Chapter 4

BRIDGE

4.1 Design Calculation of Siwarak Bridge

DESIGN CALCULATION OF SIWARAK BRIDGE

I. DESIGN CONDITION

1.1. Bridge Type

Upper structure : Simple RC T - Beam
Bina Marga Standart
Sub Structure : Spread Fondation For Stone Masonry

1.2. Seismic Coefficient

Kh : 0.18

1.3. Back Filling

Angle of internal Friction : 25°
Unit weight : γ : 1.9 t/m³
Eath Pressure Coefficient :
Normal Condotion by Coulomb analysis
Eartquake Condotion by Mononobe - Okabe analysis

II. LOADING

2.1. Dead Load

- Beam = 5 x 0.3 x 0.3 x 5.8 x 2.5 = **6.525** ton
- Slab and Curb = 0,2 x 6+0,25 x 0,75) x 5,8 x 2,5
  + 2 x 0.25 * 0.6 x 5.8 x 2.5 = **24.469** ton
- Asphalt 0.07 x 4 x 2.2 x 5,8 = **3.573** ton
- Water 0.05 x 4 x 1.0 x 5,8 = **1.160** ton

Total **35.727** ton

Reaction on abutment V1 = 35.727/2 = **17.863** ton

2.2. Live Load

- Uniform Load q = 2.2 t/m2
  q = 4 x 2.2 / 2.75 x 5.80 **18.560** ton
- Line Load P = 12.00 ton
  Inpac Coefficient K = 1 + 20/(50+5.00)
  = **1.364**
  P = K x 12 x 4 / 2.75 **23.802** ton
- Side Walk qtr = 2 x 0.6 x 5,8 x 0.50 = **3.480** ton

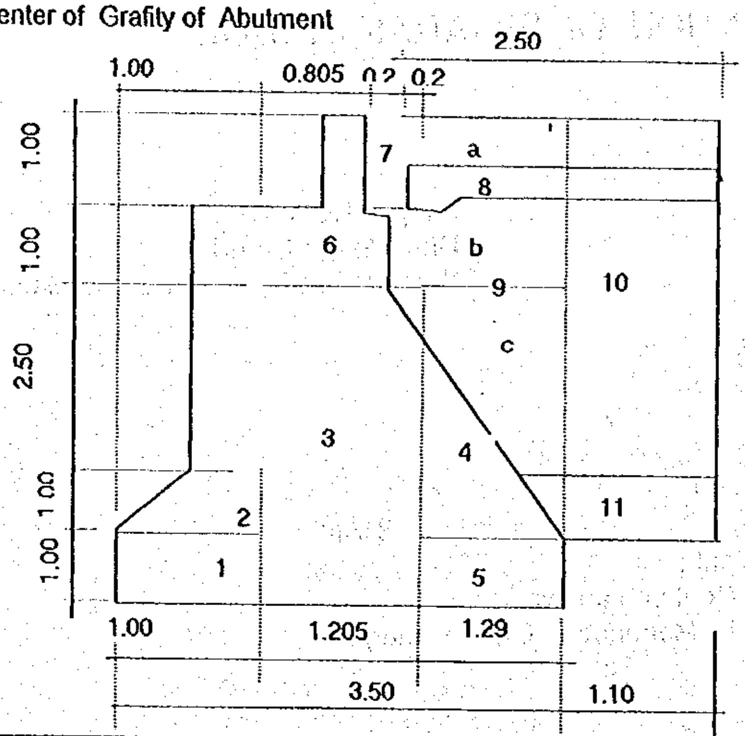
Reaction on abutment V2 = 18.56/2+3.48/2 + 23.802
= **34.822** ton
ΣV = **52.685** ton

Name of Structure	Siwarak Bridge	Category of Calculation	Design Calculation	Page	

III. DESAIN OF ABUTMEMT

3.1. Acting force at bottom of abutment

a. Center of Grafity of Abutment



NO	WEIGHT	W (ton)	X (m)	Y (m)	WX (ton m)	WY (ton m)
1	1.00 x 1.00 x 2.30 x 6.00	13.800	0.500	0.500	6.900	6.900
2	0.50 x 1.00 x 1.00 x 2.30 x 6.00	6.900	0.667	1.333	4.600	9.200
3	1.205 x 4.50 x 2.30 x 6 00	74.831	1.603	2.250	119.916	168.369
4	0.50 x 1.29.5 x 3.50 x 2.30 x 6.00	31.274	2.803	2.167	87.672	67.761
5	1.295 x 1.00 x 2.30 x 6.00	17.871	3.103	0.500	55.445	8.936
6	1.00 x 1.205 x 2.50 x 6.00	18.075	1.603	5.000	28.965	90.375
7	0.20 x 0.60 x 2.50 x 6.00	1.800	1.905	5.800	3.429	10.440
8	0.20 x 2.50 x 2.50 x 6.00	7.500	3.170	5.700	23.775	42.750
9	(0.5 x 1.25 x1.295+(0.5+2)/2x 4.07x0.5x1.295)x2.3 x 2	18.876	3.402	3.380	64.211	63.802
10	(0.5 x 1.25 x1.305+(0.5+2)/2x 4.07x1.305)x2.3 x 2	34.292	4.050	1.690	138.883	57.954
11	2.00 x 1.00 x 1.00 x 2.30 x 2	9.200	4.050	1.500	37.260	13.800
a	0.30 x 2.00 x 1.90 x 5.00	5.700	3.170	5.950	18.069	33.915
b	1.795 x 1.07 x 1.90 x 5.00	18.246	3.103	5.035	56.609	91.869
c	0.50 x 1.795 x 3.50 x 1.90 x 3.50	20.889	3.402	3.333	71.058	69.631
	Total	279.255			716.79	735.70
	x1 = WX / W =	2.567 m				
	y1 = WY / W =	2.635 m				

b. Earth Pressure

Earth Pressure Coefficient

Normal Condition

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

Where $\phi = 25°$ $\delta = 4.695°$
$\theta = 20.305°$
$\alpha = 0°$

$\cos^2(\phi - \theta) =$ 0.993
$\cos^2\theta =$ 0.880
$\cos(\theta + \delta) =$ 0.906
$\sin(\phi + \delta) =$ 0.495
$\sin(\phi - \alpha) =$ 0.422
$\cos(\theta + \delta) =$ 0.906
$\sin(\theta - \alpha) =$ 0.347

Ka = **0.38**

Pa = $1/2\,\gamma\, h^2 Ka = 1/2 \times 1.9 \times 6.07^2 \times 0.56$
= **13.23 t/m**

Pah = $Pa \times \cos\delta = 19.6 \times \cos 4.695°$
= **13.18 t/m**

Pav = $Pa \times \sin\delta = 19.6 \times \sin 4.695°$
= **1.08 t/m**

Pq = $\gamma\, h\, Ka = 1.0 \times 6.07 \times 0.56$
= **2.29 t/m**

Pqh = $Pa \times \cos\delta = 3.40 \times \cos 4.695°$
= **2.29 t/m**

Pqv = $Pa \times \sin\delta = 19.6 \times \sin 4.695°$
= **0.19 t/m**

Eartquake Condition

$$Kea = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos\theta_0 \times \cos^2\theta \times \cos(\theta + \theta_0 + \delta) \times \left[1 + \sqrt{\frac{\sin(\phi+\delta) \times \sin(\theta - \alpha - \theta_0)}{\cos(\phi+\theta_0+\delta) \times \cos(\theta - \alpha)}}\right]^2}$$

Where

$\theta_o = \tan^{-1} Kh$ $Kh = 0.18$
$\theta_o = \tan^{-1} 0.18 =$ 0.2
$\theta_o = \tan^{-1} 0.18 =$ 10.204

ϕ = 25° δ = 12.5°
θ = 20.305°
α = 0°

$Cos^2(\phi - \theta_o - \theta)$ = 0.991
$Cos^2 \theta$ = 0.880
$Cos\ \theta_0$ = 0.984
$Cos\ (\theta + \theta_o + \delta)$ = 0.732
$Sin\ (\phi + \delta)$ = 0.608
$Sin\ (\phi - \alpha - \theta_o)$ = 0.255
$Cos\ (\theta + \theta_o + \delta)$ = 0.732
$Sin\ (\theta - \alpha)$ = 0.347

Ka = 0.49

Pea = $1/2\,\gamma\, h^2\, Kea$ = $1/2 \times 1.9 \times 6.07^2 \times 0.49$
= 17.24 t/m

Peah = $Pa \times Cos\ \delta = 24.85 \times Cos\ 12.5°$
= 16.83 t/m

Peav = $Pa \times Sin\ \delta = 19.6 \times Sin\ 12.5°$
= 4.24 t/m

c. Reaction of Super Structure

Normal Condition
Rv = Σ V/L = 52.685/6 = 8.781 t/m

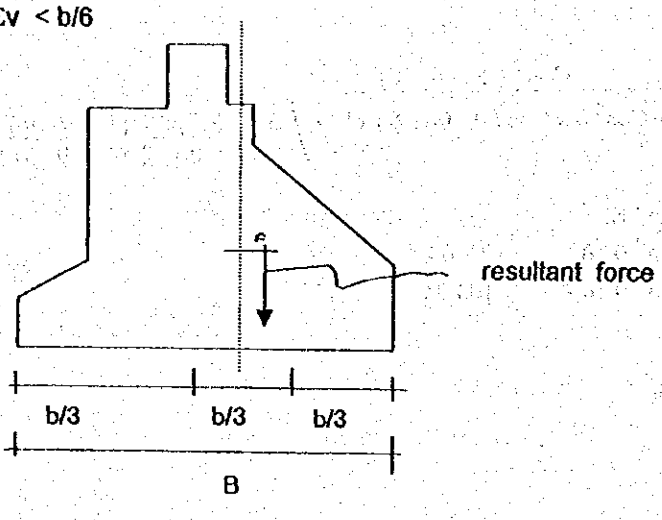
Eartquake Condition
Rv = V1/L = 17.863/6 = 2.977 t/m
Rh = 2 Rv.Kh = 2 x 2.977 x 0.18
= 1.072 t/m

3.2. Stability Analysis for abutment

Stability against overturning

The resultant force must fall within the midle third of the base. to This end, the followin condition must be satisfied.

