The Study on The Rehabilitation and Reconstruction of Agricultural Production System in The Slakou River Basin, The Kingdom of Cambodia

Japan International Cooperation Agency

Figure J-4

Kpob Trobek Reservoir;
Result of Stability Analysis Case 1

In the case that the existing dike is homogeneous
Under Normal Water Condition (HWL.37.30)

			Upstream		Downstream	
	Fs min=		2.680		2.010	
Center of circle	x	=	−8.00	(m)	10.00	(m)
	y	=	42.00	(m)	44.00	(m)
Radius	R	=	8.20	(m)	10.20	(m)
Resistingoment	Mr	=	302.17	(tf.m)	293.14	(tf.m)
Sliding moment	Mo	=	112.74	(tf.m)	145.82	(tf.m)

Zone	Saturated unit weight (tf/m^3)	Wet unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Zone I	2.250	2.000	25.00	3.00
Zone II	2.080	1.930	25.00	1.50
Existing dike	2.200	2.000	25.00	1.00

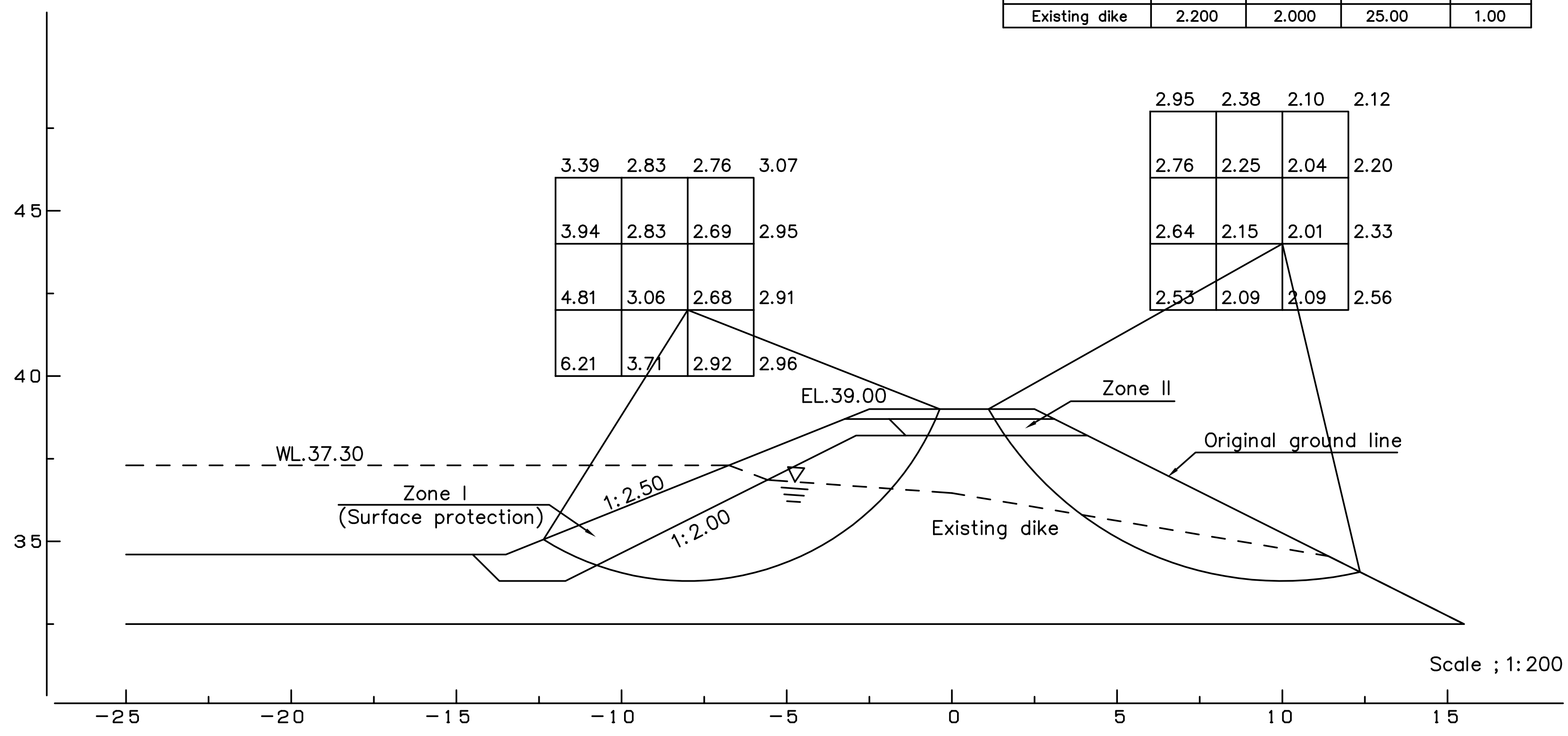

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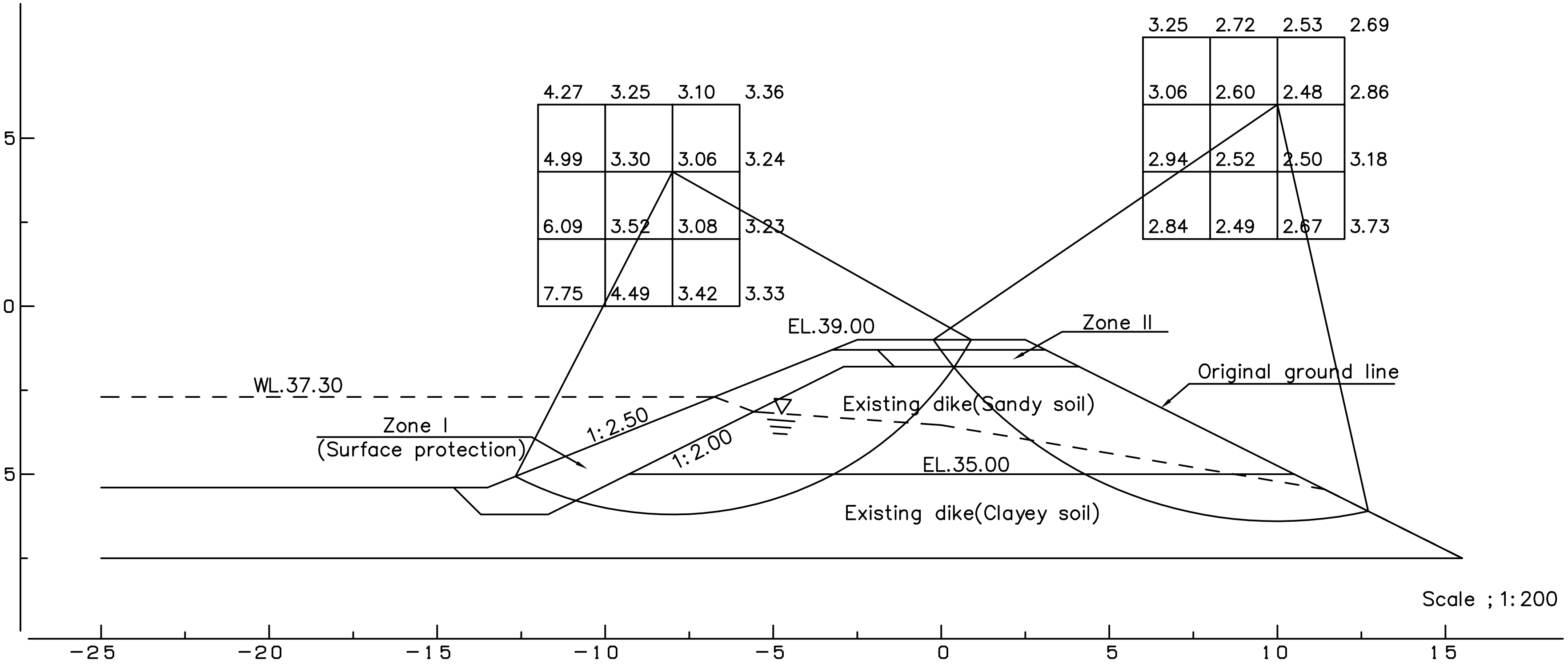
Figure J-5

Kpob Trobek Reservoir;
Result of Stability Analysis Case 2

In the case that the existing dike is composed by two zone
Under Normal Water Condition (HWL.37.30)

			Upstream	Downstream
	Fs min=		3.062	2.488
Center of circle	x	=	−8.00 (m)	10.00 (m)
	y	=	44.00 (m)	46.00 (m)
Radius	R	=	10.20 (m)	12.20 (m)
Resistingoment	Mr	=	484.43 (tf.m)	488.70 (tf.m)
Sliding moment	Mo	=	158.20 (tf.m)	196.42 (tf.m)

Zone	Saturated unit weight (tf/m^3)	Wet unit weight (tf/m^3)	Internal friction angle (°)	Cohesion (tf/m^2)
Zone I	2.250	2.000	25.00	3.00
Zone II	2.080	1.930	25.00	1.50
Existing dike(Sandy soil)	2.180	2.020	25.00	1.00
Existing dike(Clayey soil)	2.080	1.900	15.00	2.50



