	16.00	16.00	0.00	12.00	0.00	0.000	0.000
5	16.00	16.00	0.00	24.00	0.00	0.000	0.000
6	16.00	16.00	0.00	25.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	24.00	0.00	0.000	0.000
9	16.00	16.00	0.00	18.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

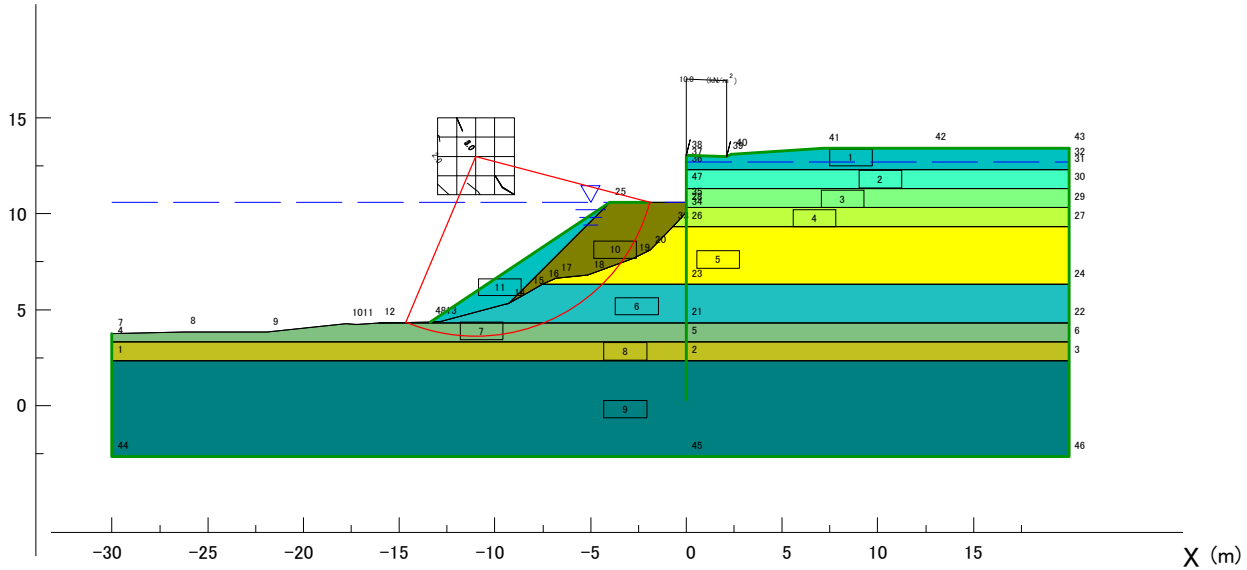
Riprap Stability Right Sta.6+471 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.215	
Center of arc	X	=	−11.00	(m)
	Y	=	13.00	(m)
Radius	R	=	9.40	(m)
Resisting moment	M_R	=	1422.1	(kNm)
Sliding moment	M_D	=	1170.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	50.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	28.00	1.00	0.00	0.000	0.000
8	18.00	18.00	28.00	1.00	0.00	0.000	0.000
9	20.00	20.00	45.00	1.00	0.00	0.000	0.000
10	19.00	19.00	40.00	0.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

SLOPE STABILITY OF RIPRAP

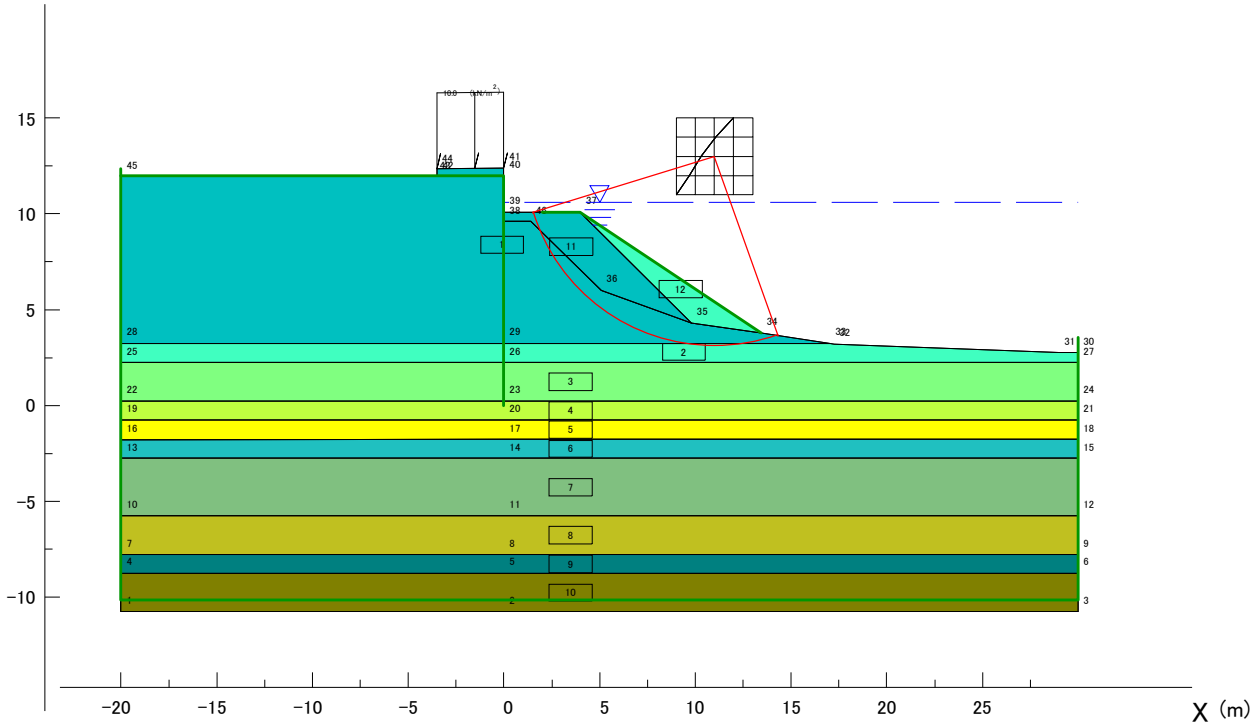
Riprap Stability Left Sta.2+931 Slope1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.215	
Center of arc	X	=	11.00	(m)
	Y	=	13.00	(m)
Radius	R	=	9.90	(m)
Resisting moment	M_R	=	1556.4	(kNm)
Sliding moment	M_D	=	1280.8	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	27.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	12.00	0.00	0.000	0.000
3	16.00	16.00	0.00	18.00	0.00	0.000	0.000
4	16.00	16.00	0.00	24.00	0.00	0.000	0.000
5	16.00	16.00	0.00	18.00	0.00	0.000	0.000
6	16.00	16.00	0.00	25.00	0.00	0.000	0.000
7	16.00	16.00	0.00	24.00	0.00	0.000	0.000
8	18.00	18.00	27.00	1.00	0.00	0.000	0.000
9	16.00	16.00	0.00	24.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000
12	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

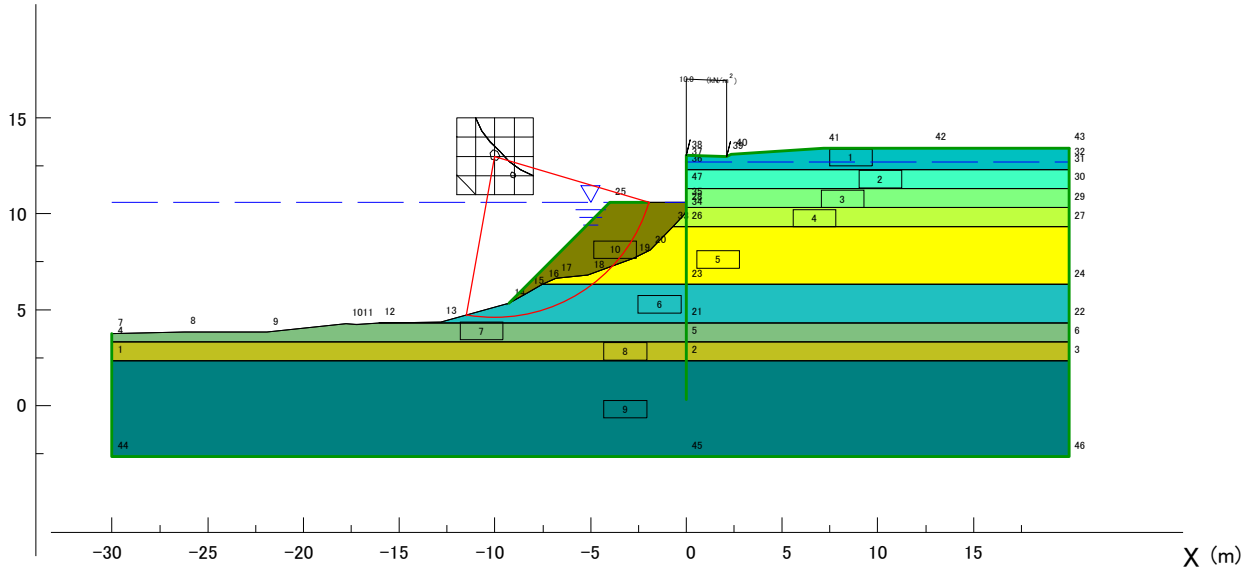
Riprap Stability Right Sta.6+471

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	0.955	
Center of arc	X	=	−10.00	(m)
	Y	=	13.00	(m)
Radius	R	=	8.40	(m)
Resisting moment	M_R	=	679.0	(kNm)
Sliding moment	M_D	=	711.3	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	50.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	28.00	1.00	0.00	0.000	0.000
8	18.00	18.00	28.00	1.00	0.00	0.000	0.000
9	20.00	20.00	45.00	1.00	0.00	0.000	0.000
10	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

SLOPE STABILITY OF RIPRAP

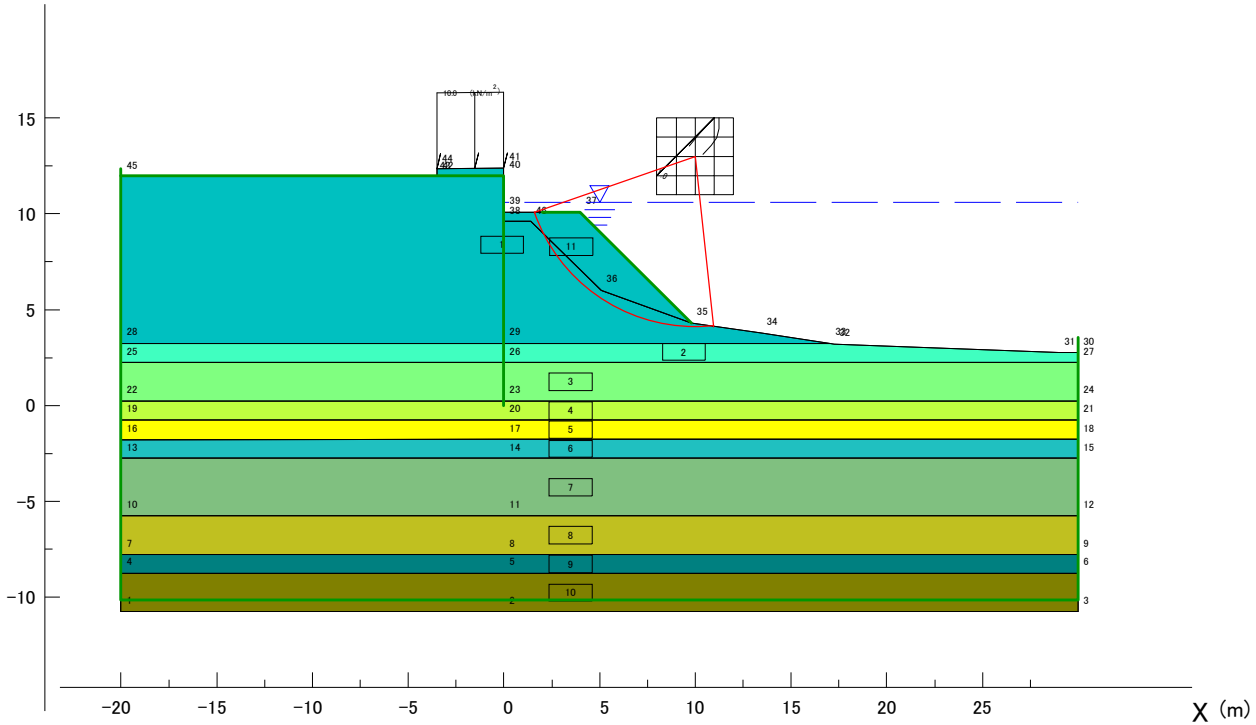
Riprap Stability Left Sta.2+931

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	0.914	
Center of arc	X	=	10.00	(m)
	Y	=	13.00	(m)
Radius	R	=	8.90	(m)
Resisting moment	M_R	=	725.8	(kNm)
Sliding moment	M_D	=	794.1	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	27.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	12.00	0.00	0.000	0.000
3	16.00	16.00	0.00	18.00	0.00	0.000	0.000
4	16.00	16.00	0.00	24.00	0.00	0.000	0.000
5	16.00	16.00	0.00	18.00	0.00	0.000	0.000
6	16.00	16.00	0.00	25.00	0.00	0.000	0.000
7	16.00	16.00	0.00	24.00	0.00	0.000	0.000
8	18.00	18.00	27.00	1.00	0.00	0.000	0.000
9	16.00	16.00	0.00	24.00	0.00	0.000	0.000
10	16.00	16.00	0.00	25.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

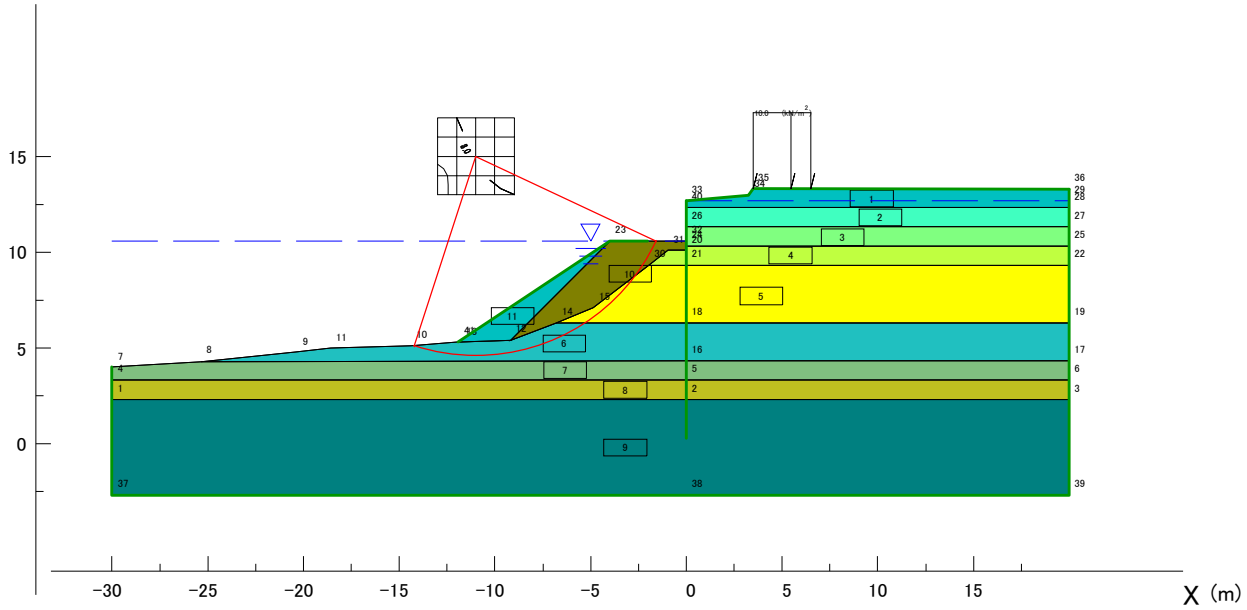
Riprap Stability Right Sta.6+415 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.215	
Center of arc	X	=	−11.00	(m)
	Y	=	15.00	(m)
Radius	R	=	10.40	(m)
Resisting moment	M_R	=	1220.3	(kNm)
Sliding moment	M_D	=	1004.5	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	50.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	28.00	1.00	0.00	0.000	0.000
8	18.00	18.00	28.00	1.00	0.00	0.000	0.000
9	20.00	20.00	45.00	1.00	0.00	0.000	0.000
10	19.00	19.00	40.00	0.00	0.00	0.000	0.000
11	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

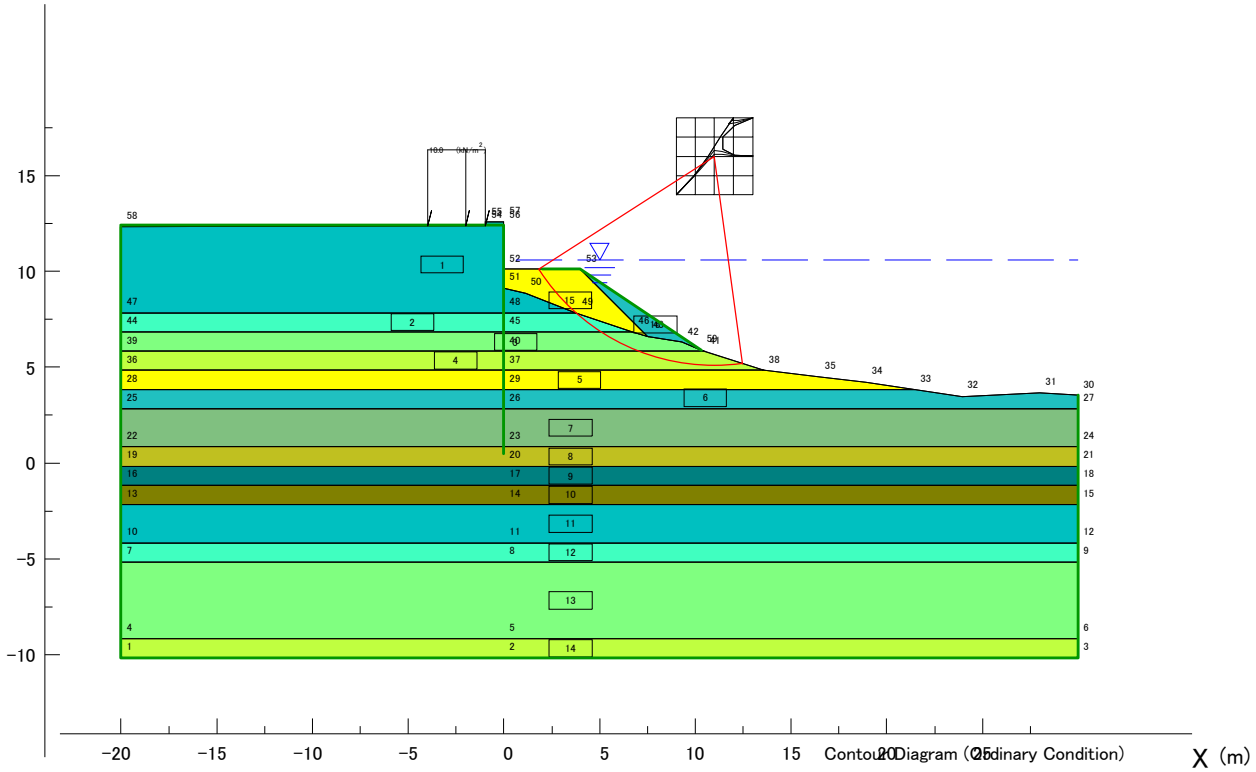
Riprap Stability Left Sta.2+600 Slope1:1.5

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.239	
Center of arc	X	=	11.00	(m)
	Y	=	16.00	(m)
Radius	R	=	10.90	(m)
Resisting moment	M_R	=	856.4	(kNm)
Sliding moment	M_D	=	691.4	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	16.00	16.00	27.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	16.00	16.00	0.00	12.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	18.00	0.00	0.000	0.000
10	16.00	16.00	0.00	12.00	0.00	0.000	0.000
11	16.00	16.00	0.00	12.00	0.00	0.000	0.000
12	16.00	16.00	0.00	18.00	0.00	0.000	0.000
13	16.00	16.00	0.00	24.00	0.00	0.000	0.000
14	16.00	16.00	0.00	25.00	0.00	0.000	0.000
15	19.00	19.00	40.00	0.00	0.00	0.000	0.000
16	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

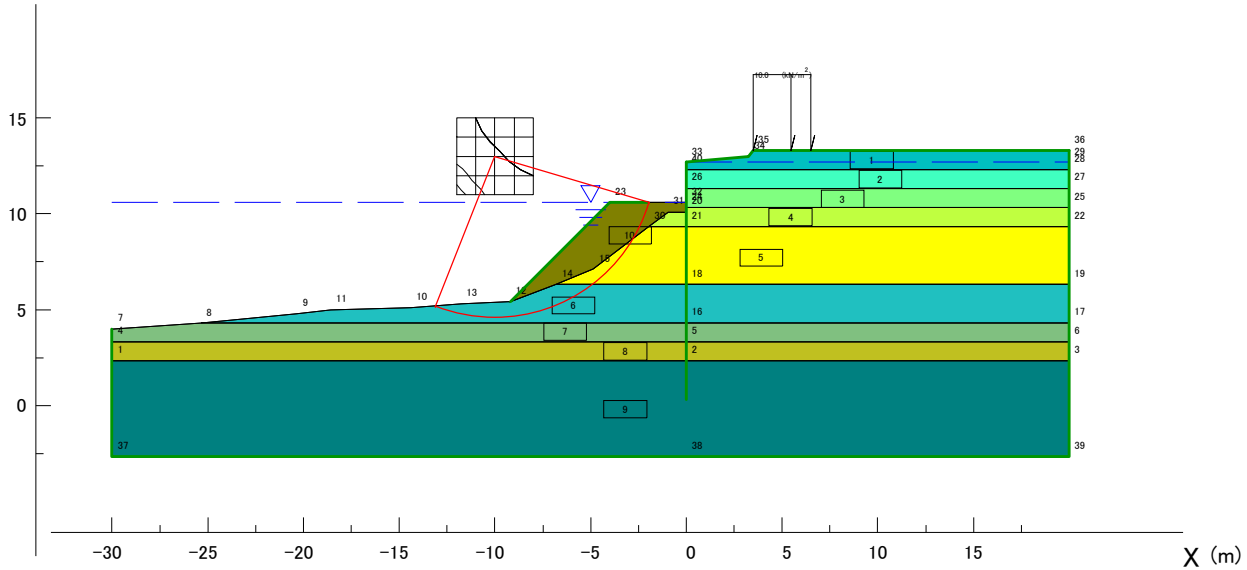
Riprap Stability Right Sta.6+415

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.016	
Center of arc	X	=	−10.00	(m)
	Y	=	13.00	(m)
Radius	R	=	8.40	(m)
Resisting moment	M_R	=	706.0	(kNm)
Sliding moment	M_D	=	694.7	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	18.00	18.00	28.00	1.00	0.00	0.000	0.000
2	16.00	16.00	0.00	50.00	0.00	0.000	0.000
3	16.00	16.00	0.00	25.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	18.00	18.00	27.00	1.00	0.00	0.000	0.000
7	18.00	18.00	28.00	1.00	0.00	0.000	0.000
8	18.00	18.00	28.00	1.00	0.00	0.000	0.000
9	20.00	20.00	45.00	1.00	0.00	0.000	0.000
10	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