$b/2 - \Sigma M/\Sigma v < b/6$



Name of Structure	Siwarak Bridge	Category of Calculation	Design Calculation	Page	

Normal Condition

	V (t/m)	H (t/m)	X (m)	Y (m)	VX (m)	HY (m)
Abutment	46.542	-	2.567	-	119.465	-
Eart Pressure	1.082	13.183	3.500	2.023	3.787	26.673
Eart Pressure (surcharge)	0.188	2.294	3.500	3.035	0.657	6.962
Superstructure	8.781	-	1.400	-	12.293	-
Σ	56.593	15.476			136.203	33.634

e = B/2 - Σ (VX - HY)/ Σ V = 3.5/2-(136.203 - 33.634 / 56.593 = (0.062) m

B/6 = 0.583 m > e (Ok)

Seismic Condition

	V (t/m)	H (t/m)	X (m)	Y (m)	VX (m)	HY (m)
Abutment	46.542	8.378		2.635	119.465	22.071
Eart Pressure	4.240	16.828	3.500	2.023	14.841	34.048
Superstructure	2.977	1.072	5.500	5.500	16.375	5.895
Σ	53.760	26.277			150.681	62.014

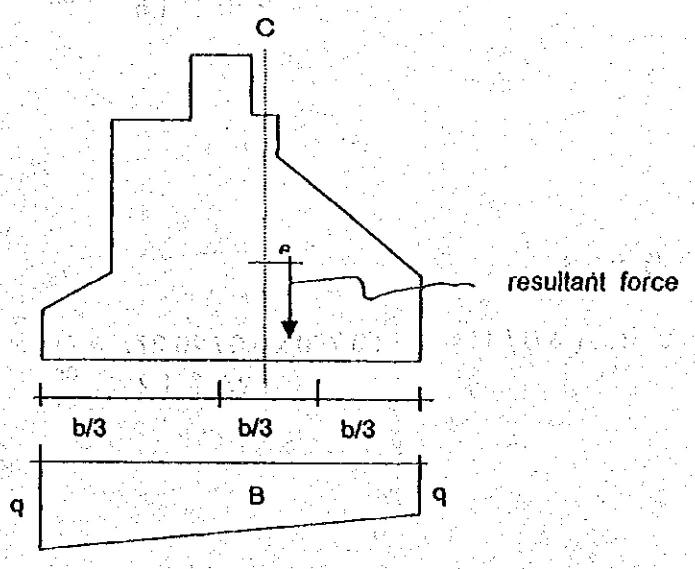
e = B/2 - Σ (VX - HY)/ Σ V = 3.5/2-(150.681 - 62.014) / 53.760 = 0.101 m

B/6 = 0.583 m > e (Ok)

Soil pressure

The Soil pressure beneath the toe of the foundation should be equal to or smaller then the allowable soil pressure. It can be obtained by the following formula.

$$q1 = V/b (1 + 6e/b)$$
$$q2 = V/b (1 - 6e/b)$$



Normal Condition

q1 = V/b (1 + 6e/b)
= 56.593/3.50 x (1+6*(-0.062)/3.5) 14.440 t/m^2

q2 = V/b (1 - 6e/b)
= 56.593/3.50 x (1-6*(-0.062)/3.5) 17.899 t/m^2

Earthquake Condition

q1 = V/b (1 + 6e/b)
= 53.76/3.50 x (1+6*0.101)/3.5) = 18.011 t/m^2

q2 = V/b (1 - 6e/b)
= 57.205/3.50 x (1-6*0.101)/3.5) = 12.709 t/m^2

Stability againt sliding

The sliding of an abutment on its base is resisted by the friction between the soil (On Rock) and the base. It is Commonly required that the factor of safety againt Sliding be at least 1.5 in normal condition and 1.2 in earthquake condition.

The Friction between the based and soil is equel to the total normal pressure on the base times the coefficient 'f' between soil and base. For silt or clay soil, the value f may be taken as 0.3 and for rock f be 0.6

on rock foundation

tan ϕ B = 0.6

f = V x tan ϕ B / H = 56.593 x 0.6 / 15.476 =
2.19 $\geq$ 1.5 OK

Seismic condition

on rock foundation

tan ϕ B = 0.6

f = V x tan ϕ B / H = 53.760 x 0.6 / 26.277 =
1.23 $\geq$ 1.2 OK

4.2 Design of Approach Bridge to Goa Kreo

4.2.1 Design of Superstructure

DESIGN APROACH BRIDGE TO GOA KREO CAVE

1. DESIGN CONDITION

General Condition

Bridge type RCT Section bridge

- Span length	:	17.00 m
- Bridge with	:	2.60 m
- Footway	:	2.00 m
- Number of spans	:	4.00

Strength of material and Allowabel Stress

1. Concrete Clas B (K 250)

- Compresive strength of concrete at relevant age	:	σbk·	=	250.00 Kg f /Cm²
- Allowabel Compressive stress due to bending	:	σca	=	75.00 Kg f /Cm²
- Allowabel Shear stres carried by concrete		τca	=	3.95 Kg f /Cm²
- Allowabel Shear stres carried by concrete and reinf.		τa2	=	16.76 Kg f /Cm²
- Modulus of Elasticity		Ec	=	25000.00 Kg f /Cm²

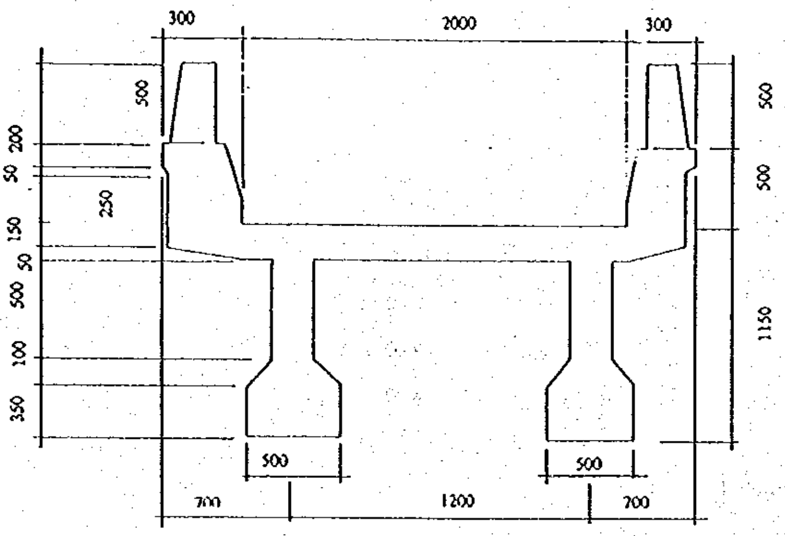
2. Reinforcement (SII 0290-80 U30)

- Allowable tensile stress	RC Slab	σsa	=	1200.00 Kg f /Cm²
	Girder	σsa	=	1800.00 Kg f /Cm²
- Modulus of elasticity of steel		Es	=	2100000.00 Kg f /Cm²
- Modular ratio of elasticity of steel	Ec / Es	n	=	15.00

3. Seismic coefficient kh = 0.15

2. DESIGN CALCULATION OF APPROACH BRIDGE TO GỤA KREO CAVE

2.1. Dimension on weight



Weight of railling / curb

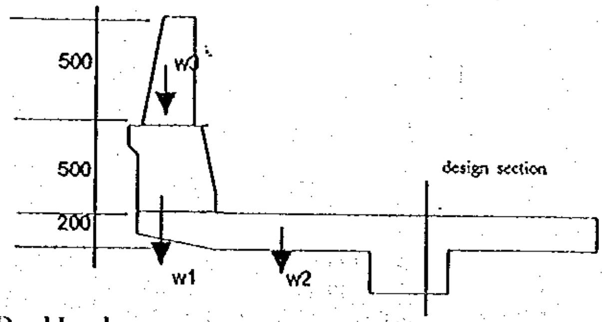
A	X	AX	A	X	XA
20 x 27.5	13.75	7562.50	(15 + 20)/2*22	19.00	7315.00
5 x 25	12.5	1562.50	20 x 25	42.50	21250.00
(20 + 22) / 2 x 15	18.5	5827.50			
10 x 22	19	4180.00			
A 1210		14952.50	A = 885.00		28565.00
A/AX =	12.357438		x =	A/AX = 32.2768362	
w1 =	3.025			w2 = 2.21	

Name of Structure		Category of calculation		Page	3

2.2. Design of slab

a. Cantilever Slab

1. Calculation of bending moment



Dead Load

W1=	3.025t x 0.4264 m =	1.290 tm	
W2=	2.213t x 0.227 m	=	0.502 tm
W3=	0.5t x 0.4264 m =	0.213 tm	
Sub Total		2.005 tm	

Live Load

P=	1.0t x 0.9m	=	0.90 tm
Q=	5.0t x 0.25 x 0.125 =	0.156 tm	
Sub Total		1.056 tm	
Total			3.062 tm

2. Reinforcement

K 250		σb =	75 Kg/Cm²
U 24		σa =	1200 Kg/Cm²
fo = sa/n sb		=	1.067
h = ht - 3		=	17 Cm
Ca = h/V n*m/n*sa		=	8.689
Taked = d = 1.00		f =	6.5667 oke
		100nw =	1.904
		A = A' =	2.158

Reinfoecement A = f 12 ---- 200 = 5.652 cm² > 2.158 cm²

Reinfoecement A' = f 12 ---- 200 = 5.652 cm² > 2.158 cm²

3. Calculation of stress

$M / b h^2$ = 306200/100*17² = 1.060

As = 5.652 Cm²

n P = 15* 5.652/(100*17) = 0.0499

by RG --------> C = 8.2

S = 22.5

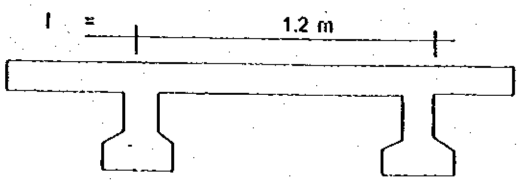
σbk' = $C \times M / (b \times h^2)$ = 8.688 Kg f /Cm² < 75 kg f / Cm²

σs = $n \times S \times M / (b \times h^2)$ = 357.587 Kg f /Cm² < 1200 kg f / Cm²

Name of Structure		Category of calculation		Page	4

a. Continuous Slab

1. Calculation of bending moment



a. RC Slab weight :

Slab :	0.2 * 25	=	5.000 KN/m^2
Live Load		=	5.000 KN/m^2
	W	=	10.000

M	= + 1/10 W x l^2	=	1.44	KN m / m	at span
M	= - 1/10 W x l^2	=	-1.44	KN m / m	Throught span

b. reinforcement

K 250	ob =	75 Kg/Cm^2
U 24	oa =	1200 Kg/Cm^2
fo = sa/n sb	=	1.067
h = ht - 3	=	17 Cm
Ca = h/V n*m/n*sa	=	12.671052