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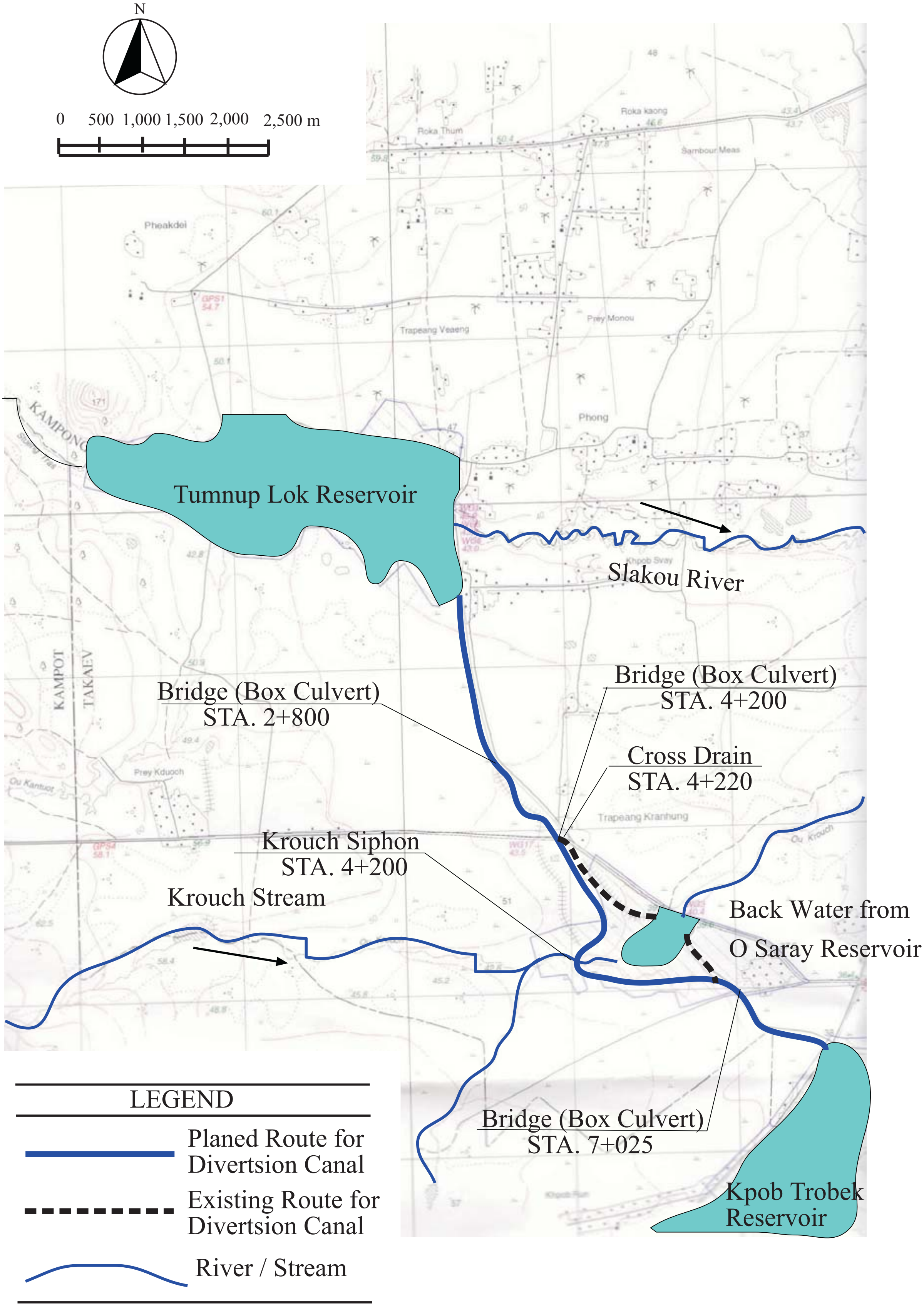

The Study on the Rehabilitation and Reconstruction of Agricultural Production System in The Slakou River Basin, The Kingdom of Kambodia	Figure J - 6 Route and Structure Layout of Diversion Canal
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Attachments

Result of Stability Analysis ; Spillway of Tumnup Lok Reservoir

Result of Stability Analysis ; Spillway of Kpob Trobek Reservoir

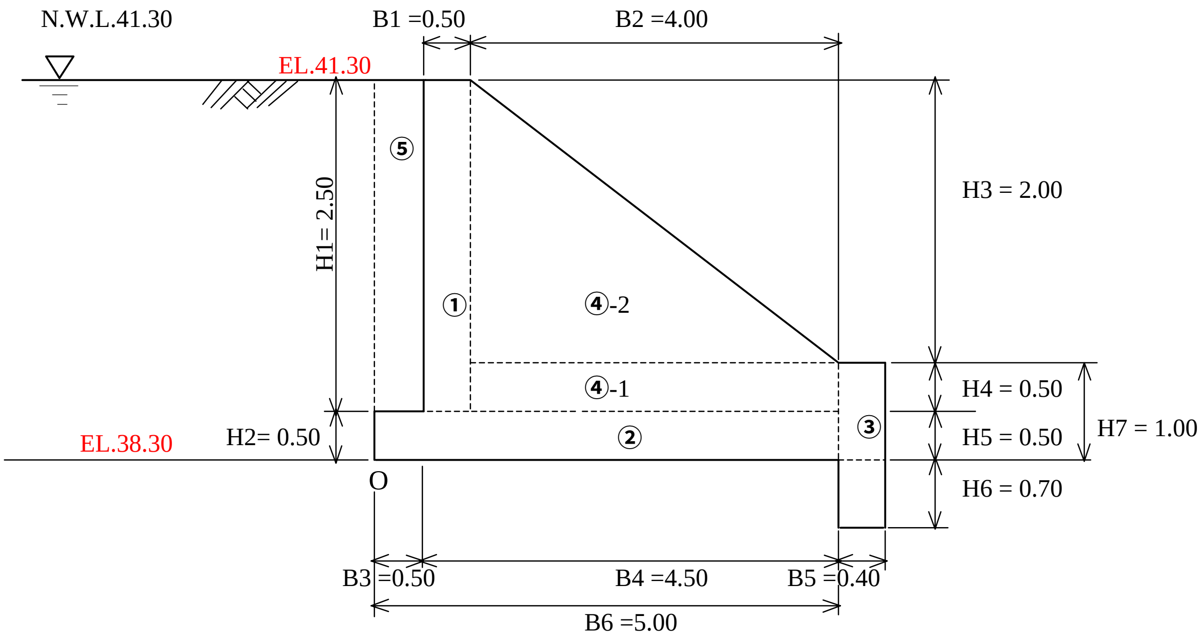
Result of Stability Analysis ; Spillway of Tumnup Lok Reservoir

1.Box of Rock Spillway

1-1. Design Condition

Unit Weight	Reinforced concrete	γc	2.40	tf/m^3
	Embankment (Wet)	γ t	1.80	tf/m^3
	(Saturated)	γsat	2.00	tf/m^3
	Rock anchor (Wet)	γ t	2.00	tf/m^3
	(Saturated)	γsat	2.20	tf/m^3
	Water	γw	1.00	tf/m^3
Internal friction angle of Embankment		ϕ	30.00	°
Embankment Slope		β	0.00	
Live Load	under normal condition		0.50	tf/m^2
Coefficient of friction		f	0.47	
Shearing stress of foundation		τ	2.00	tf/m^2
Bearing Capacity of foundation		qa	20.00	tf/m^2
Flood water level (F.W.L)			42.40	m
Normal water level (N.W.L)			41.30	m

1-2. Dimensions



H1 =	2.50 m		H5 =	0.50 m
H2 =	0.50 m		H6 =	0.70 m
H3 =	2.00 m		H7 =	1.00 m
H4 =	0.50 m			
B1 =	0.50 m		B6 =	5.00 m
B2 =	4.00 m			
B3 =	0.50 m			
B4 =	4.50 m			
B5 =	0.40 m			
Length of box L =	12.00 m		Thickness of member④ t =	0.40m

1-3. Coefficient of Earth Pressure Ka

(1) Coefficient of Active Earth Pressure

Coulomb's Formula shall be applied for calculation of earth pressure.

$$Ka = \frac{\cos^2(\phi - \alpha - \theta)}{\cos\theta \cdot \cos^2\alpha \cdot \cos(\alpha + \delta + \theta)\left\{1 + \sqrt{\frac{\sin(\phi + \delta)\cdot\sin(\phi - \beta - \theta)}{\cos(\alpha + \delta + \theta)\cdot\cos(\alpha - \beta)}}\right\}^2}$$

Where;
- Ka ; Coefficient of active earth pressure
- ϕ ; Internal friction angle =30°
- δ ; Angle of wall friction (wall and soil)
- a ; Wall angle to vertical surface
- β ; Slope angle of backfill
- θ ; = $\tan^{-1}$Kh
- Kh ; Horizontal seismic coefficient

1) Angle of wall friction（δ）

	Stability Analysis between soil and soi	Calculation of Member between concrete and soi
Under normal condition	β	2/3 ･φ
	0 °	20 °

		Under normal condition	
		Stability analysis	Calculation of member
Internal friction angle	φ	30.00	30.00
Angle of wall friction	δ	0.00	20.00
Wall angle to vertical surface	α	0.00	0.00
Slope angle of backfill	β	0.00	0.00
$\tan^{-1}$Kh	θ	0.00	0.00

2) Coefficient of earth pressure for stability analysis under normal condition

$$Ka = \frac{\cos^2(30 + 0)}{\cos 0^2 \cdot \cos(0 + 0) \times \left\{1 + \sqrt{\frac{\sin(30 + 0)\cdot\sin(30 - 0.00)}{\cos(0 + 0)\cdot\cos(0 - 0.00)}}\right\}^2} = 0.333$$

- Coefficient of horizontal earth pressure Kah

  $Kah = Ka \cdot \cos(\delta + \alpha) = 0.333 \cdot \cos(0.00 + 0.00) = 0.333$

- Coefficient of vertical earth pressure Kav

  $Kav = Ka \cdot \sin(\delta + \alpha) = 0.333 \cdot \sin(0.00 + 0.00) = 0$

The coefficient of earth pressure of every case shall be calculated by means of above mentioned, and are shown in table below.

