# DESIGN OF PIER-1, PIER-2, PIER-3 KREO BRIDGE

### DESIGN OF PIER (P1)

File:Pierl

## Case I: Water is empty + 146.33 (NORMAL CONDITION)

Parameter	of soil :

Height of Pier Width of footing Pier

Compute overturning stability:

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

part	Weight of pa	rt i
1	1.6*0.4*2.5*2.7 =	4.3200
2	(1,6+0.9)/2'0.4'2.5'(2.7+2)/2=	2.9375
3	0.7*4.3*2.5*2.0 =	19.3500
4	(3.5+0.9)/2'0.4'2.5'(3.5+2)/2=	6.0500
5	3,5'0.5'2.5'3.5 =	15.3125
6	P1 11 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	46.000
7	P2	46.000
	Total : Σ Fv =	139.970

#### 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

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

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

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

q ≃ γ \* Df

 $\gamma$ 2 = unit weight of soil on front of abutments (t/m<sup>3</sup>) = 0.8 t/m<sup>3</sup>

71 = unit weight of soil of ground foundation ( $Vm^3$ ) = 1.0  $Vm^3$ 

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

 $k = coefficient \longrightarrow k = (1 + 0.3 * Df / B')$ 

Nq, Nc,  $N\gamma$  = bearing capacity factors

A' = L' \* B' = (B · 2eb) \* (L - 2el)  
A' = (B · 2\*eb) \* (L - 2\*el) = 12.25 m\*2  

$$\alpha = (1 + 0.3B'/L') = 1.30$$

 $\beta = (1 - 4*B'/L') =$  $q = \gamma * Df =$ 6.12 t/m^2 1.0429 k = (1 + 0.3 \* (Df/B')) =For  $\tan \theta = \Sigma Fh / \Sigma Fv = 0$ Nc= 50  $\varphi=\,36$ Nq = 33Ny = 40Qu = 10170.70 ton FS = 3Qsafe = Qu / FS = 3390.232 ton  $qmax = \Sigma Fv/B =$ 39.991 t/m' 11.426 t/m^2  $qmax = \Sigma Fv/A =$ Qmax = qmax \* A =139.970 ton

Checking the bearing capacity is:

Qmax = 139.97 ton < Qsafe = 3390.23 ton OK

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	en gradien de de de la companya de l		• • •	:
1284			en de la companya de La companya de la co	
N. P. grade 1				
24.7 (*)		PI P2		
		P1   P2   P2		
		<b>1 1</b>	+152.33	
	0.40	1 1		
	0.40	\		
•		<b>→↓↓</b>		
		2		
	4.30		的 性质的 化二甲烷	
		3 .		
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	0.40	4 1		
	' 0.40	<b> \Y</b>		
	0.50		+146.33	
		130 0.96 130	e defenda Marie da como El esta desta desta	**
		DESIGN OF PIER - 1 (P-1		
in the second		Case I: water is empty + 146.	<b>33</b> Separate (1)	
		( Normal Condition )		
			Bar Steel of Alas Sun.	District.
	等等类集 等一联合物			
		4-2-37		

## DESIGN OF PIER (P1)

File:Pieril

Case II: Water is full at elevation MWL + 153.60 (NORMAL CONDITION)

Parameter of soil:

 $\phi' = 2/3\phi = 24 \text{ degree}$  $\gamma \text{sub} = 1.0 \text{ t/m}^3$ 

C'=2/3C=

12 t/ m^2

) \_\_\_\_\_\_

6.0 m

H= B=-

= 3.5 m = 3.5 m

Compute overturning stability:

Height of Pier

Set up table and refer to figure :

Width of footing Pier

part	Weight of par	t Asign
11.	(ton)	
1	1.6'0.4'2.5'2.7 =	4.3200
2	(1.6+0.9)/2*0.4*2.5*(2.7+2)/2=	2.9375
3	0.7'4.3'2.5'20 =	19.3500
4	(3.5+0.9)/2*0.4*2.5*(3.5+2)/2=	6.0500
5	3,5*0.5*2.5*3.5 =	15.3125
6	((6.77+6.37)/2)*1.4*3.5*1.0	32.1930
7	((6.77+6.37)/2)*1.4*3.5*1.0	32.1930
8	P1	46.0000
9	P2	46.0000
	Total: ΣFv =	204.356

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

$$U = (1/2)^{*}\{U1 + U2\}^{*}B^{*}\gamma w$$

where:

U = total uplift (ton/m)

U1 = buoyancy at upstream side

 $U1 = \gamma w * h1 \text{ (ton/m)}$   $U2 = \gamma w * h2 \text{ (ton/m)}$ 

U2 = buoyancy at downstream side

B = bottom width of structure (m)

w = unit weight of water (Um^3)

 $U1 = U2 = 1.0 * (153.6 \cdot 146.33) =$ 

7.27 ton /m

U =

25.445 ton/m

U=

89.0575 ton

Total Vertical Force:

 $\Sigma Fv = \Sigma Fv' - U =$ 

115.2985 ton

Checking of Bearing Capacity on soil:

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

where :

Qu = ultimate bearing capacity

A' = effective loading area on footing

ικ, β = coefficient depending on shape of footing

```
= cohesion of foundation ground (ton/m^2)
                                                                         q = \gamma * Df
       = ground surface surcharge (t/m^2)
      = unit weight of soil on front of abutments (Vm<sup>3</sup>) = 0.8 Vm<sup>3</sup>
       = unit weight of soil of ground foundation (Vm^3) = 1.0 Vm^3
  B',L' = width and length of effective loading area
       = 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 toc (m) = 0.5 m
                                       k = (1 + 0.3 * Df / B')
      = coefficient ------->
  No, No, Ny = bearing capacity factors
  A' = L' * B' = (B - 2eb) * (L - 2el)
                                                     12.25 m^2
A' =(B - 2*eb) * (L - 2*el) =
                                                       1.30
          \alpha = (1 + 0.3BVL') =
                                                         -3
           \beta = (1 - 4*B'/L') =
                                                           Vm^2
                                                   2.936
             q = \gamma sub2 * Df =
                                                  1.0429
     k = (1 + 0.3 * (Df/B')) =
                                                       Nc= 50
      For \tan \theta = \Sigma Fh / \Sigma Fv = 0
                                                      Nq = 33
                           \phi = 36
                                                      Ny = 40
                         Qu = 8629.74
                                                ton
                         FS = 3
           Qsafe = Qu / FS = 2876.58
                                                ton
                                        32,942 t/m1
  qmax = \Sigma Fv/B =
  qmax = \Sigma Fv/A =
                                         9.412 t/m^2
                                       115,299 ton
  Qmax = qmax * A =
  Checking the bearing capacity is:
                                                            Qsafe =
                                                                           2876.58 ton
                      Qmax =
                                        115.30 ton <
                                                                            OK
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Name of Structure	Category of calculation	Page 18
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and the Arman August County of the State of	The same of the sa	to a state of the late of the
The second of th	The first of the American American	ije metra keta ili tahiji
	P1 P2 P2 P2	
	1.60	+152.33 (MWL)
0.40		¥
4		
0.40	1 - J 1	er gift han de de greek blief en de geleger. Noorde de greek blief geleger blief en de greek blief de geleger.
	Compared to the contraction	
4.30		
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	그 글 첫러그는 다 하나는	
0.40	1	
+	<b>1 ♦</b>	
0.50		+146.33
1		
	130 0:90 130	
	DESIGN OF PIER - 1 (P-1)	
	Case II: water is full at elevation + 152	2.33 A A A A A A A A A A A A A
	( Normal Condition)	<u> 프로</u> 스 링크 등 이 스크를 하는 경험
	그는 보이 그 하시아의 그 나라인	

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Filo:Pierlil

#### DESIGN OF PIER (P1)

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

Parameter of soil:			∍ φ' ≕2/3φ =	24	degree
Tatallicies of cont.	4	1111	: γsub ≅	1.0	√m^3
			C'=2/3C =		t/m^2
Height of Pier			H=	6.0	m
Width of footing Pier		•	B =	3.5	m
Width of footing i ter			1 =	3.5	. m

Compute overturning stability:
Set up table and refer to figure:

Moment Arm Weight of part (ton m) (m) 4.320 1.750 7.560 1,6\*0.4\*2.5\*2.7 = 5.141 2.938 1,750 (1.6+0.9)/2\*0.4\*2.5\*(2.7+2)/2= 2 19.350 1.750 33.863 3 0.9\*4.3\*2.5\*2.0 = 10.588 1.750 6.050 4 (3.5+0.9)/2\*0.4\*2.5\*(3.5+2)/2= 26.797 1.750 15,313 5 3,5'0.5'2.5'3.5 = 6.414 0.700 9,163 ((2.07+1.67)/2)\*1.4\*3.5\*1.0 25.656 9.163 2.800 7 ((2.07+1.67)/2)\*1.4\*3.5\*1.0

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

U = (1/2)\*{U1 + U2} \* B \* YW

SFy=

where:

8

9

U = total uplift (ton/m)

Total:

U1 = buovancy at upstream side

 $UI = \gamma w * hI \pmod{m}$ 

46.000

46.000

158.296

U2 = buovancy at downstream side

 $U2 = \gamma w + h2 \pmod{m}$ 

B = bottom width of structure (m)

w= unit weight of water (Vm^3)

U1 = U2 = 1,0 \*(148.9-146.33) = 2.57 ton /m U = 8.995 ton /m U = 31.4825 ton

Total Vertical Force:

 $\Sigma F_V = \Sigma F_V - U =$ 

126.8135 ton

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

#### $P = (3/4)^*Kh^*Wo^*Ao^*h^*(b/a)^*[1-(b/4h)]$

in case b/h < 2.0

64.400

96.600

277.018

1.400

2.100

 $\Sigma Mr =$ 

where :

P = total hydrodynamic pressure during earthquake (ton) Kh = E = 0.15Kh=E = design horizontal seismic coefficient h = 2.57m h = water depth (m) Wo = 1.00  $t/m^43$ Wo = unit weight of water (tim^3) b = 2.00លា b = column width perpendicular to the acting direction of hydrodynamic pressure during earthquake (m) a = column width in acting direction of hydrodynamic pressure (m) a = m Ao = 1.8  $m^{4}2$ Ao = cross sectional area of a pier (m^2) hg =3/7 h = 1.1014 hg = hydrodynamic force acting depth from the bottom (m) m

P = (3/4)\*Kh\*Wo\*Ao\*h\*(b/a)\*[1-(b/4h)] = 0.93150

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

P1 = 46.000

21.927

ton

P2 = 46.000

ton

W = 47.970KP = 0.15 \* Ptotal = 13.800 ton ton

 $KW \approx 0.15 * W = 7.196$ 

Total horizontal force Σ Fh =

ton ton

Sum of Overturning Moments:

 $\Sigma Mo = P \cdot hg + KP \cdot h1 + KW \cdot h2 = 106.3785 \text{ ton m}$ 

Sum of Moments to Resist Overturning:

 $\Sigma Mr = \Sigma Mr - U * B/2 = 221.9236 ton m$ 

The Overturning safety factor is:

 $FS = \sum M \Gamma / \sum Mo =$ 

2.086 > 1.2

OK

Compute Stiding Force:

Use base soil parameter

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

Fr=

203,4612 ton

The sliding safety factor is:

FS = Fr/ΣFh =

9.2790 > 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:

 $\Delta M = \Sigma Mr' - \Sigma Mo =$ 

115.545 ton m

 $x = \Delta M / \Sigma Fv =$ 

0.91114 m (from toe)

 $e = \{ B/2 \} - x$ 

0.839 m

B/3=

1.167 m

< (B/3)0.839 OK 1,167 **OK** 

Compute soil pressure:

 $qmax = {\Sigma Fv/B} * {1 + (6*e)/B} =$ qmin =  $\{\Sigma \text{ Fv / B}\}^* \{1 - (6^*\text{e})/\text{B}\} =$ 

Qmax = qmax \* L =

Qmin = qmin \* L =

88.3362 ton / m

-15.8713 ton / m 309.177 ton

-55.550 ton

Checking of Bearing Capacity on soil:

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

where:

Qu = ultimate bearing capacity

= effective loading area on footing

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

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

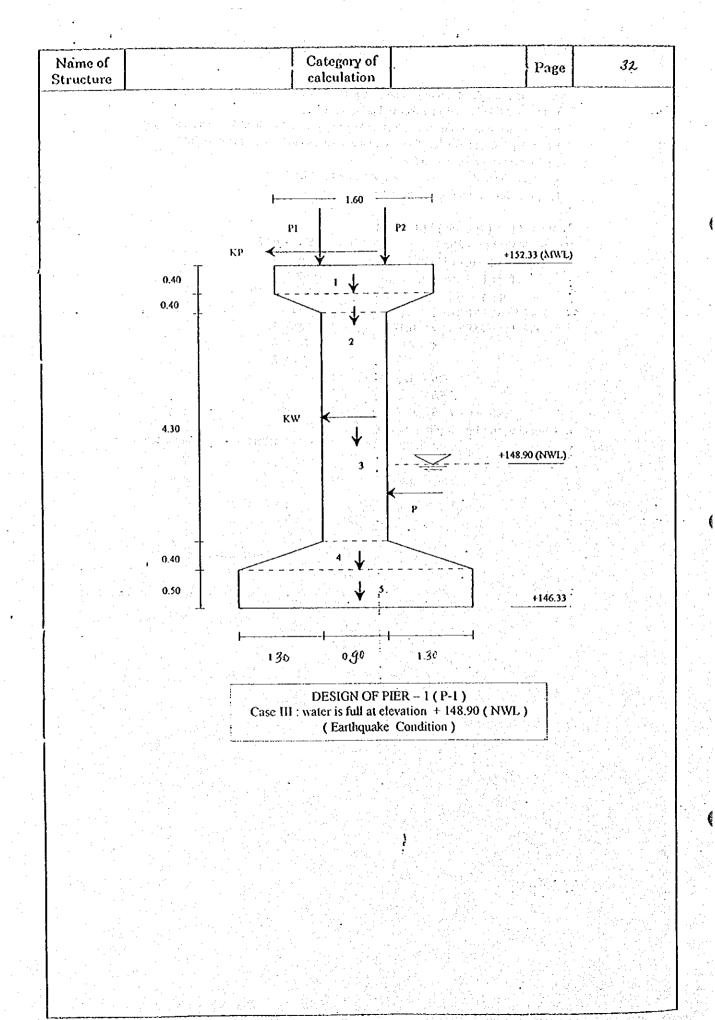
= ground surface surcharge (Vm^2)

 $q = \gamma * Df$ 

= unit weight of soil on front of abutments (Vin^3) = 0.8 Vin^3