Reinfoecement	A = f 12 ---- 200	= 5.652 cm^2	Oke
Reinfoecement	A' = f 12 ---- 200	= 5.652 cm^2	Oke

3. Calculation of stress

M / b h^2	= 14400/100*17^2 =	0.498
As	=	5.652 Cm^2
n P	= 15* 5.652/(100*17) =	0.0499

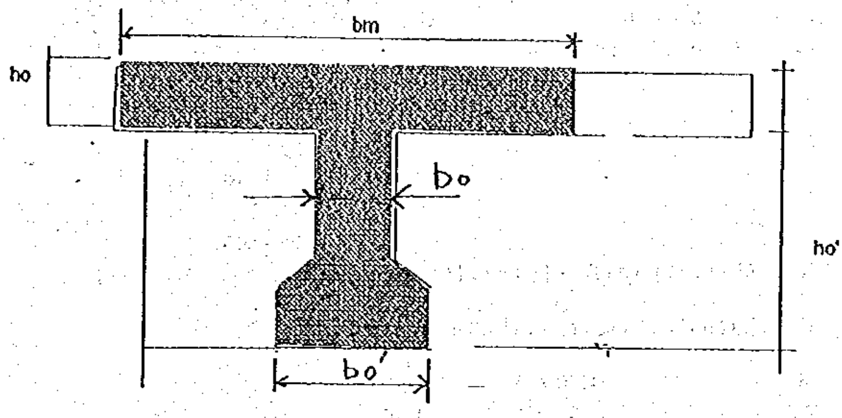
by RG -------> C = 8.2

S = 22.5

obK	= C x M/ (b x h^2)	=	4.086	Kg f /Cm^2	< 75 kg f / Cm^2 oke
oo	= n x S x M/ (b x h^2)	=	168.166	Kg f /Cm^2	< 1200 kg f / Cm^2 oke

2.3. Design of main girder

Loading



Dead Load

Slab	= 0.2 * 25	=	5.000 KN /m²
Live Load		=	3.500 KN /m²
Cantilever	W1 + W2 + w3	=	2.005 KN /m
Girder :	(0.5*0.35+0.3+0.5/2*0.1+0.3*0.5)*25	=	7.375 KN /m
Diaphragm	0.3*0.55*0.9*25/17	=	1.092 KN /m

Calculation of section force

Calculation of Load

Slab	= 5 x 0.750	=	3.750 KN /m
Live Load	3.5 x 1.00	=	3.500 KN /m
Cantilever	W1 + W2 + w3	=	2.005 KN /m
Girder :	(0.5*0.35+0.3+0.5/2*0.1+0.3*0.5)*25	=	7.375 KN /m
Diaphragm	0.3*0.55*0.9*25/17	=	1.092 KN /m
	σd	=	17.722 KN /m

b. Bending Moment

M = 1/8 x σd l² = 1/8 * 17.722 * 17² = 640.2 tm

640,200 kgm

ho	=	0.200 m
bo	=	0.300 m
bo'	=	0.400 m
ho'	=	0.950 m

bm = 2.25 ho + bo + bo' = 2.25 * 0.2 + 0.3 +0.4 = 1.150 m

or bm = a bm + bo (1 - a) ----> a < 0.7 take 0.7

bm = 0.7 * 1.15 + 0.3 * (1- 0.7) = 0.895 m

Taking smaller figure, bm=0.895 m

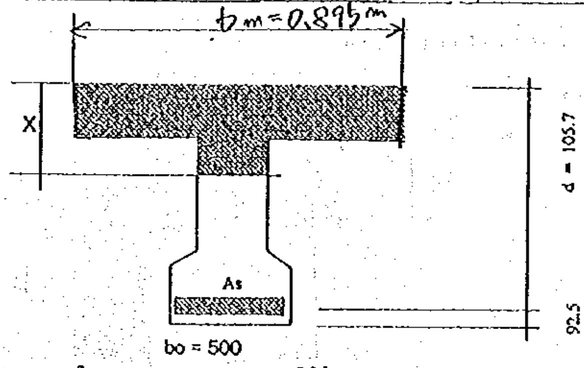
2. Reinforcement

K 250	sb =	75 Kg/Cm²
U 30	sa =	1800 Kg/Cm²
fo = sa/n sb	=	1.600
h = ht - 9.25	=	105.75 Cm
Ca = h/V n*m/b*sa	=	4.331
Taked = d = 0	f =	2.546 oke
	100nw =	5.538
	A =	37.286

Reinfoecement A = 10ϕ22 = 37.994 cm² > 37.286 cm² Oke

Name of Structure		Category of calculation		Page	6

3. Calculation of stress



σc = M x X/ Ii

σs = n x M x (d - X)/ Ii

X = [(b - bo) t + n As)/bo [(1 + bo [(b-bo)t^2+2n As d]/[(b-bo)t+nAs)^2]$^{0.5}$ -1]

Ii = 1/3 [b x^3 - (b - bo) (X - t)^3 + 3 n As (d - X)^2]

M = 64020.725 kg f m

As = 37.994 Cm^2

> 0.005 * bo d = 26.438 Cm^2

X = 32.180 Cm

Ii = 4042994.249 Cm^4

σc = M x X/ Ii = 50.957 Kg/Cm^2 < σca = 75 Kg f /Cm^2

σs = n x M x (d - X)/ Ii = = 1747.462 Kg/Cm^2 < σsa = 1800 Kg f /Cm^2

σsc = σs x (h-X-6.5)/(d-X) = 1261.142 Kg/Cm^2

4.2.2 Design of Sub Structure

Abutment A-1
Abutment A-2
Pier-1 (P-1)
Pier-2 (p-2)
Pier-3 (P-3)

SUMMARY DESIGN OF ABUTMENT A-1 = A-2 B=3.50 m L=3.50 m H = 5.00 m

	Case I + 148.60 Normal Condition	Case II MWL + 148.60 Normal Condition	Case III NWL + 148.90 Earthquake Con	Case IV SWL + 151.80 Earthquake Con	Case V + 148.60 Earthquake Con
SLIDING	SF= 13.0596 SF allowable=1.50 SF' > SF allowable	SF=7.1855 SF allowable=1.50 SF' > SF allowable	SF= 2.5727 SF allowable=1.20 SF' > SF allowable	SF= 3.4628 SF allowable=1.20 SF' > SF allowable	SF= 4.95 SF allowable=1.20 SF' > SF allowable
OVERTURNING	'c = 0.29542 m B/6= 0.58 m ' c < B/6	' c = 0.2466 m B/6= 0.58 m ' c < B/6	' c = 0.8053 m B/3= 1.17 m ' c < B/3	' c = 0.8586 m B/6= 1.17 m ' c < B/3	' c = 0.4774 m B/6= 1.17 m ' c < B/3
BEARING CAPACITY	Qmax=144.99 t Qsafe=1707.76 t Qmax < Qsafe	Qmax=88.485 t Qsafe=396.506 t Qmax < Qsafe	Qmax=226.59 t Qsafe=333.00 t Qmax < Qsafe	Qmax= 175.28 t Qsafe= 313.03 t Qmax < Qsafe	Qmax= 172.15 t Qsafe= 1137.32 t Qmax < Qsafe

SUMMARY DESIGN OF PIER – 1 (P-1) B = 3.50 m L = 3.50 m H = 6.00 m

	Case I + 146.33 Normal Condition	Case II MWL + 147.60 Normal Condition	Case III NWL + 148.90 Earthquake Con	Case IV SWL + 151.80 Earthquake Con	Case V + 146.33 Earthquake Con
SLIDING	-	-	SF= 9.279 SF allowable=1.20 SF' > SF allowable	SF= 15.7291 SF allowable=1.20 SF' > SF allowable	SF= 15.346 SF allowable=1.20 SF' > SF allowable
OVERTURNING	-	-	' c = 0.839 m B/3 = 1.167 m ' c < B/3	' c = 0.4838 m B/3 = 1.167 m ' c < B/3	' c = 0.7527 m B/3 = 1.167 m ' c < B/3
BEARING CAPACITY	Qmax=139.97 t Qsafe= 3390.23 t Qmax < Qsafe	Qmax=115.30 t Qsafe= 2876.58 t Qmax < Qsafe	Qmax= 309.18 t Qsafe= 614.55 t Qmax < Qsafe	Qmax= 219.00 t Qsafe= 985.34 t Qmax < Qsafe	Qmax= 320.57 t Qsafe= 2242.50 t Qmax < Qsafe

SUMMARY DESIGN OF PIER – 2 (P-2) B = 4.55 m L = 4.55 m H = 10.00 m

	Case I + 142.33 Normal Condition	Case II MWL + 147.60 Normal Condition	Case III NWL + 148.90 Earthquake Con	Case IV SWL + 151.80 Earthquake Con	Case V + 142.33 Earthquake Con
SLIDING	-	-	SF= 7.8035 SF allowable=1.20 SF' > SF allowable	SF= 7.4608 SF allowable=1.20 SF' > SF allowable	SF= 14.271 SF allowable=1.20 SF' > SF allowable
OVERTURNING	-	-	e = 1.493 m B/3 = 1.5167 m e < B/3	e = 1.5087 m B/3 = 1.5167 m e < B/3	e = 1.079 m B/3 = 1.5167 m e < B/3
BEARING CAPACITY	Qmax= 202.71 t Qsafe= 5392.86 t Qmax < Qsafe	Qmax= 125.94 t Qsafe= 2012.48 t Qmax < Qsafe	Qmax= 450.11 t Qsafe= 923.54 t Qmax < Qsafe	Qmax= 457.93 t Qsafe= 569.62 t Qmax < Qsafe	Qmax= 491.08 t Qsafe= 3296.61 t Qmax < Qsafe

SUMMARY DESIGN OF PIER – 3 (P-3) B = 4.00 m L = 4.00 m H = 8.00 m

	Case I + 144.33 Normal Condition	Case II MWL + 147.60 Normal Condition	Case III NWL + 148.90 Earthquake Con	Case IV SWL + 151.80 Earthquake Con	Case V + 144.33 Earthquake Con
SLIDING	-	-	SF= 8.4855 SF allowable=1.20 SF' > SF allowable	SF= 14.255 SF allowable=1.20 SF' > SF allowable	SF= 14.81 SF allowable=1.20 SF' > SF allowable
OVERTURNING	-	-	e = 1.155 m B/3 = 1.333 m e < B/3	e = 0.694 m B/3 = 1.333 m e < B/3	e = 0.933 m B/3 = 1.333 m e < B/3
BEARING CAPACITY	Qmax= 168.575 t Qsafe= 4211.96 t Qmax < Qsafe	Qmax= 129.10 t Qsafe= 1408.99 t Qmax < Qsafe	Qmax= 333.24 t Qsafe= 721.05 t Qmax < Qsafe	Qmax= 260.94 t Qsafe= 1170.14 t Qmax < Qsafe	Qmax= 353.97 t Qsafe= 2830.31 t Qmax < Qsafe