		Stability analysis	Calculation of member	Remarks
Under normal condition	Ka	0.333	0.297	
	Kah	0.333	0.279	Ka･cos(δ + α)
	Kav	0.000	0.102	Ka･sin(δ + α)

1-4. Stability Analysis

(1) Self Weight

			Area (m^2)	Unit Weight γ (tf/m^3)	Lenfth of Box (m)	Weight W(tf)
Concrete structure	①	0.50 x 2.50	1.25	2.40	12.00	36.00
	②	0.50 x 5.00	2.50	2.40	12.00	72.00
	③	0.40 x 1.00	0.40	2.40	12.00	11.52
	④-1	4.00 x 0.50 x 0.40 x 3 x 2.40 =		2.40	-	5.76
	④-2	4.00 x 2.00 / 2 x 0.40 x 3 x 2.40 =		2.40	-	11.52
Embankment	⑤	2.50 x 0.50	1.25	2.00	12.00	30.00
Rock anchor	⑥-1	4.00 x 0.50 x 5.40 x 2.20 x 2 =		2.20	5.40	47.52
	⑥-2	4.00 x 2.00 / 2 x 5.40 x 2.20 x 2 =		2.20	5.40	95.04
	Total					309.36

(2)Center of Gravity

		Weight W(t)	Arm Length (m) X	Arm Length (m) Y	Moment(tf・m) W・x	Moment(tf・m) W・y	Remark
Concrete structure	①	36.00	0.75	1.75	27.00	63.00	
	②	72.00	2.50	0.25	180.00	18.00	
	③	11.52	5.20	0.50	59.90	5.76	
	④-1	5.76	3.00	0.75	17.28	4.32	
	④-2	11.52	2.33	1.67	26.84	19.24	
Embankment	⑤	30.00	0.25	1.75	7.50	52.50	
Rock anchor	⑥-1	47.52	3.00	0.75	142.56	35.64	
	⑥-2	95.04	2.33	1.67	221.44	158.72	
	Total	309.36			682.53	357.18	

Center of Gravity

$Xo = \Sigma W \cdot x / \Sigma W$

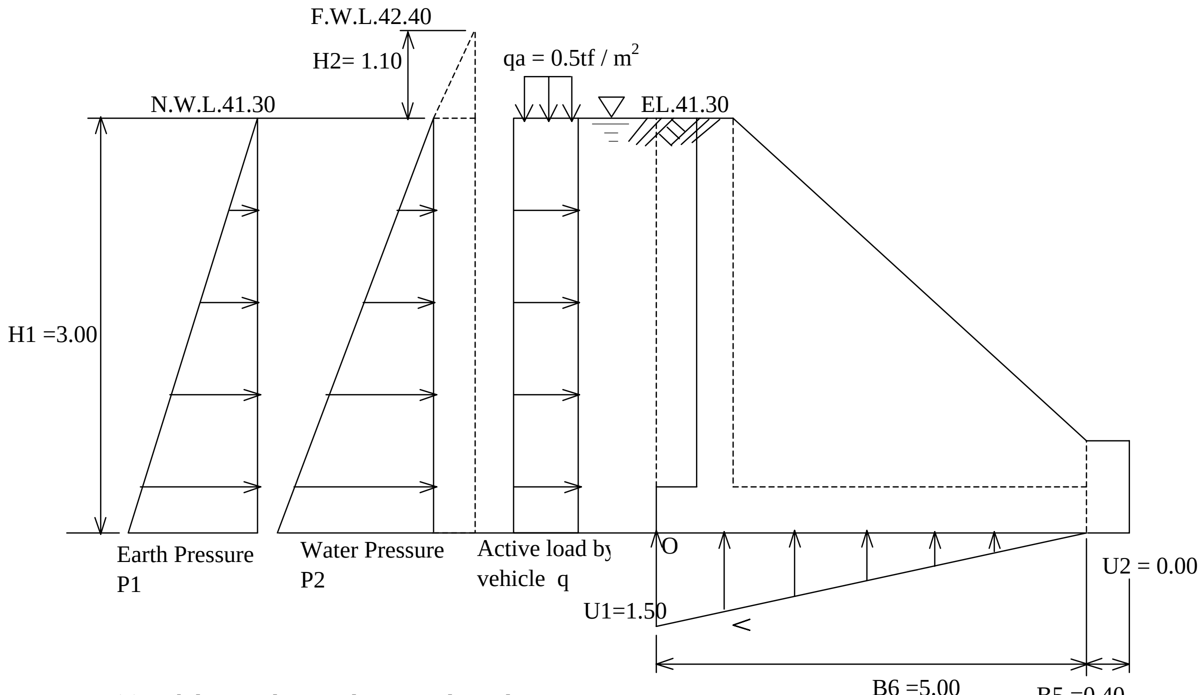
$= 682.529 / 309.360$

$= 2.206m$

$Yo = \Sigma W \cdot y / \Sigma W$

$= 682.529 / 309.360$

$= 1.155m$



(3) Stability Analysis under Normal Condition

1) Active earth pressure

Kah = 0.333

P1= Kah x γsub x $H1^2$ x 1/2 = 0.333 x 1.00 x 3.00^2 x 1/2 = 1.50 tf/m

2) Water pressure

P2= γw x $H1^2$ x 1/2 = 1.00 x 3.00^2 x 1/2 = 4.50 tf/m

3) Uplift

U1= 3.00 x 0.5 =1.50 tf / m2

U= (1.50 + 0.00) / 2 x 5.00= 3.75 tf/m

4) Active load

q = 0.50 x 3.00 x 0.333 = 0.50 tf/m

Self weight per unit width Ws = 309.36 / 12.00 = 25.78 tf/m

		Force (tf/m)		Arm length(m)		Moment (m・t)	
		Vertical (V)	Horizontal (H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		25.78	-	2.21	-	56.88	-
Earth pressure	P1	-	1.50	-	1.00	-	1.50
Water pressure	P2	-	4.50	-	1.00	-	4.50
Up-Lift	U	-3.75	-	1.67	-	-6.26	
Active load	q	-	0.50	-	1.50	-	0.75
Total	Over turning Sliding	22.03	6.50			50.62	6.75
	Ground reaction	25.78	6.50			56.88	6.75

Length of bottom slab B = 5.40 m

Coefficient of friction f = 0.47

Shearing stress of foundation τ = 2.00 t/m^2

Bearing capacity of foundation qa = 20.00 t/m^2

5) Over turning

e = B / 2 - (∑Mx - ∑My) / ∑V

= 5.40 / 2 -(50.62－6.75) / 22.03 = 0.709m < B/6 = 0.900 m -------- OK

6) Sliding

Fs = (f x ∑V + τ x B) / ∑H

= (0.47 x 22.03 + 2.00 x 5.40) / 6.50 = 3.242 > 1.50 -------- OK

7) Ground reaction

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (56.88 - 6.75) / 25.78 =$ 0.755m

$q = \sum V / B \times (1 \pm 6 e / B)$

$= 25.78 / 5.40 \times (1 \pm 6 \times 0.755 / 5.40) =$ 8.78 tf/m2 (max) < 20.000 tf/m2 ------- OK

0.77 tf/m2 (min)

(4) Stability Analysis under Flood Condition

1) Active earth pressure

Kah = 0.333

$P1 = Kah \times \gamma sub \times (H1)^2 \times 1/2 =$ 0.333 x 1.00 x 3.00^2 x 1/2 = 1.50 tf/m

2) Water pressure

$P_{2-1} = \gamma w \times H1^2 \times 1/2 =$ 1.00 x 3.00^2 x 1/2 = 4.50 tf/m

$P_{2-2} = \gamma w \times H2 \times H1 =$ 1.00 x 1.10 x 3.00 = 3.30 tf/m

3) Uplift

U1= 4.10 x 0.5 = 2.05 tf / m2

U= (2.05 + 0.00) / 2 x 5.00= 5.13 tf/m

Self weight per unit width Ws = 309.36 / 12.00 = 25.78 tf/m

		Force (tf/m)		Arm length(m)		Moment (m･t)	
		Vertical (V)	Horizontal (H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		25.78	-	2.21	-	56.88	-
Earth pressure	P1	-	1.50	-	1.00	-	1.50
Water pressure	P_{2-1}	-	4.50	-	1.00	-	4.50
	P_{2-2}	-	3.30	-	1.50	-	4.95
Up-Lift	U	-5.13	-	1.67	-	-8.57	
Total	Over turning Sliding	20.65	9.30			48.31	10.95
	Ground reaction	25.78	9.30			56.88	10.95

