BHARTIYA INSTITUTE OF ENGINEERING & TECHNOLOGY
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LAB MANUAL

8CE5A : DESIGN OF WATER RESOURCES STRUCTURE-II

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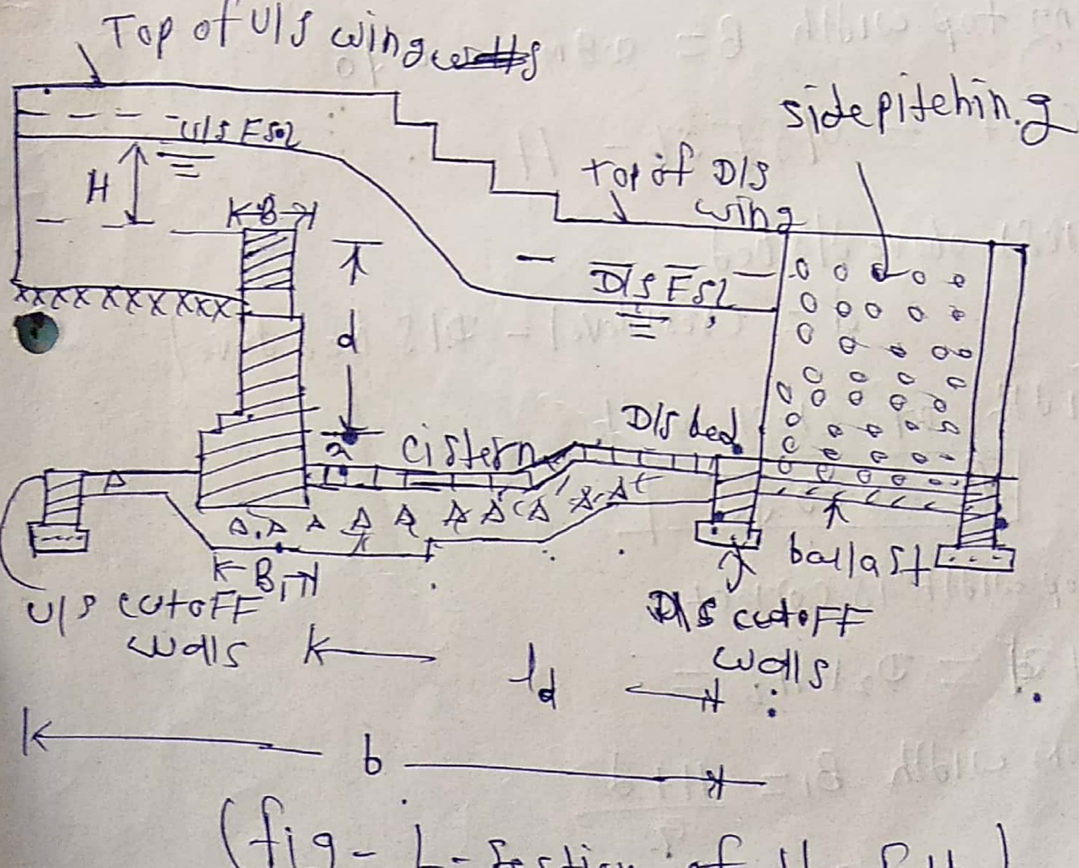
* Design of Sarda type falls →

The complete design of the Sarda type fall consists mainly of the design of the following components →

1. crest wall
2. cistern
3. Impervious floor.
4. D/S bed protection works.
5. U/S wings walls.
6. D/S wing walls.
7. D/S side protection.



(fig - L-section of the fall).

Design Steps –

① Step → crest wall → length of crest wall →

Therea are two types of crest wall are used → (a) Rectangular crest wall → $Q \leq 14$ cumecs

(b) Trapezoidal crest wall → $Q > 14$ cumecs

L = Bed width of the channel U/S.

Discharge for Rectangular crest wall

$$Q = 1.835 LH^{3/2} (H/B)^{1/6}$$

Discharge for Trapezoidal crest wall

$$Q = 1.99 LH^{3/2} (H/B)^{1/6}$$

Assuming top width B = 0.8 m to 0.90

R.L of crest = U/S FSL − H.

Height of crest above d/s bed

d = crest level − D/S bed level.

Top-width of crest wall.

$$\boxed{B = 0.55\sqrt{d}}$$

Assume top width is correct

$H + d = D_2 + H_2 =$

Bottom width $B_1 = \frac{H+d}{G}$

G = Specific gravity of the matrial of the crest wall

= 2.24 to 2.30

Step-② **cistern** → Depth of cistern →

$$x = \frac{1}{4}(H \times H_L)^{2/3}$$

R.L of cistern = D/S bed level − x

Length of cistern $L_c = 5\sqrt{H \times H_L}$

Step-③ **Imperviours floor** →

Maximum seepage head H_s = Crest level − D/S bed level

Total creep length $L = C \times H_s$

C = Bligh creep coefficient given

Depth of U/S cutoff = $D_1/3 + 0.6$

Depth of D/S cutoff = $D_2/2 + 0.6$

Vertical creep = 2 × (Depth of U/S cutoff + Depth of D/S cutoff)

Length of impervious Floor =

b = Total creep length − Vertical creep

Minimum length of D/S Floor

$$l_d = 2(D_2 + 1.2) + H_L$$

Length of U/S Floor = Length of impervious floor (b) − minimum Length of D/S floor (l_d)

* Thickness of impervious floor → The thickness of the d/s concrete floor is calculated from the residual uplift pressure (hr) found from the subsoil H.G.L using Bligh's theory.

$$t = \left(\frac{h_r}{G-1}\right)$$

A minimum thickness of concrete floor of 0.3m to 0.4m for smalls falls and 0.4 to 0.6m for large falls is usually provided.