DESIGN OF ABUTMENT A-1 = A-2

KREO BRIDGE

DESIGN OF ABUTMENT (A1 = A2)

Case I : Water is empty + 148.60 (NORMAL CONDITON)

Parameter of soil for bank fill : ϕ = 30 degree
γ = 1.9 t/m^3
C = 0 t / m^2

Coefficient of active earth pressure :

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

ϕ = 30 degree
δ = 30 degree
α = 0 degree
θ = 0 degree

Coefficient of active earth pressure :
Ka = 0.297

Acting earth pressure :
pa1 = Ka * γ *H = 2.8215 t /m^2
pa2 = Ka * q = 0.297 t /m^2

The earth pressure under the **normal condition** :

Height of Abutment	H = 5	m
Width of footing Abutment	B = 3.5	m
Length of footing Abutment	L = 2.7	m
Load	q = 1	t / m'

Pa1 = 1/2 * γ * H^2 * Ka * L = 19.04513 t
Pa2 = pa2 * H * L = 4.0095 t
Pa1h = Pa1 * cos δ = 16.49365 t
Pa1v = Pa1 * sin δ = 9.522563 t
Pa2h = Pa2 * cos δ = 3.472347 t
Pa2v = Pa2 * sin δ = 2.00475 t

Compute overturning stability :

Set up table and refer to figure : ....

part	Weight of part (ton)		Arm (m)	Moment (ton m)
1	0.3*1.27*2.5*2.7 =	2.5718	2.165	5.5678
2	1.115*0.5*2.5*2.7 =	3.7631	1.7575	6.6137
3	(1.115+0.5)/2*0.53*2.5*2.7=	2.8888	1.62327	4.6894
4	((1+0.5)/2)*1.7*2.5*2.7 =	8.6063	1.589	13.6753
5	(1+0.5)/2*1.2*2.5*2.7 =	6.0750	0.667	4.0520
6	1.0*1.0*2.5*2.7 =	6.7500	1.7	11.4750
7	(1+0.5)/2*1.3*2.5*2.7 =	6.5813	2.7667	18.2083
8	1.185*1.77*1.9*2.7 =	10.7599	2.9075	31.2845
9	(1.185+1.8)/2*0.53*1.9*2.7=	4.0580	2.74319	11.1318

10	(1.3+1.8)/2*1.7*1.9*2.7=	13.5176	2.71828	36.7445
11	0.5*1.3*0.5*1.9*2.7 =	1.6673	3.0667	5.1130
P		46.0000	1.715	78.8900
	Total : Σ Fv' =	113.2389	Σ Mr =	227.4452

Sum of Moments to Resist Overturning : Σ Mr = 227.4452 ton m

Σ Mov=Pa1v*B+Pa2v*B= 40.34559 ton m

Sum of Moments to Resist Overturning : Σ Mr' = 267.7908 ton m

Sum of Overturning Moments :

Σ Moh=Pa1h*1/3*H+Pa2h*H/2= 36.17028 ton m

Total Vertical Force : Σ Fv = Σ Fv' + Pa1v + Pa2v = 124.7662 ton

Total Horizontal Force : Σ Fh = Pa1h + Pa2h = 19.966 ton

The overturning safety factor is :

FS =Σ Mr' /Σ Mo = 7.4036 > 1.5 Ok

Compute Sliding Force : *Use base soil parameter*

Parameter of soil : ϕ = 36 degree

γ = 2 t/m^3

C = 18 t / m^2

Fr = C * B*L + Σ Fv * tan ϕ Fr = 260.7476 ton

The sliding safety factor is :

FS = Fr / Σ Fh = 13.0596 > 1.5 Ok

Located the resultant on the base of footing. From rigid body static and moment summation can be taken at any location. Using the toe, as we already have most of the moments computed :

Δ M = Σ Mr - Σ Mo = 231.621 ton m

x = Δ M / Σ Fv = 2.04542 m (*from toe*)

e = { B/2 } - x = 0.29542 m

B / 6 = 0.58333 m

→ e < (B/6) OK
0.29542 < 0.58333
OK

Compute soil pressure :

qmax = { Σ Fv / B } * { 1 + (6*e)/B } = 53.70031 ton / m

qmin = { Σ Fv / B } * { 1 - (6*e)/B } = 17.59466 ton / m

Qmax = qmax * L = 144.9908 ton

Qmin = qmin * L = 47.50558 ton

Checking of Bearing Capacity on soil :

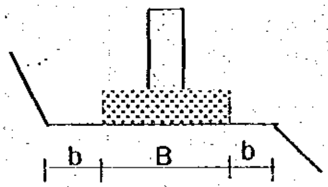
$$Qu = A' * [\alpha * k * c * Nc + 0.143 * k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma$$

b = 3

R = 6

B = 3.5

$\frac{b}{D * D}$ = 0.143



where :

Qu = ultimate bearing capacity

A' = effective loading area on footing

α, β = coefficient depending on shape of footing

c = cohesion of foundation ground (ton/m^2)

q = ground surface surcharge (t/m^2) q = γ * Df

γ2 = unit weight of soil on front of abutments (t/m^3) = 1.8 t/m^3

γ1 = unit weight of soil of ground foundation (t/m^3) = 2.0 t/m^3

B',L' = width and length of effective loading area

e = distance from entrance of footing to acting point of resultant force on footing (m)

Df = depth from ground surface on front of abutment to bottom of footing (m)

Df' = height of toe (m) = 0.5 m

k = coefficient ⟶ k = (1 + 0,3 * Df' / B')

Nq , Nc , Nγ = bearing capacity factors

A' = L' * B' = (B - 2eb) * (L - 2el)

A' =(B - 2*eb) * (L - 2*el) = 7.854757 m^2

α = (1 + 0,3B'/L') = 1.32324

β = (1 - 4*B'/L') = -3.30988

q = γ2 * Df = 6.12 t/m^2

k = (1 + 0,3 * (Df'/B')) = 1.0516

For tan θ =ΣFh/ ΣFv = 0.160 Nc= 31

ϕ = 36 Nq = 22

Nγ = 15

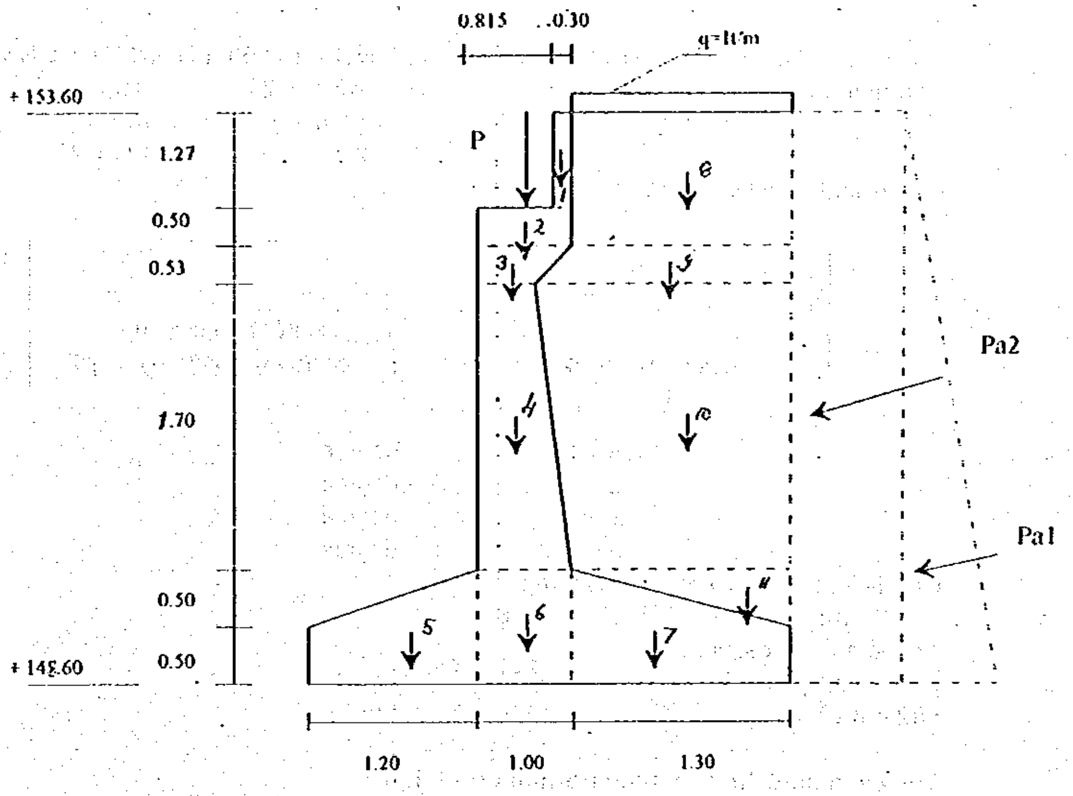
Qu = 5123.27 ton

FS = 3

Qsafe = Qu / FS = 1707.76 ton

Checking the bearing capacity is :

Qmax = 144.99 ton < Qsafe = 1707.76 ton OK



DESIGN OF ABUTMENT A-1 = A-2
Case I : water is empty + 147.60 (Normal Condition)

Case II : Water is full at elevation Max Water Level + 153.60 (NORMAL CONDITON)

Parameter of soil for bank fill : $\phi' = 2/3\,\phi = 20$ degree

$\gamma sub = 0.9$ t/m^3

$C' = 2/3\,C = 0$ t / m^2

Coefficient of active earth pressure :

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

$\phi = 20$ degree
$\delta = 20$ degree
$\alpha = 0$ degree
$\theta = 0$ degree

Coefficient of active earth pressure :

Ka = 0.42687

Acting earth pressure :

pa1 = Ka * γsub *H = 1.920915 t /m^2
pa2 = Ka * q = 0.42687 t /m^2

The earth pressure under the normal condition :

Height of Abutment	H = 5	m
Width of footing Abutment	B = 3.5	m
Length of footing Abutment	L = 2.7	m
Load	q = 1	t / m'