Length of bottom slab B = 5.40 m

Coefficient of friction f = 0.47

Shearing stress of foundation $\tau =$ 2.00 t/m^2

Bearing capacity of foundation qa = 20.00 t/m^2

4) Over turning

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (48.31 - 10.95) / 20.65 =$ 0.891m < B/3 =1.800 m -------- OK

5) Sliding

$Fs = (f \times \sum V + \tau \times B) / \sum H$

$= (0.47 \times 20.65 + 2.00 \times 5.40) / 9.30 =$ 2.197 > 1.20 -------- OK

6) Ground reaction

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (56.88 - 10.95) / 25.78 =$ 0.918m

$q = 4/3 \times \sum V / (B - 2 \times e)$

$= 4 / 3 \times 25.78 / (5.40 - 2 \times 0.918) =$ 9.64 tf/m2 (max) < 20.000 tf/m2 ------- OK

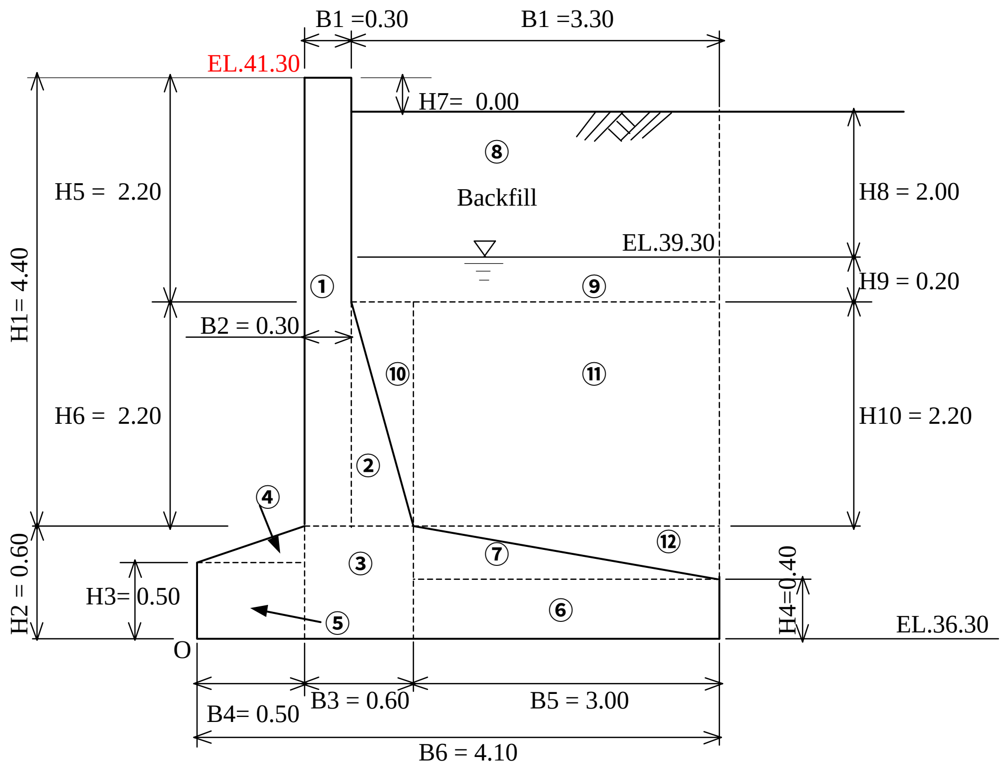
0.00 tf/m2 (min)

2. Retaining Wall

2-1. Design Condition

Unit Weight	Reinforced concrete	γc	2.40	tf/m^3
	Backfill (Wet)	γ t	1.80	tf/m^3
	Backfill (Saturated)	γsat	2.00	tf/m^3
	Water	γw	1.00	tf/m^3
Internal friction angle of backfill		φ	25.00	°
Embanked Slope of Backfill		β	0.00	°
Live Load	under normal condition		0.50	tf/m^2
Seismic coefficient		Kh	0.00	
Coefficient of friction		f	0.47	
Shearing stress of foundation		τ	2.00	tf/m^2
Bearing Capacity of foundation		qa	20.00	tf/m^2

2-2. Dimensions



H1 =	4.40	m	H6 =	2.20	m
H2 =	0.60	m	H7 =	0.00	m
H3 =	0.50	m	H8 =	2.00	m
H4 =	0.40	m	H9 =	0.20	m
H5 =	2.20	m	H10 =	2.20	m
B1 =	0.30	m	B5 =	3.00	m
B2 =	0.30	m	B6 =	4.10	m
B3 =	0.60	m	B7 =	3.30	m
B4 =	0.50	m	Slope of Wall (Back side)	0.000	
				0.136	

2-3. Coefficient of Earth Pressure Ka

Coulomb's Formula shall be applied for calculation of earth pressure.

$$Ka = \frac{\cos(\phi - \alpha - \theta)^2}{\cos\theta \cos\alpha^2 \cos(\alpha + \delta + \theta)\left\{1 - \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \beta - \theta)}{\cos(\alpha + \delta + \theta)\cos(\alpha - \beta)}}\right\}^2}$$

Where; Ka ; Coefficient of active earth pressure

ϕ ; Internal friction angle =25°

δ ; Angle of wall friction (wall and soil)

α ; Wall angle to vertical surface

β ; Slope angle of backfill

θ ; $= \tan^{-1}Kh$

Kh ; Horizontal seismic coefficient =0.00

(1) Angle of Wall Fliction (δ)

	Stability Analysis between soil and soi	Calculation of Member between concrete and soi
Under normal condition	β	2/3・ϕ
	0 °	16.667 °

		Under normal condition: Stability analysis	Under normal condition: Calculation of member
Internal friction angle	ϕ	25.00	25.00
Angle of wall friction	δ	0.00	16.67
Wall angle to vertical surface	α upper	0.00	0.00
	lower	0.00	7.74
Slope angle of backfill	β	0.00	0.00
$\tan^{-1}Kh$	θ	0.00	0.00

(2) Coefficient of Earth Pressure for Stability Analysis under Normal Condition

$$Ka = \frac{\cos(25 + 0)^{\wedge}2}{\cos 0^{\wedge}2 \cdot \cos(0 + 0) \times \left\{1 + \sqrt{\frac{\sin(25 + 0)\cdot\sin(25 - 0.00)}{\cos(0 + 0)\cdot\cos(0 - 0.00)}}\right\}^{2}} = 0.406$$

- Coefficient of horizontal earth pressure Kah

  $Kah = Ka \cdot \cos(\delta + \alpha)$ = 0.406・cos (0.00 + 0.00) = 0.406

- Coefficient of vertical earth pressure Kav

  $Kav = Ka \cdot \sin(\delta + \alpha)$ = 0.406・sin (0.00 + 0.00) = 0

The coefficient of earth pressure of every case shall be calculated by means of above mentioned, and are shown in table below.

		Stability analysis	Calculation of member: Upper	Calculation of member: Lower	Remarks
Under normal condition	Ka	0.406	0.361	0.420	
	Kah	0.406	0.346	0.382	$Ka \cdot \cos(\delta + \alpha)$
	Kav	0.000	0.104	0.174	$Ka \cdot \sin(\delta + \alpha)$

2-4. Stability Analysis

(1) Self Weight

		Area (m^2)		Unit Weight	Weight	Remark
			A	γ (tf/m^3)	W(tf)	
Reversed T type Wall	①	0.30 x 4.40	1.32	2.40	3.17	
	②	0.30 x 2.20 x 1/2	0.33	2.40	0.79	
	③	0.60 x 0.60	0.36	2.40	0.86	
	④	0.10 x 0.50 x 1/2	0.03	2.40	0.06	
	⑤	0.500 x 0.500	0.25	2.40	0.60	
	⑥	0.40 x 3.00	1.20	2.40	2.88	
	⑦	0.20 x 3.00 1/2	0.30	2.40	0.72	
Backfill	⑧	2.00 x 3.30	6.60	1.80	11.88	
	⑨	0.20 x 3.30	0.66	2.00	1.32	
	⑩	0.30 x 2.20 x 1/2	0.33	2.00	0.66	
	⑪	2.20 x 3.00	6.60	2.00	13.20	
	⑫	0.20 x 3.00 x 1/2	0.30	2.00	0.60	
Total					36.74	