```
= unit weight of soil of ground foundation (Um^3) = 1.0 Um^3
   B',L' = width and length of effective loading area
       = 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 = (1 + 0,3 * Df' / B' )
        = coefficient -----
   Nq, Nc, N\gamma = bearing capacity factors
   A' = L' * B' = (B - 2eb) * (L - 2el)
                                                            m^2
                                                   6.378
A' =( B - 2*eb) * ( L - 2*el ) =
                                                    1,16
          \alpha = (1 + 0.3B/L') =
                                                   -1.08
            \beta = (1 - 4*B'/L') =
                                                   2.936
                                                            Vm^2
              q = \gamma sub2 * Of =
                                                   1.0823
     k = (1 + 0.3 * (Df/B')) =
       For \tan \theta = \Sigma Fh / \Sigma Fv = 0.173
                                                       Nc= 13
                                                      Nq = 7
                            \phi = 24
                                                      N_1 = 3
                          Qu = 1229.106
                                                 ton
                          FS = 2
           Qsafe = Qu / FS = 614.553
   Checking the bearing capacity is:
                                                            Qsafe =
                                                                            614.55 ton
                                         309.18 ton <
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## DESIGN OF PIER (P1)

File:PierIV

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

Paran	neter of soil :				<b>φ' =2/3φ =</b>	24	degree
	٠	4 1, 1 41		·凯克特(1955年)为4日	ysub =	1.0	Vm^3
	$(x_{i+1}, x_{i+1}, \dots, x_{i+1})$				C'=2/3C =	12	t/m^2
	Height of Pier					6.0	m
	Width of footing		1.5		B≃	3.5	m
	<u></u>	-	. 3	and the first the second	լ =	3.5	m

#### Compute overturning stability:

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

part	Weight of par	t in the state of	Arm,	Moment
	(lon)		(m)	(ton m)
- 1	1.6'0.4'2.5'2.7 =	4.320	1.75	7.560
2	(1.6+0.9)/2*0.4*2.5*(2.7+2)/2=	2.938	1.75	5.141
3	0.9*4.3*2.5*2.0 =	19.350	1.75	33.863
4	(3.5+0.9)/2*0.4*2.5*(3.5+2)/2=	6.050	1.75	10.588
5	3,5'0.5'2.5'3.5 =	15.313	1.75	26.797
6	((4.97+4.57)/2)*1.4*3.5*1.0	23.373	0.70	16.361
7	((4.97+4.57)/2)*1.4*3.5*1.0	23.373	2.80	65.444
8	Pi	46.000	1.40	64.400
9	P2	46.000	2.10	96.600
	Total: ΣFv =	186.716	Σ Mr =	326.753

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

$$U = (1/2)^* \{ U1 + U2 \} * B * \gamma v$$

where:

U = total uplift (ton/m)

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

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

B = bottom width of structure (m)

 $\gamma W = -$  unit weight of water (Um<sup>3</sup>)

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

$$P = (3/4)^*Kh^*Wo^*Ao^*h^*(b/a)^*[1-(b/4h)]$$
 in case b/h < 2.0

where :

P = total hydrodynamic pressure during earthquake (ton)

Kh = E = design horizontal seismic coefficient

Kh = E = 0.15

 $\begin{array}{lll} h = water \ depth \ (m) & h = 5.47 & m \\ Wo = unit \ weight \ of water \ (t/m^3) & Wo = 1.00 & t/m^3 \\ b = column \ width \ perpendicular \ to \ the \ acting & b = 2.00 & m \end{array}$ 

direction of hydrodynamic pressure during earthquake (m)

a = column width in acting direction of hydrodynamic pressure (m)a = 0.9 m

 $Ao = cross sectional area of a pier (m^2)$ Ao ≈ 1.8 hg = hydrodynamic force acting depth from the bottom (m) hg = 3/7 h = 2.3443P = (3/4)\*Kh\*Wo\*Ao\*h\*(b/a)\*[1-(b/4h)] =2.23650 ton • The horizontal load (K) is determined using following formula: P1 = 46.000ton P2 = 46.000ton W = 47.970ton  $KP = 0.15^{*}Ptotal = 6.900$ ton KW = 0.15\*W = 3.598Total horizontal force  $\Sigma$  Fh = 12.73425 ton Total Vertical Force: Sum of Overturning Moments:  $\Sigma Mo = P * hg + KP*h1+KW*h2 = 57.91925 ton m$ Sum of Moments to Resist Overturning:  $\Sigma Mr' = \Sigma Mr - U * B/2 = 209.4899 ton m$ The Overturning safety factor is: **OK**  $FS = \sum Mr / \sum Mo =$ 3.617 > 1.2Compute Sliding Force: Use base soil parameter  $Fr = C' * B*L + \Sigma Fv * tan \phi' =$ Fr= 200.29782 ton The sliding safety factor is: FS = Fr/ΣFh = 15.7291 > 1.2 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:  $\Delta M = \Sigma Mr - \Sigma Mo =$ 151.57 ton m  $x = \Delta M / \Sigma Fv =$ 1.27 m (from toe)  $e = \{ B/2 \} - x$ 0.4838 m > e < (B/3) OK B/3 =1.1667 m 1.167 0.484OK. Compute soil pressure:  $qmax = { \Sigma Fv / B } * { 1 + (6*e)/B } =$ 62.5710 ton / m qmin =  $\{ \Sigma \text{ Fv / B} \}^* \{ 1 - (6^*e)/B \} =$ 5.8338 ton / m Qmax = qmax \* L =218.99863 ton Qmin = qmin \* L = 20.418366 ten Checking of Bearing Capacity on soil:

```
Qu = A' * [ \alpha * k * c * Nc + 0.143*k * q * Nq + 0.5 * \gamma1 * B' * \beta' * N\gamma
  where:
  Ou = ultimate bearing capacity
        = effective loading area on footing
  \alpha, \beta = coefficient depending on shape of footing
       = cohesion of foundation ground (ton/m^2)
                                                                         q = \gamma * Df
       = ground surface surcharge (1/m^2)
        = unit weight of soil on front of abutments (Vm^3) = 0.8 Vm^3
        = unit weight of soil of ground foundation (t/m^3) = 1.0 t/m^3
  B',L' = width and length of effective loading area
       = 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 = (1 + 0.3 * Df'/B')
  k = coefficient
  Nq, Nc, N\gamma = bearing capacity factors
  A' = L' * B' = (B - 2eb) * (L - 2el)
                                                    8.8632 m^2
A' = ( B - 2*eb) * (L - 2*el) =
                                                       1.22
          \alpha = (1 + 0.3B'/L') =
                                                      -1.89
           \beta = (1 - 4*B'/L') =
                                                   2.936
                                                            Vm^2
              q = \gamma sub2 * Df =
                                                  1.0592
     k = (1 + 0.3 * (Df/B')) =
                                                       Nc= 15
      For \tan \theta = \Sigma Fh/\Sigma Fv = 0.106
                                                      Nq = 8
                            \phi = 24
                                                       Ny = 4
                                       1970.68 ton
                          Qu =
                          FS = 2.00
           Qsafe = Qu / FS =
                                      🤏 985.34 ton
   Checking the bearing capacity is:
                                                                             985.34 ton
                                                             Qsafe =
                                         219.00 ton <
                       Qmax =
                                                                              ΟK
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Category of calculation Name of 36 Page Structure КP +152.33 0.40 0.40 ĸw 4.30 0.40 0.50 +146.33 1 30 1.30 0,90 DESIGN OF PIER - 1 (P-1)
Case IV: water is full at elevation + 151.80 (SWL) (Earthquake Condition)

# Case V: Water is empty at elevation + 146.33 (EARTHQUAKE CONDITION)

Paran	neter of soil :	are to the size		φ≕	36	degree
1 aran	lotor or con .			γ =	2.0	t/m^3
1.14	and the facilities	1.1 1.1 1.1		C =	18 ::	t/m^2
1.27	Height of Pier			H =	6.0	m
-	Width of footing Pier	 •	•	B =	3.5	, <b>m</b> ,
i i	trium of footing trans	+ 2		1 =	3.5	m

Compute overturning stability:

part	Weight of pa		Am ( <i>m</i> )	Moment (ton m)
1	1.6'0.4'2.5'2.7 =	4.320	1.75	7.560
2	(1.6+0.9)/2+0.4+2.5+(2.7+2)/2=	2.938	1.75	5.141
3	0.9*43*25*20 = **	19.350	1.75	33.863
4	(3.5+0.9)/2*0.4*2.5*(3.5+2)/2=	6.050	1.75	10.588
5	3.5 0.5 2.5 3.5 =	15.313	1.75	26.797
6	Pi	46.000	1.40	64.400
$-\frac{3}{7}$	P2	46.000	2.10	96.600
	Total : ΣFv =	139.970	Σ Mr =	244.948

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

Total horizontal force  $\Sigma$  Fh =

Total Vertical Force:

 $\Sigma Fv = \Sigma Fv' =$ 

Sum of Overlurning Moments:

 $\Sigma Mo = KP^h1+KW^h2 = 105.3525 \text{ ton m}$ 

Sum of Moments to Resist Overlurning:

 $\Sigma M \Gamma = \Sigma M \Gamma = 244.948$  ton m

The Overturning safety factor is:

$$FS = \sum M r / \sum Mo =$$

Compute Sliding Force:

Use base soil parameter

 $F_{\Gamma} = C' * B*L + \Sigma Fv * tan \phi' =$ 

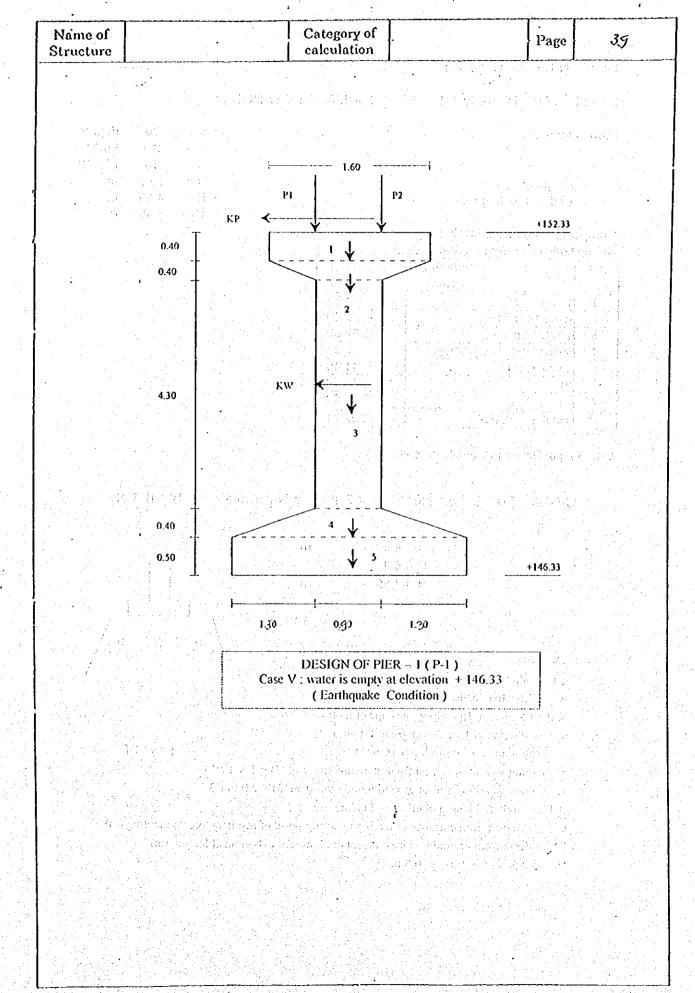
322.194 lon

The sliding safety factor is:

 $FS = Fr/\Sigma Fh = 15.346 > 1.2$ 

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:

```
139.60 ton m
\Delta M = \Sigma Mr' - \Sigma Mo =
x = \Delta M / \Sigma Fv =
                                                  1.00 m (from toe)
                                               0.7527 m
e = \{ B/2 \} - x
                                                                                             ÓΚ
                                                                                             1.167
                                               1.1667 m
 B/3 =
                                                                                             OΚ
Compute soil pressure:
                                                                        91.5927 ton / m
         qmax = {\Sigma Fv/B} * {1 + (6*e)/B} =
                                                                      -11.6098 ton / m
         qmin = \{ \Sigma \text{ Fv / B} \} * \{ 1 - (6*e)/B \} =
                                                                     320,57429 ton
          Qmax = qmax * L =
                                                                      -40,63429 ton
          Qmin = qmin * L =
 Checking of Bearing Capacity on soil:
          Qu = A' * [\alpha * k * c * Nc + 0.143*k * q * Nq + 0.5 * \gamma I * B' * \beta' * N\gamma]
          Qu = ultimate bearing capacity
               = effective loading area on footing
          \alpha, \beta = coefficient depending on shape of footing
               = cohesion of foundation ground (ton/m^2)
               = ground surface surcharge (Vm^2)
                = unit weight of soil on front of abutments (Vm^3) = 1.8 Vm^3
                = unit weight of soil of ground foundation (Um<sup>3</sup>) = 2.0 Um<sup>3</sup>
           B',L' = width and length of effective loading area
                = distance from entrance of footing to acting point of resultant force on footing (m)
           Df = dcpth from ground surface on front of abutment to bottom of footing (m)
           Df' = height of toe (m) = 0.5 m
                                                k = (1 + 0.3 * Df' / B')
                = coefficient ---->
           Nq, Nc, Ny = bearing capacity factors
           A' = L' * B' = (B - 2eb) * (L - 2el)
                                                              6.981 m^2
        A' =( B - 2*eb) * ( L - 2*el ) =
                                                               1.17
                  \alpha = (1 + 0.3B'/L') =
                                                               -1.28
                    \beta = (1 - 4*B'/L') =
                                                                     Vm^2
                                                            2.936
                      q = \gamma sub2 * Df =
                                                            1.0752
              k = (1 + 0.3 * (Df/B')) =
                                                                Nc= 32
               For \tan \theta = \Sigma Fh / \Sigma Fv = 0.150
                                    \phi = 36
                                                               Nq = 25
                                                                N_7 = 21
                                                4485.00 ton
                                  Qu =
                                  FS = 2.00
                    Qsafe = Qu / FS =
                                                2242.50 ton
           Checking the bearing capacity is:
                                                                                     2242.50 ton
                                                                      Qsafe =
                                                 320.57 ton <
                               Qmax =
                                                                                       OK
```



( )

## DESIGN OF PIER (P2)

File: PIER2-I

Case I: Water is empty + 142.33 (NORMAL CONDITION)

Parameter of soil:

φ = 36 degree
 γ = 2.0 t/m<sup>3</sup>
 C = 18 t/m<sup>2</sup>
 H = 10.0 m
 B = 4.55 m
 I = 4.55 m

Height of Pier Width of footing Pier

Compute overturning stability:

Set up table and refer to figure:

part	Weight of part (ton)	
1	1.6'0.4'2.5'2.7 =	4.320
2	(1.6+1.3)/2*0.4*2.5*(2.7+2)/2=	3.408
3	1.3'8'25'20 =	52.000
4	(4.55+1.3)/2*0.4*2.5*(4.55+2)/2=	9.579
5	4.56 0.8 2.5 4.55 =	41.405
6	P1	46.000
• 7 :	P2	46.000
	Total: Σ Fv =	202.712

Checking of Bearing Capacity on soil:

$$Q_u = A' * [\alpha * k * c * Nc + 0.1667*k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma]$$

$$b = 4.5$$
 m

 $R = 6.0$ 
 $B = 4.55$  m

 $\frac{b}{a} = 0.1667$ 

whoen

Qu = ultimate bearing capacity

A' = effective loading area on footing

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

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

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

q=γ\*Df

 $f^2$  = unit weight of soil on front of abutments ( $Vm^3$ ) = 1.8  $Vm^3$ 

 $\gamma 1$  = unit weight of soil of ground foundation (Vm<sup>3</sup>) = 2.0 Vm<sup>3</sup>

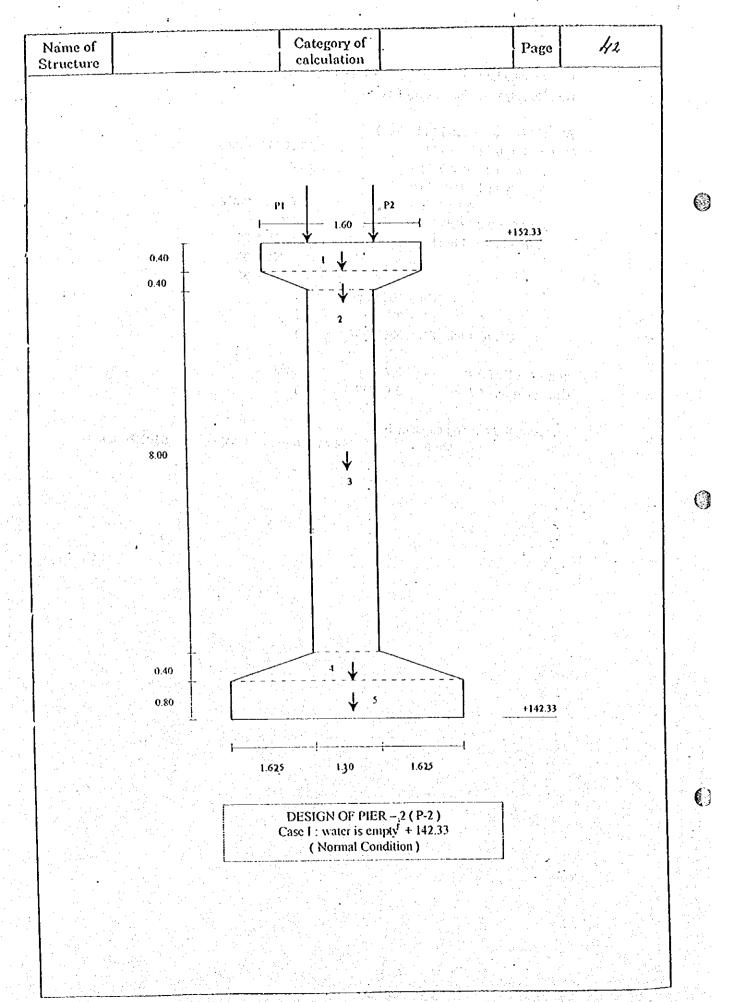
B',L' = width and length of effective loading area

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 toc (m) = 0.8 m