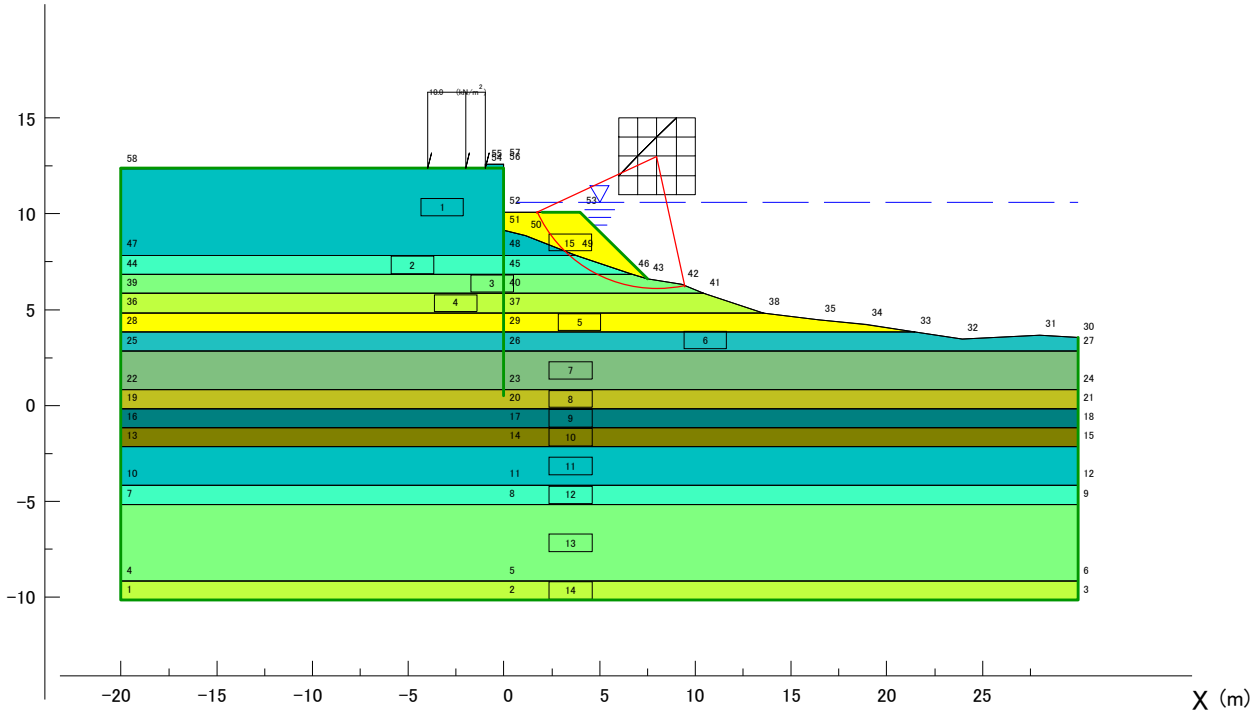
Riprap Stability Left Sta.2+600

Scale ; 1/ 396

Min. safety factor	$F_{S\,MIN}$	=	1.133	
Center of arc	X	=	8.00	(m)
	Y	=	13.00	(m)
Radius	R	=	6.90	(m)
Resisting moment	M_R	=	344.5	(kNm)
Sliding moment	M_D	=	303.9	(kNm)

Layer Number	Saturated Unit Weight (kN/m^3)	Wet Unit Weight (kN/m^3)	Friction Angle (Degree)	Cohesion (kN/m^2)	Rate of Increase of Cohesion	Horizontal Seismic Coefficient	Vertical Seismic Coefficient
1	16.00	16.00	27.00	1.00	0.00	0.000	0.000
2	18.00	18.00	27.00	1.00	0.00	0.000	0.000
3	18.00	18.00	27.00	1.00	0.00	0.000	0.000
4	18.00	18.00	27.00	1.00	0.00	0.000	0.000
5	18.00	18.00	27.00	1.00	0.00	0.000	0.000
6	16.00	16.00	0.00	12.00	0.00	0.000	0.000
7	16.00	16.00	0.00	12.00	0.00	0.000	0.000
8	16.00	16.00	0.00	18.00	0.00	0.000	0.000
9	16.00	16.00	0.00	18.00	0.00	0.000	0.000
10	16.00	16.00	0.00	12.00	0.00	0.000	0.000
11	16.00	16.00	0.00	12.00	0.00	0.000	0.000
12	16.00	16.00	0.00	18.00	0.00	0.000	0.000
13	16.00	16.00	0.00	24.00	0.00	0.000	0.000
14	16.00	16.00	0.00	25.00	0.00	0.000	0.000
15	19.00	19.00	40.00	0.00	0.00	0.000	0.000

Water unit weight = 9.80 (kN/m^3)



Contour Diagram (Ordinary Condition)

SLOPE STABILITY OF RIPRAP

CHAPTER 4 STRUCTURAL CALCULATION OF DRAINAGE FACILITIES

4.1 Design Conditions

Manhole and junction box are regard structure as fixed beam at three or four sides. And structural state is under ground structure, consequently, state of each pressure is regard as earth pressure at rest.

A passenger vehicle's passing is considered as the load effecting on cover and top slab of manhole.

(1) Concrete

Materials	f'_{ck} (N/mm^2)	E_c 10^4 (N/mm^2)
20.7	20.7	2.380

Unit weight γ_c = 24.00(kN/m^3)

(2) Reinforcing Steel Bar

Grade	F_{yk} (N/mm^2)	$E_s \times 10^5$ (N/mm^2)
275	275	2.000

(3) Groundwater Level

Depth (H) : 0.900(m)

Unit weight : 9.8(kN/m^3)

(4) Soil Conditions

Depth Z (m)	Unit weight (Wet) γ (kN/m^3)	Unit weight (saturated) γ_{sat} (kN/m^3)	Coefficient for earth pressure at rest K	Coefficient for vertical pressure α
10.000	18.000	20.000	0.5000	1.0000

(5) Live Load

(a) On Top Slab and Cover

Vehicle : T-2, 8.0 (kN)

Impact Coefficient : 0.300

(b) On the Ground

Live Load: 10.0 (kN/m^2)

(6) Calculation Case

(a) Manhole

Table R 4.1.1 Calculation Case of Manhole

Case		Inside Width b_1 (mm)	Inside Width b_2 (mm)	H (mm)	Remarks
1 -	1	1500	700	0 - 2000	Calculation Result is omitted.
	2			2000 - 2500	"
	3			2500 - 3000	"
	4			3000 - 3500	"
	5			3500 - 4000	"
	6			4000 - 4500	
2 -	1	2000	700	0 - 2000	Calculation Result is omitted.
	2			2000 - 2500	"
	3			2500 - 3000	
	4			3000 - 3500	
	5			3500 - 4000	
3 -	1	1500	1500	0 - 2000	Calculation Result is omitted
	2			2000 - 2500	"
	3			2500 - 3000	"
	4			3000 - 3500	"
	5			3500 - 4000	
4 -	1	1500	2300	0 - 2000	Calculation Result is omitted
	2			2000 - 2500	
	3			2500 - 3000	
	4			3000 - 3500	
	5			3500 - 4000	
5		1500	3500	3000 - 3500	
6		1500	3200	4000 - 4200	

(b) Junction Box

Table R 4.1.2 Calculation Case of Junction Box

Case	Inside Width b_1 (mm)	Inside Width b_2 (mm)	H (mm)	Remarks
1	900	900	0 - 1500	Calculation Result is omitted.
2			1500 - 2000	"
3			2500 - 2500	

(c) Manhole Cover

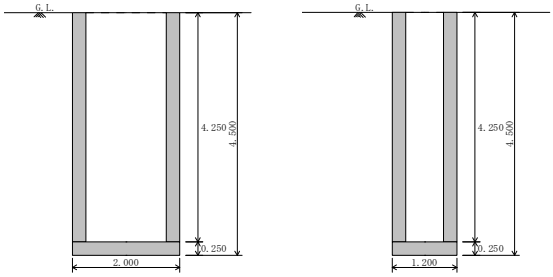
Table R 4.1.3 Calculation Case of Manhole Cover

Case	Width a (mm)	Length b (mm)	H (mm)	Remarks
1	600	1200	150	

4.2 Structural Calculation of Manhole

The detail of structural calculation of manhole is indicated from the following page.

1 CASE1-6 (1,500 X 700 X H4,500 M)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	-	-	-	-	-
Side Wall	2.000	1.500	2.000	1.500	4.250
Bottom Slab	2.000	1.500	2.000	1.500	0.250

1.1 Vertical Load

(1) Weight of Body

Top Slab	-	- (kN)
Side Wall	(2.000×1.200 - 1.500×0.700)×4.250×24.000	137.700 (kN)
Bottom Slab	2.000×1.200×0.250×24.000	14.400 (kN)

1.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

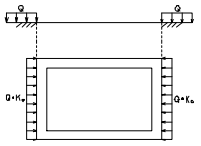
$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 10.000 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$P_l = Q \cdot K_0$

Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil γ(kN/m^3)	Ps (kN/m^2)	Pw (kN/m^2)	Pl (kN/m^2)	Total (kN/m^2)
0.000	Side Wall	Edge of Top	18.000	0.000	0.000	4.900	4.900
0.900	Side Wall	Water Surface	18.000	8.100	0.000	4.900	13.000
4.250	Side Wall	Edge of Bottom	10.000	24.850	32.830	4.900	62.580
4.375	Bottom Slab	Axis	10.000	25.475	34.055	4.900	64.430

1.3 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

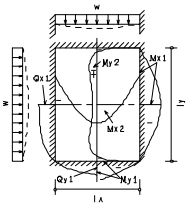
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{137.700 + 0.000}{2.400} + 0.000$$

$= 57.375$ (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 57.375 (kN/m^2)
lx : Length (short) = 0.950 (m)
ly : Length (long) = 1.750 (m)
α : ly/lx = 1.842

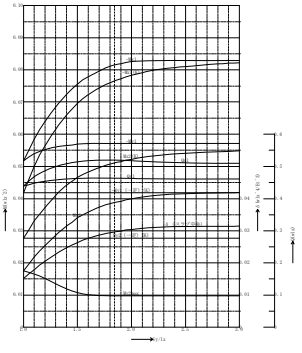


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0815	-4.221
Mx2	0.0511	2.648
long	α	M(kN.m)
My1	-0.0571	-2.957
My2	0.0277	1.434
My2max	0.0098	0.507

[2]Shear Force

short	α	Q (kN)
Qx1	0.5196	28.323
long	α	Q (kN)
Qy1	0.4632	25.250



(3) Calculation Result of Bottom Slab

(a) Back and Forth

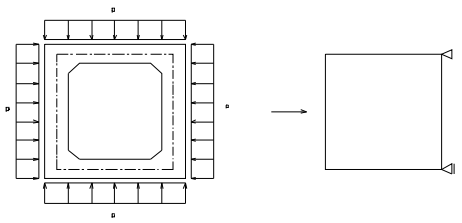
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-4.2212	2.6479	-4.2212
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	13.4162
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.9853	1.2454	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	67.7577	42.5033	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0974
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.9567	1.4343	-2.9567
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	18.0356
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.2286	0.5960	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	43.7884	21.2424	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.1208
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

1.4 Calculation of Side Wall

(1) Flame Model



Member	p (kN/m^2)	Back and Forth		Right and Left	
		A(m^2)	Geometrical moment of inertia I(m^4)	A(m^2)	Geometrical moment of inertia I(m^4)
Side Wall	63.015	0.250	0.001302	0.250	0.001302

(2) Calculation

(a) Front Wall

Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-12.008	54.758	29.725
0.250	h/2	-0.274	39.112	29.725
0.875	Center	11.949	0.000	29.725
1.500	h/2 点	-0.274	-39.113	29.725
1.750	Edge	-12.008	-54.758	29.725

(b) Back Wall

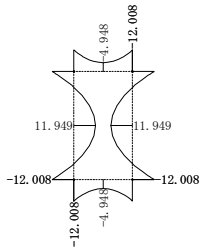
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-12.008	54.757	29.725
0.250	h/2	-0.274	39.112	29.725
0.875	Center	11.949	0.000	29.725
1.500	h/2 点	-0.274	-39.113	29.725
1.750	Edge	-12.008	-54.758	29.725

(c) Left Wall

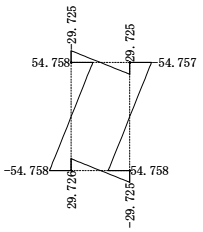
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-12.008	29.725	54.757
0.250	h/2	h/2	-6.532	14.081	54.757
0.475	Center	Center	-4.948	0.000	54.757
0.700	h/2 点	h/2	-6.532	-14.080	54.757
0.950	Edge	Edge	-12.008	-29.725	54.757

(d) Right Wall

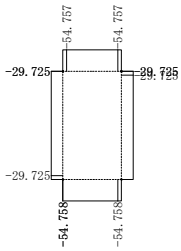
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-12.008	29.726	54.758
0.250	h/2	h/2	-6.532	14.081	54.758
0.475	Center	Center	-4.948	0.000	54.758
0.700	h/2 点	h/2	-6.532	-14.080	54.758
0.950	Edge	Edge	-12.008	-29.725	54.758



MAX = -12.008 (kN.m)



MAX = -55.758(kN)



MAX = 54.758 (kN)

(3) Calculation Results

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.0075	11.9489	-0.2738
Axial Force	N	kN	29.7255	29.7255	29.7255
Shear Force	V	kN	——	——	-39.1125
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	29.00	29.00	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	38.5632	38.6030	652.0132
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.5986	4.5738	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	130.3318	129.4506	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.2338
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.0075	-4.9477	-6.5318
Axial Force	N	kN	54.7575	54.7575	54.7575
Shear Force	V	kN	——	——	14.0805
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	53.42	53.42	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	46.3179	114.5486	74.7185
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.1591	0.9839	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	91.8718	3.5134	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.1042
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

1.5 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$

= 9.800×8.640

= 84.672 (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
1	2.000×1.200×3.350	8.040
2	2.000×1.200×0.250	0.600
Total	————	8.640

(b) Vertical Load

W = Wc + Wu

= 152.100 + 0.000

= 152.100 (kN)

(c) safety factor

Safy Factor F = W / U

= 152.100 / 84.672

= 1.796 ≧ Allowable Safety Factor F_a = 1.200

(2) Stability against Bearing

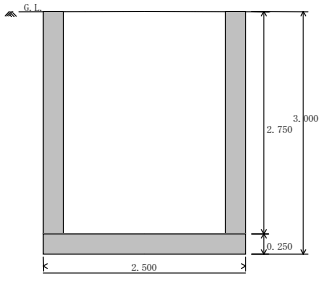
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	-	-
2	Side Wall	2.000×1.200×4.250×18.000	183.600
3	Bottom Slab	2.000×1.200×0.250×18.000	10.800
Total Ws			194.400

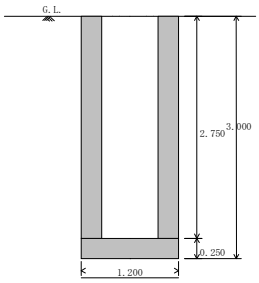
Ws / Wc = 194.400 / 152.100

= 1.278 ≧ 1.0

2 CASE1-2_3 (1,500 X 700 X H4,500 M)



Front



Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	-	-	-	-	-
Side Wall	2.500	2.000	1.200	0.700	2.750
Bottom Slab	2.500	0.000	1.200	0.000	0.250

2.1 Vertical Load

(1) Weight of Body

Top Slab	-	- (kN)
Side Wall	(2.500×1.200 - 2.000×0.700)×2.750×24.000	105.600 (kN)
Bottom Slab	2.500×1.200×0.250×24.000	18.000 (kN)

2.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

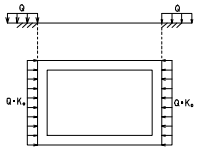
Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 10.000 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load
$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.000	Side Wall	Edge of Top	18.000	0.000	0.000	4.900	4.900
0.900	Side Wall	Water Surface	18.000	8.100	0.000	4.900	13.000
2.750	Side Wall	Edge of Bottom	10.000	17.350	18.130	4.900	40.380
2.875	Bottom Slab	Axis	10.000	17.975	19.355	4.900	42.230

2.3 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

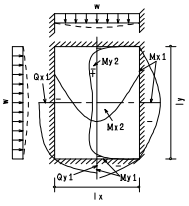
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{105.600 + 0.000}{3.000} + 0.000$$

= 35.200 (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 35.200 (kN/m^2)
lx : Length (short) = 0.950 (m)
ly : Length (long) = 2.250 (m)
α : ly/lx = 2.368



[1]Bending Moment

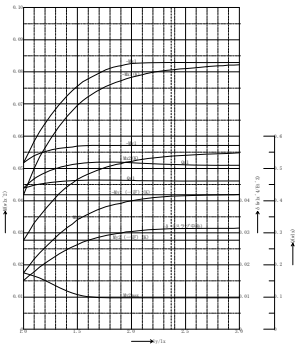
short	α	M(kN.m)
Mx1	-0.0829	-2.634
Mx2	0.0538	1.710

long	α	M(kN.m)
My1	-0.0571	-1.814
My2	0.0277	0.880
My2max	0.0098	0.311

[2]Shear Force

short	α	Q (kN)
Qx1	0.5123	17.130

long	α	Q (kN)
Qy1	0.4611	15.420



(3) Calculation Result of Bottom Slab

(a) Back and Forth

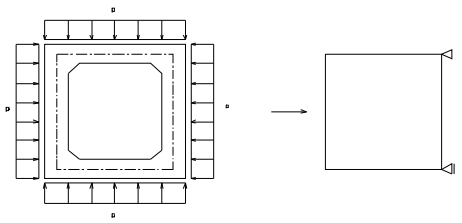
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.6336	1.7103	-2.6336
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	8.1141
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00	D12×4.00	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.2386	0.8044	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	42.2730	27.4529	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0589
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-1.8140	0.8800	-1.8140
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	11.9934
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	0.7537	0.3657	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	26.8645	13.0323	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0804
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

2.4 Calculation of Side Wall

(1) Flame Model



Member	p (kN/m^2)	Back and Forth		Right and Left	
		A(m^2)	Geometrical moment of inertia I(m^4)	A(m^2)	Geometrical moment of inertia I(m^4)
Side Wall	40.380	0.250	0.001302	0.250	0.001302

(2) Calculation

(a) Front Wall

Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-12.880	45.428	19.181
0.250	h/2	-2.785	35.333	19.181
1.125	Center	12.673	0.000	19.181
2.000	h/2 点	-2.785	-35.332	19.181
2.250	Edge	-12.880	-45.428	19.181

(b) Back Wall

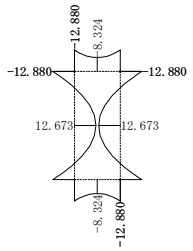
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-12.880	45.427	19.181
0.250	h/2	-2.785	35.333	19.181
1.125	Center	12.673	0.000	19.181
2.000	h/2 点	-2.785	-35.332	19.181
2.250	Edge	-12.880	-45.427	19.181

(c) Left Wall

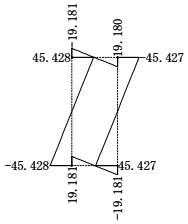
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-12.880	19.180	45.428
0.250	h/2	h/2	-9.346	9.085	45.428
0.475	Center	Center	-8.324	0.000	45.428
0.700	h/2 点	h/2	-9.346	-9.086	45.428
0.950	Edge	Edge	-12.880	-19.181	45.428

(d) Right Wall

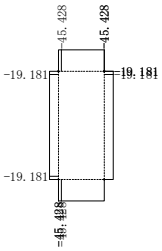
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-12.880	19.181	45.428
0.250	h/2	h/2	-9.346	9.085	45.428
0.475	Center	Center	-8.324	0.000	45.428
0.700	h/2 点	h/2	-9.346	-9.086	45.428
0.950	Edge	Edge	-12.880	-19.181	45.428



MAX = -12.880 (kN.m)



MAX = -45.428(kN)



MAX = 45.428 (kN)

(3) Calculation Results

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.8795	12.6734	-2.7845
Axial Force	N	kN	19.1805	19.1805	19.1805
Shear Force	V	kN	——	——	35.3325
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	18.71	18.71	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	45.6372	45.7136	72.0505
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.1016	4.0332	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	92.5032	90.7487	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.2598
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.8795	-8.3242	-9.3463
Axial Force	N	kN	45.4275	45.4275	45.4275
Shear Force	V	kN	——	——	-9.0855
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	44.32	44.32	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	52.9438	62.4462	59.1557
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.8398	2.2813	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	69.8801	32.0752	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0648
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

2.5 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$

9.800×6.300

61.740 (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
1	2.500×1.200×1.850	5.550
2	2.500×1.200×0.250	0.750
Total	——	6.300

(b) Vertical Load

W = Wc + Wu

= 123.600 + 0.000

= 123.600 (kN)