(2)Center of Gravity

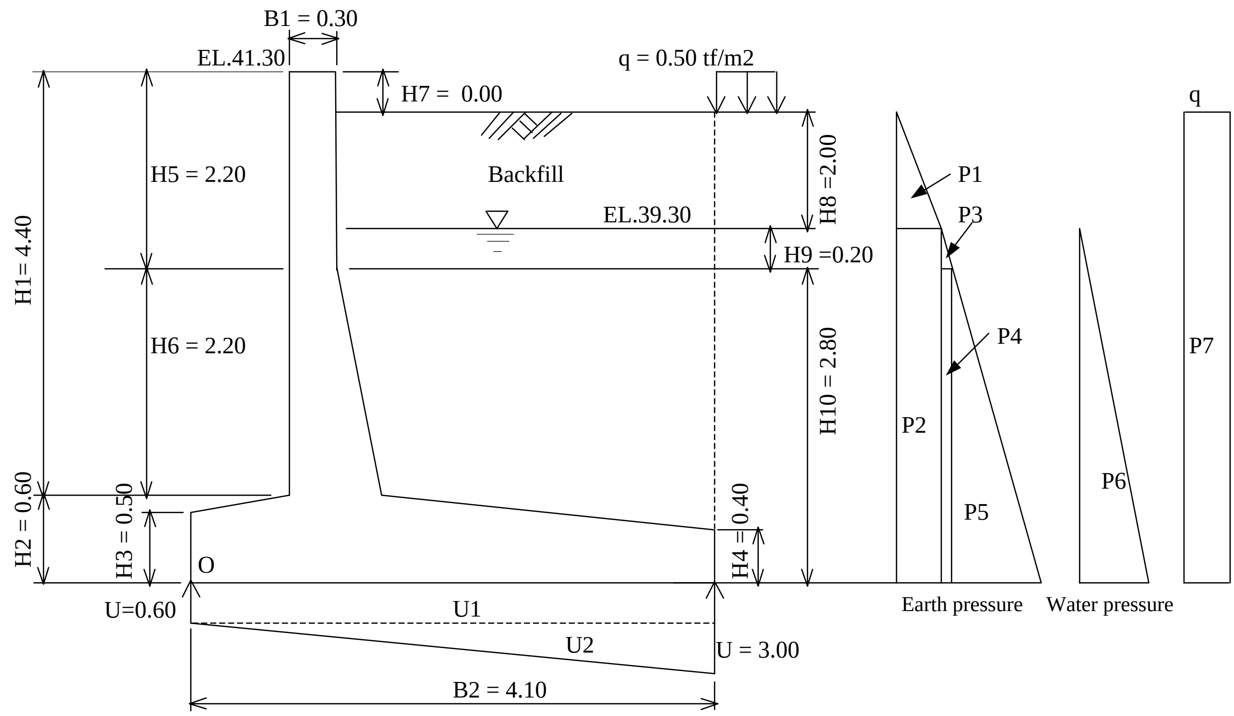
		Weight	Arm Length (m)		Moment(tf・m)		Remark
		W(t)	X	Y	W・x	W・y	
Reversed T type Wall	①	3.17	0.65	2.80	2.06	8.88	
	②	0.79	0.90	1.33	0.71	1.05	
	③	0.86	0.80	0.30	0.69	0.26	
	④	0.06	0.33	0.53	0.02	0.03	
	⑤	0.60	0.25	0.25	0.15	0.15	
	⑥	2.88	2.60	0.20	7.49	0.58	
	⑦	0.72	2.10	0.47	1.51	0.34	
Backfill	⑧	11.88	2.45	4.00	29.11	47.52	
	⑨	1.32	2.45	2.90	3.23	3.83	
	⑩	0.66	1.00	2.07	0.66	1.37	
	⑪	13.20	2.60	1.70	34.32	22.44	
	⑫	0.60	3.10	0.53	1.86	0.32	
	Total	36.74			81.81	86.77	

Center of Gravity

$Xo = \Sigma W \cdot x / \Sigma W$
$= 81.810 / 36.740$
$= 2.227m$

$Yo = \Sigma W \cdot y / \Sigma W$
$= 86.770 / 36.740$
$= 2.362m$

(3) Stability Analysis under Normal Condition



1) Earth pressure

Kah = 0.406

P1= Kah x γt x H8^2/2 = 0.406 x 1.80 x 2.00^2 x 1/2 = 1.462 tf/m

P2= Kah x γt x H8 x (H9+H10) = 0.406 x 1.80 x 2.00 x 3.00 = 4.385 tf/m

P3= Kah x γsub x H9^2 /2 = 0.406 x 1.00 x 0.20^2 x 1/2 = 0.008 tf/m

P4= Kah x γsub x H9 x H10 = 0.406 x 1.00 x 0.20 x 2.80 = 0.227 tf/m

P5= Kah x γsub x H10^2 /2 = 0.406 x 1.00 x 2.80^2 x 1/2 = 1.592 tf/m

2) Water pressure

P6= γw x H10^2 /2 = = 1.00 x 2.80^2 x 1/2 = 3.920 tf/m

3) Active load

Kah = 0.406

P7= Kah x q x (H8+H9+H10) = 0.406 x 0.50 x 5.00 = 1.015 tf/m

4) Uplift

U1=0.60 x 4.10 = 2.46 tf/m

U2 = (3.00-0.60) x 4.10 x 1/2 = 4.92 tf/m

		Force (tf/m)		Arm length(m)		Moment (m･t)	
		Vertical(V)	Horizontal(H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		36.740	-	2.227	-	81.810	-
Earth pressure	P1	-	1.462	-	3.667	-	5.361
	P2	-	4.385	-	1.500	-	6.578
	P3	-	0.008	-	2.867	-	0.023
	P4	-	0.227	-	1.400		0.318
	P5	-	1.592	-	0.933	-	1.485
Water pressure	P6	-	3.920	-	1.000	-	3.920
Active load	P7	-	1.015		2.500		2.538
Up-Lift	U1	-2.460	-	2.050	-	-5.043	-
	U2	-4.920	-	2.733	-	-13.446	-
Total	with Up-Lift	29.360	12.609			63.321	20.223
	except Up-Lift	36.740	12.609			81.810	20.223

Length of bottom slab	B =	4.10	m
Coefficient of friction	f =	0.47	
Shearing stress of foundation	τ =	2.00	t/m^2
Bearing capacity of foundation	qa =	20.00	t/m^2

5) Over turning

e = B / 2 - (∑Mx - ∑My) / ∑V

= 4.10 / 2 -(63.32－20.22) / 29.36 = 0.582m < B/6 =0.683 m -------- OK

6) Sliding

Fs = (f x ∑V + τ x B) /∑H

= （0.47 x 29.36 + 2.00 x 4.10） / 12.61 = 1.736 > 1.50 -------- OK

7) Ground reaction

In the case of taking account of Up-lift

q = ∑V / B x (1±6 e/ B)

= 29.36 / 4.10 x (1 ± 6 x 0.582 / 4.10） = 13.260 tf/m2 (max) < 20.000 tf/m2 ------- OK

1.062 tf/m2 (min)

In the case of taking no account of Up-lift

e = B / 2 - (∑Mx - ∑My) / ∑V

= 4.10 / 2 -(81.81－20.22) / 36.74 = 0.374m

q = ∑V / B x (1±6 e/ B)

= 36.74 / 4.10 x (1 ± 6 x 0.374 / 4.10） = 13.865 tf/m2 (max) < 20.000 tf/m2 ------- OK

4.056 tf/m2 (min)

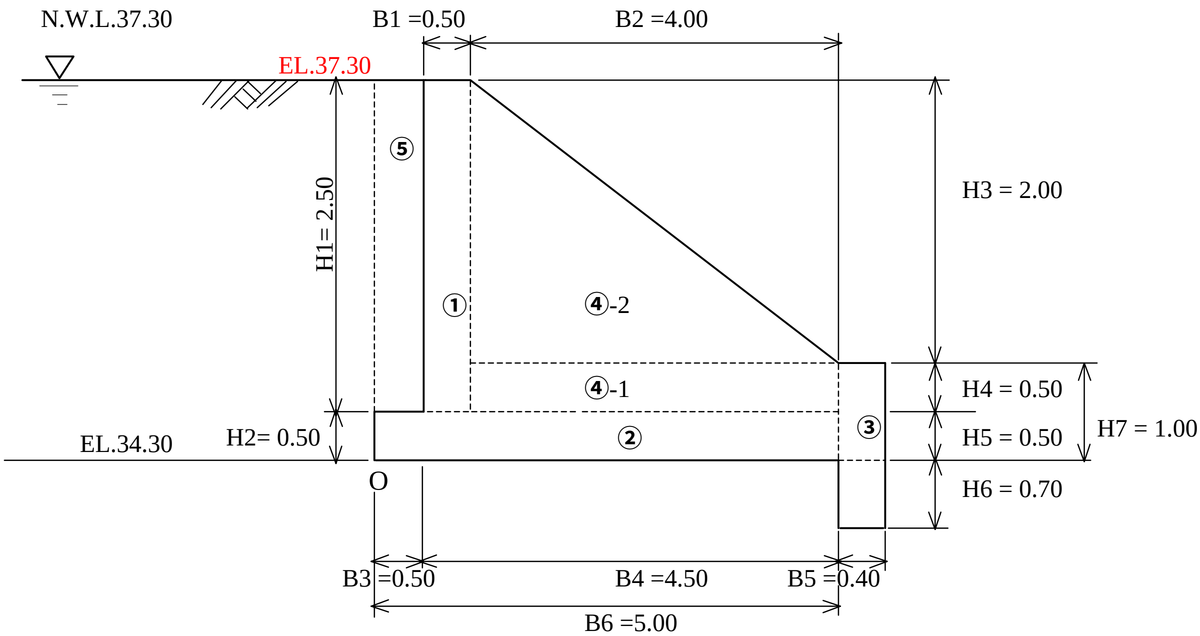
Result of Stability Analysis ; Spillway of Kpob Trobek Reservoir