Step-④ U/s wing walls →
Provide u/s wing walls splayed at an angle of 45°. (i.e slope 1:1) starting from the u/s edge of the crest wall.

Top level of U/S wing walls = (U/S FSL + free board)

Step ⑤ D/S wing walls → Length of d/s wing walls with a vertical face, measured from the crest wall.

$$= 6\sqrt{H \times H_2}$$

Step-⑥ D/S bed pitching →

Length of pitching $= 6 + 2H_2$

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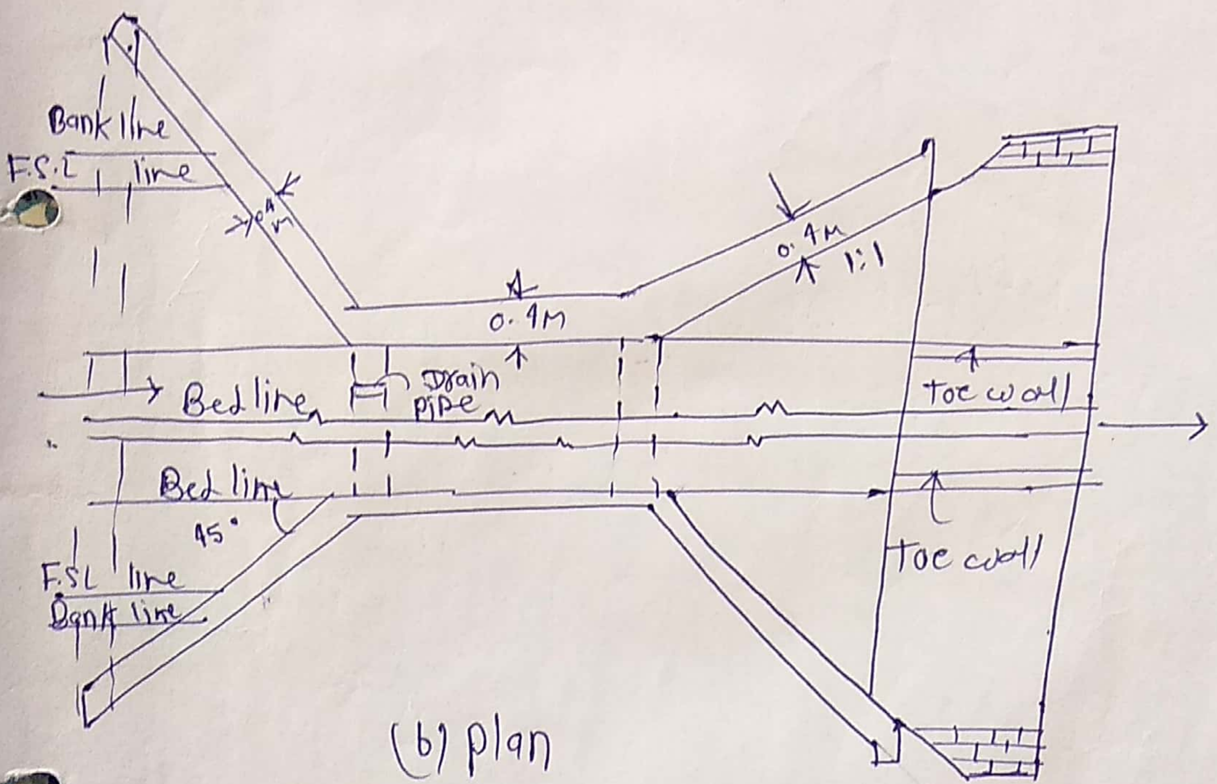

Bank line
F.S.L line
0.4 m
0.4M
0.4M
1:1
Drain pipe
Bed line
Toe wall
Bed line
45°
Toe wall
F.S.L line
Bank line

(b) plan

Step ⑦ D/S side pitching →

provide 20cm thick side pitching consisting of one brick on edge over one flat brick. The side pitching is ~~warre~~ warped from a slope of 1:1 to 1.5:1.

Q01 Design a Sarda type fall for a canal from the following data:

(i) Discharge $\frac{U/S}{D/S} = \frac{10 \text{ cumecs}}{10 \text{ cumecs}}$ (ii) Full supply level $\frac{U/S}{D/S} = \frac{201.50}{200.25}$

(iii) Drop = 1.25 m (iv) Bed Level $\frac{U/S}{D/S} = \frac{200.00}{198.75}$

(v) Bed width $\frac{U/S}{D/S} = \frac{9.0\text{ m}}{9.0\text{ m}}$ (vi) Full supply depth $\frac{U/S}{D/S} = \frac{1.50\text{ m}}{1.50\text{ m}}$

(vii) Bligh's creep coefficient = 8.

Neglect the velocity of ~~approach~~ approach. Use Bligh's theory.

Step-Ist → Crest wall → As the discharge is less than 14 cumecs, a rectangular crest wall is provided.