```
k = (1 + 0.3 * Df / B')
    = coefficient ---
Nq, Nc, Ny = bearing capacity factors
A' = L' * B' = (B - 2eb) * (L - 2el)
                                                          m^2
                                              20.7025
A' =(B - 2*eb) * (L - 2*el) =
                                              1.30
         \alpha = (1 + 0.3B'/L') =
                                              -3
           \beta = (1 - 4*B'/L') =
                                               4.806
                                                          Vm^2
                  q = \gamma * Df =
                                               1.0527
     k = (1 + 0.3 * (Df/B')) =
                                                     Nc= 50
      For \tan \theta = \Sigma Fh/\Sigma Fv = 0
                                                    Nq = 33
                           \phi = 36
                                                    Ny = 35
                         Qu = 16178.587
                                               ton
                         FS = 3
          Qsafe = Qu / FS = 5392.862
                                               ton
                                               t/m^2
 qmax = \Sigma Fv/A =
                               9.792
                                               ton
                               202.712
 Qmax = qmax * A =
 Checking the bearing capacity is:
                                                                         5392.86 ton
                                       202.71 lon <
                                                          Qsafe =
                      Qmax =
                                                                         OK
```



# DESIGN OF PIER (P2)

Case II: Water is full at elevation MWL + 153.60 (NORMAL CONDITION)

degree  $\phi' = 2/3\phi =$ Parameter of soil: t/m^3 ysub = 1.0 t/m^2 C'=2/3C = 12 10.0 H = Height of Pier 4,55 m 8 = Width of footing Pier 4.55

Compute overturning stability:

Set up table and refer to figure: ........ Weight of part part (ton) 4.320 1.6'0.4'2.5'2.7 = 3.408 (1.6+1.3)/2'0.4'2.5'(2.7+2)/2= 52.000 3 1.3'8'2.5'2.0 = 9.579 (4.55+1.3)/2'0.4'2.5'(4.55+2)/2= 4 41.405 4.55 0.8 2.5 4.55 = 78.270 (10.47+10.07)/2\*1.675\*4.55\*1.0 6 78,270 (10.47+10.07)/2\*1.675\*4.56\*1.0 46.000 8 46.000 9 P2

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

 $U = (1/2)^{*} \{ U1 + U2 \}^{*} B^{*} \gamma W$ 

ΣFv=

where :

U = total uplift (ton/m)

Total:

U1 = buoyancy at upstream side

 $UI = \gamma w * h1 \pmod{m}$ 

U2 = buoyancy at downstream side

 $U2 = \gamma w * h2 (ton/m)$ 

B = bottom width of structure (m)

yw = unit weight of water (t/m^3)

U1 = U2 = 1,0 \*(153.6-142.33) = 11.27 ton /m U = 51.278 ton /m 233.317 ton

Total Vertical Force:

 $\sum FV = \sum FV' - U =$ 

359,252

125.935 ton

Checking of Bearing Capacity on soil:

Qu = A' \* [  $\alpha$  \* k \* c \* Nc + 0.1667\*k \* q \* Nq + 0.5 \*  $\gamma$ 1 \* B' \*  $\beta$ ' \* N $\gamma$ 

Qu = ultimate bearing capacity

A' = effective loading area on footing

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

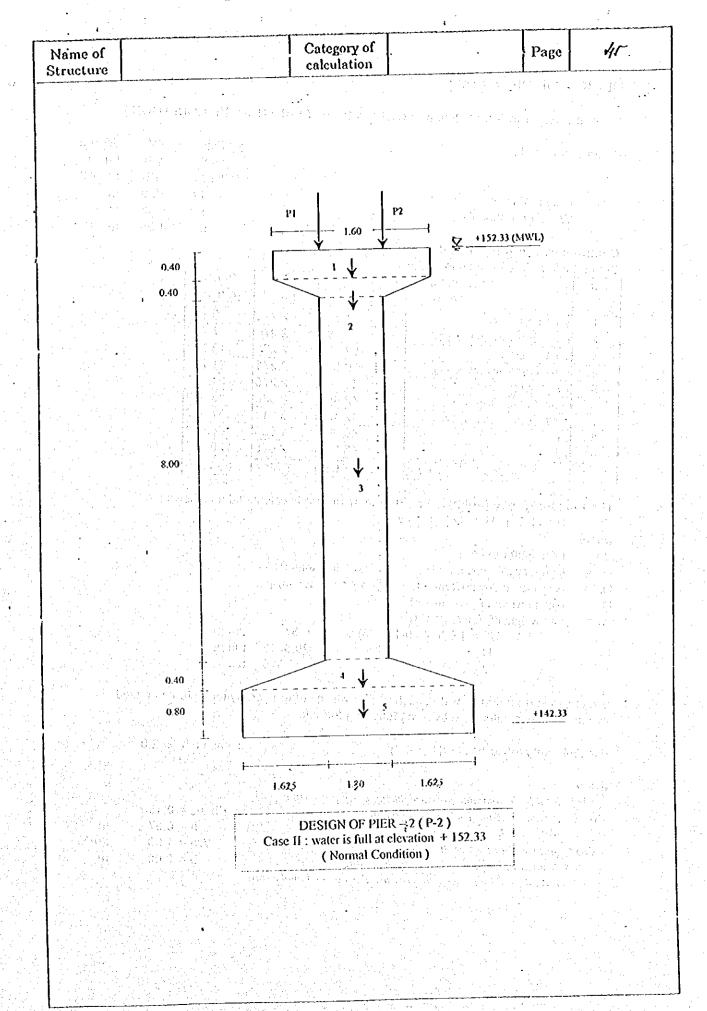
c = cohesion of foundation ground (ton/m^2)

 $q = ground surface surcharge (Um^2)$ 

 $q = \gamma * Df$ 

 $\gamma_2$  = unit weight of soil on front of abutments (Vm'3) = 0.8 Vm'3

```
= unit weight of soil of ground foundation (t/m^3) = 1.0 t/m^3
B',L' = width and length of effective loading area
    = 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) = 0.8 m
                                   k = (1 + 0.3 * Df'/B')
    = coefficient-----
Nq, Nc, N\gamma = bearing capacity factors
A' = L' * B' = (B - 2eb) * (L - 2el)
                                                       20,7025 m^2
     A' =( B - 2*eb) * ( L - 2*el ) =
                                                          1.30
               \alpha = (1 + 0.3B'/L') =
                                                       -3
                 \beta = (1 - 4*B'/L') =
                                                       2.936
                                                                Vm^2
                   q = \gamma sub2 * Df =
                                                       1.0527
           k = (1 + 0.3 * (Df/B')) =
                                                           Nc= 20
            For \tan \theta = \Sigma Fh / \Sigma Fv = 0
                                                          Nq = 8
                                                           Ny = 6
                                          6037.452 ton
                               Qu ≟
                               FS = 3
                Qsafe = Qu / FS =
                                           2012.484 ton
                                              6.083 t/m^2
 qmax = \Sigma Fv/A =
                                            125.935 ton
 Qmax = qmax * A =
 Checking the bearing capacity is:
                                                                                2012.48 ton
                                             125.94 ton <
                                                                 Qsafe =
                            Qmax =
```



File:Pier2-III

# DESIGN OF PIER (P2)

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

Parameter of soil :		φ' =2/3φ = vsub =	24 1 0	degree t/m^3
		γsuo = C'=2/3C =		
Height of Pier		 H=	10.0	
Width of footing Pier		B =	4.55	m
Trickle of Tooking 1 191	A 1 1 1 1 1 1 1 1	1 =	4 55	m

Compute overturning stability:

рагі	Weight of part		Arm <i>(m)</i>	Moment (ton m)
1	1.6'0.4'2.5'2.70 =	4.320	2.275	9.828
2	(1.6+1.3)/2*0.4*2.5*(2.7+2)/2=	3.408	2,275	7.752
3	1.3'8.0'2.5'2.0 =	52.000	2.275	118.300
4	(4.55+1.3)/2*0.4*2.5*(4.55+2)/2=	9.579	2.275	21.793
5	4.56*0.8*2.5*4.55 =	41.405	2.275	94.196
6	(5.37+5.77)/2*1.70*4.55*1.0	42.450	0.838	35:552
7	(5.37+5.77)/2*1.70*4.55*1.0	42,450	3.713	157.597
8	P1	46.000	1.925	88.550
9	P2	46.000	2.625	120.750
	Total : ΣFv =	287.613	Σ Mr =	654.319

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

where:

γw =

U= total uplift (ton/m)

 $U1 = \gamma v * h1 (ton/m)$ U1 = buoyancy at upstream side  $U2 = \gamma w * h2 (ton/m)$ buoyancy at downstream side U2 =

bottom width of structure (m) 8 ≂

unit weight of water (t/m^3)

6.57 ton /m U1 = U2 = 1,0 \*(148.9-142.33) = 29.8935 ton /m U= U =

136.015 ton

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

$$P = (3/4)^{*}Kh^{*}Wo^{*}Ao^{*}h^{*}(b/a)^{*}[1-(b/4h)]$$
 in case b/h < 2.0

where:

P = total hydrodynamic pressure during earthquake (ton)

Kh=E= design horizontal seismic coefficient

h = water depth (m)

Wo = unit weight of water (t/m^3)

b = column width perpendicular to the acting

direction of hydrodynamic pressure during earthquake (m)

Kh = E = 0.15

h = 6.57Wo = 1.00 m t/m^3

b = 2.00

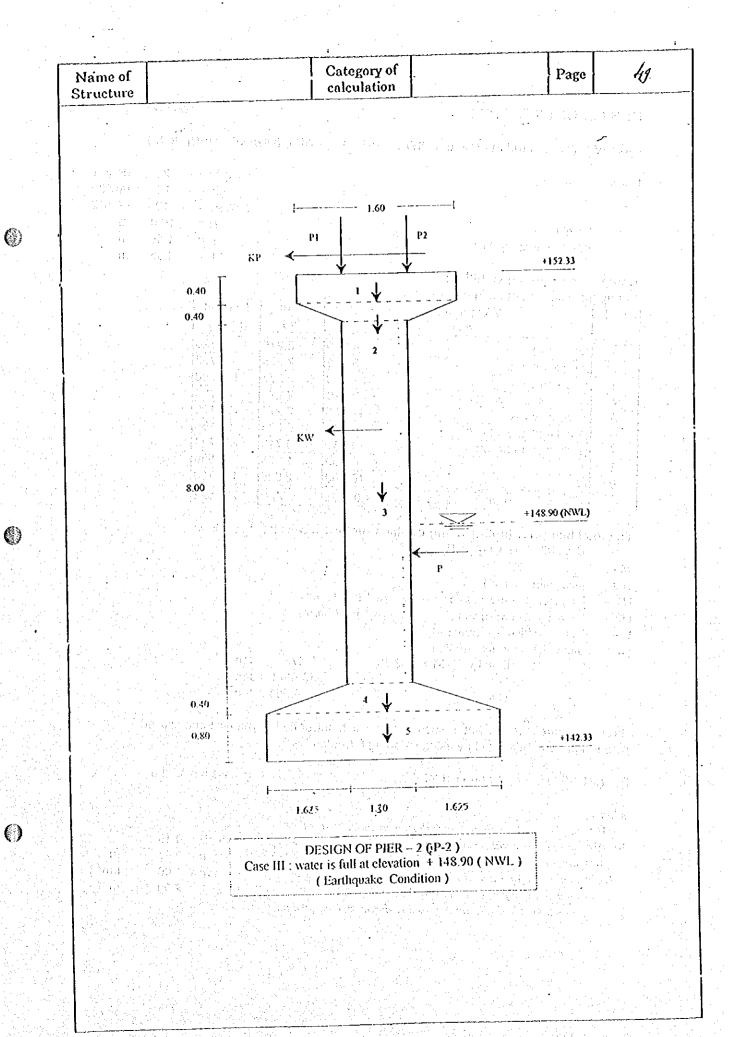
m

```
a = column width in acting direction of hydrodynamic pressure (m) a =
                                                                                        m
                                                                                        m^2
                                                                      A0 = 2.6..
  Ao = cross sectional area of a pier (m^2)
                                                                hg = 3/7 h = 2.8157
                                                                                        m 🖖
  hg = hydrodynamic force acting depth from the bottom (m)
                                                               2.73150
      P = (3/4)*Kh*Wo*Ao*h*(b/a)*[1-(b/4h)] =
The horizontal load (K) is determined using following formula:
                                P1 = 46.00
                                P2 = 46.00
                                W = 110.71
                                                     ton
                 KP = 0.15^{\circ} Ptotal = 13.80
                   KW = 0.15*W = 16.61
                                                                   33.13828 ton
Total horizontal force Σ Fh =
Total Vertical Force : \Sigma Fv = \Sigma Fv' - U =
                                                                   151.5972 ton
Sum of Overturning Moments:
                 \Sigma Mo = P * hg + KP*h1+KW*h2 = 226.3697 ton m
Sum of Moments to Resist Overturning:
                            \Sigma Mr' = \Sigma Mr - U * B/2 = 344.8836 ton m
 The Overturning safety factor is :
                          FS = \sum Mr / \sum Mo =
                                      Use base soil parameter
 Compute Sliding Force:
                                                           F_1 = 258.59561 \text{ ton}
 F_f = C' \cdot B'L + \Sigma Fv \cdot tan \phi' =
 The stiding safety factor is:
                                              7.8035 > 1.2
                    FS = Fr/\Sigma Fh =
 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:
                                              118.514 ton m
 \Delta M = \Sigma Mr - \Sigma Mo =
                                               0.7818 m (from toe)
 x = \Delta M / \Sigma Fv =
                                                1.493 m
 e = \{ B/2 \} - x
                                                                                         OK
                                                               \Rightarrow e < (B/3)
                                                                                         1.517
                                                1.517 m
  B/3 = -
                                                                                          OK
 Compute soil pressure:
                                                                     98.9245 ton / m
          qmax = \{ \Sigma \text{ Fv / B} \}^* \{ 1 + (6^*e)/B \} =
                                                                     -32,2884 ton / m
          qmin = \{\Sigma Fv/B\}^* \{1 - (6^*e)/B\} =
                                                                   450.10663 ton
          Qmax = qmax * L =
                                                                   -146,9123 ton
          Qmin = qmin * L =
```

#### Checking of Bearing Capacity on soil:

```
Qu = A' * [\alpha * k * c * Nc + 0.1667*k * q * Nq + 0.5 * \gamma i * B' * \beta' * N\gamma
```

```
where:
Ou = ultimate bearing capacity
     = effective loading area on footing
\alpha, \beta = coefficient depending on shape of footing
    = cohesion of foundation ground (ton/m^2)
    = ground surface surcharge (t/m^2)
     = unit weight of soil on front of abutments (Vm^3) = 0.8 Vm^3
     = unit weight of soil of ground foundation (Um^3) = 1.0 Um^3
B',L' = width and length of effective loading area
     = 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) = 0.8 m
                                    k = (1 + 0.3 * Df / B')
     = coefficient ----
Nq, Nc, Ny = bearing capacity factors
A' = L' * B' = (B - 2eb) * (L - 2el)
                                                    7.114 m<sup>2</sup>
A' =( B - 2*eb) * ( L - 2*el ) =
                                                    1.103
     \alpha = (1 + 0.3 \text{B/L'}) =
                                                    -0.375
           \beta = (1 - 4*B!/L') =
                                                  2.936 Vm^2
             q = \gamma sub2 * Df =
                                                  1.1535
     k = (1 + 0.3 * (Df/B')) =
                                                      Nc= 17
     For \tan \theta = \Sigma Fh / \Sigma Fv = 0.219
                                                      Nq = 7
                                                   N_y = 4
                         Qu = 1847.081
                                                tón
                          FS = 2
           Qsafe = Qu / FS = 923.541
  Checking the bearing capacity is:
                                                                            923.54 ton
                                                            Qsafe =
                      Qmax =
                                        450.11 ton <
                                                                            OΚ
```



File:Pier2-IV

#### DESIGN OF PIER (P2)

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

Parameter of soil:						.*	φ' =2/3φ = γsub =	24 1.0	degree t/m^3
		٠,		1000	1.	1.	C'=2/3C =	12	t / m^2
Mainta of Dior							H=	10.0	m
Height of Pier			100	÷			8 =	4.55	m
Width of footing	y Piei						L≡	4.55	m

Compute overturning stability: t un table and refer to figure :

part	Weight of part ((on)		Arm (m)	Moment (ton m)
1	1.6'0.4'2.5'2.7 =	4.320	2.275	9.828
2	(1.6+1.3)/2'0.4'2.5'(2.7+2)/2=	3.408	2.275	
3	1.3'8.0'2.5'2.0 =	52.000	2.275	
4	(4.55+1.3)/2*0.4*2.5*(4.55+2)/2=	9.579	2.275	21.793
5	4.55'0.8'2.5'4.55 =	41.405	2.275	
6	(9.47+9.07)/2*1.70*4.55*1.0	70.649	0.838	
7	(9.47+9.07)/2*1.70*4.55*1.0	70.649	3.713	
8	P1	46.000	1.925	
9	P2	46.000	2.625	120.750
	Total : ΣFv =	344.00985	Σ Mr =	782.622

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

where:

total uplift (ton/m) U=

buoyancy at upstream side U1 =

 $U1 = \gamma w * h1 \pmod{m}$  $U2 = \gamma w * h2 (ton/m)$ 

buoyancy at downstream side U2 = bottom width of structure (m) B =

unit weight of water (1/m^3) γw =

U1 = U2 = 1.0 \* (151.8 - 142.33) =

ton /m 9.47 ton/m

43.0885 U= ton 196.053 U=

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

in case b/h < 2.0P = (3/4)\*Kh\*Wo\*Ao\*h\*(b/a)\*[1-(b/4h)]

where:

P = total hydrodynamic pressure during earthquake (ton)

Kh=E= design horizontal seismic coefficient

Kh = E = 0.15

h = 9.47

h = water depth (m)

Wo = unit weight of water (t/m^3)

 $W_0 = 1.00$ 

t/m^3

b = column width perpendicular to the acting

b = 2.00

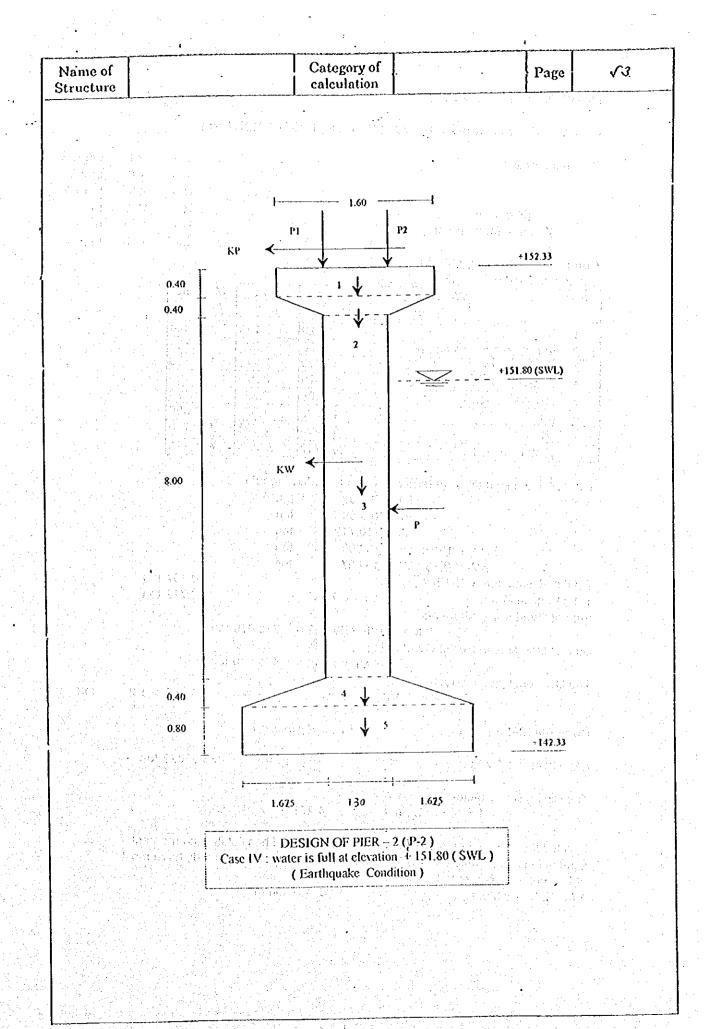
m

```
a = column width in acting direction of hydrodynamic pressure (m) a =
                                                                                            m^2
A_0 = cross sectional area of a pier (m^2)
                                                                    hg = 3/7 h = 4.0586
  hg = hydrodynamic force acting depth from the bottom (m)
                                                                     4.03650
       P = (3/4)*Kh*Wo*Ao*h*(b/a)*[1-(b/4h)] =
The horizontal load (K) is determined using following formula:
                                                         ton
                                   P1 = 46.00
                                                         ton
                                   P2 = 46.00
                                                          ton
                                    W = 110.71
                    KP = 0.15*Ptotal = 13.80
                                                          ton
                                                          ton
                      KW = 0.15^*W = 16.61
Total horizontal force \Sigma Fh =
Total Vertical Force:
Sum of Overturning Moments:
                     \Sigma Mo = P * hg + KP*h1+KW*h2 =
Sum of Moments to Resist Overturning:
                               \Sigma Mr' = \Sigma Mr - U * B/2 = 336.6026 \text{ ton m}
 The Overturning safety factor is:
                                                                                              OK
                            FS = \sum M r / \sum Mo =
                                          Use base soil parameter
 Compute Sliding Force:
                                                                Fr = \frac{1}{2} 256.975 ton
 Fr = C' * B*L + \Sigma Fv * tan \phi' =
 The sliding safety factor is:
                                                   7.4608 > 1.2
                       FS = Fr/\Sigma Fh =
 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:
                                                  101,542 ton m
  \Delta M = \Sigma Mr - \Sigma Mo =
                                                   0.6863 m (from toe)
  x = \Delta M / \Sigma Fv =
                                                    1.5087 m
  e = \{ 8/2 \} - x
                                                                                               OK.
                                                                       e < (B/3)
                                                                                               1.5167
                                                    1.5167 m
   B/3=
                                                                                               OK.
  Compute soil pressure:
                                                                          97.2126 ton / m
           qmax = { \( \Sigma\) Fv \( \B \) * { 1 + (6*e)/B } =
                                                                          -32.1764 ton / m
           qmin = \{ \Sigma Fv / B \} * \{ 1 - (6*e)/B \} =
                                                                        442,31716 ton
           Qmax = qmax * L =
                                                                         -146.4028 ton
           Qmin = qmin * L =
```

## Checking of Bearing Capacity on soil:

Qu = A' \* [
$$\alpha$$
 \* k \* c \* Nc + 0.1667\*k \* q \* Nq + 0.5 \*  $\gamma$ 1 \* B' \*  $\beta$ ' \* N $\gamma$ 