1.Box of Rock Spillway

1-1. Design Condition

Unit Weight	Reinforced concrete	γc	2.40	tf/m^3
	Embankment (Wet)	γ t	1.80	tf/m^3
	(Saturated)	γsat	2.00	tf/m^3
	Rock anchor (Wet)	γ t	2.00	tf/m^3
	(Saturated)	γsat	2.20	tf/m^3
	Water	γw	1.00	tf/m^3
Internal friction angle of Embankment		φ	25.00	°
Embankment Slope		β	0.00	
Live Load	under normal condition		0.50	tf/m^2
Coefficient of friction		f	0.47	
Shearing stress of foundation		τ	2.00	tf/m^2
Bearing Capacity of foundation		qa	20.00	tf/m^2
Flood water level (F.W.L)			38.10	m
Normal water level (N.W.L)			37.30	m

1-2. Dimensions



H1 =	2.50	m	H5 =	0.50	m
H2 =	0.50	m	H6 =	0.70	m
H3 =	2.00	m	H7 =	1.00	m
H4 =	0.50	m			
B1 =	0.50	m	B6 =	5.00	m
B2 =	4.00	m			
B3 =	0.50	m			
B4 =	4.50	m			
B5 =	0.40	m			
Length of box L =	12.00	m	Thickness of member④ t =	0.40m	

1-3. Coefficient of Earth Pressure Ka

(1) Coefficient of Active Earth Pressure

Coulomb's Formula shall be applied for calculation of earth pressure.

$$Ka = \frac{\cos^2(\phi - \alpha - \theta)}{\cos\theta \cdot \cos^2\alpha \cdot \cos(\alpha + \delta + \theta)\left\{1 + \sqrt{\frac{\sin(\phi + \delta)\cdot\sin(\phi - \beta - \theta)}{\cos(\alpha + \delta + \theta)\cdot\cos(\alpha - \beta)}}\right\}^2}$$

Where; Ka ; Coefficient of active earth pressure

ϕ ; Internal friction angle =25°

δ ; Angle of wall friction (wall and soil)

a ; Wall angle to vertical surface

β ; Slope angle of backfill

θ ; $= \tan^{-1}Kh$

Kh ; Horizontal seismic coefficient

1) Angle of wall friction (δ)

	Stability Analysis between soil and soi	Calculation of Member between concrete and soi
Under normal condition	β	2/3 ・φ
	0 °	16.667 °

		Under normal condition	
		Stability analysis	Calculation of member
Internal friction angle	φ	25.00	25.00
Angle of wall friction	δ	0.00	16.67
Wall angle to vertical surface	α	0.00	0.00
Slope angle of backfill	β	0.00	0.00
$\tan^{-1}Kh$	θ	0.00	0.00

2) Coefficient of earth pressure for stability analysis under normal condition

$$Ka = \frac{\cos^2(25 + 0)}{\cos 0^2 \cdot \cos(0 + 0) \times \left\{1 + \sqrt{\frac{\sin(25 + 0)\cdot\sin(25 - 0.00)}{\cos(0 + 0)\cdot\cos(0 - 0.00)}}\right\}^2} = 0.406$$

- Coefficient of horizontal earth pressure Kah

$Kah = Ka \cdot \cos(\delta + \alpha)$ $= 0.406 \cdot \cos(0.00 + 0.00) =$ 0.406

- Coefficient of vertical earth pressure Kav

$Kav = Ka \cdot \sin(\delta + \alpha)$ $= 0.406 \cdot \sin(0.00 + 0.00) =$ 0

The coefficient of earth pressure of every case shall be calculated by means of above mentioned, and are shown in table below.

		Stability analysis	Calculation of member	Remarks
Under normal condition	Ka	0.406	0.361	
	Kah	0.406	0.346	Ka・cos(δ + α)
	Kav	0.000	0.104	Ka・sin(δ + α)

1-4. Stability Analysis

(1) Self Weight

			Area (m^2)	Unit Weight γ (tf/m^3)	Lenfth of Box (m)	Weight W(tf)
Concrete structure	①	0.50 x 2.50	1.25	2.40	12.00	36.00
	②	0.50 x 5.00	2.50	2.40	12.00	72.00
	③	0.40 x 1.00	0.40	2.40	12.00	11.52
	④-1	4.00 x 0.50 x 0.40 x 3 x 2.40 =		2.40	-	5.76
	④-2	4.00 x 2.00 / 2 x 0.40 x 3 x 2.40 =		2.40	-	11.52
Embankment	⑤	2.50 x 0.50	1.25	2.00	12.00	30.00
Rock anchor	⑥-1	4.00 x 0.50 x 5.40 x 2.20 x 2 =		2.20	5.40	47.52
	⑥-2	4.00 x 2.00 / 2 x 5.40 x 2.20 x 2 =		2.20	5.40	95.04
	Total					309.36

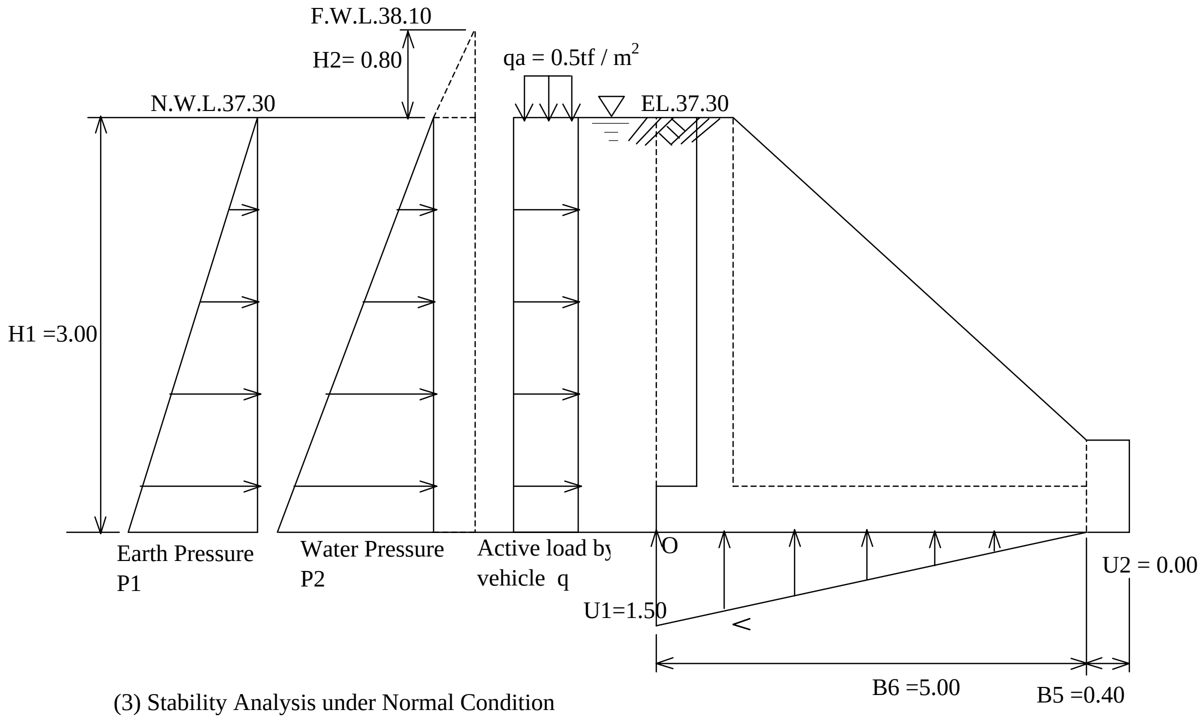
(2)Center of Gravity

		Weight W(t)	Arm Length (m)		Moment(tf・m)		Remark
			X	Y	W・x	W・y	
Concrete structure	①	36.00	0.75	1.75	27.00	63.00	
	②	72.00	2.50	0.25	180.00	18.00	
	③	11.52	5.20	0.50	59.90	5.76	
	④-1	5.76	3.00	0.75	17.28	4.32	
	④-2	11.52	2.33	1.67	26.84	19.24	
Embankment	⑤	30.00	0.25	1.75	7.50	52.50	
Rock anchor	⑥-1	47.52	3.00	0.75	142.56	35.64	
	⑥-2	95.04	2.33	1.67	221.44	158.72	
	Total	309.36			682.53	357.18	

Center of Gravity

Xo = ΣW・x / ΣW
= 682.529／309.360
= 2.206m

Yo = ΣW・y / ΣW
= 682.529／309.360
= 1.155m



(3) Stability Analysis under Normal Condition

1) Active earth pressure

Kah = 0.406

P1= Kah x γsub x $H1^2$ x 1/2 = 0.406 x 1.00 x 3.00^2 x 1/2 = 1.83 tf/m

2) Water pressure

P2= γw x $H1^2$ x 1/2 = 1.00 x 3.00^2 x 1/2 = 4.50 tf/m

3) Uplift

U1= 3.00 x 0.5 =1.50 tf / m2

U= (1.50 + 0.00) / 2 x 5.00= 3.75 tf/m

4) Active load

q = 0.50 x 3.00 x 0.406 = 0.61 tf/m

Self weight per unit width Ws = 309.36 / 12.00 = 25.78 tf/m

		Force (tf/m)		Arm length(m)		Moment (m･t)	
		Vertical (V)	Horizontal (H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		25.78	-	2.21	-	56.88	-
Earth pressure	P1	-	1.83	-	1.00	-	1.83
Water pressure	P2	-	4.50	-	1.00	-	4.50
Up-Lift	U	-3.75	-	1.67	-	-6.26	
Active load	q	-	0.61	-	1.50	-	0.92
Total	Over turning Sliding	22.03	6.94			50.62	7.25
	Ground reaction	25.78	6.94			56.88	7.25