Length of crest = bed width = 9.0 m

Let us assume the top width B as 0.8 m.

discharge $Q = 1.835\, L H^{3/2} (H/B)^{1/6}$

$10 = 1.835 \times 9 \times H^{3/2} \times (H/0.8)^{1/6}$

$H^{5/3} = 0.585$ or $H = 0.72\text{ m}$

R.L of crest = U/S FSL − H

= 201.50 − 0.72

R.L of crest = 200.78 m

Height of crest above D/S bed:

$d =$ crest level $-$ D/S bed level

$d = 200.78 - 198.75$

$d = 2.03M$

Top width of crest wall $= B = 0.55 \times \sqrt{d}$

$B = 0.55 \times \sqrt{2.03}$

$B = 0.78M$ Say $B = 0.80M$

Therefore, the assumed top width is correct.

Now $H + d = D_2 + H_L = 1.50 + 1.25$

$H + d = 2.75M.$

Bottom width $= B_1 = \frac{H+d}{G}$

$B_1 = \frac{2.75}{2.24} = 1.22M$ Say $1.25M$

provide U/S pitching for a length of 3M at a slope of 1 in 10 just U/S of the crest wall.

Step-II nd → cistern → The depth of cistern →

$x = \frac{1}{4}(H \times H_L)^{2/3} = \frac{1}{4} \times (0.72 \times 1.25)^{2/3}$

$x = 0.23M$ Say $x = 0.25M.$

R.L of cistern = D/S bed Level − η.

= 198.75 − 0.25

R.L of cistern = 198.50

Length of cistern $L_c = 5 \times \sqrt{H \times H_L}$

$L_c = 5 \times \sqrt{0.72 \times 1.25}$

$L_c = 4.74$ m Say $L_c = 4.75$ M

Step-III[rd] Impervious floor →

Maximum seepage head

H_s = crest level − D/S bed Level

H_s = 200.~~83~~ − 198.75

H_s = 2.03 M

Total creep length = L = $C \times H_s$

$L = 8 \times 2.03$

$L = 16.24$ m Say L = 16.25 M.

Depth of U/S cutoFF = $D/3 + 0.6$

$= \frac{1.50}{3} + 0.6 = 1.1$ M

Depth of D/S cutoFF = $D/2 + 0.6 = \frac{1.50}{2} + 0.6$

= 1.35 M Say = 1.5 M

width of U/S and D/S cutoff = 0.30 m

vertical creep = $2 \times (1.1 + 1.50) = 5.20$ M.

Length of impervious floor =

$(b) = 16.25 - 5.20$

$b = 11.05M$

minimum length of d/s floor

$l_d = 2(D_2 + 1.2) + H_L$

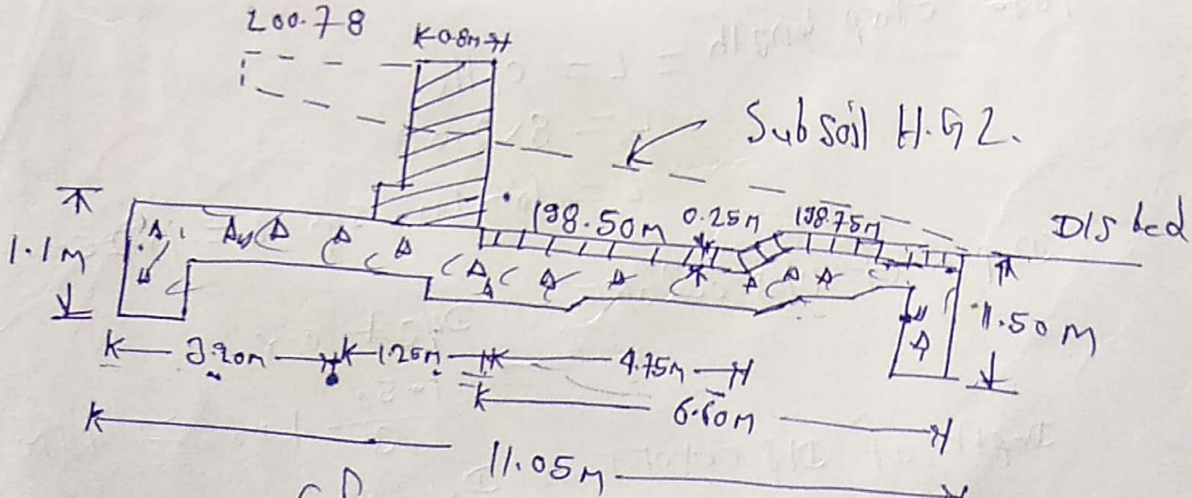
$l_d = 2 \times (1.5 + 1.2) + 1.25$

$l_d = 6.60M$

Length of u/s Floor $= 11.05 - 6.6 - 1.25$

$= 3.20M$

fig-a shows the details of the floor.



(fig-a)

* Thickness of impervious floor →

(a) Residual head at the d/s toe of the crest wall

~~hr = 0.25+~~

$$h_r = 0.25 + \left(\frac{200.78 - 198.75}{16.25}\right) \times (6.60 + 3)$$

$$h_r = 1.45M$$

Thickness of floor $t = \frac{h_r}{(G-1)}$

$$t = \frac{1.45}{(2.24-1)}$$

$t = 1.17M$ Say 1.20M

provide 0.2M brick on edge over 1.20M thick concrete. The brick on edge are in cement mortar and are therefore impervious.