(c) safety factor

Safety Factor F = W / U

= 123.600 /61.740

= 2.002 ≧ Allowable Safety Factor F_a = 1.200

(2) Stability against Bearing

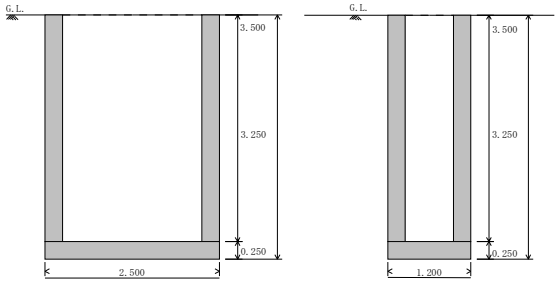
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	-	-
2	Side Wall	2.500×1.200×2.750×18.000	148.500
3	Bottom Slab	2.500×1.200×0.250×18.000	13.500
Total Ws			162.000

Ws / Wc = 162.000 / 123.600

= 1.311 ≧1.0

3 CASE2-4 (2,000 X 700 X H3,500 MM)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	-	-	-	-	-
Side Wall	2.500	2.000	1.200	0.700	3.250
Bottom Slab	2.500	0.000	1.200	0.000	0.250

3.1.1 Vertical Load

(1) Weight of Body

Top Slab	-	- (kN)
Pedestrian Load	-	- (kN)
Side Wall	(2.500×1.200 - 2.000×0.700)×3.250×24.000	124.800 (kN)
Bottom Slab	2.500×1.200×0.250×24.000	18.000 (kN)

(2) Water Pressure for Bottom Slab

$$Ww = \gamma w \cdot (h - hw)$$
$$= 9.800 \times (3.500 - 0.900)$$
$$= 25.480\ (kN/m^2)$$

3.1.2 Horizontal Load

(1) Earth Pressure

$$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

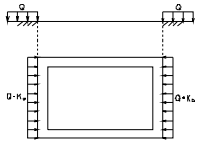
$$Pw = \gamma w \cdot hw$$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water =9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$$P_l = Q \cdot K_0$$

Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.000	Sidewall	Top	18.000	0.000	0.000	4.900	4.900
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.250	Sidewall	Bottom	10.000	19.850	23.030	4.900	47.780
3.375	Bottom	Center	10.000	20.475	24.255	4.900	49.630

3.1.3 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

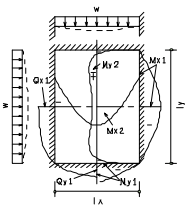
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{124.800 + 0.000}{3.000} + 0.000$$
$$= 41.600\ (kN/m^2)$$

(2) Moment and Shear Force

$$M = \alpha \cdot w \cdot lx^2$$
$$Q = \alpha \cdot w \cdot lx$$

ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 41.600 (kN/m^2)
lx : Length (short) = 0.950 (m)
ly : Length (long) = 2.250 (m)
α : ly/lx = 2.368



[1] Bending Moment

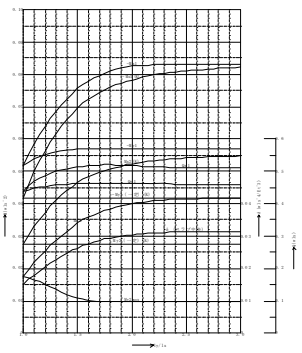
sh rt	α	M (kN. m)
Mx1	-0.0829	-3.112
Mx2	0.0538	2.021

long	α	M (kN. m)
My1	-0.0571	-2.144
My2	0.0277	1.04
My2max	0.0098	0.368

[2] Shear Force

short	α	Q (kN)
Qx1	0.5123	20.244

long	α	Q (kN)
Qyl	0.4611	18.224



(3) Calculation Result of Bottom Slab

(a) Back and Forth

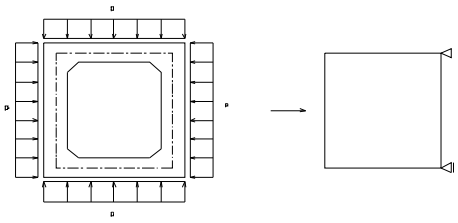
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.1124	2.0213	-3.1124
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	9.5894
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.4638	0.9506	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	49.9590	32.4444	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0696
Allowable Stress Intensity by Shear Force	$\tau_{\_al}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.1438	1.0400	-2.1438
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	14.1740
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_e	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	0.8908	0.4321	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	31.7490	15.4019	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0950
Allowable Stress Intensity by Shear Force	$\tau_{\_al}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

3.1.4 Calculation of Side Wall

(1) Flame Model



Member	p (kN/m^2)	Back and Forth		Right and Left	
		A(m^2)	Geometrical moment of inertia I(m^4)	A(m^2)	Geometrical moment of inertia I(m^4)
Side Wall	47.780	0.250	0.001302	0.250	0.001302

(2) Calculation

(a) Front Wall

Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-15.240	53.753	22.696
0.250	h/2	-3.295	41.808	22.696
1.125	Center	14.996	0.000	22.696
2.000	h/2	-3.295	-41.807	22.696
2.250	Edge	-15.240	-53.753	22.696

(b) Back Wall

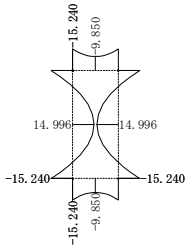
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-15.240	53.752	22.695
0.250	h/2	-3.295	41.808	22.695
1.125	Center	14.996	0.000	22.695
2.000	h/2	-3.295	-41.807	22.695
2.250	Edge	-15.240	-53.752	22.695

(c) Left Wall

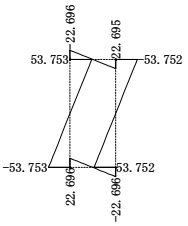
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-15.240	22.695	53.753
0.250	h/2	-11.059	10.751	53.753
0.475	Center	-9.850	0.000	53.753
0.700	h/2	-11.059	-10.750	53.753
0.950	Edge	-15.240	-22.696	53.753

(d) Right Wall

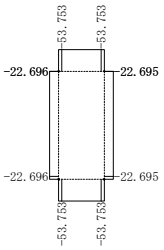
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-15.240	22.696	53.753
0.250	h/2	-11.059	10.751	53.753
0.475	Center	-9.850	0.000	53.753
0.700	h/2	-11.059	-10.750	53.753
0.950	Edge	-15.240	-22.696	53.753



MAX = -15.240 (kN.m)



MAX = -54.753 (kN)



MAX = 54.753 (kN)

(3) Calculation Results

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-15.2398	14.9960	-3.2948
Axial Force	N	kN	22.6955	22.6955	22.6955
Shear Force	V	kN	——	——	41.8075
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	22.14	22.14	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	45.6372	45.7136	72.0505
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.8532	4.7723	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	109.4553	107.3792	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.3074
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-15.2398	-9.8496	-11.0591
Axial Force	N	kN	53.7525	53.7525	53.7525
Shear Force	V	kN	——	——	10.7505
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	52.44	52.44	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	52.9438	62.4462	59.1557
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.5435	2.6994	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	82.6862	37.9533	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0766
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

3.1.5 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_b$

$= 9.800 \times 7.800$

$= 76.440$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
1	2.500×1.200×2.350	7.050
2	2.500×1.200×0.250	0.750
Total	——	7.800

(b) Vertical Load

$W = Wc + Wu$

$= 142.800 + 0.000$

$= 142.800$ (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 142.800 / 76.440$

$= 1.868 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

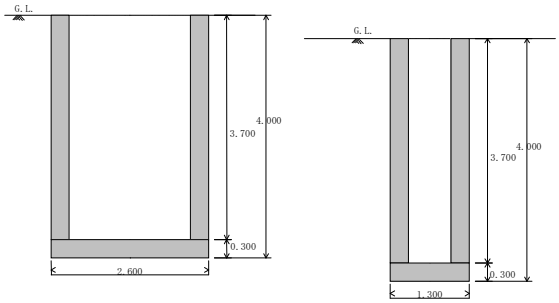
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	-	-
2	Side Wall	2.500×1.200×3.250×18.000	175.500
3	Bottom Slab	2.500×1.200×0.250×18.000	13.500
Total Ws			189.000

$Ws / Wc = 189.000 / 142.800$

$= 1.324 \geqq 1.0$

4 CASE1-2_5 (1,500 X 700 X H4,500 M)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	-	-	-	-	-
Side Wall	2.600	2.000	1.300	0.700	3.700
Bottom Slab	2.600	0.000	1.300	0.000	0.300

4.1 Vertical Load

(1) Weight of Body

Top Slab	-	- (kN)
Side Wall	(2.600×1.300 - 2.000×0.700)×3.700×24.000	175.824 (kN)
Bottom Slab	2.600×1.300×0.300×24.000	24.336 (kN)

4.2 Horizontal Load

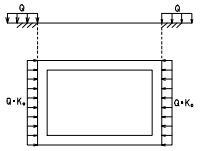
(1) Earth Pressure

Ps = $\Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$
Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

Pw = $\gamma w \cdot hw$
Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load
$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.000	Side Wall	Edge of Top	18.000	0.000	0.000	4.900	4.900
0.900	Side Wall	Water Surface	18.000	8.100	0.000	4.900	13.000
3.700	Side Wall	Edge of Bottom	10.000	22.100	27.440	4.900	54.440
3.850	Bottom Slab	Axis	10.000	22.850	28.910	4.900	56.660

4.3 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

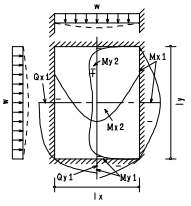
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{175.824 + 0.000}{3.380} + 0.000$$

= 52.019 (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 52.019 (kN/m^2)
lx : Length (short) = 1.000 (m)
ly : Length (long) = 2.300 (m)
α : ly/lx = 2.300



[1]Bending Moment

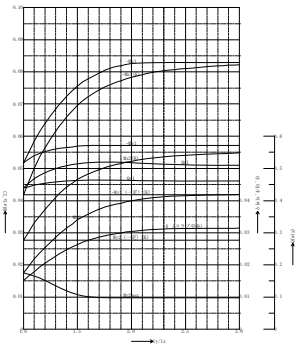
short	α	M(kN.m)
Mx1	-0.0829	-4.312
Mx2	0.0536	2.788

long	α	M(kN.m)
My1	-0.0571	-2.970
My2	0.0277	1.441
My2max	0.0098	0.510

[2]Shear Force

short	α	Q (kN)
Qx1	0.5132	26.696

long	α	Q (kN)
Qy1	0.4614	24.002



(3) Calculation Result of Bottom Slab

(a) Back and Forth

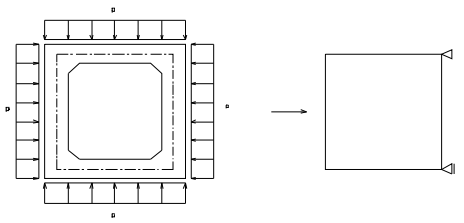
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-4.3124	2.7882	-4.3124
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.6784
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	198.0	198.0	198.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	36.2915	36.2915	36.2915
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.2786	0.8267	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	51.2739	33.1518	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0574
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.9703	1.4409	-2.9703
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	17.7403
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	37.4817	37.4817	37.4817
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	0.8025	0.3893	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	33.2425	16.1264	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0898
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

4.4 Calculation of Side Wall

(1) Flame Model



Member	p (kN/m^2)	Back and Forth		Right and Left	
		$A(m^2)$	Geometrical moment of inertia $I(m^4)$	$A(m^2)$	Geometrical moment of inertia $I(m^4)$
Side Wall	54.440	0.300	0.002250	0.300	0.002250

(2) Calculation

(a) Front Wall

Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-18.101	62.606	27.220
0.300	h/2	-1.769	46.274	27.220
1.150	Center	17.897	0.000	27.220
2.000	h/2 点	-1.769	-46.274	27.220
2.300	Edge	-18.101	-62.606	27.220

(b) Back Wall

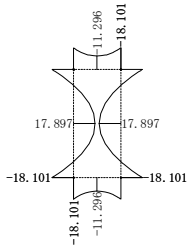
Distance (m)	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	-18.101	62.606	27.220
0.300	h/2	-1.769	46.274	27.220
1.150	Center	17.897	0.000	27.220
2.000	h/2 点	-1.769	-46.274	27.220
2.300	Edge	-18.101	-62.606	27.220

(c) Left Wall

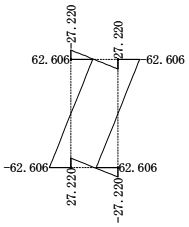
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-18.101	27.220	62.606
0.300	h/2	h/2	-12.385	10.888	62.606
0.500	Center	Center	-11.296	0.000	62.606
0.700	h/2 点	h/2	-12.385	-10.888	62.606
1.000	Edge	Edge	-18.101	-27.220	62.606

(d) Right Wall

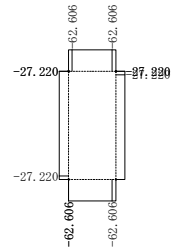
Distance (m)	Location	Location	M(kN.m)	S(kN)	N(kN)
0.000	Edge	Edge	-18.101	27.220	62.606
0.300	h/2	h/2	-12.385	10.888	62.606
0.500	Center	Center	-11.296	0.000	62.606
0.700	h/2 点	h/2	-12.385	-10.888	62.606
1.000	Edge	Edge	-18.101	-27.220	62.606



MAX = -18.101 (kN.m)



MAX = -62.606(kN)



MAX = 62.606 (kN)

(3) Calculation Results

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-18.1013	17.8972	-1.7693
Axial Force	N	kN	27.2200	27.2200	27.2200
Shear Force	V	kN	——	——	-46.2740
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	26.56	26.56	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	55.2030	55.2798	251.4691
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.7319	3.6883	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	94.1837	92.9067	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.2287
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-18.1013	-11.2963	-12.3851
Axial Force	N	kN	62.6060	62.6060	62.6060
Shear Force	V	kN	——	——	10.8880
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D16×4.00 804.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	61.08	61.08	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	66.9365	85.6654	80.4821
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.4798	1.9369	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	66.9358	25.3004	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0594
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

4.5 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$

9.800×10.478

102.684 (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
1	2.600×1.300×2.800	9.464
2	2.600×1.300×0.300	1.014
Total	——	10.478

(b) Vertical Load

W = Wc + Wu

= 200.160 + 0.000

= 200.160 (kN)

(c) safety factor

Safety Factor F = W / U

= 200.160 /102.684

= 1.949 ≧ Allowable Safety Factor F_a = 1.200

(2) Stability against Bearing

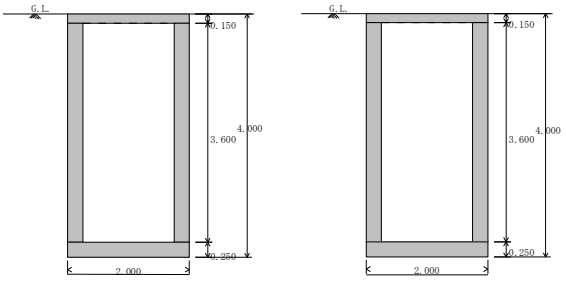
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	-	-
2	Side Wall	2.600×1.300×3.700×18.000	225.108
3	Bottom Slab	2.600×1.300×0.300×18.000	18.252
Total Ws			243.360

Ws / Wc = 243.360 /200.160

= 1.216 ≧1.0

5 CASE2-5 (1,500 X1,500 X H4,000 MM)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.000	0.000	2.000	0.000	0.150
Side Wall	2.000	1.500	2.000	1.500	3.600
Bottom Slab	2.000	0.000	2.000	0.000	0.250

5.1 Vertical Load

(1) Weight of Body

Top Slab	2.000×2.000×0.150×24.500	14.700 (kN)
Pedestrian Load	2.000×2.000×5.000	20.000 (kN)
Side Wall	(2.000×2.000 - 1.500×1.500)×3.600×24.000	151.200 (kN)
Bottom Slab	2.000×2.000×0.250×24.000	24.000 (kN)

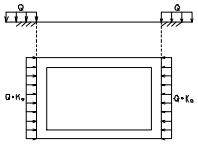
(2) Water Pressure for Bottom Slab

$Ww = \gamma w \cdot (h - hw)$
$= 9.800 \times (4.000 - 0.900)$
$= 30.380\ (kN/m^2)$

(3) Horizontal load by live load

$P_l = Q \cdot K_0$

Q : $= 9.800\ (kN/m^2)$



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.750	Sidewall	Bottom	10.000	22.350	27.930	4.900	55.180
3.875	Bottom Slab	Center	10.000	22.975	29.155	4.900	57.030

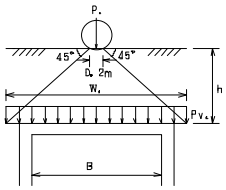
(3) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$$= 7.564\ (kN/m)$$

(b) Vertical Load of Live Load

$$P_{vl} = \frac{P_l \cdot \beta}{W_l} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$$= 34.036\ (kN/m^2)$$



$$\frac{1}{8} \cdot q_{vl} \cdot B_0^2 = \frac{1}{8} \cdot P_{vl} \cdot W_l \cdot (2B_0 - W_l) \quad \text{より}$$
$$q_{vl} = \frac{P_{vl} \cdot W_l}{B_0^2} \cdot (2B_0 - W_l)$$
$$q_{vl} = \frac{34.036 \times 0.200}{2.000^2} \cdot (2 \times 2.000 - 0.200)$$
$$= 6.467\ (kN/m^2)$$

5.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

5.3 Calculation of Top Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

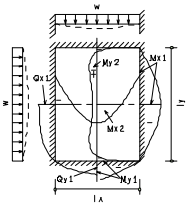
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W1 = \frac{34.700 + 0.000}{4.000} + 6.467$$
$$= 15.142\ (kN/m^2)$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、

M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 15.142 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 1.750 (m)
α : ly/lx = 1.000



[1] Bending Moment

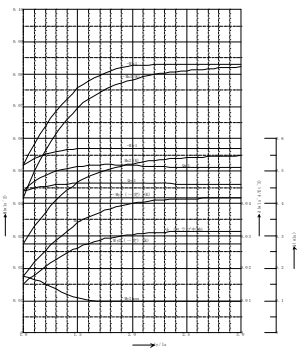
short	α	M (kN. m)
Mx1	-0.0518	-2.402
Mx2	0.0277	1.285

long	α	M (kN. m)
My1	-0.0518	-2.402
My2	0.0277	1.285
y2max	0.0176	0.816

[2] Shear Force

short	α	Q (kN)
Qx1	0.4390	11.633

long	α	Q (kN)
Qyl	0.4390	11.633



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.4021	1.2845	-2.4021
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	8.9739
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.3650	1.5802	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	37.7229	23.2224	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
	J		——	——	0.880
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1275
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

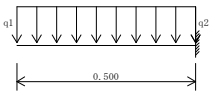
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.4021	1.2845	-2.4021
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	8.9739
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.3650	1.5802	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	37.7229	23.2224	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
	J		——	——	0.880
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1275
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

5.4 Calculation of Open of Top Slab

(1) Design Condition

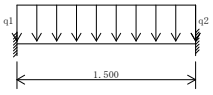
(a) Cantilever Beam

Span Length L (m)	0.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	21.783
Load q_2 (kN/m^2)	21.783



(b) Fixed Ended Beam

Span Length L (m)	1.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	6.467
Load q_2 (kN/m^2)	6.467



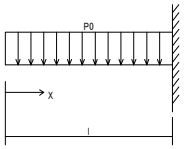
(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = -\frac{p_0 x^2}{2}$$

$$Qx = -p_0 x$$

p_0 : Effective Load = 21.783 (kN/m^2)
l : Span Length = 0.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)



1]Bending Moment

	x (m)	Mx (kN.m)
End	0.500	-2.723
Center	0.250	-0.681

[2]Shear Force

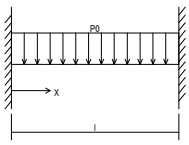
	x (m)	Qx (kN)
End	0.500	-10.892

(b) Fixed Ended Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$

p_0 : Effective Load = 6.467 (kN/m^2)
l : Span Length = 1.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)



[1]Bending Moment

	x (m)	Mx (kN.m)
Edge	0.000	-1.213
Center	0.750	0.606

[2]Shear Force

	x (m)	Qx (kN)
Edge	0.000	4.850

(3) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	80.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6809	0.6702
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	42.7608	10.6902
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.1548	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-1.2126	0.6063
Axial Force	N	kN	——	——
Shear Force	V	kN	4.8502	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.1939	0.7458
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	19.0424	10.9609
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0689	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

5.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

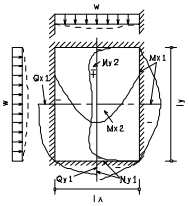
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{185.900 + 0.000}{4.000} + 6.467$$

$= 52.942$ (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 52.942 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 1.750 (m)
α : ly/lx = 1.000

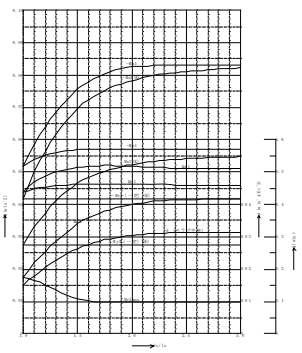


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0518	-8.399
Mx2	0.0277	4.491
long	α	M(kN.m)
My1	-0.0518	-8.399
My2	0.0277	4.491
My2max	0.0176	2.854

[2]Shear Force

short	α	Q (kN)
Qx1	0.4390	40.673
long	α	Q (kN)
Qy1	0.4390	40.673



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.3986	4.4911	-8.3986
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	29.0519
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.9500	2.1123	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	134.8108	72.0899	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2110
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

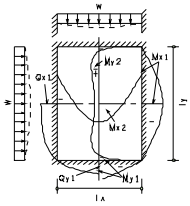
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.3986	4.4911	-8.3986
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	29.0519
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f'_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.4898	1.8662	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	124.3822	66.5133	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1947
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

5.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.171

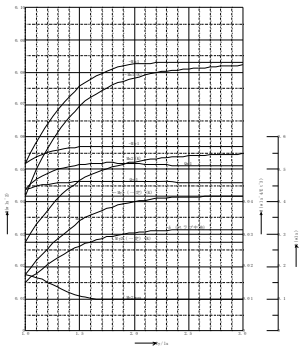


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-1.414
Mx2	0.0532	0.908
long	α	M(kN.m)
My1	-0.0571	-0.975
My2	0.0277	0.473
My2max	0.0098	0.167

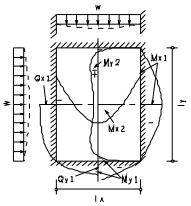
[2]Shear Force

short	α	Q (kN)
Qx1	0.5146	5.021
long	α	Q (kN)
Qy1	0.4613	4.501



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 51.455 (kN/m^2)
lx : Length (short) =1.750 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.171