Pa1 = 1/2 * γ * H^2 * Ka * L = 12.96618 t
Pa2 = pa2 * H * L = 5.762745 t
Pa1h = Pa1 * cos δ = 11.2291 t
Pa1v = Pa1 * sin δ = 6.483088 t
Pa2h = Pa2 * cos δ = 4.99071 t
Pa2v = Pa2 * sin δ = 2.881373 t

Compute overturning stability :

Set up table and refer to figure : ....

part	Weight of part (ton)		Arm (m)	Moment (ton m)
1	0.3*1.27*2.5*2.7 =	2.5718	2.165	5.5678
2	1.115*0.5*2.5*2.7 =	3.7631	1.7575	6.6137
3	(1.115+0.5)/2*0.53*2.5*2.7=	2.8888	1.62327	4.6894
4	((1+0.5)/2)*1.7*2.5*2.7 =	8.6063	1.589	13.6753
5	(1+0.5)/2*1.2*2.5*2.7 =	6.0750	0.667	4.0520
6	1.0*1.0*2.5*2.7 =	6.7500	1.7	11.4750
7	(1+0.5)/2*1.3*2.5*2.7 =	6.5813	2.7667	18.2083
8	1.185*1.77*0.9*2.7 =	5.0968	2.9075	14.8190
9	(1.185+1.8)/2*0.53*0.9*2.7=	1.9222	2.74319	5.2729

10	(1.3+1.8)/2*1.7*0.9*2.7=	6.4031	2.71828	17.4053
11	0.5*1.3*0.5*0.9*2.7 =	0.7898	3.0667	2.4219
12	((4.5+4)/2)*1.2*2.7*1.0	13.7700	0.6	8.2620
P		46.0000	1.715	78.8900
	Total : Σ Fv' =	111.2180	Σ Mr =	191.3527

Sum of Moments to Resist Overturning : Σ Mr = 191.3527 ton m

Σ Mov=Pa1v*B+Pa2v*B= 32.7756 ton m

Sum of Moments to Resist Overturning : Σ Mr' = 224.1283 ton m

Sum of Overturning Moments :

Σ Mo=Pa1h*1/3*H+Pa2h*H/2= 31.19194 ton m

The total buoyancy (uplift) acting on the structure is calculated as follows :

U = (1/2)*{ U1 + U2 } * B * γw

where :

U = total uplift (ton /m)

U1 = buoyancy at upstream side U1 = γw * h1 (ton/m)

U2 = buoyancy at downstream side U2 = γw * h2 (ton/m)

B = bottom width of structure (m)

γw = unit weight of water (t/m^3)

U1 = U2 = 1,0 * (153.6-148.6) = 5 ton /m

U = 17.5 ton /m

U = 47.25 ton

Total Vertical Force : Σ Fv = Σ Fv' + Pa1v + Pa2v - U = 73.3325 ton

Total Horizontal Force : Σ Fh = Pa1h + Pa2h = 16.21981 ton

Total Moment : Σ Mr' = Σ Mr - U * B/2 = 141.4408 ton m

The overturning safety factor is :

FS =Σ Mr /Σ Mo = 7.1855 > 1.5 Ok

Compute Sliding Force : *Use base soil parameter*

Parameter of soil : φ' =2/3 φ = 24 degree

γ sub = 1 t/m^3

C'=2/3 C = 12 t / m^2

Fr = C * B*L + Σ Fv * tan φ' Fr = 146.0498 ton

The sliding safety factor is :

FS = Fr / Σ Fh = 9.0044 > 1.5 Ok

Located the resultant on the base of footing. From rigid body static and moment summation can be taken at any location. Using the toe, as we already have most of the moments computed :

Δ M = Σ Mr - Σ Mo = 110.249 ton m

x = Δ M / Σ Fv = 1.50341 m (*from toe*)

e = { B/2 } - x = 0.24659 m

B / 6 = 0.58333 m

-> e < (B/6) OK

0.24659 < 0.58333

OK

Compute soil pressure :

q_{max} = { Σ Fv / B } * { 1 + (6*e)/B } =	29.80909 ton / m
q_{min} = { Σ Fv / B } * { 1 - (6*e)/B } =	12.09518 ton / m
Q_{max} = q_{max} * L =	80.48453 ton
Q_{min} = q_{min} * L =	32.65698 ton

Checking of Bearing Capacity on soil :

$$Qu = A' * [\, \alpha * k * c * Nc \;+\; 0.143 * k * q * Nq \;+\; 0.5 * \gamma_1 * B' * \beta' * N\gamma$$

where :

Qu = ultimate bearing capacity

A' = effective loading area on footing

α, β = coefficient depending on shape of footing

c = cohesion of foundation ground (ton/m^2)

q = ground surface surcharge (t/m^2)   q = γ * Df

γ_2 = unit weight of soil on front of abutments (t/m^3) = 0.8 t/m^3

γ_1 = unit weight of soil of ground foundation (t/m^3) = 1.0 t/m^3

B',L' = width and length of effective loading area

e = distance from entrance of footing to acting point of resultant force on footing (m)

Df = depth from ground surface on front of abutment to bottom of footing (m)

Df' = height of toe (m) = 0.5 m

k = coefficient ——▶ k = (1 + 0,3 * Df' / B')

Nq , Nc , Nγ = bearing capacity factors

A' = L' * B' = (B - 2eb) * (L - 2el)

A' =(B - 2*eb) * (L - 2*el) = 8.118422 m^2

α = (1 + 0,3B'/L') = 1.33409

β = (1 - 4*B'/L') = -3.45455

q = γsub2 * Df = 2.72 t/m^2

k = (1 + 0.3 * (Df'/B')) = 1.0499

For tan θ =ΣFh/ ΣFv = 0.221   Nc= 9

ϕ' = 24   Nq = 4

Nγ = 1.3

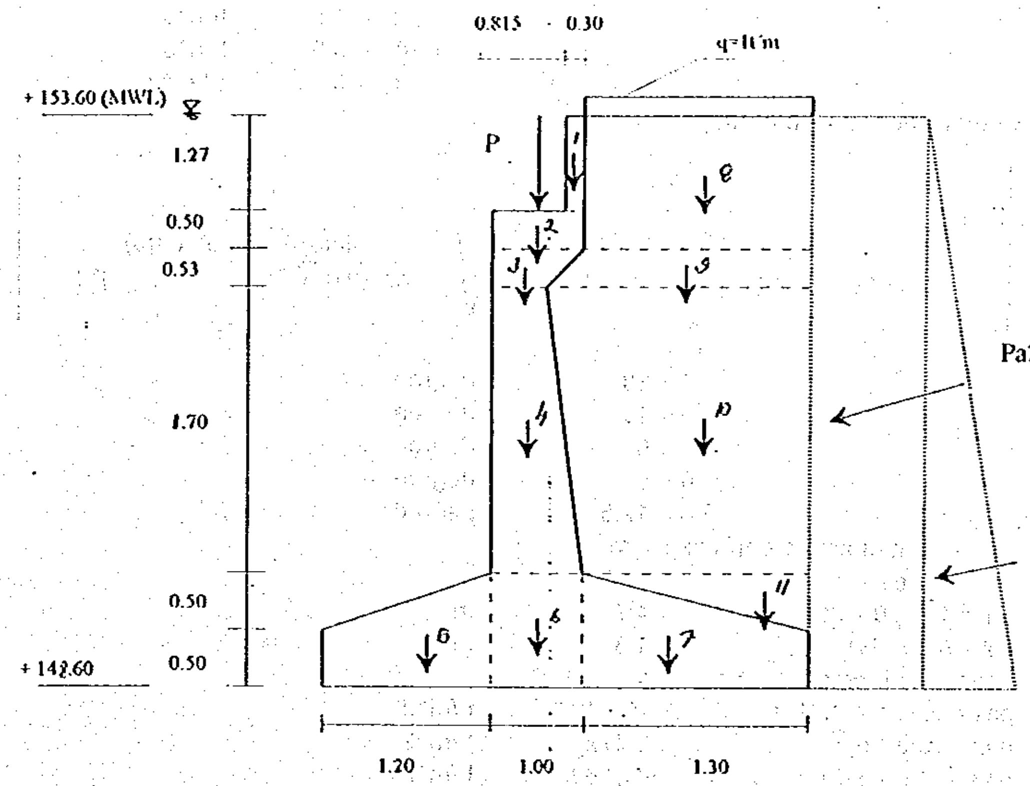
Qu = 1186.519 ton

FS = 3

Qsafe = Qu / FS = 395.506 ton

Checking the bearing capacity is :

Qmax = 80.485 ton < Qsafe = 395.506 ton OK



DESIGN OF ABUTMENT A-1 = A-2
Case II : water is full at elevation MWL + 153.60
(Normal Condition)

DESIGN OF ABUTMENT (A1 = A2)

Case III : Water is full at elevation NWL + 148.90 (EARTHQUAKE CONDITON)

Parameter of soil for bank fill :		
	ϕ = 30	degree
	γl = 1.9	t/m^3
	$\gamma l sub$ = 0.9	t/m^3
	C = 0	t / m^2

Coefficient of active earth pressure :

$$K\varepsilon a = \frac{\cos^2(\phi-\theta o-\theta)}{\cos\theta o * \cos^2(\theta) * \cos(\theta+\theta o+\delta) * \left[1+\sqrt{\dfrac{\sin(\phi+\delta)*\sin(\phi-\alpha-\theta o)}{\cos(\theta+\theta o+\delta)*\cos(\theta-\alpha)}}\right]^2}$$

ϕ = 30	degree
δ = 15	degree
α = 0	degree
θ = 0	degree
θo = 12.5	degree

Coefficient of active earth pressure :

Kea =	0.472	
H1 = 153.60 - 148.90 =	4.7	m
H2 = 6.00 - H1 =	1.3	m
Acting earth pressure :		
pa1 = Kea * γl *H1 =	4.21496	t /m^2
pa2 = Kea * q =	0.472	t /m^2
pa3 = (pa1+pa2) =	4.68696	t /m^2
pa4 = Kea*($\gamma l-\gamma \omega$)*H2 =	0.55224	t /m^2

The earth pressure under the earthquake condition :

Height of Abutment	H = 5	m
Width of footing Abutment	B = 3.5	m
Length of footing Abutment	L = 2.7	m
Load	q = 1	t / m'