```
where:
Ou = ultimate bearing capacity
     = effective loading area on footing
\alpha, \beta = coefficient depending on shape of footing
    = cohesion of foundation ground (ton/m^2)
     = ground surface surcharge (t/m^2)
     = unit weight of soil on front of abutments (Vm^3) = 0.8 Vm^3
     = unit weight of soil of ground foundation (Vm^3) = 1.0 Vm^3
B',L' = width and length of effective loading area
     = 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) = 0.8 m
     = coefficient \rightarrow k = (1 + 0,3 * Df / B')
Nq, Nc, N\gamma = bearing capacity factors
A' = L' * B' = (B - 2eb) * (L - 2el)
                                                       4.804 m^2
  A' =( B - 2*eb) * (L - 2*el) =
                                                       1.118
            \alpha = (1 + 0.3B'/L') =
                                                       -0.569
              \beta = (1 - 4*B'/L') =
                                                     2.936
                q = \gamma sub2 * Df =
                                                     1.1749
        k = (1 + 0.3 * (Df/B')) =
                                                         Nc= 15
         For \tan \theta = \Sigma Fh/\Sigma Fv = 0.233
                                                        Nq = 7
                                                         Ny = 2.5
                            Qu = 1139.248
                            FS = 2
              Qsafe = Qu / FS = 569.624
                                                   ton
  Checking the bearing capacity is :
                                                                               569.62 ton
                                           457.93 ton <
                                                               Qsafe =
                                                                               OK
```



(in chi)

## DESIGN OF PIER (P2)

File:Pier2-V

# Case V: Water is empty + 146.33 (EARTHQUAKE CONDITION)

Parameter of soil:

degree 36 Vm^3 2.0 γ = C = 18 t/m^2 10.0 m H = 8 = 4.55 m L = 4.55 m

Height of Pier Width of footing Pier

Compute overturning stability:

part	Weight of part		Arm (m)	Moment (ton m)
	1.6 0.4 2.5 2.7 =	4.320	2.275	9.828
2	(1.6+1.3)/2*0.4*2.5*(2.7+2)/2=	3.408	2.275	7.752
3	1.3'8'2.5'2.0 =	52.000	2.275	118.300
- <del>-</del>	(4.55+1.2)/2'0.4'2.5'(4.55+2)/2=	9.579	2.275	21.793
5	456'08'25'456 =	41.405	2.275	94.196
6	P1	46,000	1.925	
1 7	P2	46.000	2.625	120.750
	Total : Σ Fv =	202.712	Σ Mr =	461.170

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

P1 = 46.000

ton

P2 = 46.000 W = 110.712 ton i

KP = 0.15\*Ptotal = 13.800KW = 0.15\*W = 16.607 ton

Total horizontal force  $\Sigma$  Fh =

 $\Sigma Fv = \Sigma Fv' =$ 

30.407 ton 202.712 ton

Sum of Overturning Moments:

 $\Sigma$  Mo =KP\*h1+KW\*h2 = 218.679 ton m

Sum of Moments to Resist Overturning:

 $\Sigma Mr = \Sigma Mr = 461.170 \text{ ton m}$ 

The Overturning safety factor is:

 $FS = \Sigma Mr / \Sigma Mo =$ 

2.109 > 1.2

OK

**Compute Sliding Force:** 

Total Vertical Force:

Use base soil parameter

 $F_1 = C^*B^*L + \Sigma Fv^* \tan \phi =$ 

Fr=

433.92829 ton

The sliding safety factor is:

 $FS = Fr/\Sigma Fh =$ 

14,271 > 1.2

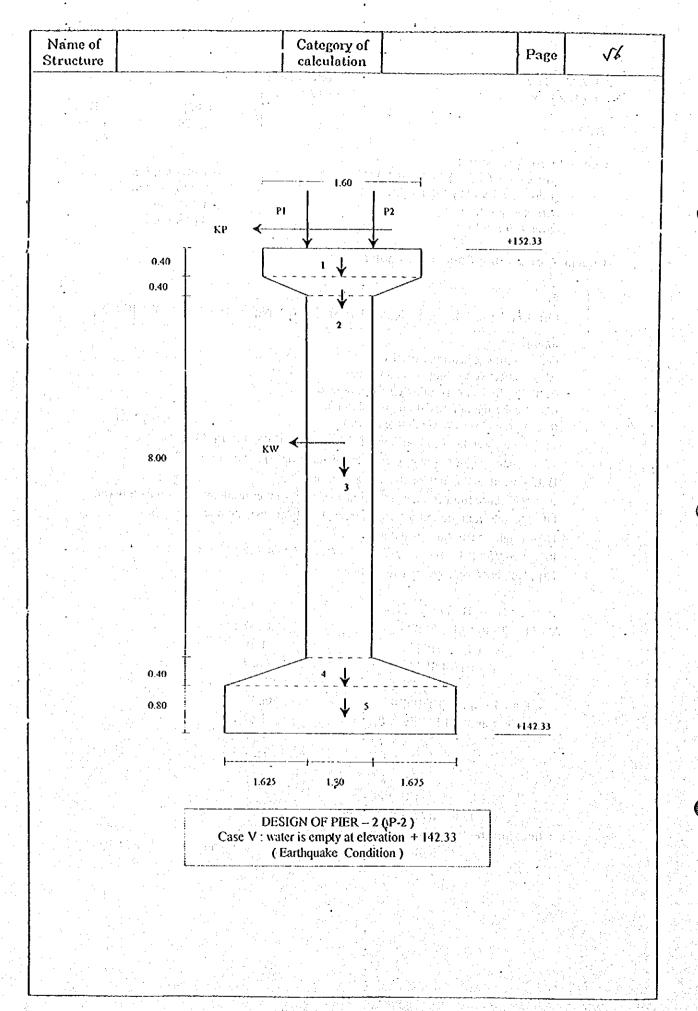
Ok

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:

 $\Delta M = \Sigma Mr - \Sigma Mo =$ 

242.491 ton m

```
1.19623 m (from toe)
x = \Delta M / \Sigma Fv =
                                                 1.079 m
e = \{ B/2 \} - x
                                                                                            OK
                                                                ⇒ e < (B/3)
                                                                                            1,517
                                                 1.517 m
                                                                         1.079
B/3=
                                                                                            OK
Compute soil pressure:
        qmax = { \Sigma Fv / B } * { 1 + (6*e)/B } =
                                                                       107.929 ton / m
                                                                       -18.825 ton / m
        qmin = \{ \Sigma \text{ Fv / B} \} * \{ 1 - (6*e)/B \} =
                                                                       491.079 ton
        Qmax = qmax * L =
                                                                       -85.655 ton
        Qmin = qmin * L =
Checking of Bearing Capacity on soil:
        Q_u = A' * [\alpha * k * c * Nc + 0.1667*k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma]
        where:
              = ultimate bearing capacity
         Ou
              = effective loading area on footing
         \alpha, \beta = coefficient depending on shape of footing
             = cohesion of foundation ground (ton/m^2)
             = ground surface surcharge (t/m^2)
              = unit weight of soil on front of abutments (Vm^3) = 1.8 Vm^3
              = unit weight of soil of ground foundation (Vm^3) = 2.0 Vm^3
         B' L' = width and length of effective loading area
             = 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 toc (m) = 0.8 m
                                         k = (1 + 0,3 * Df / B')
             = coefficient ----
         Nq, Nc, Ny = bearing capacity factors
         A' = L' * B' = (B - 2eb) * (L - 2el)
                                                          10.8857 m^2
        A' =( B - 2*eb) * ( L - 2*el ) =
                                                              1.16
                  \alpha = (1 + 0.3BVL') =
                                                         -1.10327
                    \beta = (1 - 4*B'/L') =
                                                          6.606 · t/m^2
                      q = \gamma sub2 * Df =
                                                          1.1003
             k = (1 + 0.3 * (Df/8')) =
                                                              Nc=30
           For \tan \theta = \Sigma Fh / \Sigma Fv = 0.150
                                                              Nq = 15
                                                              Ny = 20
                                  Qu = 6593.22
                                                        ton
                                  FS = 2
                   Qsafe = Qu / FS = 3296.61
                                                        ton
         Checking the bearing capacity is:
                                                                                   3296.61 ton
                              Qmax = 491.08
                                                        ton <
                                                                    Qsafe =
```



## DESIGN OF PIER (P3)

File: PIER3-I

Case I: Water is empty + 144.33 (NORMAL CONDITION)

Parameter of soil: Height of Pier

Width of footing Pier

degree 36 t/m/3 t/m^2 18 C= m H= m 4.0 8 = m 4.0

Compute overturning stability:

(

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

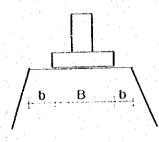
part	Weight of par	t
	(ton)	
1	1.6'0.4'2.5'2.7 =	4.320
2	(1.6+1.1)/2*0.4*2.5*(2.7+2)/2=	3.055
3	1.1'6.1'2.5'2.0 =	33.550
<u> </u>	(4+1.1)/2*0.4*2.5*(4+2)/2=	7.650
5	4'0.7'2.5'4.0 =	28.000
6	P1	46.000
7	P2	46.000
	Total : $\Sigma Fv =$	168.575

Checking of Bearing Capacity on soil:

 $Qu = A' * [\alpha * k * c * Nc + 0.167*k * q * Nq + 0.5 * yı * B' * \beta' * Ny$ 

$$R = 6.0$$

$$B = 4.0$$



where:

= ultimate bearing capacity

Rx B

= effective loading area on footing

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

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

= ground surface surcharge (1/m^2) q

$$q = \gamma * Df$$

= unit weight of soil on front of abutments (Um^3) = 1.8 Um^3

= unit weight of soil of ground foundation (Um^3) = 2.0 Um^3

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

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

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

Df = height of toc (m) = 0.7 m

```
= coefficient \longrightarrow k = (1 + 0,3 * Df' / B')
  Nq , Nc , Ny = bearing capacity factors
  A' = L' * B' = (B \cdot 2eb) * (L - 2el)
                                                           m^2
                                                16
A' = (B - 2*eb) * (L - 2*el) =
                                               1.30
          \alpha = (1 + 0.3BVL') =
                                               -3
           \beta = (1 - 4*B'/L') =
                                               6.606
                   q = \gamma * Df =
                                                1.0525
     k = (1 + 0.3 * (Df/B')) =
                                                      Nc= 50 d. ( about the plant and )
     For \tan \theta = \Sigma Fh / \Sigma Fv = 0
                                                100 Nq = 33 M The had all all and a second
                           \phi = 36
                                               N\gamma = 40
                         Qu = 12635.87
                                                ton
                          FS = 3
           Qsafe = Qu / FS = 4211.96
                                                ton
                                                t/m^2
   qmax = \Sigma Fv/A =
                                10.536
                                                tòn -
                                168.575
    Qmax = qmax * A =
    Checking the bearing capacity is:
                                                                           4211.96 ton
                                                            Qsafe =
                                       168.575 ton <
                       Qmax =
                                                                             OK-
```

Name of		Category	of	Page	<b>1</b> 9
Structure.		calculation	on	Page	
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S 1 4 4 5	And the second of the second o	1.60			
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		DESIGN OF F	PIER - 3 ( P-3 ) empty + 144.33		
		Case 1. water is	Condition)		
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(a)

## DESIGN OF PIER (P3)

File Pier3-II

Case II: Water is full at elevation MWL + 153.60 (NORMAL CONDITION)

Parameter of soil:

**φ' =2/3φ =** 24 degree t/m^3 ysub = 1.0 C'=2/3C = 12 t/m^2 8.0 H == m B = 4.0 m

4.0

m

Height of Pier

Width of footing Pier

Compute overturning stability:

Set up	table and refer to figure :				
part	Weight of part				
	(ton)				
1	1.6'0.4'2.5'2.7 =	4.320			
2	(1.6+1.1)/2'0.4'2.5'(2.7+2)/2=	3.055			
3	1.1*6.1*2.5*2.0 =	33.550			
4	(4+1.1)/2*0.4*2.5*(4+2)/2=	7.650			
5	4'0.7*2.5*4.0 =	28,000			
6	((9.27+8.87)/2)*1.50*4.0*1.0	54.42			
7	((9.27+8.87)/2)*1.50*4.0*1.0	54.42			
8	P1	46.000			
9	P2	46.000			
	Total: ΣFv =	277.415			

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

 $U = (1/2)^{*} \{ U1 + U2 \} * B * \gamma W$ 

where:

U = total uplift (ton/m)

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

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

8 ≈ bottom width of structure (m)

unit weight of water (1/m^3)

U1 = U2 = 1,0 \* (153.6-142.33) =9.27 ton /m U=

37.08 ton /m

148.32 ton

**Total Vertical Force:**  $\Sigma Fv = \Sigma Fv' \cdot U =$ 129.095 ton

Checking of Bearing Capacity on soil:

 $Qu = A' * [\alpha * k * c * Nc + 0.167*k * q * Nq + 0.5 * yı * B' * \beta' * Ny]$ 

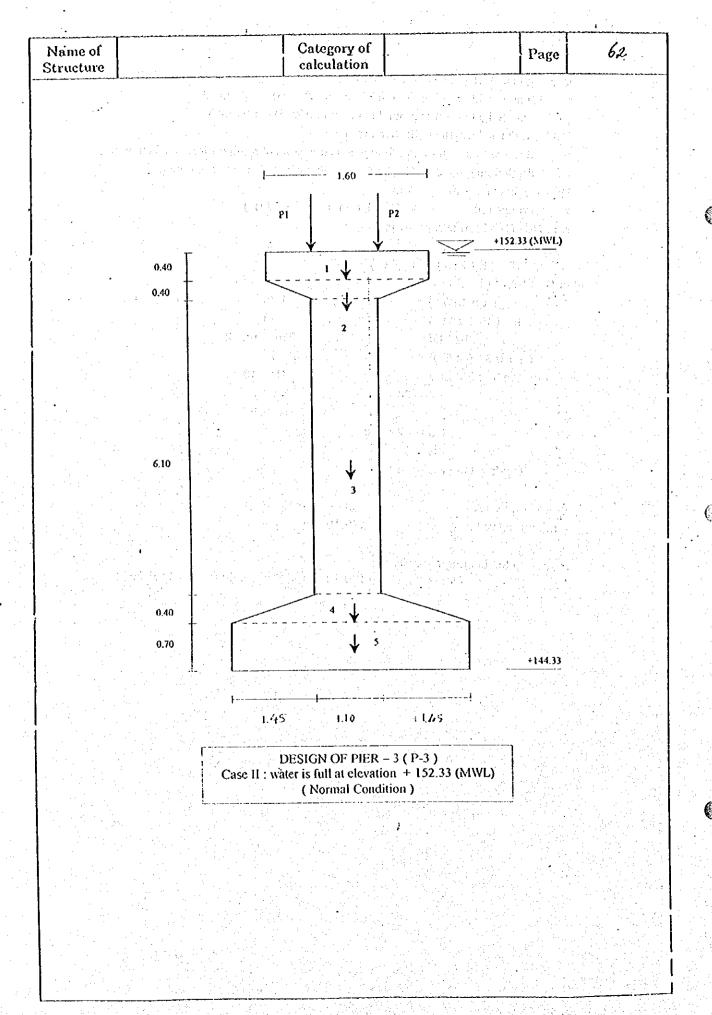
= ultimate bearing capacity

= effective loading area on footing

 $\alpha$ ,  $\beta$  = coefficient depending on shape of footing

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