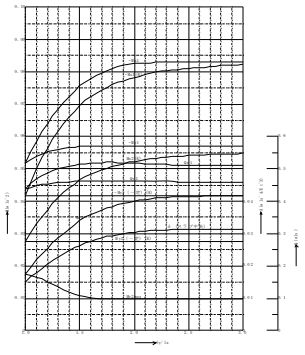


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0418	-6.594
Mx1max	-0.0507	-7.985
Mx2	0.0207	3.260
long	α	M(kN.m)
My1	-0.0463	-7.294
My2	0.0010	0.153
My2max	0.0100	1.576
My3	-0.0099	-1.556

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3641	32.782
long	α	Q (kN)
Qy1	0.4076	36.707
Qy3	0.0640	5.762



(c) Total Moment and Shear Force

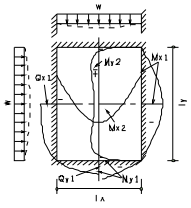
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.414	-7.985	-9.399
	Center	0.908	3.260	4.168
Vertical	Top	-0.975	-1.556	-2.530
	Center	0.473	1.576	2.049
	Bottom	-0.975	-7.294	-8.269

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.021	32.782	37.803
	Center	3.586	23.416	27.002
Vertical	Top	4.501	5.762	10.263
	Center	3.909	33.913	37.821
	Bottom	4.501	36.707	41.208

(2) Right and Left

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.171

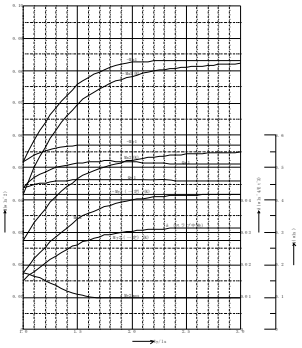


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-1.414
Mx2	0.0532	0.908
long	α	M(kN.m)
My1	-0.0571	-0.975
My2	0.0277	0.473
My2max	0.0098	0.167

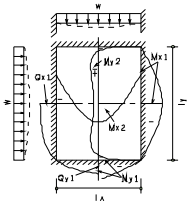
[2]Shear Force

short	α	Q (kN)
Qx1	0.5146	5.021
long	α	Q (kN)
Qy1	0.4613	4.501



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 51.455 (kN/m^2)
lx : Length (short) =1.750 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.171

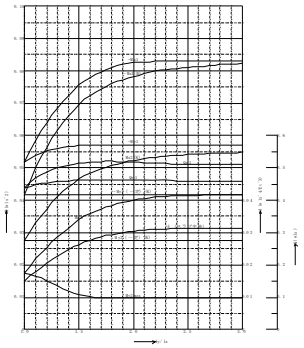


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0418	-6.594
Mx1max	-0.0507	-7.985
Mx2	0.0207	3.260
long	α	M(kN.m)
My1	-0.0463	-7.294
My2	0.0010	0.153
My2max	0.0100	1.576
My3	-0.0099	-1.556

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3641	32.782
long	α	Q (kN)
Qy1	0.4076	36.707
Qy3	0.0640	5.762



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.414	-7.985	-9.399
	Center	0.908	3.260	4.168
Vertical	Top	-0.975	-1.556	-2.530
	Center	0.473	1.576	2.049
	Bottom	-0.975	-7.294	-8.269

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.021	32.782	37.803
	Center	3.586	23.416	27.002
Vertical	Top	4.501	5.762	10.263
	Center	3.909	33.913	37.821
	Bottom	4.501	36.707	41.208

(3) Calculation Result of Side wall

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.2686	2.0487	-8.2686
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	37.8214
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.8889	0.9636	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	132.7251	32.8857	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2747
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-9.3993	4.1677	-9.3993
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	27.0019
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.9056	1.7318	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	139.2024	61.7239	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1809
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.2686	2.0487	-8.2686
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	37.8214
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.8889	0.9636	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	132.7251	32.8857	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2747
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-9.3993	4.1677	-9.3993
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	27.0019
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.9056	1.7318	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	139.2024	61.7239	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1809
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

5.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_W \cdot V_h$

$= 9.800 \times 12.400$

$= 121.520$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.000×2.000×2.850	11.400
3	2.000×2.000×0.250	1.000
Total	————	12.400

(b) Vertical Load

W = Wc + Wu

= 209.900 + 0.000

= 209.900 (kN)

(c) safety factor

Safety Factor F = W / U

= 209.900 / 121.520

= 1.727 ≧ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

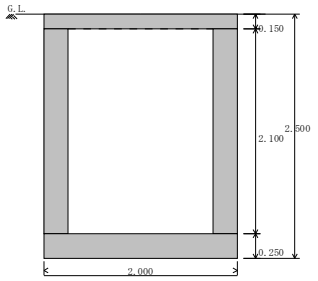
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.000×2.000×0.150×18.000	10.800
2	Side Wall	2.000×2.000×3.600×18.000	259.200
3	Bottom Slab	2.000×2.000×0.250×18.000	18.000
Total Ws			288.000

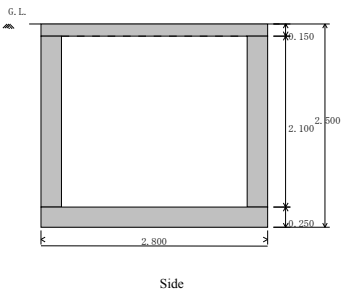
Ws / Wc = 288.000 / 209.900

= 1.372 ≧ 1.0

6 CASE4-2 (1,500 X 2,300 X H2,500 MM)



Front



Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.000	0.000	2.800	0.000	0.150
Side Wall	2.000	1.500	2.800	2.300	2.100
Bottom Slab	2.000	0.000	2.800	0.000	0.250

6.1 Vertical Load

(1) Weight of Body

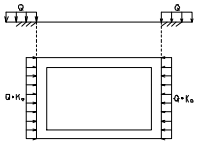
Top Slab	2.000×2.800×0.150×24.500	20.580 (kN)
Pedestrian Load	2.000×2.800×5.000	28.000 (kN)
Side Wall	(2.000×2.800 - 1.500×2.300)×2.100×24.000	108.360 (kN)
Bottom Slab	2.000×2.800×0.250×24.000	33.600 (kN)

(2) Water Pressure for Bottom Slab

$Ww = \gamma w \cdot (h - hw)$
$= 9.800 \times (2.500 - 0.900)$
$= 15.680\ (kN/m^2)$

(3) Horizontal load by live load

$P_l = Q \cdot K_0$
Q : $= 9.800\ (kN/m^2)$



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
2.250	Sidewall	Bottom	10.000	14.850	13.230	4.900	32.980
2.375	Bottom Slab	Center	10.000	15.475	14.455	4.900	34.830

6.3 Calculation of Top Slab

(1) Load

$$W1 = \frac{Wc + Wu}{A} + P_{vl}$$

W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W1 = \frac{48.580 + 0.000}{5.600} + 6.467$$

$= 15.142\ (kN/m^2)$

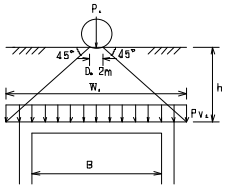
(3) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$= 7.564\ (kN/m)$

(b) Vertical Load of Live Load

$$P_{vl} = \frac{P_l \cdot \beta}{W_l} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$= 34.036\ (kN/m^2)$



$$\frac{1}{8} \cdot q_{vl} \cdot B_0^2 = \frac{1}{8} \cdot P_{vl} \cdot W_l \cdot (2B_0 - W_l) \quad \text{より}$$
$$q_{vl} = \frac{P_{vl} \cdot W_l}{B_0^2} \cdot (2B_0 - W_l)$$
$$q_{vl} = \frac{34.036 \times 0.200}{2.000^2} \cdot (2 \times 2.000 - 0.200)$$
$= 6.467\ (kN/m^2)$

6.2 Horizontal Load

(1) Earth Pressure

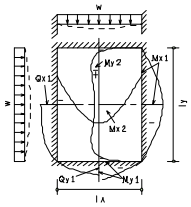
$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$
Ps : Horizontal Earth Pressure (kN/m^2)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$
Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 15.142 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.457



[1] Bending Moment

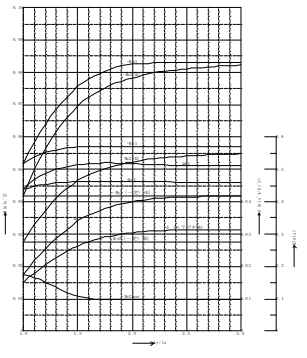
short	α	M (kN. m)
Mx1	-0.0743	-3.446
Mx2	0.0456	2.113

long	α	M (kN. m)
My1	-0.0567	-2.631
My2	0.0277	1.285
My2max	0.0112	0.521

[2] Shear Force

short	α	Q (kN)
Qx1	0.5124	13.578

long	α	Q (kN)
Qyl	0.4623	12.249



(3) Calculation Result of Top Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.6306	1.2845	-2.6306
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.3279
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 904.80	D12×4.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.5901	1.5802	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	41.3121	23.2224	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1467
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

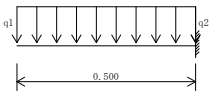
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.4461	2.1132	-3.4461
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.4746
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.4495	1.9971	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	64.2439	32.3339	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0741
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

6.4 Calculation of Open of Top Slab

(1) Design Condition

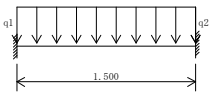
(a) Cantilever Beam

Span Length L (m)	0.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	21.783
Load q_2 (kN/m^2)	21.783



(b) Fixed Ended Beam

Span Length L (m)	1.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	6.467
Load q_2 (kN/m^2)	6.467

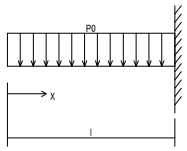


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = -\frac{p_0 x^2}{2}$$

$$Qx = -p_0 x$$



p_0 : Effective Load = 21.783 (kN/m^2)
l : Span Length = 0.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

1]Bending Moment

	x (m)	Mx (kN.m)
End	0.500	-2.723
Center	0.250	-0.681

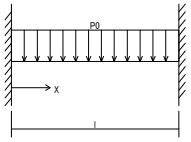
[2]Shear Force

	x (m)	Qx (kN)
End	0.500	-10.892

(b) Fixed Ended Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 6.467 (kN/m^2)
l : Span Length = 1.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

[1]Bending Moment

	x (m)	Mx (kN.m)
Edge	0.000	-1.213
Center	0.750	0.606

[2]Shear Force

	x (m)	Qx (kN)
Edge	0.000	4.850

(3) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	150.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	26.1108	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5157	0.8789
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	50.7610	12.6903
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0771	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-1.2126	0.6063
Axial Force	N	kN	——	——
Shear Force	V	kN	4.8502	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.1939	0.7458
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	19.0424	10.9609
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0689	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

6.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

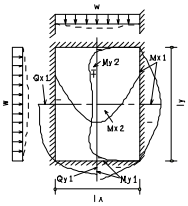
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{156.940 + 0.000}{5.600} + 6.467$$

$= 34.492$ (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 34.492 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.457

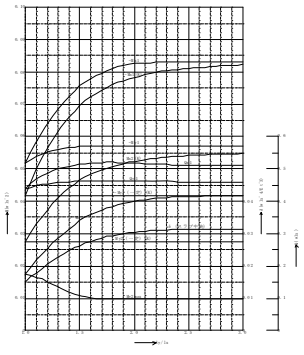


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0743	-7.850
Mx2	0.0456	4.814
long	α	M(kN.m)
My1	-0.0567	-5.992
My2	0.0277	2.926
My2max	0.0112	1.186

[2]Shear Force

short	α	Q (kN)
Qx1	0.5124	30.930
long	α	Q (kN)
Qy1	0.4623	27.903



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-5.9923	2.9260	-5.9923
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	22.4319
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.8183	1.3761	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	96.1865	46.9669	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1629
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

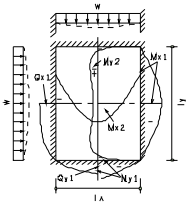
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-7.8499	4.8138	-7.8499
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	22.0927
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.2619	2.0003	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	116.2568	71.2917	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1480
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

6.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.300 (m)
α : ly/lx = 1.314

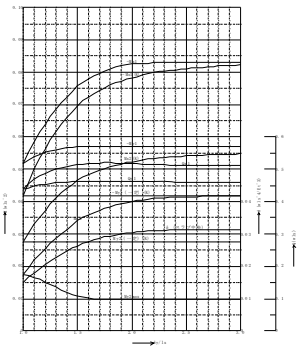


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0691	-1.201
Mx2	0.0416	0.722
long	α	M(kN.m)
My1	-0.0561	-0.975
My2	0.0277	0.481
My2max	0.0132	0.230

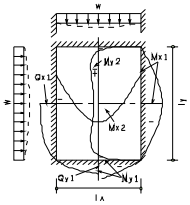
[2]Shear Force

short	α	Q (kN)
Qx1	0.5010	4.975
long	α	Q (kN)
Qy1	0.4587	4.555



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 29.255 (kN/m^2)
lx : Length (short) =1.750 (m)
ly : Length (long) = 2.300 (m)
α : ly/lx = 1.314

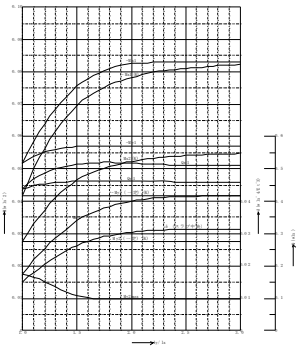


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0348	-3.117
Mx1max	-0.0369	-3.309
Mx2	0.0145	1.299
long	α	M(kN.m)
My1	-0.0402	-3.602
My2	0.0067	0.596
My2max	0.0100	0.896
My3	-0.0167	-1.495

[2]Shear Force

short	α	Q (kN)
Qx1max	0.2981	15.260
long	α	Q (kN)
Qy1	0.3665	18.766
Qy3	0.1065	5.455



Total Moment and Shear Force

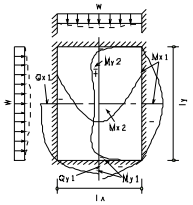
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.201	-3.309	-4.509
	Center	0.722	1.299	2.021
Vertical	Top	-0.975	-1.495	-2.470
	Center	0.481	0.896	1.377
	Bottom	-0.975	-3.602	-4.576

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	4.975	15.260	20.235
	Center	3.554	10.900	14.454
Vertical	Top	4.555	5.455	10.010
	Center	3.565	16.133	19.698
	Bottom	4.555	18.766	23.321

(2) Left and Right

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 2.300 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.109



[1]Bending Moment

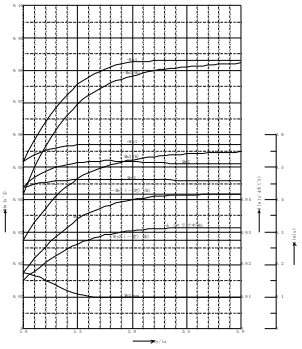
short	α	M(kN.m)
Mx1	-0.0589	-1.769
Mx2	0.0335	1.005

long	α	M(kN.m)
My1	-0.0540	-1.622
My2	0.0277	0.832
My2max	0.0164	0.492

[2]Shear Force

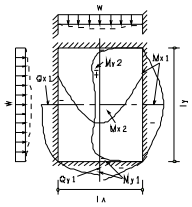
short	α	Q (kN)
Qx1	0.4699	6.134

long	α	Q (kN)
Qy1	0.4487	5.856



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 29.255 (kN/m^2)
lx : Length (short) = 2.300 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.109



[1]Bending Moment

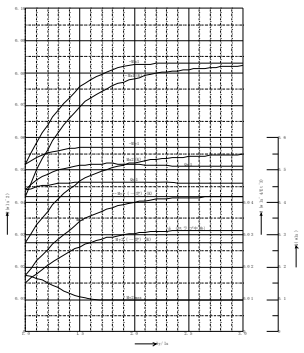
short	α	M(kN.m)
Mx1	-0.0376	-5.818
Mx2	0.0111	1.711
Mx2max	0.0123	1.897
Mx3	-0.0213	-3.303

long	α	M(kN.m)
My1	-0.0271	-4.192
My1max	-0.0279	-4.310
My2	0.0082	1.276
My2max	0.0082	1.276

[2]Shear Force

short	α	Q (kN)
Qx1	0.3432	23.092
Qx3	0.1374	9.248

long	α	Q (kN)
Qy1max	0.2437	16.395



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.622	-4.310	-5.932
	Center	0.832	1.276	2.108
Vertical	Top	-1.769	-3.303	-5.072
	Center	1.005	1.897	2.901
	Bottom	-1.769	-5.818	-7.587

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.856	16.395	22.251
	Center	4.708	13.180	17.888
Vertical	Top	6.134	9.248	15.382
	Center	4.800	19.576	24.377
	Bottom	6.134	23.092	29.225

(3) Calculation Result of Side Slab

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-4.5764	1.3774	-4.5764
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	19.6981
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.1524	0.6478	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	73.4588	22.1087	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1430
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-4.5095	2.0214	-4.5095
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	14.4539
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.8738	0.8399	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	66.7853	29.9361	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0968
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-7.5871	2.9015	-7.5871
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	24.3769
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.39	D12×4.00 452.39	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5684	1.3646	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	121.7876	46.5737	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1770
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-5.9321	2.1080	-5.9321
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	17.8879
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.4650	0.8759	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	87.8547	31.2193	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1199
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

6.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$

$= 9.800 \times 8.960$

$= 87.808$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.000×2.800×1.350	7.560
3	2.000×2.800×0.250	1.400
Total	———	8.960

(b) Vertical Load

$W = Wc + Wu$

$= 190.540 + 0.000$

$= 190.540$ (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 190.540 / 87.808$

$= 2.170 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

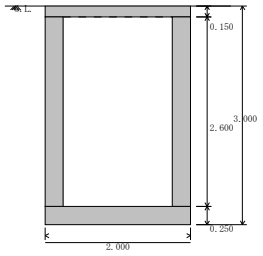
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.000×2.800×0.150×18.000	15.120
2	Side Wall	2.000×2.800×2.100×18.000	211.680
3	Bottom Slab	2.000×2.800×0.250×18.000	25.200
Total Ws			252.000

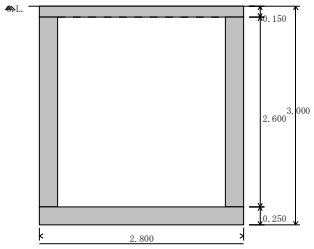
$Ws / Wc = 252.000 / 190.540$

$= 1.323 \geqq 1.0$

7 CASE4-3 (1,500 X 2,300 X H3,000 MM)



Front



side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.000	0.000	2.800	0.000	0.150
Side Wall	2.000	1.500	2.800	2.300	2.600
Bottom Slab	2.000	0.000	2.800	0.000	0.250

7.1 Vertical Load

(1) Weight of Body

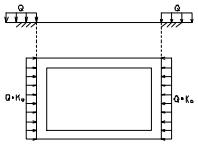
Top Slab	2.000×2.800×0.150×24.500	20.580 (kN)
Pedestrian Load	2.000×2.800×5.000	28.000 (kN)
Side Wall	(2.000×2.800 - 1.500×2.300)×2.600×24.000	134.160 (kN)
Bottom Slab	2.000×2.800×0.250×24.000	33.600 (kN)

(2) Water Pressure for Bottom Slab

$Ww = \gamma w \cdot (h - hw)$
$= 9.800 \times (3.000 - 0.900)$
$= 20.580\ (kN/m^2)$

(3) Horizontal load by live load

$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m²)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m²)	Pw (kN/m²)	P_l (kN/m²)	Total (kN/m²)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
2.750	Sidewall	Bottom	10.000	17.350	18.130	4.900	40.380
2.875	Bottom Slab	Center	10.000	17.975	19.355	4.900	42.230

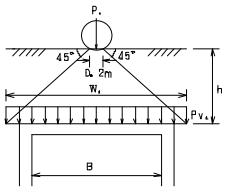
(3) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$$= 7.564\ (kN/m)$$

(b) Vertical Load of Live Load

$$P_{vl} = \frac{P_l \cdot \beta}{W_1} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$$= 34.036\ (kN/m^2)$$



$$\frac{1}{8} \cdot q_{vl} \cdot B_0^2 = \frac{1}{8} \cdot P_{vl} \cdot W_1 \cdot (2B_0 - W_1) \quad \text{上下}$$
$$q_{vl} = \frac{P_{vl} \cdot W_1}{B_0^2} \cdot (2B_0 - W_1)$$
$$q_{vl} = \frac{34.036 \times 0.200}{2.000^2} \cdot (2 \times 2.000 - 0.200)$$
$$= 6.467\ (kN/m^2)$$

7.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m²)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m³)
γ' : Submerged unit weight (kN/m³)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m²)
γw : Unit weight of water = 9.800 (kN/m³)
hw : Depth (m)

7.3 Calculation of Top Slab

(1) Load

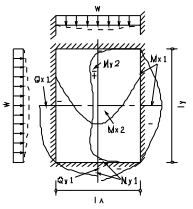
$$W1 = \frac{Wc + Wu}{A} + P_{vl}$$

W3 : Subgrage Reaction for Bottom Slab (kN/m²)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m²)
P_{vl} : Vertical Load by by Live Load (kN/m²)

$$W1 = \frac{48.580 + 0.000}{5.600} + 6.467$$
$$= 15.142\ (kN/m^2)$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 15.142 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.457



[1] Bending Moment

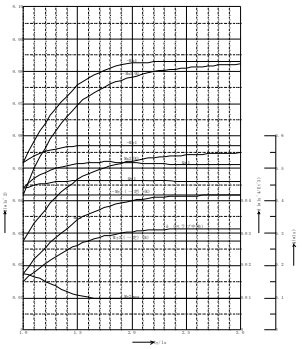
short	α	M (kN. m)
Mx1	-0.0743	-3.446
Mx2	0.0456	2.1 3

long	α	M (kN. m)
My1	-0.0567	-2.631
My2	0.0277	1.285
My2max	0.0112	0.521

[2] Shear Force

short	α	Q (kN)
Qx1	0.5124	13.578

long	α	Q (kN)
Qyl	0.4623	12.249



(3) Calculation Result of Top Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.6306	1.2845	-2.6306
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.3279
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 904.80	D12×4.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.5901	1.5802	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	41.3121	23.2224	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1467
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