Pa1 = 1/2 * γl * H1^2 * Kea * L =	26.74392 t
Pa2 = pea2 * H1 * L =	5.98968 t
Pa3 = pa3 * H2 * L =	16.45123 t
Pa4 = pa4 * H2 / 2 * L =	0.969181 t
Pa1h = Pa1 * cos δ =	25.83276 t
Pa1v = Pa1 * sin δ =	6.921862 t
Pa2h = Pa2 * cos δ =	5.785612 t
Pa2v = Pa2 * sin δ =	1.550249 t
Pa3h = Pa3 * cos δ =	15.89074 t
Pa3v = Pa3 * sin δ =	4.257907 t
Pa4h = Pa4 * cos δ =	0.936161 t
Pa4v = Pa4 * sin δ =	0.250843 t

Compute overturning stability :

Set up table and refer to figure : ....

part	Weight of part (ton)		Arm (m)	Moment (ton m)
1	0.3*1.27*2.5*2.7 =	2.5718	2.1650	5.5678
2	1.115*0.5*2.5*2.7 =	3.7631	1.7575	6.6137
3	(1.115+0.5)/2*0.53*2.5*2.7 =	2.8888	1.6233	4.6894
4	((1+0.5)/2)*1.7*2.5*2.7 =	8.6063	1.5870	13.6581
5	(1+0.5)/2*1.2*2.5*2.7 =	6.0750	0.6667	4.0502
6	1.0*1.0*2.5*2.7 =	6.7500	1.7000	11.4750
7	(1+0.5)/2*1.3*2.5*2.7 =	6.5813	2.7667	18.2083
8	1.185*1.77*1.9*2.7=	10.7599	2.9075	31.2845
9	(1.185+1.8)/2*0.53*1.9*2.7=	4.0580	2.7432	11.1318
10	(1.3+1.8)/2*1.7*1.9*2.7=	13.5176	2.7183	36.7445
11	0.5*1.3*0.5*1.9*2.7 =	1.6673	3.0667	5.1130
P		46.0000	1.7150	78.8900
	Total : Σ Fv' =	113.2389	Σ Mr =	227.4262

Sum of Moments to Resist Overturning : Σ Mr = 227.4262 ton m

The horizontal earthquake load (K) is determined using the following formula :

P = 46 ton
Wabutment = 37.2362 ton
Wsoil = 30.0027 ton
KP = 0,15 *1.0* P = 6.9000 ton
KW1 = 0,15*1.0*Wabut = 5.5854 ton
Kw2= 0,15*1.0*Wsoil = 4.5004 ton

part	Weight of part (ton)		Arm (m)	Moment (ton m)
KP	Horizontal Force	6.9000	3.8	26.2200
KW1	Horizontal Force	5.5854	1.4854	8.2966
KW2	Horizontal Force	4.5004	2.445	11.0035
	Total : Σ Fh' =	16.9858	Σ Mo' =	45.5201

Sum of Overturning Moments :

Σ Moh=Pa1h*(H1/3+H2)+Pa2h*(H1/2+H2)+Pa3h*(H2/2)+Pa4h*(H2/3)+Pa5h*(H2/3)= 105.906 ton m

Σ Mov=(Pa1v+Pa2v+Pa3v+Pa4v)*B= 45.43301 ton m

Σ Motol= Σ Mo' + Σ Moh - Σ Mov = 105.9931 ton m

The total buoyancy (uplift) acting on the structure is calculated as follows :

U = (1/2)*{ U1 + U2 } * B * γw

where :

U = total uplift (ton /m)

U1 = buoyancy at upstream side U1 = γw * h1 (ton/m)

U2 = buoyancy at downstream side U2 = γw * h2 (ton/m)

B = bottom width of structure (m)

γw = unit weight of water (t/m^3)

U1 = U2 = 1.0 *(148.9-148.6) = 0.3 ton /m

	U =	1.05	ton /m	
	U =	2.835	ton	
Total Vertical Force :	$\Sigma Fv = \Sigma Fv' + Pa1vtot - U$ =			123.3847 ton
Total Horizontal Force :	$\Sigma Fh = Pa1htot + KP + KW1 + KW2$ =			65.4311 ton
Total Moment : $\Sigma Mr' = \Sigma Mr - U * B/2$ =		222.4650 ton m		

The overturning safety factor is :

FS = $\Sigma Mr / \Sigma Mo$ = 2.1006 > 1.2 Ok

Compute Sliding Force : *Use base soil parameter*

Parameter of soil :	$\phi' = 2/3*\phi$ = 24		degree
	γ sub = 1		t/m^3
	C'=2/3C = 12		t / m^2
Fr = C'* B*L + $\Sigma Fv * \tan \phi'$		Fr =	168.335 ton

The sliding safety factor is :

FS = Fr / ΣFh = 2.5727 > 1.2 Ok

Located the resultant on the base of footing. From rigid body static and moment summation can be taken at any location. Using the toe, as we already have most of the moments computed :

$\Delta M = \Sigma Mr - \Sigma Mo$ = 116.559 ton m

$x = \Delta M / \Sigma Fv$ = 0.94468 m (*from toe*)

e = { B/2 } - x = 0.80532 m

B / 3 = 1.16667 m

→ e < (B/3) OK
0.80532 < 1.16667
OK

Compute soil pressure :

qmax = { ΣFv / B } * { 1 + (6*e)/B } =	83.9211 ton / m
qmin = { ΣFv / B } * { 1 - (6*e)/B } =	-13.4155 ton / m
Qmax = qmax * L =	226.587 ton
Qmin = qmin * L =	-36.2218 ton

Checking of Bearing Capacity on soil :

$$Qu = A' * [\, \alpha * k * c * Nc + k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma$$

where :

- Qu = ultimate bearing capacity
- A' = effective loading area on footing
- α, β = coefficient depending on shape of footing
- c = cohesion of foundation ground (ton/m^2)
- q = ground surface surcharge (t/m^2) q = γ * Df
- γ_2 = unit weight of soil on front of abutments (t/m^3) = 0.8 t/m^3
- γ_1 = unit weight of soil of ground foundation (t/m^3) = 1.0 t/m^3

B',L' = width and length of effective loading area

e = distance from entrance of footing to acting point of resultant force on footing (m)

Df = depth from ground surface on front of abutment to bottom of footing (m)

Df' = height of toe (m) = 0.5 m

k = coefficient ——→ k = (1 + 0,3 * Df' / B')

Nq , Nc , Nγ = bearing capacity factors

A' = L' * B' = (B - 2eb) * (L - 2el)

A' =(B - 2*eb) * (L - 2*el) = 5.101264 m^2

α = (1 + 0,3B'/L') = 1.20993

β = (1 - 4*B'/L') = -1.79905

q = γsub2 * Df = 1.92 t/m^2

k = (1 + 0,3 * (Df'/B')) = 1.0794

For tan θ =ΣFh/ ΣFv = 0.530	Nc= 8
φ' = 24	Nq = 2.5
	Nγ = 0

Qu = 666.000 ton

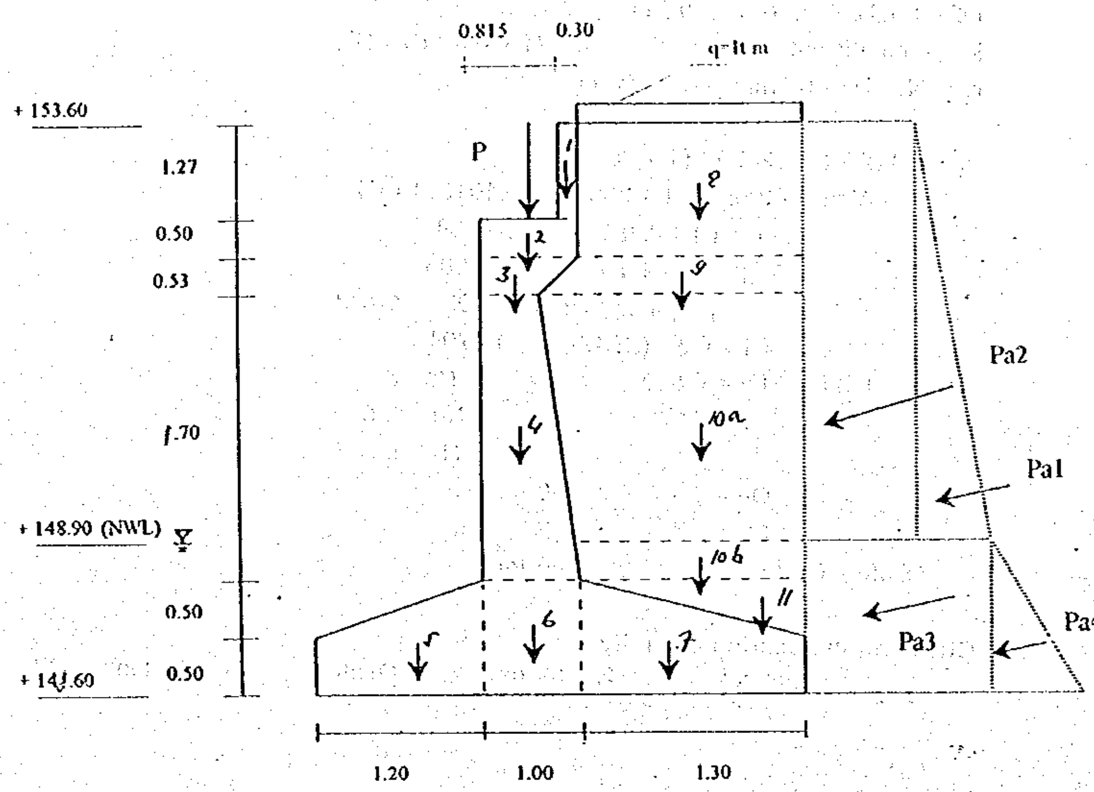
FS = 2

Qsafe = Qu / FS = 333.000 ton

Checking the bearing capacity is :

Qmax = 226.59 ton < Qsafe = 333.00 ton OK

Name of Structure		Category of calculation		Page	/3



DESIGN OF ABUTMENT A-1 = A-2
Case III : water is full at elévation NWL + 148.90
(Earthquake Çondition)

DESIGN OF ABUTMENT (A1 = A2)

Case IV : Water is full at elevation SWL + 151.80 (EARTHQUAKE CONDITON)

Parameter of soil for bank fill :

ϕ =	30	degree
γl =	1.9	t/m^3
γsub =	0.9	t/m^3
C =	0	t / m^2

Coefficient of active earth pressure :

$$K\varepsilon a = \frac{\cos^2(\phi-\theta_o-\theta)}{\cos\theta_o \cdot \cos^2(\theta)\cdot\cos(\theta+\theta_o+\delta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\alpha-\theta_o)}{\cos(\theta+\theta_o+\delta)\cdot\cos(\theta-\alpha)}}\right]^2}$$