(b) Residual head at 2M from the toe of the crest wall →

$$h_r = 0.25 + \left(\frac{200.78 - 198.75}{(16.25)}\right)(4.6 + 3)$$

$h_r = 1.20M$

Thickness of floor $= \frac{1.20}{(2.24-1)} = 0.97M$ Say 1.0M

provide 0.2M thick brick on edge over 1.00m thick concrete.

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(c) Residual head at 4.75 m from the toe of the crest wall →

$$hr = 0.25 + \left(\frac{200.78 - 198.75}{16.25}\right) \times (1.85 + 3.00)$$

$$hr = 0.86\,m$$

Thickness of floor $= \dfrac{0.86}{2.24 - 1} = 0.70\,m$

provide 0.2m thick brick on edge over 0.70m thick concrete.

(d) Residual head at end of d/s floor →

$$hr = \left(\frac{200.78 - 198.75}{16.25}\right) \times 3.0$$

$$hr = 0.37\,m$$

Thickness of floor $= \dfrac{0.37}{(2.24 - 1)} = 0.3\,m$

provide 0.2m thick brick on edge over 0.4m thick concrete.

* u/s floor → The uplift pressure on the u/s floor will be counter-balanced by the weight of water and soil. provide a nominal thickness of 0.40m.

Step-IV th → **U/S wing walls** → provide U/S wing walls Splayed at an angle of 45° (i.e slope 1:1) Starting from the U/S edge of the crest wall. Continue these walls into banks of the canal till they are embedded for a minimum distance of 1M from the F.S.L.

U/S F.S.L + free board

Top level of U/S wing walls = 201.50 + 0.50

= 202.00 M

Step-V th → **D/S wing walls** → Length of d/s wing walls with a vertical face, measured from the crest wall,

$= 6\sqrt{H \times H_2} = 6 \times \sqrt{0.72 \times 1.25}$

$= 5.70\ M$

Keep it 6.60m i.e upto the end of impervious floor.

The d/s wing walls are then warped from the vertical face to 1:1 slope on a splay of 3:1.

Length of warped wall $= 3(1.5 + 0.5) = 6.00\ M$

Total Length of d/s wing wall $= 6.6 + 6.00 = 12.6\ M$

Top Level of D/S wing walls $= 200.25 + 0.50$

$= 200.75$

Step-VI th → **D/S bed pitching** → From table

	Head ~~upto~~ over crest H (M)	Length of d/s pitching (M)
(i)	upto 0.30	3.0
(ii)	0.30 to 0.45	3.0 + $2H_L$
(iii)	0.45 to 0.60	4.5 + $2H_L$
(iv)	0.60 to 0.75	6.0 + $2H_L$
(v)	0.75 to 0.90	9 + $2H_L$
(vi)	0.90 to 1.05	13.5 + $2H_L$
(vii)	1.05 to 1.20	18.0 + $2H_L$
(viii)	1.20 to 1.50	22.5 + $2H_L$

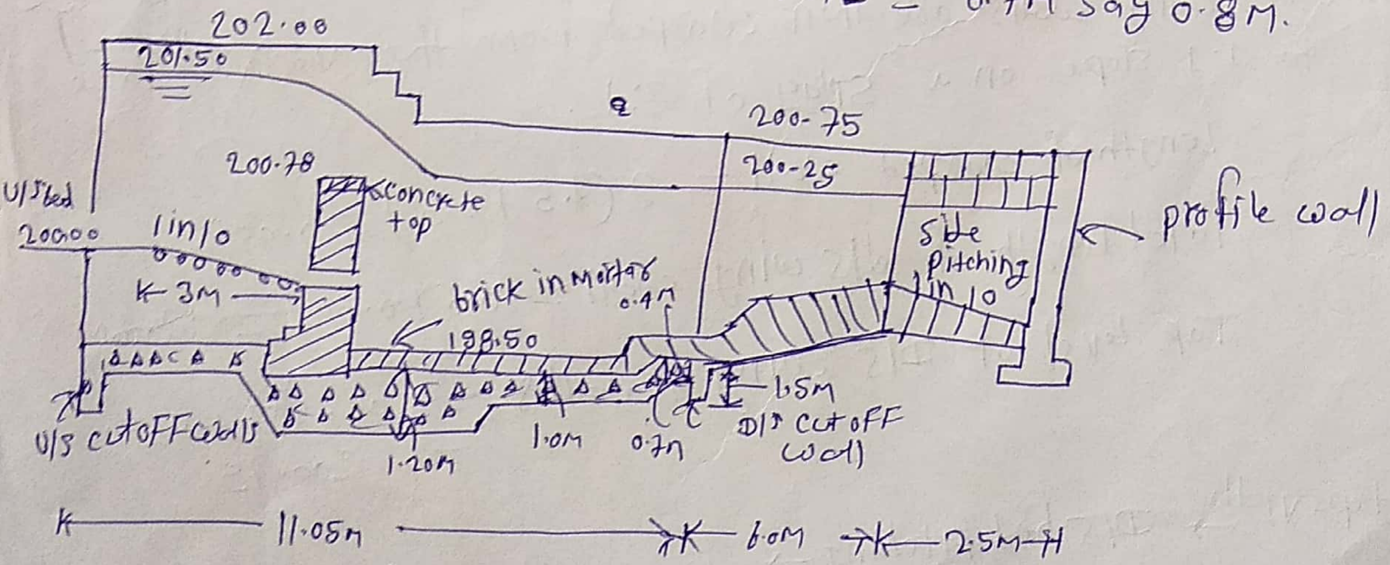
Length of pitching $= 6 + 2H_L = 6 + 2 \times 1.25 = 8.50M$

The bed pitching is provided horizontal upto the end of d/s wing for 6.0M and the remaining 2.50M slopping at 1 in 10. One curtain wall 0.3m thick and 0.6m deep is provided at the end of bed pitching.