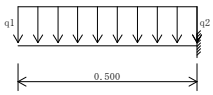
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.4461	2.1132	-3.4461
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.4746
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.4495	1.9971	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	64.2439	32.3339	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0741
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

7.4 Calculation of Open of Top Slab

(1) Design Condition

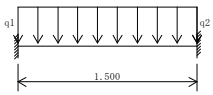
(a) Cantilever Beam

Span Length L (m)	0.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	21.783
Load q_2 (kN/m^2)	21.783



(b) Fixed Ended Beam

Span Length L (m)	1.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	6.467
Load q_2 (kN/m^2)	6.467

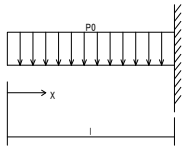


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = -\frac{p_0 x^2}{2}$$

$$Qx = -p_0 x$$



p_0 : Effective Load = 21.783 (kN/m^2)
l : Span Length = 0.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

1]Bending Moment

	x (m)	Mx (kN.m)
End	0.500	-2.723
Center	0.250	-0.681

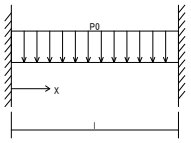
[2]Shear Force

	x (m)	Qx (kN)
End	0.500	-10.892

(b) Fixed Ended Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 6.467 (kN/m^2)
l : Span Length = 1.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

[1]Bending Moment

	x (m)	Mx (kN.m)
Edge	0.000	-1.213
Center	0.750	0.606

[2]Shear Force

	x (m)	Qx (kN)
Edge	0.000	4.850

(3) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	150.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	26.1108	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5157	0.8789
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	50.7610	12.6903
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0771	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-1.2126	0.6063
Axial Force	N	kN	——	——
Shear Force	V	kN	4.8502	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.1939	0.7458
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	19.0424	10.9609
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0689	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

7.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

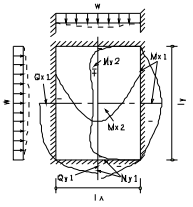
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{182.740 + 0.000}{5.600} + 6.467$$

$$= 39.099 \text{ (kN/m}^2\text{)}$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 39.099(kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.457

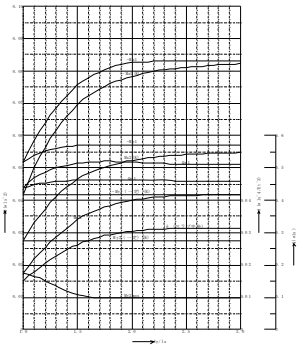


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0743	-8.898
Mx2	0.0456	5.457
long	α	M(kN.m)
My1	-0.0567	-6.793
My2	0.0277	3.317
My2max	0.0112	1.345

[2]Shear Force

short	α	Q (kN)
Qx1	0.5124	35.061
long	α	Q (kN)
Qy1	0.4623	31.630



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-6.7927	3.3168	-6.7927
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	25.4282
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	148.0	148.0	148.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	30.8838	30.8838	30.8838
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.1947	1.5600	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	109.0343	53.2404	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1847
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

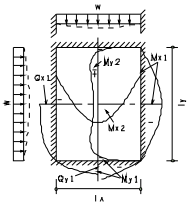
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.8985	5.4568	-8.8985
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	25.0436
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	41.4429	32.2571	41.4429
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.9388	2.2674	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	75.6649	80.8142	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1713
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

7.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 1.750 (m)
ly : Length (long) = 2.800 (m)
α : ly/lx = 1.600

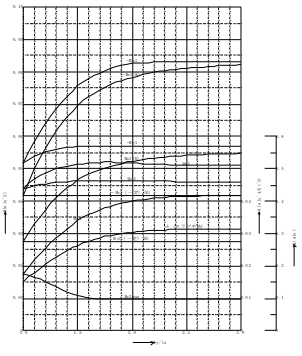


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0779	-1.354
Mx2	0.0483	0.839
long	α	M(kN.m)
My1	-0.0571	-0.992
My2	0.0277	0.481
My2max	0.0101	0.176

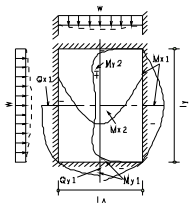
[2]Shear Force

short	α	Q (kN)
Qx1	0.5178	5.142
long	α	Q (kN)
Qy1	0.4632	4.600



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 36.655 (kN/m^2)
lx : Length (short) =1.750 (m)
ly : Length (long) = 2.800 (m)
α : ly/lx = 1.600

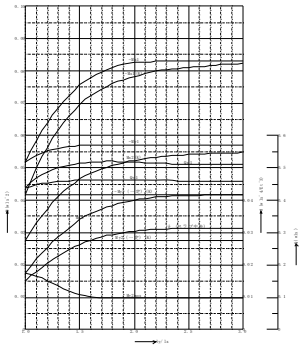


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0393	-4.412
Mx1max	-0.0438	-4.917
Mx2	0.0180	2.021
long	α	M(kN.m)
My1	-0.0433	-4.861
My2	0.0045	0.505
My2max	0.0100	1.123
My3	-0.0138	-1.549

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3294	21.130
long	α	Q (kN)
Qy1	0.3854	24.722
Qy3	0.0876	5.619



(c) Total Moment and Shear Force

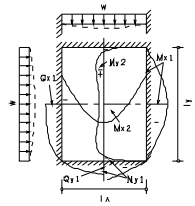
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.354	-4.917	-6.271
	Center	0.839	2.021	2.860
Vertical	Top	-0.992	-1.549	-2.542
	Center	0.481	1.123	1.604
	Bottom	-0.992	-4.861	-5.853

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.142	21.130	26.272
	Center	3.673	15.093	18.766
Vertical	Top	4.600	5.619	10.219
	Center	3.779	22.013	25.792
	Bottom	4.600	24.722	29.322

(2) Right and Left

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 2.550 (m)
ly : Length (long) = 2.800 (m)
α : ly/lx = 1.098

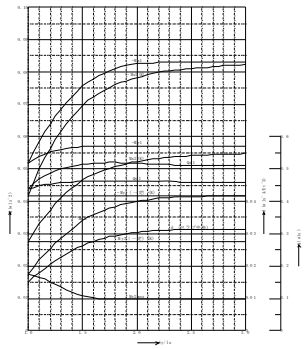


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0583	-2.150
Mx2	0.0330	1.218
long	α	M(kN.m)
My1	-0.0539	-1.988
My2	0.0277	1.022
My2max	0.0165	0.610

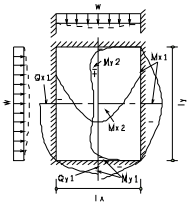
[2]Shear Force

short	α	Q (kN)
Qx1	0.4676	6.766
long	α	Q (kN)
Qy1	0.4480	6.483



(a) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 36.655 (kN/m^2)
lx : Length (short) = 2.550 (m)
ly : Length (long) = 2.800 (m)
α : ly/lx = 1.098

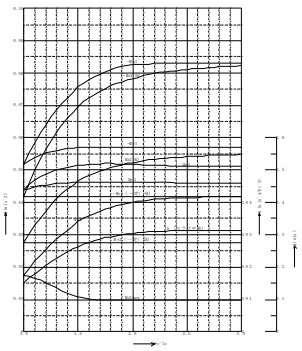


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0295	-7.039
Mx1max	-0.0304	-7.253
Mx2	0.0109	2.589
long	α	M(kN.m)
My1	-0.0362	-8.640
My2	0.0083	1.980
My2max	0.0102	2.431
My3	-0.0180	-4.290

[2]Shear Force

short	α	Q (kN)
Qx1max	0.2617	24.461
long	α	Q (kN)
Qy1	0.3455	32.292
Qy3	0.1187	11.094



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-2.150	-7.253	-9.403
	Center	1.218	2.589	3.806
Vertical	Top	-1.988	-4.290	-6.278
	Center	1.022	2.431	3.453
	Bottom	-1.988	-8.640	-10.628

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	6.766	24.461	31.227
	Center	5.440	19.665	25.104
Vertical	Top	6.483	11.094	17.577
	Center	5.326	28.418	33.744
	Bottom	6.483	32.292	38.775

(3) Calculation Result of side wall

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-5.8531	1.6040	-5.8531
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	25.7916
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	146.0	148.0	146.0
Applied area of Reinforcement	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	39.3066	30.8838	39.3066
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.2411	0.7544	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	54.7499	25.7464	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1941
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-6.2707	2.8600	-6.2707
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	18.7658
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6056	1.1884	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	92.8684	42.3571	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1257
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-10.6276	3.4533	-10.6276
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	33.7435
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	146.0	148.0	146.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	39.3066	30.8838	39.3066
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.0693	1.6242	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	99.4115	55.4317	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2539
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-9.4033	3.8062	-9.4033
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	25.1042
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	250.0	250.0	250.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	160.0	160.0	160.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcemen 0.0020・B・H	As_{min}	mm^2	500.00	500.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	32.2571	32.2571	32.2571
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.9073	1.5816	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	139.2615	56.3695	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1682
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

7.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$
$= 9.800 \times 11.760$
$= 115.248$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.000×2.800×1.850	10.360
3	2.000×2.800×0.250	1.400
Total	———	11.760

(b) Vertical Load

$W = Wc + Wu$
$= 216.340 + 0.000$
$= 216.340$ (kN)

(c) safety factor

Safety Factor $F = W / U$
$= 216.340 / 115.248$
$= 1.877 \geqq$ Allowable Safety Factor $F_a = 1.200$

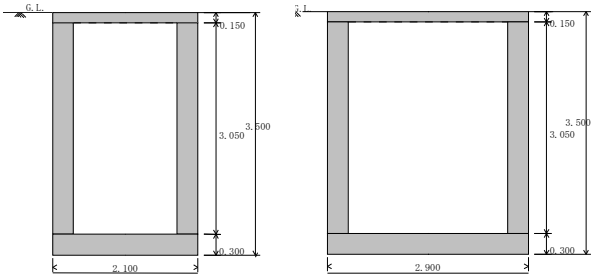
(2) Stability against Bearing

Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.000×2.800×0.150×18.000	15.120
2	Side Wall	2.000×2.800×2.600×18.000	262.080
3	Bottom Slab	2.000×2.800×0.250×18.000	25.200
Total Ws			302.400

$Ws / Wc = 302.400 / 216.340$
$= 1.398 \geqq 1.0$

8 CASE1-4_4-2 (1,500 X 700 X H4,500 M)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.100	0.000	2.900	0.000	0.150
Side Wall	2.100	1.500	2.900	2.300	3.050
Bottom Slab	2.100	0.000	2.900	0.000	0.300

8.1 Vertical Load

(1) Weight of Body

Top Slab	2.100×2.900×0.150×24.500	22.381 (kN)
Pedestrian Load	2.100×2.900×5.000	30.450 (kN)
Side Wall	(2.100×2.900 - 1.500×2.300)×3.050×24.000	193.248 (kN)
Bottom Slab	2.100×2.900×0.300×24.000	43.848 (kN)

(1) Water Pressure for Bottom Slab

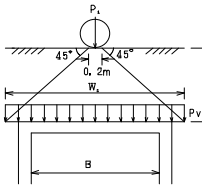
$$Ww = \gamma w \cdot (h - hw)$$
$$= 9.800 \times (3.500 - 0.900)$$
$$= 25.480\ (kN/m^2)$$

(2) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$$= 7.564\ (kN/m)$$

(b) Vertical Load of Live Load



$$P_{vl} = \frac{P_l \cdot \beta}{W_l} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$$= 34.036\ (kN/m^2)$$

$$\frac{1}{8} \cdot q_{vl} \cdot B_0^2 = \frac{1}{8} \cdot P_{vl} \cdot W_l \cdot (2B_0 - W_l) \quad \text{모멘트}$$
$$q_{vl} = \frac{P_{vl} \cdot W_l}{B_0^2} \cdot (2B_0 - W_l)$$
$$q_{vl} = \frac{34.036 \times 0.200}{2.100^2} \cdot (2 \times 2.100 - 0.200)$$
$$= 6.174\ (kN/m^2)$$

8.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

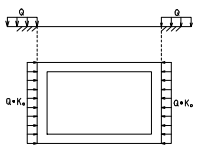
Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load
$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.200	Sidewall	Bottom	10.000	19.600	22.540	4.900	47.040
3.350	Bottom Slab	Center	10.000	20.350	24.010	4.900	49.260

8.3 Calculation of Bottom Slab

(1) Load

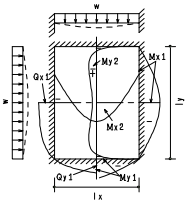
$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W1 = \frac{52.831 + 0.000}{6.090} + 6.174$$
$$= 14.849\ (kN/m^2)$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 14.849 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 2.600 (m)
α : ly/lx = 1.444

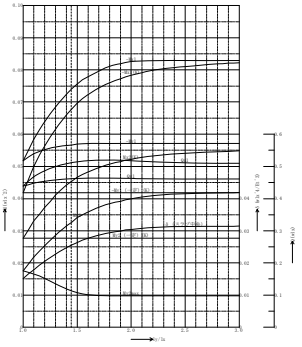


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0739	-3.556
Mx2	0.0453	2.178
long	α	M(kN.m)
My1	-0.0567	-2.727
My2	0.0277	1.333
My2max	0.0114	0.547

[2]Shear Force

short	α	Q (kN)
Qx1	0.5117	13.678
long	α	Q (kN)
Qy1	0.4621	12.351



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.7269	1.3327	-2.7269
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.2129
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6848	1.6395	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	42.8238	24.0937	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.1451
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

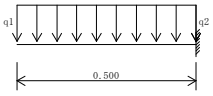
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.5560	2.1779	-3.5560
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.2586
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・$10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.5914	2.0582	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	66.2928	33.3228	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0726
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

8.4 Calculation of Open of Top Slab

(1) Design Condition

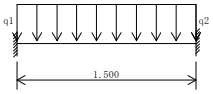
(a) Cantilever Beam

Span Length L (m)	0.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	21.783
Load q_2 (kN/m^2)	21.783



(b) Fixed Ended Beam

Span Length L (m)	1.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	6.174
Load q_2 (kN/m^2)	6.174

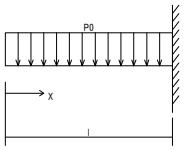


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = -\frac{p_0 x^2}{2}$$

$$Qx = -p_0 x$$



p_0 : Effective Load = 21.783 (kN/m^2)
l : Span Length = 0.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

1]Bending Moment

	x (m)	Mx (kN.m)
End	0.500	-2.723
Center	0.250	-0.681

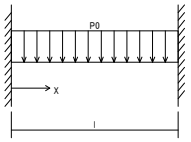
[2]Shear Force

	x (m)	Qx (kN)
End	0.500	-10.892

(b) Fixed Ended Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 6.174 (kN/m^2)
l : Span Length = 1.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

[1]Bending Moment

	x (m)	Mx (kN.m)
Edge	0.000	-1.158
Center	0.750	0.579

[2]Shear Force

	x (m)	Qx (kN)
Edge	0.000	4.631

(1) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	150.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D16×8.00 1608.80	D16×8.00 1608.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	32.1899	32.1899
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.9526	0.7381
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	29.5614	7.3904
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	168.0000	168.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0782	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-1.1576	0.5788
Axial Force	N	kN	——	——
Shear Force	V	kN	4.6305	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Tension)	As'	mm^2	0.00	0.00
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.1398	0.7121
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	18.1797	10.4642
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	168.0000	168.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0658	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

8.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

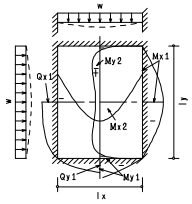
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{246.079 + 0.000}{6.090} + 6.174$$

= 46.581 (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 46.581 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 2.600 (m)
α : ly/lx = 1.444

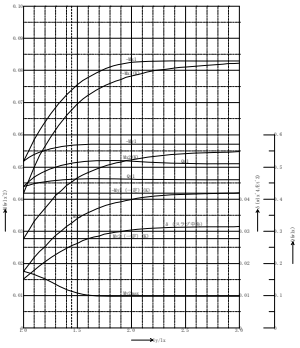


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0739	-11.155
Mx2	0.0453	6.832
long	α	M(kN.m)
My1	-0.0567	-8.554
My2	0.0277	4.181
My2max	0.0114	1.716

[2]Shear Force

short	α	Q (kN)
Qx1	0.5117	42.907
long	α	Q (kN)
Qy1	0.4621	38.743



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.5540	4.1806	-8.5540
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	29.8021
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	46.2524	36.2915	46.2524
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.0712	1.2395	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	59.5468	49.7071	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1669
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

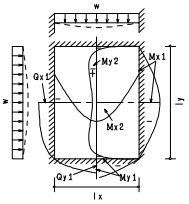
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-11.1549	6.8318	-11.1549
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	28.6047
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.3788	1.8458	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	71.5272	76.4596	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1475
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

8.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.819

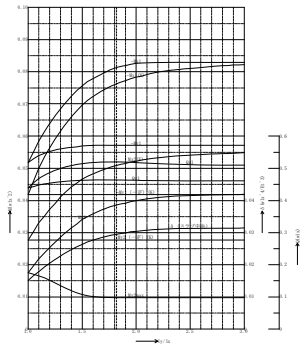


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0813	-1.495
Mx2	0.0510	0.937
long	α	M(kN.m)
My1	-0.0571	-1.050
My2	0.0277	0.509
My2max	0.0098	0.180

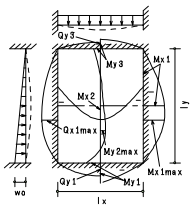
[2]Shear Force

short	α	Q (kN)
Qx1	0.5197	5.309
long	α	Q (kN)
Qy1	0.4634	4.733



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 43.685 (kN/m^2)
lx : Length (short) =1.800 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.819

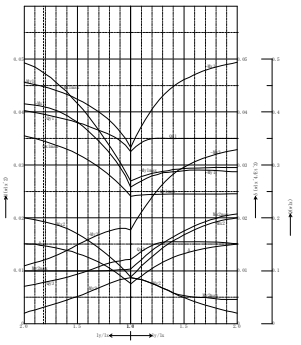


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0410	-5.800
Mx1max	-0.0475	-6.719
Mx2	0.0193	2.729
long	α	M(kN.m)
My1	-0.0448	-6.343
My2	0.0031	0.436
My2max	0.0100	1.415
My3	-0.0120	-1.696

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3451	27.137
long	α	Q (kN)
Qy1	0.3959	31.133
Qy3	0.0776	6.099



Total Moment and Shear Force

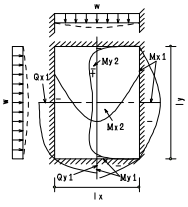
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.495	-6.719	-8.214
	Center	0.937	2.729	3.665
Vertical	Top	-1.050	-1.696	-2.746
	Center	0.509	1.415	1.925
	Bottom	-1.050	-6.343	-7.393

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.309	27.137	32.446
	Center	3.539	18.091	21.630
Vertical	Top	4.733	6.099	10.832
	Center	3.866	27.722	31.588
	Bottom	4.733	31.133	35.866

(2) Left and Right

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 2.600 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.260

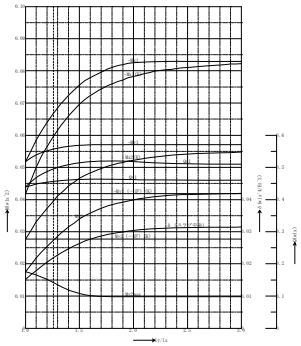


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0668	-2.563
Mx2	0.0396	1.518
long	α	M(kN.m)
My1	-0.0558	-2.139
My2	0.0277	1.063
My2max	0.0142	0.546

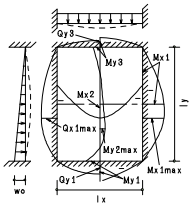
[2]Shear Force

short	α	Q (kN)
Qx1	0.4951	7.305
long	α	Q (kN)
Qy1	0.4566	6.737



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 43.685 (kN/m^2)
lx : Length (short) = 2.600 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.260

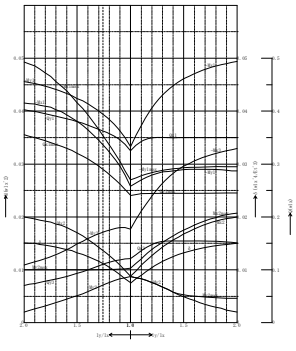


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0336	-9.926
Mx1max	-0.0354	-10.445
Mx2	0.0137	4.032
long	α	M(kN.m)
My1	-0.0394	-11.645
My2	0.0071	2.104
My2max	0.0100	2.953
My3	-0.0171	-5.057

[2]Shear Force

short	α	Q (kN)
Qx1max	0.2897	32.907
long	α	Q (kN)
Qy1	0.3625	41.172
Qy3	0.1107	12.579



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-2.563	-10.445	-13.008
	Center	1.518	4.032	5.550
Vertical	Top	-2.139	-5.057	-7.196
	Center	1.063	2.953	4.016
	Bottom	-2.139	-11.645	-13.784

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	7.305	32.907	40.212
	Center	5.620	25.313	30.932
Vertical	Top	6.737	12.579	19.316
	Center	5.503	36.248	41.751
	Bottom	6.737	41.172	47.909

(3) Calculation Result of Side Slab

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-7.3932	1.9247	-7.3932
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	31.5883
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.38	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	46.2524	36.2915	46.2524
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.7902	0.5707	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	51.4662	22.8855	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1769
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.2140	3.6655	-8.2140
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	21.6304
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.7516	0.9903	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	52.6691	41.0230	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1116
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-13.7845	4.0158	-13.7845
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	41.7513
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×3.86 776.66	D12×3.86 436.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	45.5566	35.7056	45.5566
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f'_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.3845	1.2078	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	99.2544	49.4075	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2335
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-13.0077	5.5500	-13.0077
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	30.9324
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f'_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.7739	1.4994	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	83.4074	62.1136	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1595
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

8.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$

$= 9.800 \times 15.834$

$= 155.173$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.100×2.900×2.300	14.007
3	2.100×2.900×0.300	1.827
Total	——	15.834

(b) Vertical Load

$W = Wc + Wu$

$= 289.927 + 0.000$

$= 289.927$ (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 289.927 / 155.173$