ϕ' =	30	degree
δ =	15	degree
α =	0	degree
θ =	0	degree
θ_o =	12.5	degree

Coefficient of active earth pressure :

Kea = 0.472

Acting earth pressure :

H1 = + 153.60 - 151.80 =	1.8	m
H2 = H - H1 =	3.2	m
pa1 = Kea * γl *H1 =	1.61424	t /m^2
pa2 = Kea * q =	0.472	t /m^2
pa3 = (pa1 + pa2) =	2.08624	t /m^2
pa4 = Kea * γsub *H2 =	1.35936	t /m^2

The earth pressure under the earthquake condition :

Height of Abutment	H =	5	m
Width of footing Abutment	B =	3.5	m
Length of footing Abutment	L =	2.7	m
Load	q =	1	t / m'

Pa1 = 1/2 * γl * H1^2 * Kea * L =	3.922603	t
Pa2 = pea2 * H1 * L =	2.29392	t
Pa3 = pea3*H2*L =	18.02511	t
Pa4 =pea4*H2/2*L =	5.872435	t

cos 15 =	0.96593			
sin 15 =	0.25882		length from bottom of footing	
Pa1h = Pa1 * cos δ =	3.788960109	t	h1 =	3.8 m
Pa1v = Pa1 * sin δ =	1.01524816	t		
Pa2h = Pa2 * cos δ =	2.215766146	t	h2 =	4.1 m
Pa2v = Pa2 * sin δ =	0.593712374	t		
Pa3h = Pa3 * cos δ =	17.41099798	t	h3 =	1.6 m
Pa3v = Pa3 * sin δ =	4.665259902	t		

Pa4h = Pa4 * cos δ = 5.672361333 t h4 = 1.066667 m

Pa4v = Pa4 * sin δ = 1.519903678 t

Compute earth force resultant :

Total Pav = Pav1 + Pav2 + Pav3 + Pav4 = 7.794124 t

Total Pah = Pah1 + Pah2 + Pah3 + Pah4 = 29.08809 t

Compute overturning stability :

Set up table and refer to figure : ....

part	Weight of part (ton)		Arm (m)	Moment (ton m)
1	0.3*1.27*2.5*2.7=	2.5718	2.165	5.5678
2	1.115*0.5*2.5*2.7 =	3.7631	1.7575	6.6137
3	(1.115+0.5)/2*0.53*2.5*2.7=	2.8888	1.62327	4.6894
4	((1+0.5)/2)*1.7*2.5*2.7 =	8.6063	1.589	13.6753
5	(1+0.5)/2*1.2*2.5*2.7 =	6.0750	0.667	4.0520
6	1.0*1.0*2.5*2.7 =	6.7500	1.7	11.4750
7	(1+0.5)/2*1.3*2.5*2.7 =	6.5813	2.7667	18.2083
8	1.185*(1.77+0.03)*1.9*2.7 =	10.9423	2.9075	31.8147
9	(1.185+1.8)/2*0.5*0.9*2.7=	1.8134	2.74319	4.9745
10	(1.3+1.8)/2*1.7*0.9*2.7 =	6.4031	2.71828	17.4053
11	0.5*1.3*0.5*0.9*2.7 =	0.7898	3.0667	2.4219
12	((3.7+3.2)/2)*1.2*2.7*1.0	11.178	0.6	6.7068
P		46.0000	1.715	78.8900
	Total : Σ Fv' =	114.3627	Σ Mr =	206.4948

Sum of Moments to Resist Overturning : Σ Mr = 206.4948 ton m

The horizontal earthquake load (K) is determined using the following formula :

P = 46 ton

Wabutment = 37.2362 ton

Wsoil = 19.9485 ton

KP = 0,15* P = 6.9000 ton

KW1 = 0,15*Wabut = 5.5854 ton

Kw2= 0,15*Wsoil = 2.9923 ton

part	Weight of part (ton)		Arm (m)	Moment (ton m)
KP	Horizontal Force	6.9000	3.8	26.2200
KW1	Horizontal Force	5.5854	1.4854	8.2966
KW2	Horizontal Force	2.9923	2.34352	7.0124
	Total : Σ Fh' =	15.4777	Σ Mo' =	41.5290

Sum of Overturning Moments :

Σ Mo=Pa1h*h1+Pa2h*h2+Pa3h*h3+Pa4h*h4-Pavtot*B+ΣMo'= 71.64042 ton m

The total buoyancy (uplift) acting on the structure is calculated as follows :

U = (1/2)*{ U1 + U2 } * B * γw

where :

U = total uplift (ton /m)

U1 = buoyancy at upstream side $U1 = \gamma w * h1$ (ton/m)

U2 = buoyancy at downstream side $U2 = \gamma w * h2$ (ton/m)

B = bottom width of structure (m)

γw = unit weight of water (t/m^3)

U1 = U2 = 1.0 *(151.8-148.6) = 3.2 ton /m

U = 11.2 ton /m

U = 30.24 ton

Total Vertical Force : $\Sigma Fv = \Sigma Fv' + Pa1vtot - U$ = 91.9168 ton

Total Horizontal Force : $\Sigma Fh = Pa1htot+KP+KW1+KW2$ = 44.5658 ton

Total Moment : $\Sigma Mr' = \Sigma Mr - U * B/2$ = 153.5748 ton m

The overturning safety factor is :

$FS = \Sigma Mr / \Sigma Mo$ = 2.1437 > 1.2 Ok

Compute Sliding Force : *Use base soil parameter*

Parameter of soil : $\phi' = 2/3\ \phi$ = 24 degree

γsub = 1.0 t/m^3

C' = 2/3C = 12 t / m^2

$Fr = C' * B * L + \Sigma Fv * \tan \phi'$ Fr = 154.3241 ton

The sliding safety factor is :

$FS = Fr / \Sigma Fh$ = 3.4628 > 1.2 Ok

Located the resultant on the base of footing. From rigid body static and moment summation can be taken at any location. Using the toe, as we already have most of the moments computed :

$\Delta M = \Sigma Mr - \Sigma Mo$ = 81.934 ton m

$x = \Delta M / \Sigma Fv$ = 0.89140 m (*from toe*)

e = { B/2 } - x = 0.85860 m

B / 3 = 1.16667 m

→ e < (B/3) OK

0.85860 > 1.16667

OK

Compute soil pressure :

$q_{max} = \{ \Sigma Fv / B \} * \{ 1 + (6*e)/B \}$ = 64.91667 ton / m

$q_{min} = \{ \Sigma Fv / B \} * \{ 1 - (6*e)/B \}$ = -12.39278 ton / m

$Q_{max} = q_{max} * L$ = 175.275 ton

$Q_{min} = q_{min} * L$ = -33.4605 ton

Checking of Bearing Capacity on soil :

$$Qu = A' * [\alpha * k * c * Nc + k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma$$

where :

Qu = ultimate bearing capacity

A' = effective loading area on footing
α, β = coefficient depending on shape of footing
c = cohesion of foundation ground (ton/m^2)
q = ground surface surcharge (t/m^2) $q = \gamma * Df$
γ2 = unit weight of soil on front of abutments (t/m^3) = 0.8 t/m^3
γ1 = unit weight of soil of ground foundation (t/m^3) = 1.0 t/m^3
B',L' = width and length of effective loading area
e = distance from entrance of footing to acting point of resultant force on footing (m)
Df = depth from ground surface on front of abutment to bottom of footing (m)
Df' = height of toe (m) = 0.5 m
k = coefficient ⟶ k = (1 + 0.3 * Df' / B')
Nq , Nc , Nγ = bearing capacity factors

A' = L' * B' = (B - 2eb) * (L - 2el)

A' =(B - 2*eb) * (L - 2*el) = 4.813543 m^2

α = (1 + 0.3B'/L') = 1.19809

β = (1 - 4*B'/L') = -1.64118

q = γsub2 * Df = 1.92 t/m^2

k = (1 + 0.3 * (Df'/B')) = 1.0841

For tan θ = ΣFh/ ΣFv = 0.485 Nc= 8

ϕ' = 24 Nq = 3

Nγ = 0.6

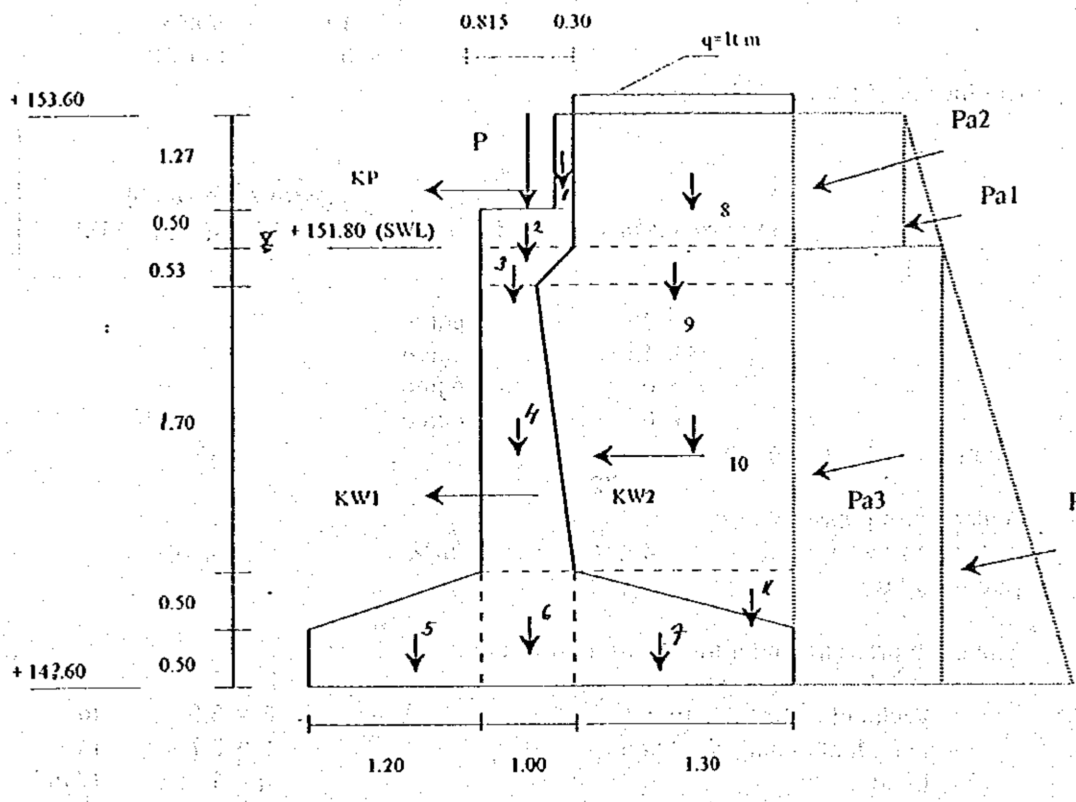
Qu = 626.052 ton

FS = 2

Qsafe = Qu / FS = 313.026 ton

Checking the bearing capacity is :