Step-VII th → D/S Side pitching → provide 20CM thick side pitching consisting of one brick on edge over one flat brick. The side pitching is warped from a slope of 1:1 to 1.5:1.

It is supported on a toe wall 0.4M thick.

Depth of toe wall $= 1.5/2 = 0.7M$ say 0.8M.



(a) (L-Section).

* Design steps For Sarda type Fall by Khosla Theory →

Step-Ist → crest wall → As the discharge is more than 14 cumecs, provide a trapezoidal crest wall.

$$Q = 1.99\, L H^{3/2} \left(\frac{H}{B}\right)^{1/6}$$

Less than 14 cumecs Rectangular crest wall provide

$$Q = \underline{1.835}\, L H^{3/2} (H/B)^{1/6}$$

Note $\boxed{H+d = H_L + D_2}$

Top width $B = 0.55 \times \sqrt{H+d}$

Velocity approach $\boxed{V_a = \frac{Q}{a}}$

head due to velocity of approach

$$\boxed{h_a = \frac{V_a^2}{2g}}$$

$$\boxed{D/S\ TEL = D/S\ FSL + h_a}$$

Again Discharge Formula.

$$Q = 1.99\, L \times E^{3/2} \left(\frac{E}{B}\right)^{1/6}$$

$$\boxed{\text{crest level} = U/S\ TEL - E}$$

height of crest above D/S bed =

d = crest level − D/S FSL + FSL Depth (D/S)

height of crest above U/S bed.

d = crest level − U/S FSL + FSL Depth (U/S)

provide a trapezoidal crest wall U/S slope of (1:3) and D/S Slope of 1:8.

Step-IInd → cistern → Length of cistern →

$$\boxed{L_c = 5 \times (EH_L)^{2/3}}$$

Depth of cistern (x)

$$x = \frac{1}{4}(EH_L)^{2/3}$$

H_L = Drop given in questions.

R.L of cistern = D/S bed Level − x

Height of crest wall above cistern Level.

= crest Level − R.L of cistern

Bottom width of crest wall →

$$B_1 = 1.10 + \left(\frac{1}{3} \times H.C.W.A.CL\right) + \left(\frac{1}{8} \times H.C.W.A.CL\right)$$

U/S pitching → provide U/S bed pitching for length equal to $D_1 = 2.0m$. The pitching should be Slope down towards the crest at a slope of 1 in 10.

Step-IIIrd → Design of Impervious floor →

Depth of U/S cut off $\boxed{d_1 = \left(\frac{D}{3}\right) + 0.60}$

Depth of D/S cut off —

$$d_2 = \left(\frac{D}{2}\right) + 0.60$$

* Now

$$G_E = \left[\frac{H_s}{d_2 \pi \sqrt{\lambda}}\right]$$

H_s = seepage head = crest level − D/s bed level.

And $\lambda = \dfrac{1 + \sqrt{1+\alpha^2}}{2}$

Total Length $(b) = \alpha d_2$

Minimum Length of D/s impervious floor-

$$L_d = 2 \times (D + 1.2) + H_2$$

Length of U/S Floor

L_u = Total length − bottom width of crest wall − L_d

* uplift pressure calculations →

(a) U/S cut-off wall →

$\boxed{\alpha = \dfrac{b}{d_1}}$ λ = Now findout (From above equation)

$$\phi_E = \frac{100}{\pi} \cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

$\cancel{\phi_{E_1}}$ =

$$\boxed{\phi_{E_1} = 100 - \phi_E}$$

$$\phi_D = \frac{100}{\pi} \cos^{-1}\left(\frac{\lambda - 1}{\lambda}\right) \quad \boxed{\phi_{D_1} = 100 - \phi_D}$$

Assume the thickness of U/S floor as ~~1.0M~~ 0.4M

$$\text{correction for thickness} = +\left(\frac{\phi_{D_1} - \phi_{E_1}}{\text{Depth of U/S cutoff}}\right) \times \text{thickness}$$

Correction For mutual interference.

$$= 19 + \left(\frac{d+D}{b}\right) \times \sqrt{\frac{D}{b}}$$

Assume $\left.\begin{matrix} d = 0.9 \\ D = 0.9 \end{matrix}\right\}$ For U/S case.

corrected $\phi_{E_1} = \phi_{E_1}$ + correction For thickness + correction For mutual interference.