$= 1.868 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

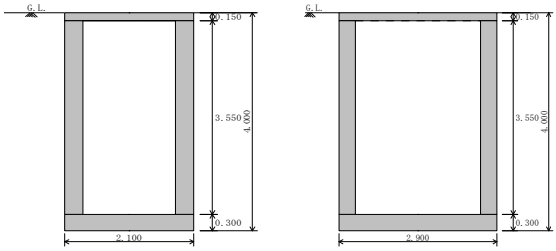
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.100×2.900×0.150×18.000	16.443
2	Side Wall	2.100×2.900×3.050×18.000	334.341
3	Bottom Slab	2.100×2.900×0.300×18.000	32.886
Total Ws			383.670

$Ws / Wc = 383.670 / 289.927$

$= 1.323 \geqq 1.0$

9 CASE4_5 (1,500 X 2,300 X H4, 000 MM)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.100	0.000	2.900	0.000	0.150
Side Wall	2.100	1.500	2.900	2.300	3.550
Bottom Slab	2.100	0.000	2.900	0.000	0.300

9.1.1 Vertical Load

(1) Weight of Body

Top Slab	2.100×2.800×0.150×24.500	21.609 (kN)
Pedestrian Load	2.100×2.800×5.000	29.400 (kN)
Side Wall	(2.100×2.900 - 1.500×2.300)×3.550×24.000	224.928 (kN)
Bottom Slab	2.100×2.800×0.300×24.000	42.336 (kN)

(2) Water Pressure for Bottom Slab

$Ww = \gamma w \cdot (h - hw)$
$= 9.800 \times (4.000 - 0.900)$
$= 30.380\ (kN/m^2)$

(3) Live Load

(a) Vehicle

$P_1 = \frac{2 \cdot P}{2.75} \cdot (1+i)$

$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$

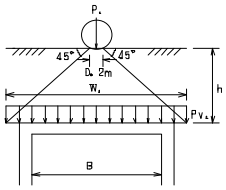
$= 7.564\ (kN/m)$

(b) Vertical Load of Live Load

$P_{v1} = \frac{P_1 \cdot \beta}{W_1} = \frac{P_1 \cdot \beta}{2 \cdot h + 0.2}$

$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$

$= 34.036\ (kN/m^2)$



$\frac{1}{8} \cdot q_{v1} \cdot B_0^2 = \frac{1}{8} \cdot P_{v1} \cdot W_1 \cdot (2B_0 - W_1)$ より

$q_{v1} = \frac{P_{v1} \cdot W_1}{B_0^2} \cdot (2B_0 - W_1)$

$q_{v1} = \frac{34.036 \times 0.200}{2.000^2} \cdot (2 \times 2.000 - 0.200)$

$= 6.174 (kN/m^2)$

9.1.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

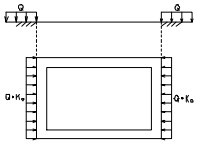
$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$P_1 = Q \cdot K_0$

Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_1 (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.700	Sidewall	Bottom	0.200	8.380	27.440	4.900	40.720
3.850	Bottom Slab	Center	0.200	8.395	28.910	4.900	42.205

9.1.3 Calculation of Top Slab

(1) Load

$W1 = \frac{Wc + Wu}{A} + P_{v1}$

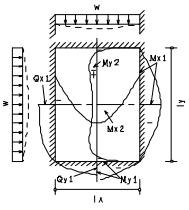
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$W1 = \frac{51.009 + 0.000}{5.880} + 6.174$

$= 14.849\ (kN/m^2)$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load =14.849 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.417



[1] Bending Moment

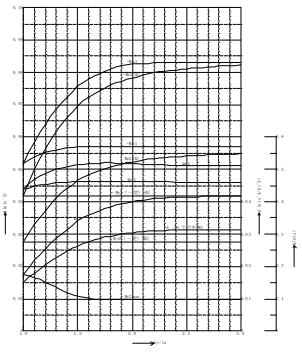
short	α	M (kN. m)
Mx1	-0.0730	-3.511
Mx2	0.0446	2.146

long	α	M (kN. m)
My1	-0.0566	-2.722
M 2	0.0277	1.333
My2max	0.0117	0.563

[2] Shear Force

short	α	Q (kN)
Qx1	0.5099	13.629

long	α	Q (kN)
Qyl	0.4614	12.333



(3) Calculation Result of Top Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.7215	1.3327	-2.7215
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.3982
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6796	1.6395	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	42.7398	24.0937	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1477
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

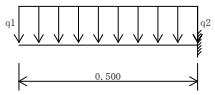
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.5106	2.1458	-3.5106
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.2218
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.5327	2.0279	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	65.4457	32.8320	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0723
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

9.1.4 Calculation of Open of Top Slab

(1) Design Condition

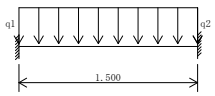
(a) Cantilever Beam

Span Length L (m)	0.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	21.783
Load q_2 (kN/m^2)	21.783



(b) Fixed Ended Beam

Span Length L (m)	1.500
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	19.401
Load q_2 (kN/m^2)	19.401

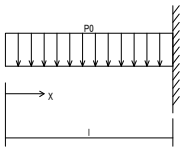


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = -\frac{p_0 x^2}{2}$$

$$Qx = -p_0 x$$



p_0 : Effective Load = 21.783 (kN/m^2)
l : Span Length = 0.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

1]Bending Moment

	x (m)	Mx (kN.m)
End	0.500	-2.723
Center	0.250	-0.681

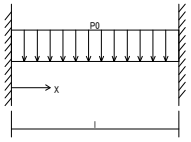
[2]Shear Force

	x (m)	Qx (kN)
End	0.500	-10.892

(b) Fixed Ended Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 19.401 (kN/m^2)
l : Span Length = 1.500 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

[1]Bending Moment

	x (m)	Mx (kN.m)
Edge	0.000	-3.638
Center	0.750	1.819

[2]Shear Force

	x (m)	Qx (kN)
Edge	0.000	14.551

(3) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	150.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	26.1108	26.1108
Concrete	f'_{ck}	N/mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5157	0.8789
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	50.7610	12.6903
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0771	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-3.6377	1.8188
Axial Force	N	kN	——	——
Shear Force	V	kN	14.5508	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5816	2.2375
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	57.1273	32.8826
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.2067	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

9.1.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

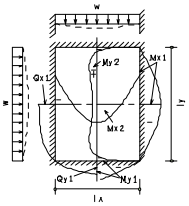
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{277.759 + 0.000}{6.090} + 6.174$$

$= 51.783\ (kN/m^2)$

(2) Moment and Shear Force

$M = \alpha・w・lx^2$
$Q = \alpha・w・lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 51.783(kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 2.550 (m)
α : ly/lx = 1.444

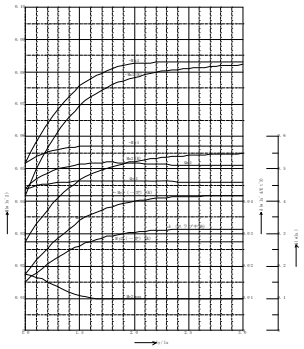


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0739	-12.401
Mx2	0.0453	7.595
long	α	M(kN.m)
My1	-0.0567	-9.509
My2	0.0277	4.647
My2max	0.0114	1.907

[2]Shear Force

short	α	Q (kN)
Qx1	0.5117	47.699
long	α	Q (kN)
Qy1	0.4621	43.069



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-9.5093	4.6475	-9.5093
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	33.1302
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	46.2524	36.2915	46.2524
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.3025	1.3779	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	66.1967	55.2581	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1855
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

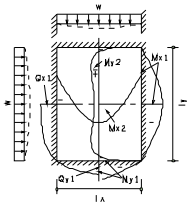
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.4007	7.5948	-12.4007
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	31.7991
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6445	2.0519	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	79.5150	84.9982	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1640
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

9.1.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 3.775 (m)
α : ly/lx = 2.097

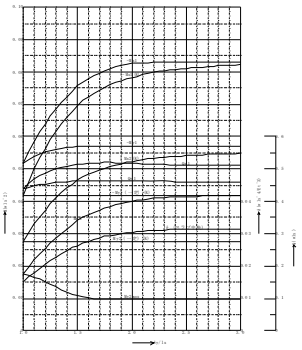


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-1.522
Mx2	0.0527	0.969
long	α	M(kN.m)
My1	-0.0571	-1.050
My2	0.0277	0.509
My2max	0.0098	0.180

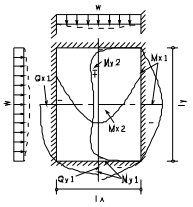
[2]Shear Force

short	α	Q (kN)
Qx1	0.5159	5.269
long	α	Q (kN)
Qy1	0.4614	4.713



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 36.630 (kN/m^2)
lx : Length (short) =1.800 (m)
ly : Length (long) = 3.775 (m)
α : ly/lx = 2.097

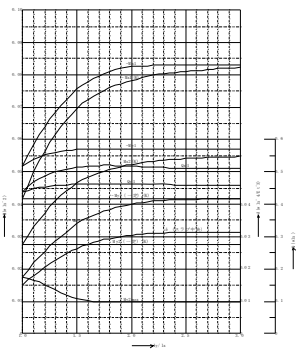


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0417	-4.948
Mx1max	-0.0501	-5.943
Mx2	0.0204	2.420
long	α	M(kN.m)
My1	-0.0460	-5.458
My2	0.0014	0.168
My2max	0.0100	1.187
My3	-0.0103	-1.224

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3600	23.740
long	α	Q (kN)
Qy1	0.4054	26.731
Qy3	0.0668	4.405



(c) Total Moment and Shear Force

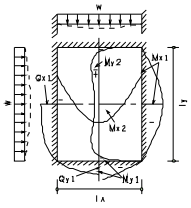
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.522	-5.943	-7.466
	Center	0.969	2.420	3.389
Vertical	Top	-1.050	-1.224	-2.274
	Center	0.509	1.187	1.696
	Bottom	-1.050	-5.458	-6.508

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.269	23.740	29.009
	Center	3.659	16.486	20.145
Vertical	Top	4.713	4.405	9.118
	Center	4.027	24.463	28.489
	Bottom	4.713	26.731	31.444

(2) Right and Left

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.675 (kN/m^2)
lx : Length (short) = 2.600 (m)
ly : Length (long) = 3.775 (m)
α : ly/lx = 1.452



[1]Bending Moment

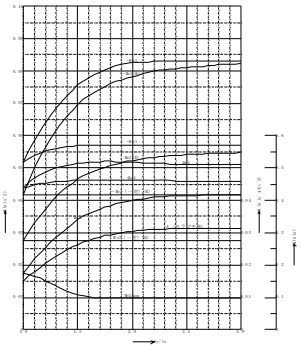
short	α	M(kN.m)
Mx1	-0.0742	-2.845
Mx2	0.0454	1.743

long	α	M(kN.m)
My1	-0.0567	-2.175
My2	0.0277	1.063
My2max	0.0113	0.433

[2]Shear Force

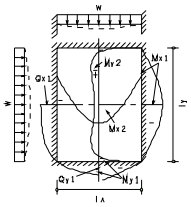
short	α	Q (kN)
Qx1	0.5122	7.557

long	α	Q (kN)
Qy1	0.4622	6.820



(a) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 36.630 (kN/m^2)
lx : Length (short) = 2.600 (m)
ly : Length (long) = 3.775 (m)
α : ly/lx = 1.462



[1]Bending Moment

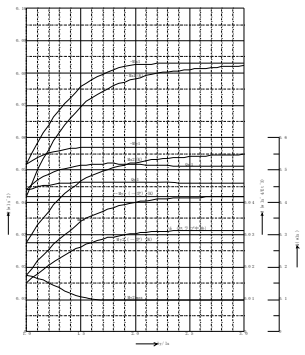
short	α	M(kN.m)
Mx1	-0.0373	-9.244
Mx1max	-0.0405	-10.039
Mx2	0.0164	4.067

long	α	M(kN.m)
My1	-0.0419	-10.380
My2	0.0055	1.358
My2max	0.0100	2.476
My3	-0.0154	-3.809

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3153	30.028

long	α	Q (kN)
Qy1	0.3773	35.934
Qy3	0.0966	9.197



(b) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-2.845	-10.039	-12.884
	Center	1.743	4.067	5.810
Vertical	Top	-2.175	-3.809	-5.984
	Center	1.063	2.476	3.539
	Bottom	-2.175	-10.380	-12.555

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	7.557	30.028	37.585
	Center	5.813	23.099	28.912
Vertical	Top	6.820	9.197	16.017
	Center	5.736	32.348	38.084
	Bottom	6.820	35.934	42.754

(3) Calculation Result of side wall

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-6.5079	1.6961	-6.5079
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	28.2206
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.38	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	46.2524	36.2915	46.2524
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.5758	0.5029	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	45.3033	20.1676	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1580
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-7.4656	3.3886	-7.4656
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	19.3393
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.5921	0.9155	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	47.8708	37.9238	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0998
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(a) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.5555	3.5388	-12.5555
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	38.0839
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	194.0	198.0	194.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×3.86 776.66	D12×3.86 436.79	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	45.5566	35.7056	45.5566
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.0828	1.0643	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	90.4048	43.5404	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2130
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-12.8839	5.8101	-12.8839
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	28.9119
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement (Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.7475	1.5697	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	82.6139	65.0250	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1491
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

9.1.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_W \cdot V_h$

$= 9.800 \times 18.879$

$= 185.014$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.100×2.900×2.800	17.052
3	2.100×2.900×0.300	1.827
Total	——	18.879

(b) Vertical Load

$W = Wc + Wu$

$= 321.607 + 0.000$

$= 321.607$ (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 321.670 / 185.014$

$= 1.788 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

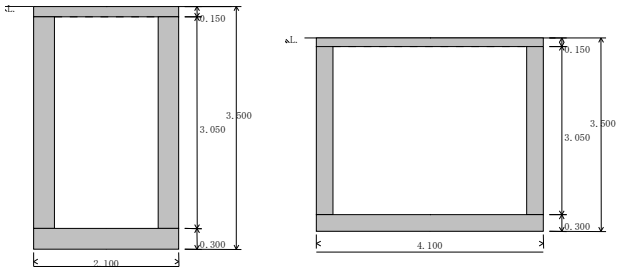
Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.100×2.800×0.150×18.000	15.876
2	Side Wall	2.100×2.900×3.550×18.000	389.151
3	Bottom Slab	2.100×2.800×0.300×18.000	31.752
Total Ws			438.480

$Ws / Wc = 438.480 / 321.607$

$= 1.363 \geqq 1.0$

11 CASE1-5_1 (1,500 X 700 X H4,500 M)



Front Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.100	0.000	4.100	0.000	0.150
Side Wall	2.100	1.500	4.100	3.500	3.050
Bottom Slab	2.100	0.000	4.100	0.000	0.300

11.1 Vertical Load

(1) Weight of Body

Top Slab	2.100×4.100×0.150×24.000	30.996 (kN)
Pedestrian Load	2.100×4.100×5.000	43.050 (kN)
Side Wall	(2.100×4.100 - 1.500×3.500)×3.050×24.000	245.952 (kN)
Bottom Slab	2.100×4.100×0.300×24.000	61.992 (kN)

(1) Water Pressure for Bottom Slab

$$Ww = \gamma w \cdot (h - hw)$$
$$= 9.800 \times (3.500 - 0.900)$$
$$= 25.480\ (kN/m^2)$$

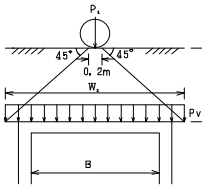
(2) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$$= 7.564\ (kN/m)$$

(b) Vertical Load of Live Load

$$P_{vl} = \frac{P_l \cdot \beta}{W_l} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$$= 34.036\ (kN/m^2)$$



$$\frac{1}{8} \cdot q_{vl} \cdot B_0^2 = \frac{1}{8} \cdot P_{vl} \cdot W_l \cdot (2B_0 - W_l) \quad 모멘트$$
$$q_{vl} = \frac{P_{vl} \cdot W_l}{B_0^2} \cdot (2B_0 - W_l)$$
$$q_{vl} = \frac{34.036 \times 0.200}{2.100^2} \cdot (2 \times 2.100 - 0.200)$$
$$= 6.174\ (kN/m^2)$$

11.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

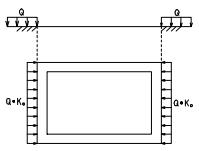
$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$P_l = Q \cdot K_0$

Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.200	Sidewall	Bottom	10.000	19.600	22.540	4.900	47.040
3.350	Bottom Slab	Center	10.000	20.350	24.010	4.900	49.260

11.3 Calculation of Bottom Slab

(1) Load

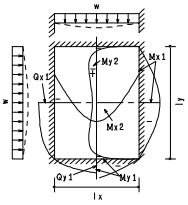
$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W1 = \frac{74.046 + 0.000}{8.610} + 6.174$$
$$= 14.774\ (kN/m^2)$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 14.774 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.111

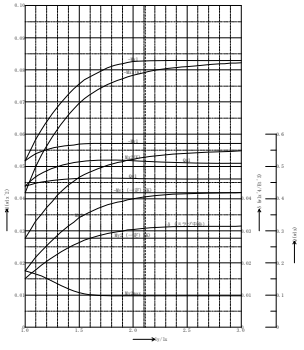


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-3.964
Mx2	0.0528	2.527
long	α	M(kN.m)
My1	-0.0571	-2.733
My2	0.0277	1.326
My2max	0.0098	0.469

[2]Shear Force

short	α	Q (kN)
Qx1	0.5156	13.712
long	α	Q (kN)
Qy1	0.4614	12.269



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.7333	1.3260	-2.7333
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.8163
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.6912	1.6312	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	42.9249	23.9720	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.1537
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

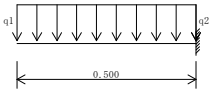
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-3.9636	2.5270	-3.9636
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.2843
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×8.00 904.80	D12×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	5.1176	2.3881	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	73.8904	38.6639	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0728
Allowable Stress Intensity by Shear Force	τ_{a1}	N/mm^2	——	——	0.3600
Evaluation			——	——	○

11.4 Calculation of Open of Top Slab

(1) Design Condition

(a) Cantilever Beam

Span Length L (m)	1.100
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	7.977
Load q_2 (kN/m^2)	7.977

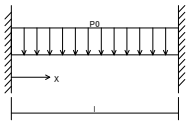


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 7.977 (kN/m^2)
l : Span Length = 1.100 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

1]Bending Moment

	x (m)	Mx (kN.m)
End	0.000	-0.804
Center	0.550	0.402

[2]Shear Force

	x (m)	Qx (kN)
End	0.000	4.387

(1) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-2.7229	-0.6807
Axial Force	N	kN	——	——
Shear Force	V	kN	-10.8915	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	150.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D13×8.00 904.80	D13×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement				
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	26.1108	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5157	0.8789
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	50.7610	12.6903
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	168.0000	168.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0771	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

(b) Fixed Ended Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-0.8043	0.4022
Axial Force	N	kN	——	——
Shear Force	V	kN	4.3874	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As'	mm^2	D12×8.00 904.80	D12×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
0.0020・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/ mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	0.7919	0.4948
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	12.6317	7.2708
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0623	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

11.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

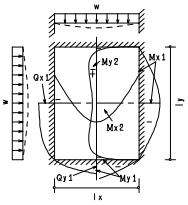
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{319.998 + 0.000}{8.610} + 6.174$$

= 43.340 (kN/m^2)

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 43.340 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 2.111

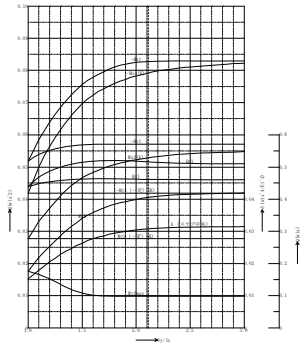


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-11.627
Mx2	0.0528	7.413
long	α	M(kN.m)
My1	-0.0571	-8.018
My2	0.0277	3.890
My2max	0.0098	1.376

[2]Shear Force

short	α	Q (kN)
Qx1	0.5156	40.225
long	α	Q (kN)
Qy1	0.4614	35.991



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.0181	3.8897	-8.0181
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	30.3086
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	180.0	198.0	180.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D20×4.00 1256.80	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	53.5034	36.2915	53.5034
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.8487	1.1533	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	39.3383	46.2484	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1869
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

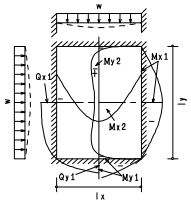
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-11.6270	7.4127	-11.6270
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	26.8166
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D20×4.00 1256.80	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	58.5205	37.4817	58.5205
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.0849	2.0027	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	48.5711	82.9612	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1408
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

11.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 1.800 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.819

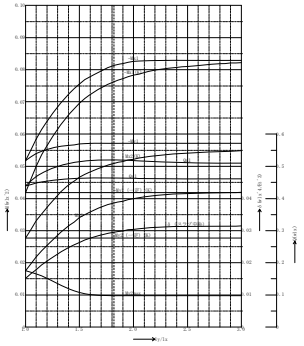


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0813	-1.468
Mx2	0.0510	0.920
long	α	M(kN.m)
My1	-0.0571	-1.031
My2	0.0277	0.500
My2max	0.0098	0.177

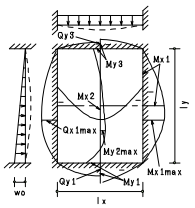
[2]Shear Force

short	α	Q (kN)
Qx1	0.5197	5.215
long	α	Q (kN)
Qy1	0.4634	4.650



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 43.685 (kN/m^2)
lx : Length (short) =1.800 (m)
ly : Length (long) = 3.275 (m)
α : ly/lx = 1.819

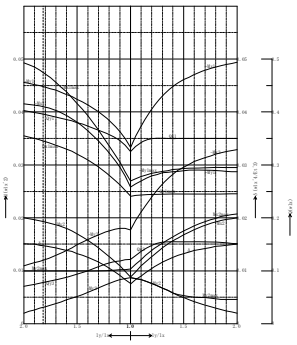


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0410	-5.800
Mx1max	-0.0475	-6.719
Mx2	0.0193	2.729
long	α	M(kN.m)
My1	-0.0448	-6.343
My2	0.0031	0.436
My2max	0.0100	1.415
My3	-0.0120	-1.696