Length of bottom slab B = 5.40 m

Coefficient of friction f = 0.47

Shearing stress of foundation τ = 2.00 t/m^2

Bearing capacity of foundation qa = 20.00 t/m^2

5) Over turning

e = B / 2 - ($\sum$Mx - $\sum$My) / $\sum$V

= 5.40 / 2 -(50.62－7.25) / 22.03 = 0.731m < B/6 = 0.900 m -------- OK

6) Sliding

Fs = (f x $\sum$V + τ x B) / $\sum$H

= （0.47 x 22.03 + 2.00 x 5.40） / 6.94 = 3.036 > 1.50 -------- OK

7) Ground reaction

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (56.88 - 7.25) / 25.78 =$ 0.775m

$q = \sum V / B \times (1 \pm 6 e / B)$

$= 25.78 / 5.40 \times (1 \pm 6 \times 0.775 / 5.40) =$ 8.89 tf/m2 (max) < 20.000 tf/m2 ------- OK

0.66 tf/m2 (min)

(4) Stability Analysis under Flood Condition

1) Active earth pressure

Kah = 0.406

$P1 = Kah \times \gamma sub \times (H1)^2 \times 1/2 =$ 0.406 x 1.00 x 3.00^2 x 1/2 = 1.83 tf/m

2) Water pressure

$P_{2-1} = \gamma w \times H1^2 \times 1/2 =$ 1.00 x 3.00^2 x 1/2 = 4.50 tf/m

$P_{2-2} = \gamma w \times H2 \times H1 =$ 1.00 x 0.80 x 3.00 = 2.40 tf/m

3) Uplift

U1= 3.80 x 0.5 = 1.90 tf / m2

U= (1.90 + 0.00) / 2 x 5.00= 4.75 tf/m

Self weight per unit width Ws = 309.36 / 12.00 = 25.78 tf/m

		Force (tf/m)		Arm length(m)		Moment (m・t)	
		Vertical (V)	Horizontal (H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		25.78	-	2.21	-	56.88	-
Earth pressure	P1	-	1.83	-	1.00	-	1.83
Water pressure	P_{2-1}	-	4.50	-	1.00	-	4.50
	P_{2-2}	-	2.40	-	1.50	-	3.60
Up-Lift	U	-4.75	-	1.67	-	-7.93	
Total	Over turning Sliding	21.03	8.73			48.95	9.93
	Ground reaction	25.78	8.73			56.88	9.93

Length of bottom slab B = 5.40 m

Coefficient of friction f = 0.47

Shearing stress of foundation $\tau =$ 2.00 t/m^2

Bearing capacity of foundation qa = 20.00 t/m^2

4) Over turning

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (48.95 - 9.93) / 21.03 =$ 0.845m < B/3 =1.800 m -------- OK

5) Sliding

$Fs = (f \times \sum V + \tau \times B) / \sum H$

$= (0.47 \times 21.03 + 2.00 \times 5.40) / 8.73 =$ 2.36 > 1.20 -------- OK

6) Ground reaction

$e = B / 2 - (\sum Mx - \sum My) / \sum V$

$= 5.40 / 2 - (56.88 - 9.93) / 25.78 =$ 0.879m

$q = \sum V / B \times (1 \pm 6 e / B)$

$= 25.78 / 5.40 \times (1 \pm 6 \times 0.879 / 5.40) =$ 9.44 tf/m2 (max) < 20.000 tf/m2 ------- OK

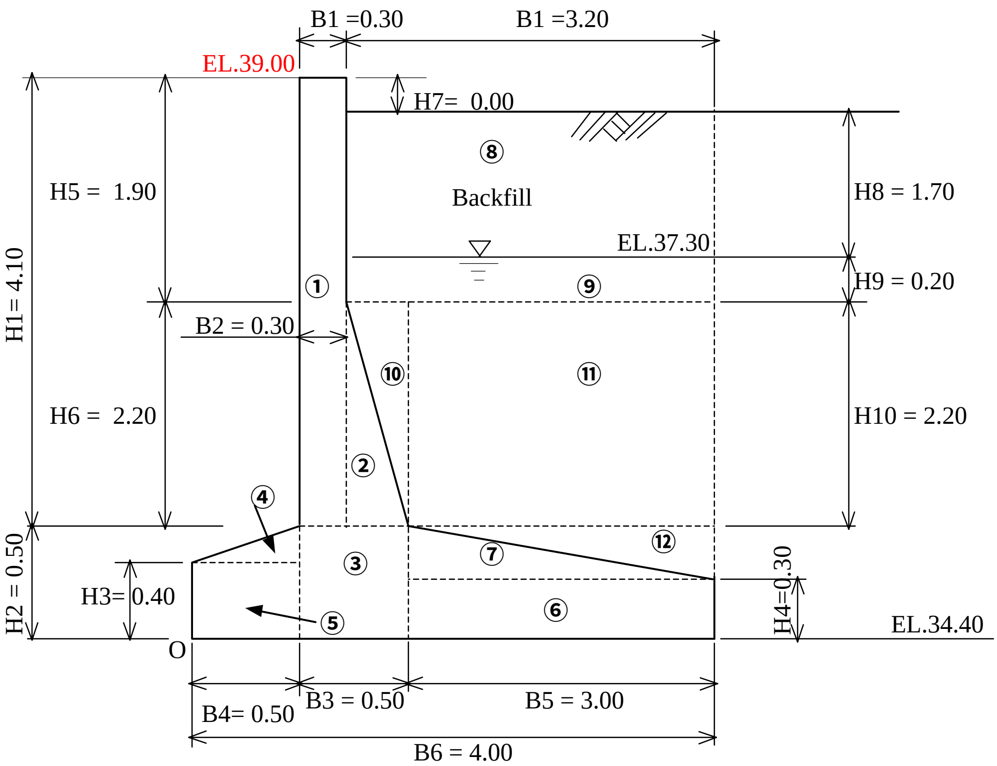
0.11 tf/m2 (min)

2. Retaining wall (1)

2-1. Design Condition

Unit Weight Reinforced concrete	γc	2.40	tf/m^3
Backfill (Wet)	γt	1.80	tf/m^3
Backfill (Saturated)	γsat	2.00	tf/m^3
Water	γw	1.00	tf/m^3
Internal friction angle of backfill	ϕ	25.00	°
Embanked Slope of Backfill	β	0.00	°
Live Load under normal condition		0.50	tf/m^2
Seismic coefficient	Kh	0.00	
Coefficient of friction	f	0.47	
Shearing stress of foundation	τ	2.00	tf/m^2
Bearing Capacity of foundation	qa	20.00	tf/m^2

2-2. Dimensions



H1 =	4.10	m	H6 =	2.20	m
H2 =	0.50	m	H7 =	0.00	m
H3 =	0.40	m	H8 =	1.70	m
H4 =	0.30	m	H9 =	0.20	m
H5 =	1.90	m	H10 =	2.20	m
B1 =	0.30	m	B5 =	3.00	m
B2 =	0.30	m	B6 =	4.00	m
B3 =	0.50	m	B7 =	3.20	m
B4 =	0.50	m	Slope of Wall (Back side)	0.000	
				0.091	

2-3. Coefficient of Earth Pressure Ka

Coulomb's Formula shall be applied for calculation of earth pressure.

$$Ka = \frac{\cos(\phi - \alpha - \theta)^2}{\cos\theta \cos\alpha^2 \cos(\alpha + \delta + \theta)\left\{1 - \sqrt{\frac{\sin(\phi+\delta)\sin(\phi-\beta-\theta)}{\cos(\alpha+\delta+\theta)\cos(\alpha-\beta)}}\right\}^2}$$

Where;

Ka ; Coefficient of active earth pressure
ϕ ; Internal friction angle =25°
δ ; Angle of wall friction (wall and soil)
α ; Wall angle to vertical surface
β ; Slope angle of backfill
θ ; $= \tan^{-1}Kh$
Kh ; Horizontal seismic coefficient =0.00

(1) Angle of wall fliction (δ)

	Stability Analysis between soil and soi	Calculation of Member between concrete and soi
Under normal condition	β	2/3・ϕ
	0 °	16.667 °

		Under normal condition: Stability analysis	Under normal condition: Calculation of member
Internal friction angle	ϕ	25.00	25.00
Angle of wall friction	δ	0.00	16.67
Wall angle to vertical surface	α upper	0.00	0.00
	lower	0.00	5.20
Slope angle of backfill	β	0.00	0.00
$\tan^{-1}Kh$	θ	0.00	0.00

(2) Coefficient of earth pressure for stability analysis under normal condition

$$Ka = \frac{\cos(\ 25 + 0\ )\text{^}2}{\cos 0\text{^}2 \cdot \cos(\ 0 + 0\ ) \times \left\{ 1 + \sqrt{\frac{\sin(\ 25 + 0\ )\cdot\sin(\ 25 - 0.00\ )}{\cos(\ 0 + 0\ )\cdot\cos(\ 0 - 0.00\ )}} \right\}^2} = 0.406$$

- Coefficient of horizontal earth pressure Kah

  Kah = Ka・cos(δ + α) = 0.406・cos (0.00 + 0.00) = 0.406

- Coefficient of vertical earth pressure Kav

  Kav = Ka・sin(δ + α) = 0.406・sin (0.00 + 0.00) = 0

The coefficient of earth pressure of every case shall be calculated by means of above mentioned, and are shown in table below.