```
q = \gamma * Df
       = ground surface surcharge (Vm^2)
       = unit weight of soil on front of abutments (Vm^3) = 0.8 Vm^3
       = unit weight of soil of ground foundation (Um^3) = 1.0 Um^3
  71
  B',L' = width and length of effective loading area
       = 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) = 0.7 m
                                    k = (1 + 0.3 * Df/B')
       = coefficient ——→
  Nq, Nc, N\gamma = bearing capacity factors
  A' = L' * B' = (B - 2eb) * (L - 2el)
                                                        16 m^2
A' = (B - 2*eb) * (L - 2*el) =
                                                      1.30
         \alpha = (1 + 0.3B'/L') =
                                                        -3
           \beta = (1 - 4*B'/L') =
                                                  2.936
                                                         Vm^2
             q = \gamma sub2 * Df =
                                                 1.0525
     k = (1 + 0.3 * (Df/B')) =
                                                      Nc≈ 18
      For \tan \theta = \Sigma Fh / \Sigma Fv = 0
                           \phi = 24
                                                     Nq = 9
                                                      N_7 = 6
                         Qu = 4226.98
                                               ton
                         FS = 3
           Qsafe = Qu / FS = 1408.99
                                               ton
                                        8.068 t/m^2
   qmax = \Sigma Fv/A =
                                       129.10 lon
   Qmax = qmax * A =
   Checking the bearing capacity is:
                                                                          1408.99 ton
                      Qmax =
                                        129.10 ton <
                                                           Qsafe =
                                                                            OK
```



### DESIGN OF PIER (P3)

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

Parameter of soil :		φ' =2/3φ =	24	degree
Talamotor of son .	V	γsub ≕	1.0	t/m^3
		C'=2/3C =	12	t/m^2
Height of Pier	100	H≡	8.0	m
Width of footing Pier		B =	4.0	m
Triatt of tooting 1 io.		1 =	4.0	m

Compute overturning stability:

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

part	Weight of par		Am	Moment
	(ton)		(m)	(ton m)
1	1.6'0.4'2.5'2.7 =	4.320	2.00	8.640
2	(1.6+1.1)/2'0.4'2.5'(2.7+2)/2=	3.055	2.00	6.110
3	1.1'6.1'2.5'2.0 =	33.550	2.00	67.100
4	(4+1.1)/2'0.4'2.5'(4+2)/2=	7.650	2.00	15.300
5	4'0.7'2.5'4.0 =	28.000	2.00	56.000
6	((3.87+3.47)/2)*1.5*4*1.0	22.02	0.75	16.513
7	((3.87+3.47)/2)*1.5*4.0*1.0	22.02	3.25	71.565
8	P1	46.000	1.65	75.900
- 9	P2	46.000	2.35	108.100
	Total : ΣFv =	212.615	Σ Mr =	425.230

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

$$U = (1/2)^{*} \{ U1 + U2 \} * B * w$$

b = column width perpendicular to the acting

where:

U = total uplift (ton/m)

U1 = buoyancy at upstream side

 $UI = \gamma n * h1 \pmod{m}$ 

U2 = buoyancy at downstream side

 $U2 = \gamma w * h2 (ton/m)$ 

B = bottom width of structure (m)

yw = unit weight of water (Vm^3)

Total Vertical Force:

 $\Sigma Fv = \Sigma Fv' - U =$ 

139,4950 ton

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

P = (3/4)\*Kh\*Wo\*Ao\*h\*(b/a)\*[1-(b/4h)] in case b/h < 2.0

where:

P = total hydrodynamic pressure during earthquake (ton)

Kh=E= design horizontal seismic coefficient

h = water depth (n) h = 4.57 m

Wo = unit weight of water (t/m/3) Wo = 1.00 t/m/3

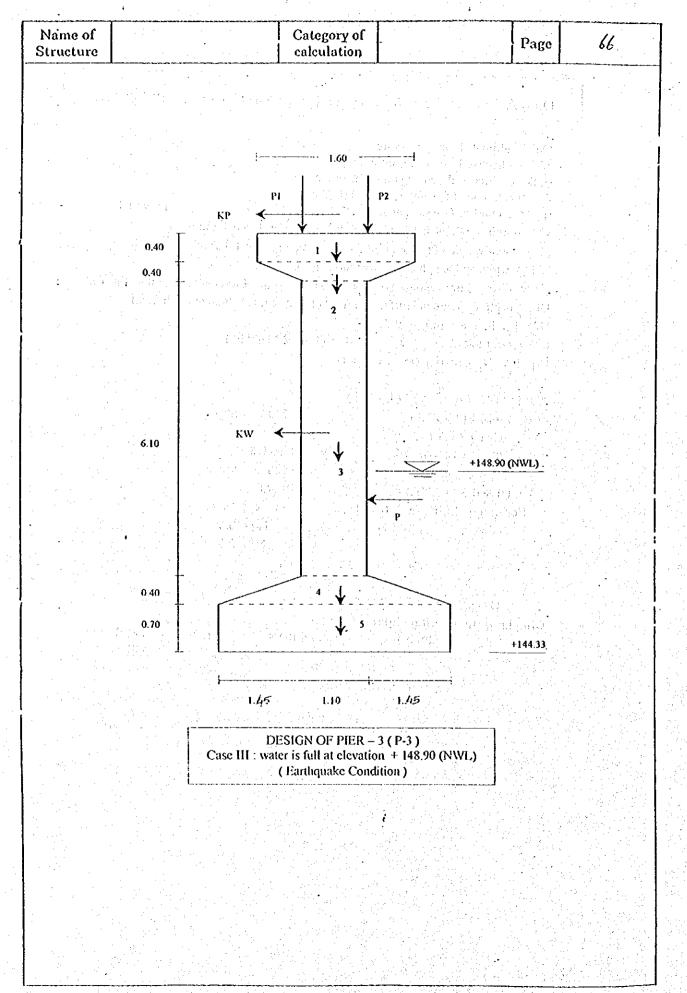
direction of hydrodynamic pressure during earthquake (m) a = column width in acting direction of hydrodynamic pressure (m)a =  $Ao = cross sectional area of a pier (m^2)$  $A_0 = 2.2$  $m^2$ hg = hydrodynamic force acting depth from the bottom (m) hg = 3/7 h = 1.9586P = (3/4)\*Kh\*Wo\*Ao\*h\*(b/a)\*[1-(b/4h)] =1.83150 ton The horizontal load (K) is determined using following formula: P1 = 46.000ton P2 = 46.000ton  $\dot{W} = 76.575$ ton KP = 0.15 \* Ptotal = 13.800ton KW = 0.15 \* W = 11.486ton Total horizontal force  $\Sigma$  Fh =  $\frac{1}{2}$ 27.118 Sum of Overturning Moments:  $\Sigma Mo = P * ha + KP*h1+KW*h2 = 160.8981 ton m$ Sum of Moments to Resist Overturning:  $\Sigma Mr = \Sigma Mr - U * B/2 =$ 278.99 ton m The Overturning safety factor is:  $FS = \Sigma Mr / \Sigma Mo =$ 1.734 > 1.2OK Compute Sliding Force: Use base soil parameter  $Fr = C' *B*L + \Sigma Fv * tan \phi' =$ 230,10736 ton The sliding safety factor is:  $FS = Fr/\Sigma Fh =$ 8.4855 > 1.2 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:  $\Delta M = \Sigma Mr - \Sigma Mo =$ 118.092 ton m  $x = \Delta M / \Sigma Fv =$ 0.847 m (from toe)  $e = \{ B/2 \} - x$ (B/3)OK B/3 =1.333 m 1.333 OK Compute soil pressure:

 $\begin{array}{lll} qmax = \{ \; \Sigma \; Fv \; / \; B \; \} \; \; \; \; \{ \; 1 \; + \; (6^*e) / B \; \} \; & \; \; 95.2105 \; ton \; / \; m \\ qmin = \{ \; \Sigma \; Fv \; / \; B \; \} \; \; \; \{ \; 1 \; - \; (6^*e) / B \; \} \; = & \; \; -25.4630 \; ton \; / \; m \\ Qmax = qmax \; \; \; L \; = & \; \; 333.23691 \; ton \\ Qmin = qmin \; \; \; L \; = & \; \; -89.12066 \; ton \end{array}$ 

Checking of Bearing Capacity on soil:

#### where: = ultimate bearing capacity Ou = effective loading area on footing $\alpha$ , $\beta$ = coefficient depending on shape of footing = cohesion of foundation ground (ton/m^2) $q = \gamma * Df$ = ground surface surcharge (1/m^2) = unit weight of soil on front of abutments ( $Vm^3$ ) = 0.8 $Vm^3$ = unit weight of soil of ground foundation ( $Vm^3$ ) = 1.0 $t/m^3$ B',L' = width and length of effective loading area = 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) = 0.7 mk = (1 + 0.3 \* Df / B')= coefficient ---> Nq, Nc, Ny = bearing capacity factorsA' = L' \* B' = (B - 2eb) \* (L - 2el)6.773 m^2 A' =( B - 2\*eb) \* ( L - 2\*el ) = 1.13 $\alpha = (1 + 0.3BVL') =$ -0.69313 $\beta = (1 - 4*BVL') =$ t/m^2 2.936 $q = \gamma sub2 * Df =$ 1.1240 k = (1 + 0.3 \* (Df/B')) =Nc= 14 For $\tan \theta = \Sigma Fh/\Sigma Fv = 0.194$ Nq = 6.5φ = **24** $N_7 = 2.5$ Qu = 1442.10ton FS = 2Qsafe = Qu / FS = 721.05 ton Checking the bearing capacity is: 721.05 ton Qsafe = 333.24 ton < Qmax ≃ OK

 $Q_u = A' * [\alpha * k * c * Nc + 0.167*k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma]$ 



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

			<b>φ' =2/3</b> φ =	24	degree
Parameter of soil :			ysub =	1.0	t/m^3
	At the second of the least	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	C'=2/3C =	: 12	1/m^2
and the second s			H =	8.0	m
Height of Pier		1000	8 =	4.0	m
Width of footing Pic	51 		L≔	4.0	m

Compute overturning stability:

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

Weight of na		Arm	Moment
	Takan k	(m)	(ton m)
	4.320	2.000	8.640
	3.055	2.000	6.110
	33.550	2.000	67.100
	7.650	2.000	15.300
	28.000	2.000	56.000
	39.42	0.750	29.565
	39.42	3.250	128.115
	46.000	1.650	75.900
	46.000	2.350	108.100
	247,415	Σ Mr =	494.830
		Weight of part (ton)	Weight of part (ton)  1.6'0.4'2.5'2.7 = 4.320 2.000  (1.6+1.1)/2'0.4'2.5'(2.7+2)/2 3.055 2.000  1.1'6.1'2.5'2.0 = 33.550 2.000  (4+1.1)/2'0.4'2.5'(4+2)/2 7.650 2.000  4'0.7'2.5'4.0 = 28.000 2.000  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 0.750  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 3.250  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 3.250  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 3.250  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 3.250  ((6.77+6.37)/2)'1.5'4.0'1.0 39.42 3.250

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

where:

total uplift (ton/m) U≔

 $U1 = \gamma w * h1 \pmod{m}$ buoyancy at upstream side U1 =

 $U2 = \gamma n + h2 \pmod{m}$ buoyancy at downstream side U2 =

bottom width of structure (m) B =

unit weight of water (1/m^3) γv =

ton/m 7.47 U1 = U2 = 1.0 \* (151.8-144.33) =29.88 ton/m U=

119.520 ton U =

Structures surrounded by water, such as pier which suffer hydrodynamic force caused by earthquake is calculated by using following formulas:

in case b/h < 2.0 $P = (3/4)^*Kh^*Wo^*Ao^*h^*(b/a)^*[1-(b/4h)]$ 

P = total hydrodynamic pressure during earthquake (ton)

Kh = E = 0.15(h =E = design horizontal seismic coefficient h = 7.47

m h = water depth (m)  $W_0 = 1.00$ t/m^3 Wo = unit weight of water (t m^3) b = 2.00

b = column width perpendicular to the acting direction of hydrodynamic pressure during earthquake (in)