Qmax = 175.28 ton < Qsafe = 313.03 ton OK



DESIGN OF ABUTMENT A-1 = A-2
Case IV : water is full at elevation SWL + 151.60
(Earthquake Condition)

DESIGN OF ABUTMENT (A1 = A2) *File:AbutmentV*

Case V : Water is empty + 148.60 (EARTHQUAKE CONDITON)

Parameter of soil for bank fill : ϕ = 30 degree

γ = 1.9 t/m^3

C = 0 t / m^2

Coefficient of active earth pressure :

$$Kea = \frac{\cos^2(\phi-\theta o-\theta)}{\cos^2(\theta)\cdot\cos^2(\theta+\theta o+\delta)\cdot\left[1+\sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\alpha-\theta o)}{\cos(\theta+\theta o+\delta)\cdot\cos(\theta-\alpha)}}\right]^2}$$

ϕ = 30 degree

δ = 15 degree

α = 0 degree

θ = 0 degree

Coefficient of active earth pressure :

Kea = 0.472

Acting earth pressure :

pa1 = Kea * γ *H = 4.484 t /m^2

pa2 = Ka * q = 0.472 t /m^2

The earth pressure under the normal condition :

Height of Abutment	H = 5	m
Width of footing Abutment	B = 3.5	m
Length of footing Abutment	L = 2.7	m
Load	q = 1	t / m'

Pa1 = 1/2 * γ * H^2 * Kea * L =	30.267 t
Pa2 = pa2 * H * L =	6.372 t
Pa1h = Pa1 * cos δ =	29.2358 t
Pa1v = Pa1 * sin δ =	7.833705 t
Pa2h = Pa2 * cos δ =	6.154906 t
Pa2v = Pa2 * sin δ =	1.649201 t

Compute overturning stability :

Set up table and refer to figure : ....

part	Weight of part *(ton)*		Arm *(m)*	Moment *(ton m)*
1	0.3*1.27*2.5*2.7 =	2.5718	2.165	5.5678
2	1.115*0.5*2.5*2.7 =	3.7631	1.7575	6.6137
3	(1.115+0.5)/2*0.53*2.5*2.7=	2.8888	1.62327	4.6894
4	((1+0.5)/2)*1.7*2.5*2.7 =	8.6063	1.589	13.6753
5	(1+0.5)/2*1.2*2.5*2.7 =	6.0750	0.667	4.0520
6	1.0*1.0*2.5*2.7 =	6.7500	1.7	11.4750
7	(1+0.5)/2*1.3*2.5*2.7 =	6.5813	2.7667	18.2083
8	1.185*1.77*1.9*2.7 =	10.7599	2.9075	31.2845
9	(1.185+1.8)/2*0.53*1.9*2.7=	4.0580	2.74319	11.1318

10	(1.3+1.8)/2*1.7*1.9*2.7=	13.5176	2.71828	36.7445
11	0.5*1.3*0.5*1.9*2.7 =	1.6673	3.0667	5.1130
P		46.0000	1.715	78.8900
	Total : Σ Fv' =	113.2389	Σ Mr =	227.4452

Sum of Moments to Resist Overturning : Σ Mr = 227.4452 ton m

The horizontal earthquake load (K) is determined using the following formula :

P = 46 ton

Wabutment = 37.2362 ton

Wsoil = 30.0027 ton

KP = 0,15 *1.0* P = 6.9000 ton

KW1 = 0,15*1.0*Wabut = 5.5854 ton

Kw2= 0,15*1.0*Wsoil = 4.5004 ton

part	Weight of part *(ton)*		Arm *(m)*	Moment *(ton m)*
KP	Horizontal Force	6.9000	4.8	33.1200
KW1	Horizontal Force	5.5854	1.4854	8.2966
KW2	Horizontal Force	4.5004	2.44352	10.9968
	Total : Σ Fh' =	16.9858	Σ Mo' =	52.4134

Sum of Overturning Moments :

Σ Moh=Pa1h*(H/3)+Pa2h*(H/2)-Pa1v*B-Pa2v*B+Σ Mo'= 83.33685 ton m

Total Vertical Force : Σ Fv = Σ Fv' + Pa1v + Pa2v = 122.7218 ton

Total Horizontal Force : Σ Fh = Pa1h + Pa2h+ Σ Fh'= 52.3765 ton

The overturning safety factor is :

FS =Σ Mr / Σ Mo = 2.7292 > 1.2 Ok

Compute Sliding Force : *Use base soil parameter*

Parameter of soil : ϕ = 36 degree

γ = 2 t/m^3

C = 18 t / m^2

Fr = C * B*L + Σ Fv * tan ϕ Fr = 259.2623 ton

The sliding safety factor is :

FS = Fr / Σ Fh = 4.9500 > 1.5 Ok

Located the resultant on the base of footing. From rigid body static and moment summation can be taken at any location. Using the toe, as we already have most of the moments computed :

Δ M = Σ Mr - Σ Mo = 144.108 ton m

x = Δ M / Σ Fv = 1.27261 m (*from toe*)

e = { B/2 } - x = 0.47739 m

B / 3 = 1.16667 m

→ e < (B/3) OK

0.47739 < 1.16667

OK

Compute soil pressure :

q_{max} = { Σ Fv / B } * { 1 + (6*e)/B } = 63.759 ton / m

q_{min} = { Σ Fv / B } * { 1 - (6*e)/B } = 6.368 ton / m

Q_{max} = qmax * L = 172.149 ton

Q_{min} = qmin * L = 17.193 ton

Checking of Bearing Capacity on soil :

$$Qu = A' * [\alpha * k * c * Nc + k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma$$

where :

Qu = ultimate bearing capacity

A' = effective loading area on footing

α, β = coefficient depending on shape of footing

c = cohesion of foundation ground (ton/m^2)

q = ground surface surcharge (t/m^2) $q = \gamma * Df$

$\gamma 2$ = unit weight of soil on front of abutments (t/m^3) = 1.8 t/m^3

$\gamma 1$ = unit weight of soil of ground foundation (t/m^3) = 2.0 t/m^3

B',L' = width and length of effective loading area

e = distance from entrance of footing to acting point of resultant force on footing (m)

Df = depth from ground surface on front of abutment to bottom of footing (m)

Df' = height of toe (m) = 0.5 m

k = coefficient ⟶ k = (1 + 0,3 * Df' / B')

Nq , Nc , Nγ = bearing capacity factors

A' = L' * B' = (B - 2eb) * (L - 2el)

A' =(B - 2*eb) * (L - 2*el) = 6.872068 m^2

α = (1 + 0.3B'/L') = 1.28280

β = (1 - 4*B'/L') = -2.77068

q = γ2 * Df = 4.32 t/m^2

k = (1 + 0,3 * (Df'/B')) = 1.0589

For tan θ =ΣFh/ ΣFv = 0.427 Nc= 15

ϕ = 36 Nq = 10

Nγ = 6

Qu = 2274.644 ton

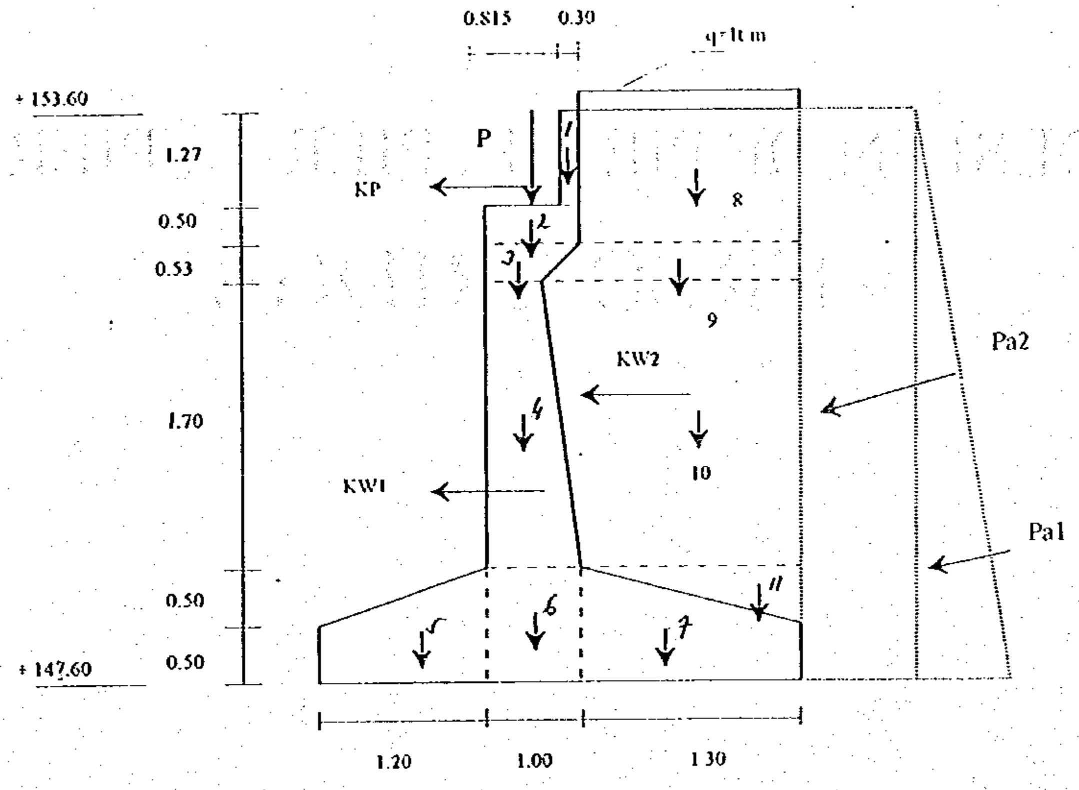
FS = 2

Qsafe = Qu / FS = 1137.322 ton

Checking the bearing capacity is :

Qmax = 172.15 ton < Qsafe = 1137.32 ton OK

Name of Structure		Category of calculation		Page	22



DESIGN OF ABUTMENT A-1 = A-2
Case V : water is empty at elevation + 147.60
(Earthquake Condition)