(b) D/S cut-off wall $\longrightarrow$

$\alpha = \frac{b}{d_2}$ $\quad \lambda$ = from equation.

$$\phi_E = \frac{100}{\pi} \cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

$$\phi_D = \frac{100}{\pi} \cos^{-1}\left(\frac{\lambda - 1}{\lambda}\right)$$

Assume the thickness at the D/S floor as 0.8M.

$$\text{correction for thickness} = +\left(\frac{\phi_E - \phi_D}{d_2}\right) \times \text{thickness.}$$

correction due to mutual interference

$$= -\left(\frac{d+D}{b}\right) \times \sqrt{\frac{D}{b}}$$

Now Assume

$d = 1.0$
$D = 1.0$ } in D/S case.

corrected $\phi_{D_1} = \phi_E$ + correction for thickness + correction for mutual interference.

* Thickness of Floor →

(a) At D/S toe of crest wall →

uplift pressure (%) = corrected ϕ_{D_1} + $\left(\frac{\text{corrected } \phi_{E_1} + \text{corrected } \phi_{D_1}}{b}\right) \times u_d$

Residual Head = n + uplift pressure × correction for thickness

Thickness of Floor

$$t = \frac{\text{Residual Head}}{G - 1}$$

G = Specific gravity of material

2.24 to 2.30.

~~(b) At~~ Remaining uplift pressure can be calculated from different length of crest wall.

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* Design of U/S wing walls →

Radius = 5 to 6 times of (H).

So ~~R~~

provide U/S wing walls having Segmental portion with suitable Radius and subtending an angle of 60° at the centre and starting from the U/S edge of the crest wall.

Top level of U/S wing wall

= FSL (U/S) + Free board.

* D/S wing walls → length of D/S wing wall with a vertical face.

$= 6 \times \sqrt{E \times H_2}$

The wing walls are then warped to a slope of 1:1 at a splay of 3:1.

Top level of wall = D/S FSL + free board.

Height of wall above bed = Top level − D/S bed level

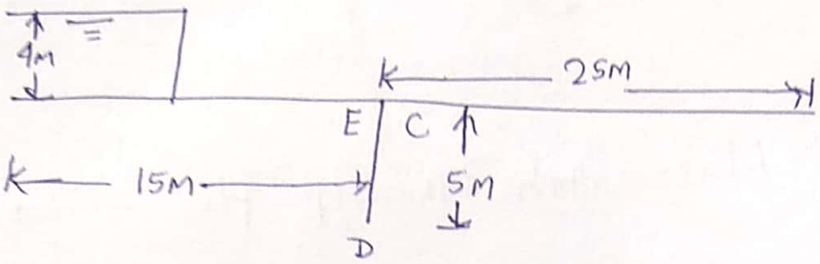
length of warped wing with a splay of 1 in 3.

Total length of D/S wingwall = length of wingwall + length of warped wall

* D/S bed pitching → from which, length of D/S bed pitching
$= 9 + 2H_2$
provide horizontal pitching upto the end of Masonry wing walls for a length of 6.3m and then ~~stepping~~ sloping at 1 in 10 for a length of 6m. provide 0.2m thick dry brick pitching on 0.1m thick ballast.

* D/S side pitching → The side pitching is warped from a side slope of 1:1 to 1.5:1. provide 0.2m thick dry brick pitching.

③ Determine the uplift pressure at the salient points E, D and C of the intermediate pile as shown in fig.



In this case, $b_1 = 15m$, $b_2 = 25m$, $b = 40m$
$d = 5m$ and $H = 4m$

from eq

$$\lambda = \frac{\sqrt{1+\alpha_1^2} + \sqrt{1+\alpha_2^2}}{2}$$

where $\alpha_1 = b_1/d = 15/5 = 3$ and $\alpha_2 = b_2/d = 25/5 = 5$

Therefore
$$\lambda = \frac{\sqrt{1+(3)^2} + \sqrt{1+(5)^2}}{2}$$

$$\lambda = \frac{3.16 + 5.10}{2} = 4.13$$

$$\lambda_1 = \frac{\sqrt{1+(3)^2} - \sqrt{1+(5)^2}}{2} = \frac{3.18 - 5.10}{2}$$

$$\boxed{\lambda_1 = -0.97}$$

from eq
$$P_E = \frac{H}{\pi} \cos^{-1}\left(\frac{\lambda_1 - 1}{\lambda}\right) = \frac{4}{\pi} \cos^{-1}\left(\frac{-0.97-1}{4.13}\right)$$

$$P_E = \frac{4}{\pi} \times \left(\frac{118.489^\circ \times \pi}{180}\right) = 2.633m$$

③

from eq $P_c = \frac{H}{\pi} \cos^{-1}\left(\frac{\lambda_1 + 1}{\lambda}\right) = \frac{4}{\pi} \cos^{-1}\left(\frac{-0.97+1}{4.13}\right)$

$P_c = \frac{4}{\pi} \times \frac{89.584}{180} \times \pi$

$\boxed{P_c = 1.991\ m}$

and $P_D = \frac{H}{\pi} \cos^{-1}\left(\frac{\lambda_1}{\lambda}\right)$

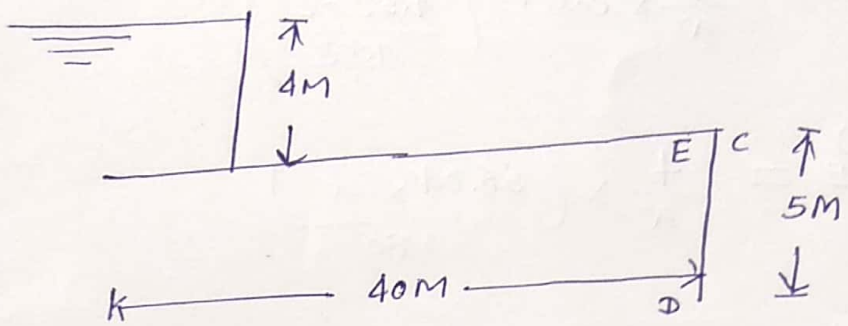
$P_D = \frac{4}{\pi} \cos^{-1}\left(\frac{-0.97}{4.13}\right)$

$P_D = \frac{4}{\pi} \times \frac{103.584}{180} \times \pi$

$\boxed{P_D = 2.302\ m}$

Problem No-3 → Based on uplift pressure on D/S pile.