```
a = column width in acting direction of hydrodynamic pressure (m) a =
                                                                     A_0 = 2.2
  Ao = cross sectional area of a pier (m^2)
                                                               hg = 3/7 h = 3.2014
  hg = hydrodynamic force acting depth from the bottom (m)
                                                               3.13650
    P = (3/4)*Kh*Wo*Ao*h*(b/a)*[1-(b/4h)] =
The horizontal load (K) is determined using following formula:
                              P1 = 46
                              P2 = 46
                                                    ton
                               W = 76.575
                                                    ton
                                                    ton
           KP = 0.15*0.5*Ptotal = 6.9
             KW = 0.15*0.5*W = 5.743
                                                                    15.780 ton
Total horizontal force \Sigma Fh = -\infty
                                                                   127,895 ton
                                    \Sigma Fv = \Sigma Fv' - U =
Total Vertical Force:
Sum of Overturning Moments:
                                                        88,697 ton m
                \Sigma Mo = P * hg + KP*h1+KW*h2 =
Sum of Moments to Resist Overturning:
                          \Sigma Mr = \Sigma Mr - U * B/2 =
                                                      255,790 ton m
The Overturning safety factor is:
                                                                      2.884 > 1.2
                                                                                        OK
                         FS = \Sigma M \Gamma / \Sigma Mo =
                               🤫 - Use base soil parameter
Compute Sliding Force:
                                                                   224.943 ton
F_{\Gamma} = C' * B*L + \Sigma Fv * tan \phi' =
                                                     Fr =
The sliding safety factor is:
                                             14.255 > 1.2
                  FS = Fr/ΣFh =
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:
                                            167.093 ton m
 \Delta M = \Sigma Mr - \Sigma Mo =
                                               1.306 m (from toe )
x = \Delta M / \Sigma Fv =
                                               0.694 m
 e = \{ B/2 \} - x = 5 = 5
                                                                                         OK.
                                                                e < (B/3)
                                                                      0.694
                                                                                         1.333
                                               1.333 m
 B/3 =
                                                                                         OK
 Compute soil pressure:
                                                                    65,2350 ton / m
         qmax = { \Sigma Fv / B } * { 1 + (6*e)/B } =
                                                                  -1.2875 ton / m
         qmin = \{ \Sigma Fv / B \}^* \{ 1 - (6^*e)/B \} =
                                                                  260.94017 ton
         Qmax = qmax * L =
```

Qmin = qmin \* L =

-5.150171 ton

## Checking of Bearing Capacity on soil:

(

()

```
Qu = A' * [\alpha * k * c * Nc + 0.167*k * q * Nq + 0.5 * \gamma 1 * B' * \beta' * N\gamma]
  where:
  Qu = ultimate bearing capacity
       = effective loading area on footing
  \alpha, \beta = coefficient depending on shape of footing
       = cohesion of foundation ground (ton/m^2)
                                                                         q = y * Df
       = ground surface surcharge (t/m^2)
  q
       = unit weight of soil on front of abutments (Vm^3) = 0.8 t/m^3
        = unit weight of soil of ground foundation (Vm^3) = 1.0 Vm^3
  B',L' = width and length of effective loading area
       = 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) = 0.7 m
                                       k = (1 + 0.3 * Df' / B')
       = coefficient ----
  Nq, Nc, Ny = bearing capacity factors
  A' = L' * B' = (B - 2eb) * (L - 2el)
                                                   10.4519 m^2
A' = (B - 2*eb) * (L - 2*el) =
                                                       1.20
           \alpha = (1 + 0.3B'/L') =
                                                    -1.613
            \beta = (1 - 4*B'/L') =
                                                             t/m^2
                                                   2.936
              q = \gamma sub2 * Di =
                                                   1.0804
     k = (1 + 0.3 * (0f/8)) =
                                                       Nc= 15
       For \tan \theta = \Sigma Fh / \Sigma Fv = 0.123
                                                       Nq = 8
                                                       N_7 = 4
                                    2340.289
                                                 ton
                           FS =
                                        2
                                    1170.144
            Qsafe = Qu / FS =
                                                 ton
   Checking the bearing capacity is:
                                                                             1170.14 ton
                                                             Qsafe ≈
                                         260.94 ton <
                       Qmax =
                                                                              OK
```

Category of calculation Name of Page Structure 1.60 КР 0,40 0.40 ĸw 6.10 0.40 0.70 +144.33 1.45 1.10 1.45 DESIGN OF PIER - 3 (P-3)
Case IV: water is full at elevation + 151.80 (SWL) ( Earthquake Condition )

## DESIGN OF PIER (P3)

File:Pier3-V

Case V: Water is empty + 144.33 (EARTHQUAKE CONDITION)

Parameter of soil :	100		φ=	36	degree
Tataliteter of Jon.	•		7 =	2.0	t/m^3
			C =	18	t/m^2
Height of Pier	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	garan da ka	H≔	8.0	m
Width of footing Pier		J. 45 E. S. S.		4.0	m
Addition tooking i to	,			4.0	m

Compute overturning stability:

part	Weight of part (ton)		Arm :   (m)	Moment (ton m)
1	1,6'0.4'2.5'2.7 =	4.320	2.00	8.640
$-\frac{1}{2}$	(1.6+1.1)/2*0.4*2.5*(2.7+2)/2=	3.055	2.00	6.110
	1.1'6.1'2.5'2.0 =	33.550	2.00	67.100
4	(4+1.1)/2*0.4*2.5*(4+2)/2=	7.650	2.00	15.300
5	4'0.7'2.5'4.0 =	28.000	2.00	56,000
6	P1 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/	46.000	1.65	75.900
<del></del>	P2	46.000	2.35	108,100
	· -			

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

Total horizontal force  $\Sigma$  Fh =

25.286 ton.

Total Vertical Force:

Total:

 $\Sigma Fv = \Sigma Fv' =$ 

168.575 ton

Sum of Overlurning Moments:

 $\Sigma Fv =$ 

 $\Sigma$  Mo =KP\*h1+KW\*h2 = 157.311 ton m

168.575

 $\Sigma Mr =$ 

Sum of Moments to Resist Overturning:

337,150 ton m - $\sum Mr' = \sum Mr =$ 

The Overturning safety factor is:

$$FS = \sum Mr' / \sum Mo =$$

OK

Compute Sliding Force:

Use base soil parameter

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

The sliding safety factor is:

FS = Fr/ΣFh =

at right if

14.81 > 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:

 $\Delta M = \Sigma Mr - \Sigma Mo =$ 

179.839 ton m

```
x = \Delta M / \Sigma Fv =
                                               1.067 m (from toe)
                                               0.933 m
e = \{ B/2 \} - x
                                                                                           OK
                                                                                            1.333
                                                1.333 m
                                                                         0.933 <
B/3 =
                                                                                            OK
Compute soil pressure:
                                                                     101.1354 ton/m
         qmax = {\Sigma FV/B}^* {1 + (6*e)/B} =
         qmin = \{ \Sigma \text{ Fv / B} \}^* \{ 1 - (6^*e)/B \} =
                                                                     -16.8479 ton / m
                                                                    353.97381 ton
         Qmax = qmax * L =
                                                                    -58,96756 ton
         Qmin = qmin * L =
Checking of Bearing Capacity on soil:
         Q_u = A' * [\alpha * k * c * Nc + 0.167*k * q * Nq + 0.5 * \gamma_1 * B' * \beta' * N\gamma]
         where:
         Qu = ultimate bearing capacity
              = effective loading area on footing
         \alpha, \beta = coefficient depending on shape of footing
              = cohesion of foundation ground (ton/m^2)
              = ground surface surcharge (Um^2)
               = unit weight of soil on front of abutments (U/m^3) = 1.8 U/m^3
         \gamma 1 = unit weight of soil of ground foundation (Um<sup>3</sup>) = 2.0 Um<sup>3</sup>
         B',L' = width and length of effective loading area
              = 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 toc (m) = 0.7 m
                                              k = (1 + 0.3 * Df / B')
              = coefficient ----
         Nq, Nc, N\gamma = bearing capacity factors
         A' = L' * B' = (B - 2eb) * (L - 2el)
                                                            8.535 m^2
      A' =(B - 2*eb) * (L - 2*el) =
                 \alpha = (1 + 0.3BVL') =
                                                              1.16
                   \beta = (1 - 4*B'/L') =
                                                        ·- -1.134
                                                          6.606
                                                                   Vm^2
                          q = \gamma * Df =
                                                         1.0984
            k = (1 + 0.3 \cdot (Df/B')) =
                                                              Nc= 32
             For \tan \theta = \Sigma Fh / \Sigma Fv = 0.150
                                                             Nq = 24
                                   \phi = 36
                                                              N_7 = 22
                                 Qu = 5660.624
                                                        ton :
                                 FS = 2
                   Qsafe = Qu / FS = 2830.312
          Checking the bearing capacity is:
                                                                    Qsafe = 2830.31 ton
```

Qmax = 353.97

Category of calculation Name of Page Structure 1.60 0.40 0.40 6.10 0.40 0.70 ±144.33 1.45 -1.1) 1.45 DESIGN OF PIER - 3 ( P-3 )
Case V: water is empty at elevation + 144.33 (Earthquake Condition)