		Stability analysis	Calculation of member: Upper	Calculation of member: Lower	Remarks
Under normal condition	Ka	0.406	0.361	0.400	
	Kah	0.406	0.346	0.371	Ka・cos(δ + α)
	Kav	0.000	0.104	0.149	Ka・sin(δ + α)

2-4. Stability Analysis

(1) Self weight

		Area (m^2)		Unit Weight	Weight	Remark
			A	γ (tf/m^3)	W(tf)	
Reversed T type Wall	①	0.30 x 4.10	1.23	2.40	2.95	
	②	0.20 x 2.20 x 1/2	0.22	2.40	0.53	
	③	0.50 x 0.50	0.25	2.40	0.60	
	④	0.10 x 0.50 x 1/2	0.03	2.40	0.06	
	⑤	0.400 x 0.500	0.20	2.40	0.48	
	⑥	0.30 x 3.00	0.90	2.40	2.16	
	⑦	0.20 x 3.00 1/2	0.30	2.40	0.72	
Backfill	⑧	1.70 x 3.20	5.44	1.80	9.79	
	⑨	0.20 x 3.20	0.64	2.00	1.28	
	⑩	0.20 x 2.20 x 1/2	0.22	2.00	0.44	
	⑪	2.20 x 3.00	6.60	2.00	13.20	
	⑫	0.20 x 3.00 x 1/2	0.30	2.00	0.60	
Total					32.81	

(2)Center of Gravity

		Weight	Arm Length (m)		Moment(tf・m)		Remark
		W(t)	X	Y	W・x	W・y	
Reversed T type Wall	①	2.95	0.65	2.55	1.92	7.52	
	②	0.53	0.87	1.23	0.46	0.65	
	③	0.60	0.75	0.25	0.45	0.15	
	④	0.06	0.33	0.43	0.02	0.03	
	⑤	0.48	0.25	0.20	0.12	0.10	
	⑥	2.16	2.50	0.15	5.40	0.32	
	⑦	0.72	2.00	0.37	1.44	0.27	
Backfill	⑧	9.79	2.40	3.75	23.50	36.71	
	⑨	1.28	2.40	2.80	3.07	3.58	
	⑩	0.44	0.93	1.97	0.41	0.87	
	⑪	13.20	2.50	1.60	33.00	21.12	
	⑫	0.60	3.00	0.43	1.80	0.26	
	Total	32.81			71.59	71.58	

Center of Gravity

$Xo = \Sigma W \cdot x / \Sigma W$

$= 71.590 / 32.810$

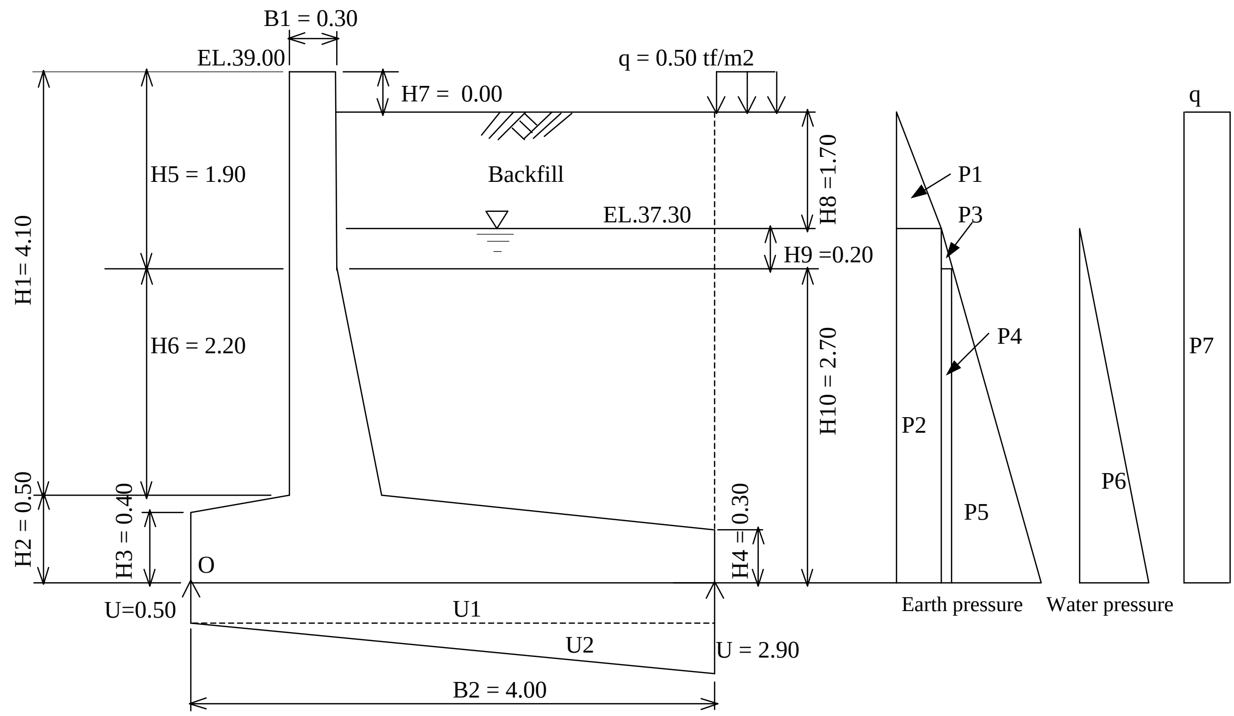
$= 2.182m$

$Yo = \Sigma W \cdot y / \Sigma W$

$= 71.580 / 32.810$

$= 2.182m$

(3) Stability analysisi under normal condition



1) Earth pressure

Kah = 0.406

P1= Kah x γt x $H8^2$/2 = 0.406 x 1.80 x 1.70^2 x 1/2 = 1.056 tf/m

P2= Kah x γt x H8 x (H9+H10) = 0.406 x 1.80 x 1.70 x 2.90 = 3.603 tf/m

P3= Kah x γsub x $H9^2$ /2 = 0.406 x 1.00 x 0.20^2 x 1/2 = 0.008 tf/m

P4= Kah x γsub x H9 x H10 = 0.406 x 1.00 x 0.20 x 2.70 = 0.219 tf/m

P5= Kah x γsub x $H10^2$ /2 = 0.406 x 1.00 x 2.70^2 x 1/2 = 1.480 tf/m

2) Water pressure

P6= γw x $H10^2$ /2 = = 1.00 x 2.70^2 x 1/2 = 3.645 tf/m

3) Active load

Kah = 0.406

P7= Kah x q x (H8+H9+H10) = 0.406 x 0.50 x 4.60 = 0.934 tf/m

4) Uplift

U1=0.50 x 4.00 = 2.00 tf/m

U2 = (2.90-0.50) x 4.00 x 1/2 = 4.80 tf/m

		Force (tf/m)		Arm length(m)		Moment (m･t)	
		Vertical(V)	Horizontal(H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		32.810	-	2.182	-	71.590	-
Earth pressure	P1	-	1.056	-	3.467	-	3.661
	P2	-	3.603	-	1.450	-	5.224
	P3	-	0.008	-	2.767	-	0.022
	P4	-	0.219	-	1.350		0.296
	P5	-	1.480	-	0.9	-	1.332
Water pressure	P6	-	3.645	-	0.967	-	3.525
Active load	P7	-	0.934		2.300		2.148
Up-Lift	U1	-2.000	-	2.000	-	-4.000	-
	U2	-4.800	-	2.667	-	-12.802	-
Total	with Up-Lift	26.010	10.945			54.788	16.208
	except Up-Lift	32.810	10.945			71.590	16.208

Length of bottom slab	B =	4.00	m
Coefficient of friction	f =	0.47	
Shearing stress of foundation	τ =	2.00	t/m^2
Bearing capacity of foundation	qa =	20.00	t/m^2

5) Over turning

e = B / 2 - (∑Mx - ∑My) / ∑V

= 4.00 / 2 -(54.79－16.21) / 26.01 = 0.517m < B/6 =0.667 m -------- OK

6) Sliding

Fs = (f x ∑V + τ x B) /∑H

= （0.47 x 26.01 + 2.00 x 4.00） / 10.95 = 1.839 > 1.50 -------- OK

7) Ground reaction

In the case of taking account of Up-lift

q = ∑V / B x (1±6 e/ B)

= 26.01 / 4.00 x (1 ± 6 x 0.517 / 4.00） = 11.545 tf/m2 (max) < 20.000 tf/m2 ------- OK

1.460 tf/m2 (min)

In the case of taking no account of Up-lift

e = B / 2 - (∑Mx - ∑My) / ∑V

= 4.00 / 2 -(71.59－16.21) / 32.81 = 0.312m

q = ∑V / B x (1±6 e/ B)

= 32.81 / 4.00 x (1 ± 6 x 0.312 / 4.00） = 12.041 tf/m2 (max) < 20.000 tf/m2 ------- OK

4.364 tf/m2 (min)