Q: Determine the uplift pressure at the points E, D and C of the D/S pile shown in fig. Also determine the exit gradient.



So, in this case $b = b_1 = 40M$, $d = 5M$

and Height of water level

$H = 4M$

from eq. $\lambda = \dfrac{1 + \sqrt{1+\alpha^2}}{2}$

$\alpha = b/d = 40/5$

$\boxed{\alpha = 8}$ putting this value above eq.

$$\lambda = \frac{1 + \sqrt{1 + (8)^2}}{2}$$

$\boxed{\lambda = 4.53}$

The uplift pressure at the salient points E, D and C are given by the following equations.

$$P_E = \frac{H}{\pi} \cos^{-1}\left(\frac{\lambda - 2}{\lambda}\right)$$

$$P_E = \frac{4}{\pi} \times \cos^{-1}\left(\frac{4.53-2}{4.53}\right)$$

$$P_E = \frac{4}{\pi} \times \left(\frac{56.04 \times \pi}{180}\right)$$

$$\boxed{P_E = 1.245 \text{ m}}$$

Similarly $$P_D = \frac{H}{\pi} \cos^{-1}\left(\frac{\lambda - 1}{\lambda}\right)$$

$$= \frac{4}{\pi} \cos^{-1}\left(\frac{4.53-1}{4.53}\right)$$

$$P_D = \frac{4}{\pi} \times \left(\frac{38.80 \times \pi}{180}\right)$$

$$\boxed{P_D = 0.862 \text{ m}}$$

And $$\boxed{P_c = 0}$$

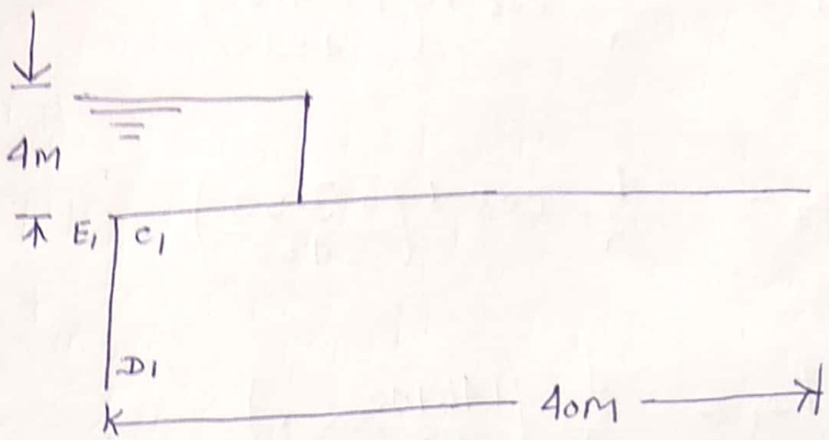
Also Exit gradient $$G_E = \frac{H}{d} \times \frac{1}{\pi \times \sqrt{\lambda}} = \frac{4}{5} \times \frac{1}{\pi \times \sqrt{4.53}}$$

$$\boxed{G_E = 0.119}$$

* calculate uplift pressure on U/S pile →

problem No-4

→ Determine the uplift pressure at the salient points E_1, D_1 and C_1 of the upstream pile shown in (fig).



Solution → In this case $b_2 = b = 40M$

$d = 5M$ $\alpha = b/d = 40/5 = 8$

from eq $\lambda = \dfrac{1+\sqrt{1+\alpha^2}}{2} = \dfrac{1+\sqrt{1+(8)^2}}{2}$

$\boxed{\lambda = 4.53}$

From eq $\boxed{P_{E_1} = H}$

$\boxed{P_{E_1} = 4M}$

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$$P_{D_1} = \frac{H}{\pi} \cos^{-1}\left(\frac{1-\lambda}{\lambda}\right)$$