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3451	27.137
long	α	Q (kN)
Qy1	0.3959	31.133
Qy3	0.0776	6.099



Total Moment and Shear Force

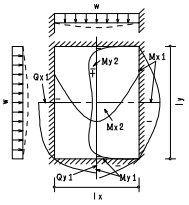
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.468	-6.719	-8.188
	Center	0.920	2.729	3.649
Vertical	Top	-1.031	-1.696	-2.728
	Center	0.500	1.415	1.916
	Bottom	-1.031	-6.343	-7.375

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.215	27.137	32.352
	Center	3.477	18.091	21.568
Vertical	Top	4.650	6.099	10.749
	Center	3.798	27.722	31.520
	Bottom	4.650	31.133	35.783

(2) Left and Right

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 3.275 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 1.160

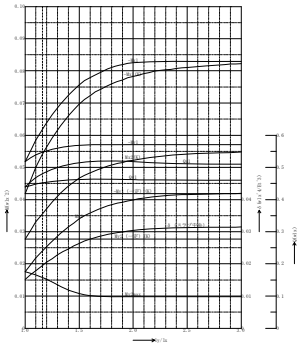


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0619	-3.702
Mx2	0.0356	2.129
long	α	M(kN.m)
My1	-0.0547	-3.272
My2	0.0277	1.656
My2max	0.0158	0.942

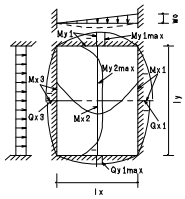
[2]Shear Force

short	α	Q (kN)
Qx1	0.4804	8.771
long	α	Q (kN)
Qy1	0.4515	8.243



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 43.685 (kN/m^2)
lx : Length (short) = 3.275 (m)
ly : Length (long) = 3.800 (m)
α : ly/lx = 1.160

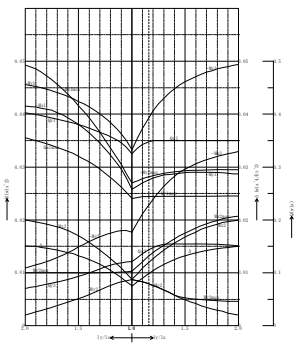


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0393	-18.428
Mx2	0.0120	5.616
Mx2max	0.0132	6.168
Mx3	-0.0228	-10.678
long	α	M(kN.m)
My1	-0.0276	-12.924
My1max	-0.0282	-13.195
My2	0.0079	3.710
My2max	0.0079	3.710

[2]Shear Force

short	α	Q (kN)
Qx1	0.3475	49.716
Qx3	0.1435	20.532
long	α	Q (kN)
Qy1max	0.2440	34.903



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-3.272	-13.195	-16.467
	Center	1.656	3.710	5.366
Vertical	Top	-3.702	-10.678	-14.380
	Center	2.129	6.168	8.298
	Bottom	-3.702	-18.428	-22.130

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	8.243	34.903	43.146
	Center	6.941	29.392	36.333
Vertical	Top	8.771	20.532	29.303
	Center	7.164	43.281	50.445
	Bottom	8.771	49.716	58.487

(3) Calculation Result of Side Slab

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-7.3747	1.9157	-7.3747
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	31.5202
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	192.0	198.0	192.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D20×4.00 1256.80	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	55.5542	36.2915	55.5542
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.5302	0.5680	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	33.8251	22.7781	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1817
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-8.1876	3.6490	-8.1876
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	21.5681
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.7460	0.9858	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	52.5002	40.8382	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1112
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-22.1302	8.2978	-22.1302
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	50.4451
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	192.0	198.0	192.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D20×4.00 1256.80	D12×4.00 424.81	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	55.5542	35.2661	55.5542
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.5919	2.5255	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	101.5028	104.8845	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2908
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-16.4674	5.3661	-16.4674
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	36.3335
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	300.0	300.0	300.0
Effective Width	b_e	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	210.0	210.0	210.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	600.00	600.00	——
$0.008・N・10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	48.3765	37.4817	48.3765
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f'_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.5117	1.4498	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	105.5916	60.0557	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1874
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

11.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_w \cdot V_h$
$= 9.800 \times 22.386$
$= 219.383$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.100×4.100×2.300	19.803
3	2.100×4.100×0.300	2.583
Total	——	22.386

(b) Vertical Load

$W = Wc + Wu$
$= 381.990 + 0.000$
$= 381.990$ (kN)

(c) safety factor

Safety Factor $F = W / U$
$= 381.990 / 219.383$
$= 1.741 \geqq$ Allowable Safety Factor $F_a = 1.200$

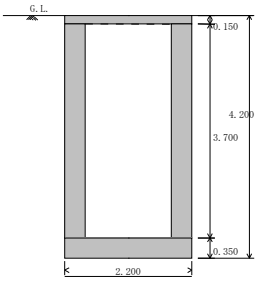
(2) Stability against Bearing

Weight of Soil Same Volume as Body

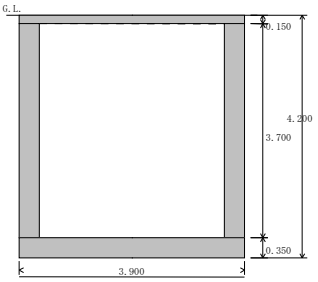
Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.100×4.100×0.150×18.000	23.247
2	Side Wall	2.100×4.100×3.050×18.000	472.689
3	Bottom Slab	2.100×4.100×0.300×18.000	46.494
Total Ws			542.430

$Ws / Wc = 542.430 / 381.990$
$= 1.420 \geqq 1.0$

12 CASE6 (1,500 X 700 X H4,500 M)



Front



Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	2.200	0.000	3.900	0.000	0.150
Side Wall	2.200	1.500	3.900	3.200	3.700
Bottom Slab	2.200	0.000	3.900	0.000	0.350

12.1 Vertical Load

(1) Weight of Body

Top Slab	2.200×3.900×0.150×24.000	30.888 (kN)
Pedestrian Load	2.200×3.900×5.000	42.900 (kN)
Side Wall	(2.200×3.900 - 1.500×3.200)×3.700×24.000	335.664 (kN)
Bottom Slab	2.200×3.900×0.350×24.000	72.072 (kN)

(1) Water Pressure for Bottom Slab

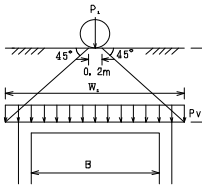
$$Ww = \gamma w \cdot (h - hw)$$
$$= 9.800 \times (4.200 - 0.900)$$
$$= 32.340\ (kN/m^2)$$

(2) Live Load

(a) Vehicle

$$P_l = \frac{2 \cdot P}{2.75} \cdot (1+i)$$
$$= \frac{2 \times 8.000}{2.75} \times (1+0.300)$$
$$= 7.564\ (kN/m)$$

(b) Vertical Load of Live Load



$$P_{v1} = \frac{P_l \cdot \beta}{W_1} = \frac{P_l \cdot \beta}{2 \cdot h + 0.2}$$
$$= \frac{7.564 \times 0.9}{2 \times 0.000 + 0.2}$$
$$= 34.036\ (kN/m^2)$$

$$\frac{1}{8} \cdot q_{v1} \cdot B_0^2 = \frac{1}{8} \cdot P_{v1} \cdot W_1 \cdot (2B_0 - W_1) \quad 从中$$
$$q_{v1} = \frac{P_{v1} \cdot W_1}{B_0^2} \cdot (2B_0 - W_1)$$
$$q_{v1} = \frac{34.036 \times 0.200}{2.200^2} \cdot (2 \times 2.200 - 0.200)$$
$$= 5.907\ (kN/m^2)$$

12.2 Horizontal Load

(1) Earth Pressure

$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$

Ps : Horizontal Earth Pressure (kN/m^2)
K_0 : Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

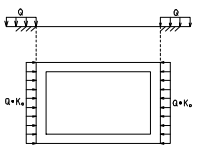
(2) Water Pressure

$Pw = \gamma w \cdot hw$

Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m^2)



(4) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.075	Top Slab	Center	18.000	0.675	0.000	4.900	5.575
0.150	Sidewall	Top	18.000	1.350	0.000	4.900	6.250
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
3.850	Sidewall	Bottom	10.000	22.850	28.910	4.900	56.660
4.025	Bottom Slab	Center	10.000	23.725	30.625	4.900	59.250

12.3 Calculation of Bottom Slab

(1) Load

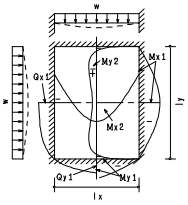
$$W3 = \frac{Wc + Wu}{A} + P_{v1}$$

W3 : Subgrade Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W1 = \frac{73.788 + 0.000}{8.580} + 5.907$$
$$= 14.507\ (kN/m^2)$$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 14.507 (kN/m^2)
lx : Length (short) = 1.850 (m)
ly : Length (long) = 3.550 (m)
α : ly/lx = 1.919

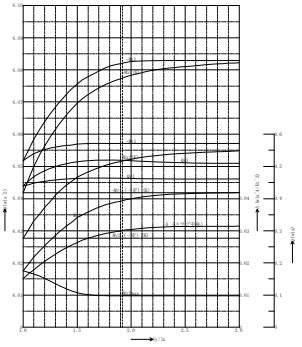


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0821	-4.077
Mx2	0.0517	2.566
long	α	M(kN.m)
My1	-0.0571	-2.835
My2	0.0277	1.375
My2max	0.0098	0.487

[2]Shear Force

short	α	Q (kN)
Qx1	0.5188	13.924
long	α	Q (kN)
Qy1	0.4631	12.428



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.8351	1.3753	-2.8351
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.6779
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	80.0	150.0	80.0
Applied area of Reinforcement (Tension)	As	mm^2	D13×8.00 904.80	D13×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	28.8574	26.5869	28.8574
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	2.7913	1.6919	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	44.5225	24.8642	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.1517
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

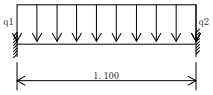
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-4.0770	2.5664	-4.0770
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.1610
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	82.0	150.0
Applied area of Reinforcement (Tension)	As	mm^2	D13×8.00 904.80	D13×8.00 904.80	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	26.1108	29.2969	26.1108
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	5.2640	2.4254	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	76.0051	39.2675	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm^2	——	——	0.0719
Allowable Stress Intensity by Shear Force	$\tau_{\_a1}$	N/mm^2	——	——	0.3600
Evaluation			——	——	○

12.4 Calculation of Open of Top Slab

(1) Design Condition

(a) Cantilever Beam

Span Length L (m)	1.100
Member Thickness t (m)	0.150
Load q_1 (kN/m^2)	5.907
Load q_2 (kN/m^2)	5.907

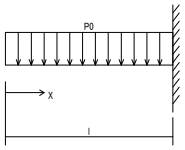


(2) Moment and Shear Force

(a) Cantilever Beam

$$Mx = \frac{p_0 l^2}{2}\left\{-\frac{1}{6} + \frac{x}{l} - \left(\frac{x}{l}\right)^2\right\}$$

$$Qx = \frac{p_0 l}{2} - p_0 x$$



p_0 : Effective Load = 5.907 (kN/m^2)
l : Span Length = 1.100 (m)
Mx : Bending Moment at position x (kN.m)
Qx : Shear Force at position x (kN)

[1]Bending Moment

	x (m)	Mx (kN.m)
End	0.000	-0.596
Center	0.550	0.298

[2]Shear Force

	x (m)	Qx (kN)
End	0.000	3.249

(1) Calculation Results

(a) Cantilever Beam

Item		Unit	Edge	Center
Bending Moment	M	kN.m	-0.5956	0.2978
Axial Force	N	kN	——	——
Shear Force	V	kN	3.2489	——
Width of Member	B	mm	1000.0	1000.0
Height of Member	H	mm	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0
Effective Height	d	mm	80.0	150.0
Applied area of Reinforcement				
(Tension)	As	mm^2	D13×8.00 904.80	D13×8.00 904.80
(Compression)	As	mm^2	0.00	0.00
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	300.00	300.00
0.008・N・10^3/σca	As_{min}	mm^2	——	——
Young's modulus	n		9	9
Neutral Axis	X	mm	28.8574	26.5869
Concrete	f'_{ck}	N/mm^2	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	0.5864	0.3664
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000
Evaluation of Compression			○	○
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	9.3538	5.3841
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000
Evaluation of Compression			○	○
Stress Intensity by Shear Force	τ	N/mm2	0.0462	——
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	0.3600	——
Evaluation			○	——

12.5 Calculation of Bottom Slab

(1) Load

$$W3 = \frac{Wc + Wu}{A} + P_{vl}$$

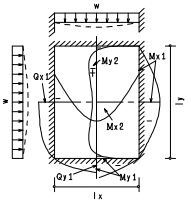
W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{409.452 + 0.000}{8.580} + 5.907$$

$= 53.629\ (kN/m^2)$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 53.629 (kN/m^2)
lx : Length (short) = 1.850 (m)
ly : Length (long) = 3.550 (m)
α : ly/lx = 1.919

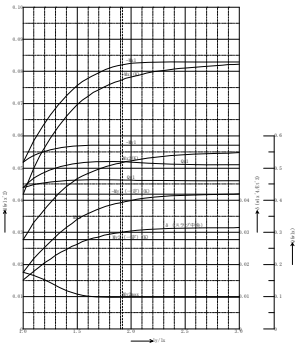


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0821	-15.071
Mx2	0.0517	9.487
long	α	M(kN.m)
My1	-0.0571	-10.480
My2	0.0277	5.084
My2max	0.0098	1.799

[2]Shear Force

short	α	Q (kN)
Qx1	0.5188	51.474
long	α	Q (kN)
Qy1	0.4631	45.944



(3) Calculation Result of Bottom Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-10.4804	5.0842	-10.4804
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	36.8849
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	240.0	248.0	240.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D19×4.00 1256.80	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	700.00	700.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	63.2324	41.0583	63.2324
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.5140	1.0573	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	38.0919	47.9603	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1685
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

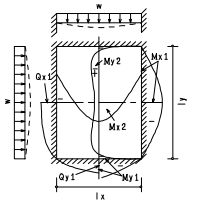
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-15.0715	9.4873	-15.0715
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	31.9975
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	260.0	260.0	260.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D19×4.00 1256.80	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement $0.002 \cdot B \cdot H$	As_{min}	mm^2	700.00	700.00	——
$0.008 \cdot N10^3/\sigma ca$	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	66.2231	42.1265	66.2231
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.9137	1.8317	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	50.3983	85.2600	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1345
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

12.6 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 1.850 (m)
ly : Length (long) = 3.950 (m)
α : ly/lx = 2.135

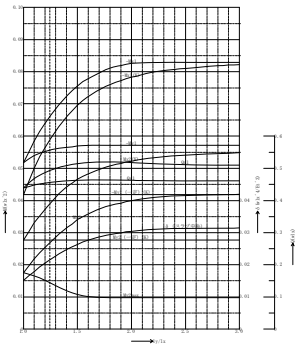


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0828	-1.580
Mx2	0.0530	1.011
long	α	M(kN.m)
My1	-0.0571	-1.089
My2	0.0277	0.529
My2max	0.0098	0.187

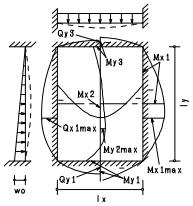
[2]Shear Force

short	α	Q (kN)
Qx1	0.5152	5.314
long	α	Q (kN)
Qy1	0.4613	4.757



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 53.675 (kN/m^2)
lx : Length (short) =1.850 (m)
ly : Length (long) = 3.950 (m)
α : ly/lx = 2.135

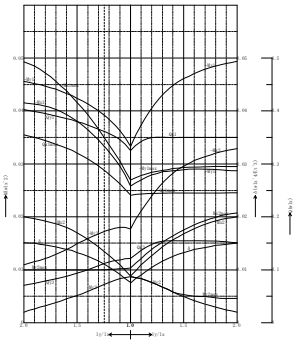


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0418	-7.673
Mx1max	-0.0504	-9.255
Mx2	0.0205	3.773
long	α	M(kN.m)
My1	-0.0461	-8.476
My2	0.0012	0.218
My2max	0.0100	1.837
My3	-0.0101	-1.853

[2]Shear Force

short	α	Q (kN)
Qx1max	0.3621	35.956
long	α	Q (kN)
Qy1	0.4066	40.370
Qy3	0.0654	6.491



Total Moment and Shear Force

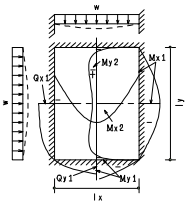
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-1.580	-9.255	-10.835
	Center	1.011	3.773	4.784
Vertical	Top	-1.089	-1.853	-2.943
	Center	0.529	1.837	2.366
	Bottom	-1.089	-8.476	-9.566

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	5.314	35.956	41.270
	Center	3.303	22.351	25.654
Vertical	Top	4.757	6.491	11.248
	Center	3.914	36.218	40.132
	Bottom	4.757	40.370	45.128

(2) Left and Right

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 5.575 (kN/m^2)
lx : Length (short) = 3.550 (m)
ly : Length (long) = 3.950 (m)
α : ly/lx = 1.113

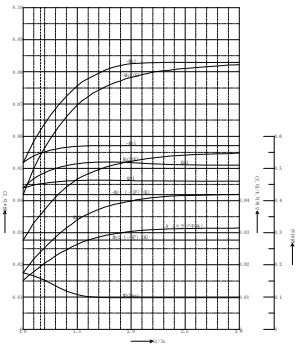


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0592	-4.157
Mx2	0.0336	2.363
long	α	M(kN.m)
My1	-0.0541	-3.799
My2	0.0277	1.946
My2max	0.0163	1.149

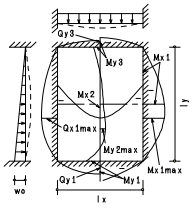
[2]Shear Force

short	α	Q (kN)
Qx1	0.4708	9.317
long	α	Q (kN)
Qy1	0.4489	8.884



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 53.675 (kN/m^2)
lx : Length (short) = 3.550 (m)
ly : Length (long) = 3.950 (m)
α : ly/lx = 1.113

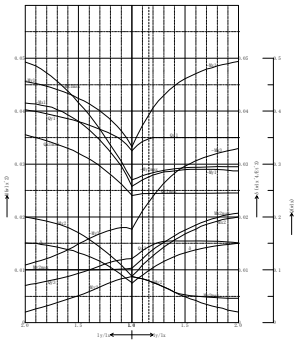


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0300	-20.263
Mx1max	-0.0309	-20.889
Mx2	0.0111	7.528
long	α	M(kN.m)
My1	-0.0366	-24.743
My2	0.0082	5.563
My2max	0.0102	6.883
My3	-0.0179	-12.142

[2]Shear Force

short	α	Q (kN)
Qx1max	0.2644	50.382
long	α	Q (kN)
Qy1	0.3475	66.215
Qy3	0.1181	22.507



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-4.157	-20.889	-25.045
	Center	2.363	7.528	9.891
Vertical	Top	-3.799	-12.142	-15.941
	Center	1.946	6.883	8.829
	Bottom	-3.799	-24.743	-28.543

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	9.317	50.382	59.699
	Center	7.480	40.447	47.928
Vertical	Top	8.884	22.507	31.391
	Center	7.310	58.353	65.663
	Bottom	8.884	66.215	75.099

(3) Calculation Result of Side Slab

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-9.5656	2.3656	-9.5656
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	40.1323
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	240.0	248.0	240.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D19×4.00 1256.80	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	700.00	700.00	——
0.008・N10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	63.2324	41.0583	63.2324
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.3819	0.4919	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	34.7671	22.3148	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1833
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-10.8350	4.7843	-10.8350
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	25.6542
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	260.0	260.0	260.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	700.00	700.00	——
0.008・N10³/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	54.5593	42.1265	54.5593
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.6435	0.9237	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	55.6968	42.9950	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1061
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-28.5428	8.8287	-28.5428
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	65.6628
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	240.0	246.0	240.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D19×4.00 1256.80	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	700.00	700.00	——
0.008・N10³/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	63.2324	40.8875	63.2324
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	4.1233	1.8600	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	103.7414	83.9743	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.2999
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-25.0452	9.8905	-25.0452
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	47.9276
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	350.0	350.0	350.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	260.0	260.0	260.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D16×4.00 804.40	D13×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.002・B・H	As_{min}	mm^2	700.00	700.00	——
0.008・N10³/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	54.5593	42.1265	54.5593
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.7990	1.9095	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	128.7435	88.8838	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1982
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

12.7 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_W \cdot V_h$

$= 9.800 \times 28.314$

$= 277.477$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
2	2.200×3.900×2.950	25.311
3	2.200×3.900×0.350	3.003
Total	——	28.314

(b) Vertical Load

$W = Wc + Wu$

$= 481.524 + 0.000$

$= 481.524$ (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 481.524 / 277.477$

$= 1.735 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	2.200×3.900×0.150×18.000	23.166
2	Side Wall	2.200×3.900×3.700×18.000	571.428
3	Bottom Slab	2.200×3.900×0.350×18.000	54.054
Total Ws			648.648

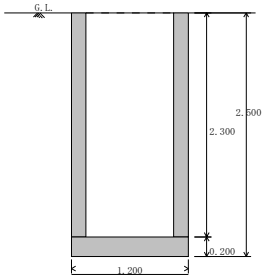
$Ws / Wc = 648.648 / 481.524$

$= 1.347 \geqq 1.0$

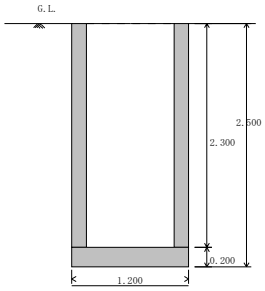
4.3 Structural Calculation of Junction Box

The detail of structural calculation of junction box is indicated from the following page.

1 CASE1_3 (900 X 900 X H2, 500 MM)



Front



Side

Member	Front		Side		Height (m)
	Outside (m)	Inside (m)	Outside (m)	Inside (m)	
Top Slab	-	-	-	-	-
Side Wall	1.200	0.900	1.200	0.900	2.300
Bottom Slab	1.200	0.000	1.200	0.000	0.200

1.1 Vertical Load

(1) Weight of Body

Top Slab	-	- (kN)
Pedestrian Load	-	- (kN)
Side Wall	(1.200×1.200 - 0.900×0.900)×2.300×24.000	34.776 (kN)
Bottom Slab	1.200×1.200×0.200×24.000	6.912 (kN)

(2) Water Pressure for Bottom Slab

$Ww = \gamma w \cdot (h - hw)$
$= 9.800 \times (2.500 - 0.900)$
$= 15.680\ (kN/m^2)$

1.2 Horizontal Load

(1) Earth Pressure

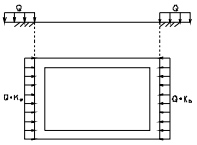
$Ps = \Sigma K_0 \cdot \gamma t \cdot (h - hw) + \Sigma K_0 \cdot \gamma' \cdot hw$
Ps : Horizontal Earth Pressure (kN/m^2)
K_0 :Coefficient of earth pressure at rest
γt : Wet unit weight (kN/m^3)
γ' : Submerged unit weight (kN/m^3)
h : Thickness (m)
hw : Thickness inside water (m)

(2) Water Pressure

$Pw = \gamma w \cdot hw$
Pw : Water Pressure (kN/m^2)
γw : Unit weight of water = 9.800 (kN/m^3)
hw : Depth (m)

(3) Horizontal load by live load

$P_l = Q \cdot K_0$
Q : = 9.800 (kN/m^2)



(3) Total of Horizontal Load

Depth (m)	Member	Location	Unit weight of soil	Ps (kN/m^2)	Pw (kN/m^2)	P_l (kN/m^2)	Total (kN/m^2)
0.000	Sidewall	Top	18.000	0.000	0.000	4.900	4.900
0.900	Sidewall	Water surface	18.000	8.100	0.000	4.900	13.000
2.300	Sidewall	Bottom	10.000	15.100	13.720	4.900	33.720
2.400	Bottom Slab	Center	10.000	15.600	14.700	4.900	35.200

1.3 Calculation of Bottom Slab

(1) Load

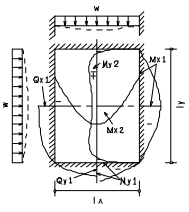
$$W1 = \frac{Wc + Wu}{A} + P_{vl}$$

W3 : Subgrage Reaction for Bottom Slab (kN/m^2)
Wc : Weight of Body (kN)
Wu : Weight of Soil (kN)
A : Area (m^2)
P_{vl} : Vertical Load by by Live Load (kN/m^2)

$$W3 = \frac{34.776 + 0.000}{1.440} + 0.000$$
$= 24.150\ (kN/m^2)$

(2) Moment and Shear Force

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 24.150 (kN/m^2)
lx : Length (short) = 1.050 (m)
ly : Length (long) = 1.050 (m)
α : ly/lx = 1.000



[1] Bending Moment

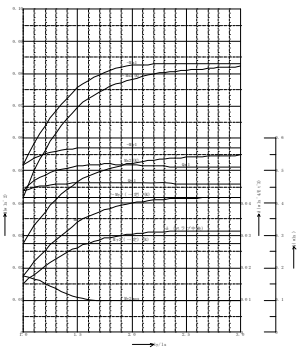
short	α	M (kN. m)
Mx1	-0.0518	-1.379
Mx2	0.0277	0.738

long	α	M (kN. m)
My1	-0.0518	-1.379
My2	0.0277	0.738
My2max	0.0176	0.469

[2] Shear Force

short	α	Q (kN)
Qx1	0.4390	11.132

long	α	Q (kN)
Qyl	0.4390	11.132



(3) Calculation Result of Top Slab

(a) Back and Forth

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-1.3792	0.7375	-1.3792
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	7.4213
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	200.0	200.0	200.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	102.0	200.0	102.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	400.00	400.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	25.0244	24.4629	25.0244
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.1760	0.6708	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	32.5560	18.1471	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0792
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Right and Left

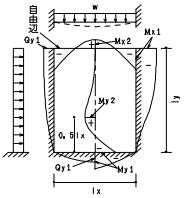
Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-1.3792	0.7375	-1.3792
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	7.4213
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	200.0	200.0	200.0
Effective Width	b_e	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	200.0	110.0	200.0
Applied area of Reinforcement					
(Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement					
0.0020・B・H	As_{min}	mm^2	400.00	400.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	23.3032	26.1230	23.3032
Concrete	f'_{ck}	N/mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	1.4393	0.5570	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	37.0743	16.0969	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0386
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

1.4 Calculation of Side Wall

(1) Back and Forth

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 4.900 (kN/m^2)
lx : Length (short) = 1.050 (m)
ly : Length (long) = 2.400 (m)
α : ly/lx = 2.286

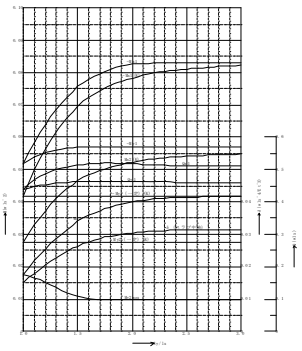


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0822	-0.444
Mx2	0.0416	0.225
long	α	M(kN.m)
My1	-0.0577	-0.312
My2max	0.0092	0.050

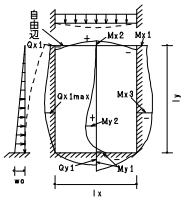
[2]Shear Force

short	α	Q (kN)
Qx1	0.4920	2.531
long	α	Q (kN)
Qy1	0.3687	1.897



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 30.300 (kN/m^2)
lx : Length (short) =1.050 (m)
ly : Length (long) = 2.400 (m)
α : ly/lx = 2.286

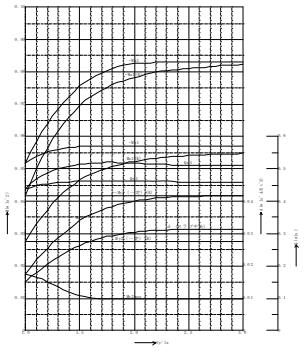


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0059	-0.196
Mx2max	0.0042	0.141
Mx3max	-0.0514	-1.716
long	α	M(kN.m)
My1	-0.0491	-1.640
My2max	0.0094	0.314

[2]Shear Force

short	α	Q (kN)
Qx1	0.0365	1.161
Qx1max	0.3827	12.176
long	α	Q (kN)
Qy1	0.4039	12.851



(c) Total Moment and Shear Force

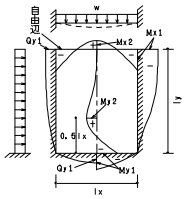
		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-0.444	-1.716	-2.160
	Center	0.225	0.141	0.366
Vertical	Top	-0.312	-1.640	-1.951
	Center	0.050	0.314	0.364
	Bottom	-0.312	-1.640	-1.951

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	2.531	12.176	14.707
	Center	1.808	8.697	10.505
Vertical	Top	1.897	12.851	14.748
	Center	1.620	10.977	12.597
	Bottom	1.897	12.851	14.748

(2) Right and Left

(a) Moment and Shear Force by Uniformly Distributed Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 4.900 (kN/m^2)
lx : Length (short) = 1.050 (m)
ly : Length (long) = 2.400 (m)
α : ly/lx = 2.286

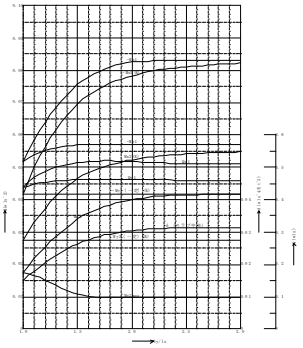


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0822	-0.444
Mx2	0.0416	0.225
long	α	M(kN.m)
My1	-0.0577	-0.312
My2max	0.0092	0.050

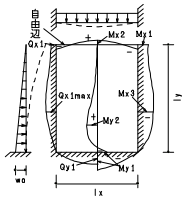
[2]Shear Force

short	α	Q (kN)
Qx1	0.4920	2.531
long	α	Q (kN)
Qy1	0.3687	1.897



(b) Moment and Shear Force by Uniformly Varying Load

$M = \alpha \cdot w \cdot lx^2$
$Q = \alpha \cdot w \cdot lx$
ここに、
M : Bending Moment (kN.m)
Q : Shear Force (kN)
w : Distributed Load = 30.300 (kN/m^2)
lx : Length (short) = 1.050 (m)
ly : Length (long) = 2.400 (m)
α : ly/lx = 2.286

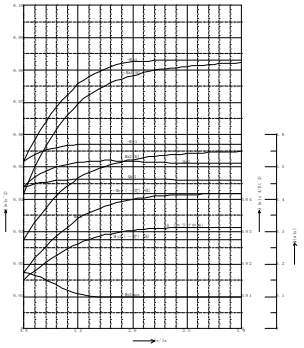


[1]Bending Moment

short	α	M(kN.m)
Mx1	-0.0059	-0.196
Mx2max	0.0042	0.141
Mx3max	-0.0514	-1.716
long	α	M(kN.m)
My1	-0.0491	-1.640
My2max	0.0094	0.314

[2]Shear Force

short	α	Q (kN)
Qx1	0.0365	1.161
Qx1max	0.3827	12.176
long	α	Q (kN)
Qy1	0.4039	12.851



(c) Total Moment and Shear Force

		Bending Moment (kN.m)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	-0.444	-1.716	-2.160
	Center	0.225	0.141	0.366
Vertical	Top	-0.312	-1.640	-1.951
	Center	0.050	0.314	0.364
	Bottom	-0.312	-1.640	-1.951

		Shear Force (kN)		
		Uniformly Distributed Load	Uniformly Varying Load	Total
Horizontal	Edge	2.531	12.176	14.707
	Center	1.808	8.697	10.505
Vertical	Top	1.897	12.851	14.748
	Center	1.620	10.977	12.597
	Bottom	1.897	12.851	14.748

(3) Calculation Result of side wall

(a) Back and Forth (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-1.9515	0.3637	-1.9515
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	12.5974
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	87.0	150.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	18.9423	22.8516	18.9423
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.6351	0.4009	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	76.0940	10.1284	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0877
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(b) Back and Forth (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.1598	0.3661	-2.1598
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.5053
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	75.0	75.0	75.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	20.9747	20.9747	20.9747
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.0283	0.5134	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	70.1999	11.9006	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1545
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(c) Right and Left (Vertical)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-1.9515	0.3637	-1.9515
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	12.5974
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	150.0	87.0	150.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	18.9423	22.8516	18.9423
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.6351	0.4009	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	76.0940	10.1284	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.0877
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

(d) Right and Left (Horizontal)

Item		Unit	Edge	Center	h/2
Bending Moment	M	kN.m	-2.1598	0.3661	-2.1598
Axial Force	N	kN	——	——	——
Shear Force	V	kN	——	——	10.5053
Width of Member	B	mm	1000.0	1000.0	1000.0
Height of Member	H	mm	150.0	150.0	150.0
Effective Width	b_w	mm	1000.0	1000.0	1000.0
Effective Height	d	mm	75.0	75.0	75.0
Applied area of Reinforcement (Tension)	As	mm^2	D12×4.00 452.40	D12×4.00 452.40	——
(Compression)	As	mm^2	0.00	0.00	——
Required area of Reinforcement 0.0020・B・H	As_{min}	mm^2	300.00	300.00	——
0.008・N・10^3/σca	As_{min}	mm^2	——	——	——
Young's modulus	n		9	9	9
Neutral Axis	X	mm	20.9747	20.9747	20.9747
Concrete	f'_{ck}	N/ mm^2	20.7	20.7	20.7
Reinforcement Bar	f_{yk}	N/ mm^2	415.0	415.0	415.0
Stress Intensity (Concrete)	σ_c	N/mm^2	3.0283	0.5134	——
Allowable Stress Intensity (Concrete)	σ_{ca}	N/mm^2	8.2000	8.2000	——
Evaluation of Compression			○	○	——
Stress Intensity (Reinforcing Bar)	σ_s	N/mm^2	70.1999	11.9006	——
Allowable Stress Intensity (Reinforcing Bar)	σ_{sa}	N/mm^2	140.0000	140.0000	——
Evaluation of Compression			○	○	——
Stress Intensity by Shear Force	τ	N/mm2	——	——	0.1545
Allowable Stress Intensity by Shear Force	τ_a1	N/mm2	——	——	0.3600
Evaluation			——	——	○

1.5 Stability Analysis

(1) Stability against Buoyancy Force

(a) Buoyancy Force

$U = \gamma_W \cdot V_h$

$= 9.800 \times 2.304$

$= 22.579$ (kN)

Volume of body under water

Number	Area × Height	Volume (m^3)
1	1.200×1.200×1.400	2.016
2	1.200×1.200×0.200	0.288
Total	———	2.304

(b) Vertical Load

W = Wc + Wu

= 41.688 + 0.000

= 41.688 (kN)

(c) safety factor

Safety Factor $F = W / U$

$= 41.688 / 22.579$

$= 1.846 \geqq$ Allowable Safety Factor $F_a = 1.200$

(2) Stability against Bearing

Weight of Soil Same Volume as Body

Number	Member	Volume of body × Unit Weight	Weight (kN)
1	Top Slab	-	-
2	Side Wall	1.200×1.200×2.300×18.000	59.616
3	Bottom Slab	1.200×1.200×0.200×18.000	5.184
Total Ws			64.800

Ws / Wc = 64.800 / 41.688

$= 1.554 \geqq 1.0$

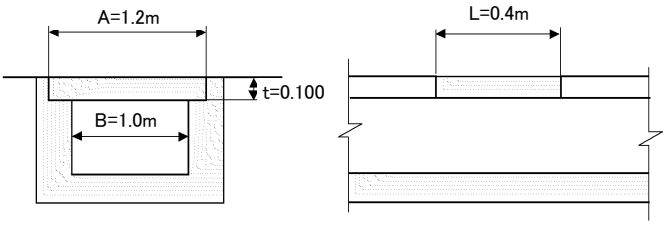
4.4 Structural Calculation of Manhole Cover

The detail of structural calculation of Manhole Cover is indicated from the following page.

1.Disign Conditon

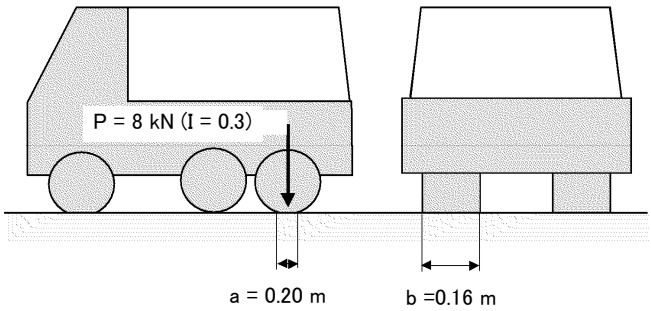
(1) Dimension

Width	A=	1.2	m
Inside Width	B=	1.0	m
Length	L=	0.4	m
Tickness	t=	0.100	m



2) Load

Load of 1 wheel	p=	8.0	kN	Considering passenger vehicle.
Inpact Factor	I=	0.3		
Length of Wheel	a=	0.16	m	
Width of Wheel	b=	0.2	m	



2) Material and allowable Stress

a. Concrete

Compressive Strength	σ_{ck} =	20.7	N/mm^2

・Allowable Stress

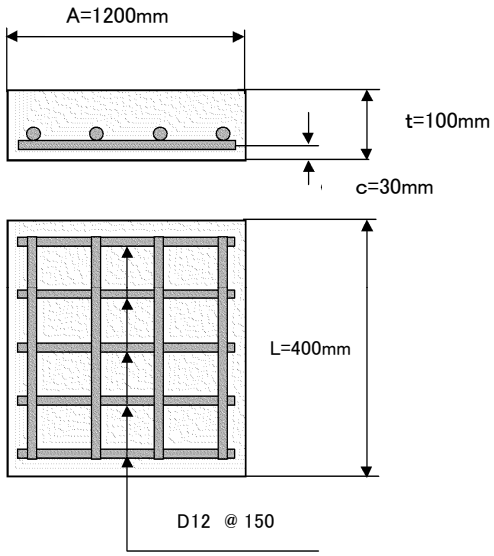
Flexture Compression	σ_{ca} =	8.2	N/mm^2
Shearing	τ_{ca} =	0.4	N/mm^2

b. Rainforing bar

Grade		275.0	
Diameter		12.0	mm
Nunber of Rainforcing bar	N=	4.0	
Total Cross Sectional Area	A=	452.4	mm

・Allowable Stress

Tensile	σ_{sa} =	140.0	N/mm^2



2. Calculation of Load

1) Active Load

a ≦ A u' = a + t

a > A u' = a

a = 0.2 ≦ A= 1.2

a + t = 0.26

Effective Load $p = P(1+I)$ = 8× (1+0.3) / 0.26

= 40.00 kN/m

Loading Width u = a + t = 0.26 m

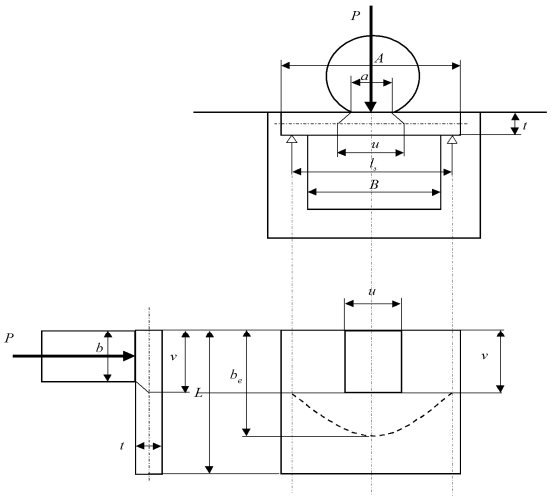
v = b + t/2 = 0.25 m

Effective Width for Moment

be = v + 0.3 l_s= 0.58 m > L= 0.4

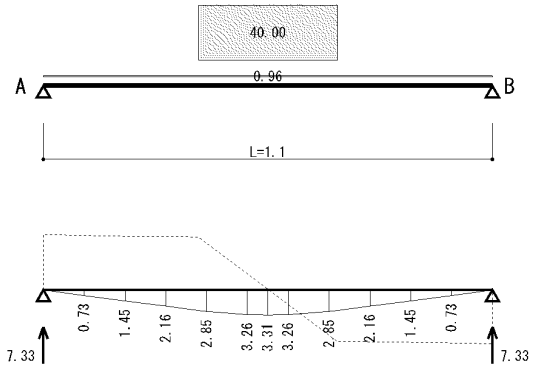
Is= 1.1 m

→ be = 0.4 m



1) Sectional force

･Bending Moment



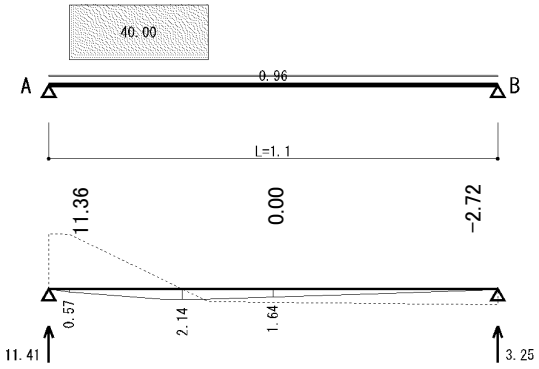
Positon (X =)	Bending Moment (kN/m^2)
0	0.00
0.1	0.73
0.2	1.45
0.3	2.16
0.4	2.85
0.5	3.26
0.55	3.31
0.6	3.26
0.7	2.85
0.8	2.16
0.9	1.45
1.0	0.73
1.1	0.00

M_{max}= 3.31 kN/m^2

Bending Moment with considering effctive width is calculated as below.

M' = M × L / be = 3.31 × 0.4 / 0.4 = 3.31 kNm

･Shear Force



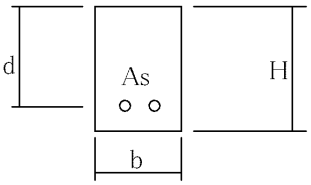
Positon (X =)	Sheer Force
0	-
0.075	11.36
0.55	0
1.025	-2.72
0.4	-

S_{max}= 11.36 kN

3. Rainfocement Calcularion

Position of Rainforcing Bar

Diameter	12	mm
Number of Rainforcing Bar	4.0	
Cover Concrete	3.0	cm



Bending Moment	M =	3.31	kN・m
Shear Force	S =	11.36	kN
Width of Member	b =	50.0	cm
Hight of Member	H =	10.0	cm
Equivalent Height（Tensile Side）	d =	7.000	cm
Total Cross-Sectional（Tensile Side）	A_s =	4.524	cm^2
Modulous of Elasticity	n =	9.000	

Compressive Stress of Concrete σc=	8.145	N/mm^2	○
Tensile Stress of Rainforcing Bar σs=	119.675	N/mm^2	○
Shearing Stress of Concrete τ =	0.372	N/mm^2	×

→ Only concrete deos't have enough shearing capacity.

Allowable Compressive Stress of Concrete σca=	8.2	N/mm^2
Allowable Tensile Stress of Rainforcing Bar σsa=	140.0	N/mm^2
Allowable Shear Stress of Concrete τa =	0.36	N/mm^2

Single Rainforcing Bar

p ＝ As/(b*d)　　x ＝ k*d

＝ 0.0129257　　＝ 2.659

k ＝ √(2*n*p+(n*p)^2)-n*p

＝ 0.3798498

j ＝ 1-(k/3)

＝ 0.8733834

σc＝ (2*M*10^5)/(b*d^2*k*j)

＝ 814.4698714

σs＝ (M*10^5)/(b*d^2*p*j)

＝ 11967.47233

τ＝ (S*10^3)/(b*j*d)

＝ 37.1625376

4. Shearing Calculation

Channel type of section steel is attached around the concrete cover. The shear stress is supported by this channel.

Structural Steel Type	SS400							
Alloable Stress	Bending	140	N/mm^2					
	Shearing	80	N/mm^2					
Type of Steel	2*[-100*50*5*7.5							
	Area	11.92	cm^2	=	1.19E-03	m^2	×2	2.38E-03 m^2
	I	189	cm^4	=	1.89E-06	m^4	×2	3.78E-06 m^4
	z	37.8	cm^3	=	3.78E-05	m^3	×2	7.56E-05 m^3
Shearing Force		11.36	kN					
Shearing Stress	$\tau = S / A =$	4765	kN/m^2	=	4.77	N/mm^2	≦	80 N/mm^2