$$P_{D_1} = \frac{4}{\pi} \cos^{-1}\left(\frac{1-4.53}{4.53}\right)$$

$$P_{D_1} = \frac{4}{\pi} \cos^{-1}\left(\frac{-3.53}{4.53}\right)$$

or $$P_{D_1} = \frac{4}{\pi}\left(\frac{141.192}{180} \times \pi\right)$$

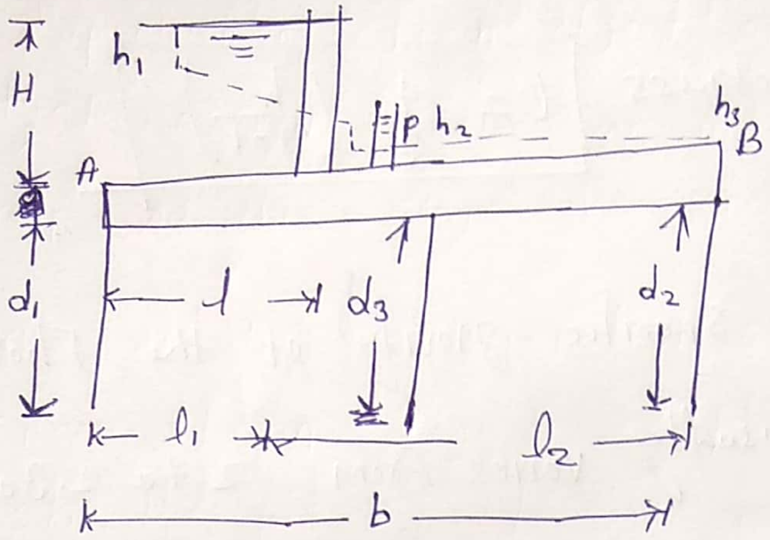
$$\boxed{P_{D_1} = 3.14M}$$

similarly $$P_{C_1} = \frac{H}{\pi} \cos^{-1}\left(\frac{2-\lambda}{\lambda}\right)$$

$$P_{C_1} = \frac{4}{\pi} \cos^{-1}\left(\frac{2-4.53}{4.53}\right) = \frac{4}{\pi} \times \left(\frac{123.952}{180} \times \pi\right)$$

$$\boxed{P_{C_1} = 2.75M}$$

* Bligh creep theory → Calculate uplift pressure on pile.



Total creep length $L = 2d_1 + l_1 + 2d_3 + l_2 + 2d_2$

where d_1, d_2 and d_3 are the depths of the U/P, D/S and intermediate piles respectively. l_1 and l_2 are the length of the U/P and D/S floors.

The subsoil hydraulic gradient is given by

$$\boxed{J = H/L}$$

uplift pressure Formula →

$$\boxed{h = H - \left(\frac{H}{L}\right) \times l}$$

where (l) is the horizontal length from the entry point A to point P.

thickness of Floor →

thickness $\boxed{t = \frac{4}{3}\left(\frac{h}{G-1}\right)}$

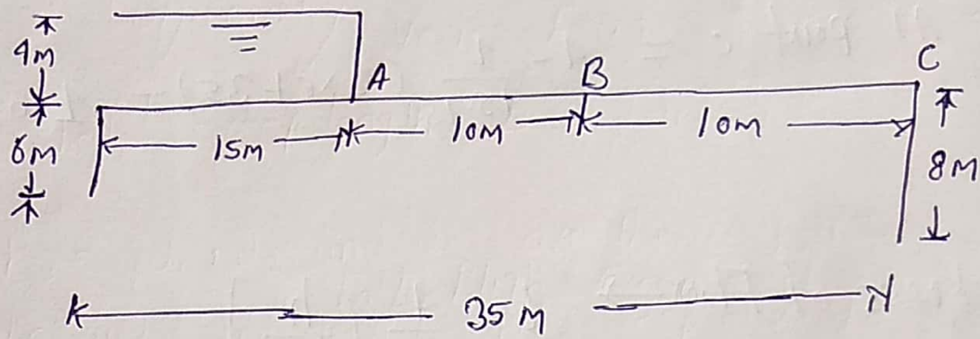
G = specific gravity of the Floor Material.
(G) usually varies From 2 to 2.30

Table → Bligh's Creep coefficient

S.No	Types of Soil	Creep Coefficient (C)	Safe hydraulic gradient 1/C
1	Light Sand and mud ~~[illegible]~~	18	1/18
2	Fine micaceous sand	15	1/15
3	Coarse grained sand	12	1/12
4	Boulders or shingles, and gravel mixed with sand	5 to 9	1/5 to 1/9

Numerical based on Bligh creep theory to determine the uplift pressure.

Example-⑤ fig shows a hydraulic structures built on fine sand ($C=15$). Determine uplift pressure at point, A, B and C at distance 15m, 25m and 35m from the u/s end. And also calculate thickness of Floor. Use Bligh creep theory $G = 2.24$.



Solution–

Total creep length

$$L = 2d_1 + l_1 + 2d_3 + l_2$$

$$L = 2\times6 + 25 + 2\times8 + 10$$

$$\boxed{L = 63M}$$

Hydraulic gradient $i = H/L = 4/63$

$$i = \frac{1}{15.75} < \frac{1}{15} \text{ safe}$$

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uplift pressure →

uplift pressure head $h = H - \left(\frac{H}{L}\right) \times l$

At point A $= 4 - \frac{1}{15.75}(2 \times 6 + 15) = 2.29M$

At point B $= 4 - \frac{1}{15.75}(2 \times 6 + 25) = 1.65M$

At point C $= 4 - \frac{1}{15.75}(2 \times 6 + 35) = 1.02M$

* Thickness of Floor → $t = \frac{4}{3}\left(\frac{h}{G-1}\right)$

At point A $t = \frac{4}{3} \times \left(\frac{2.29}{2.24-1}\right)$

$\boxed{t = 2.46M}$

At point B $t = \frac{4}{3} \times \left(\frac{1.65}{2.24-1}\right)$

$\boxed{t = 1.77M}$

At point C $t = \frac{4}{3} \times \left(\frac{1.02}{2.24-1}\right)$

$\boxed{t = 1.10M}$

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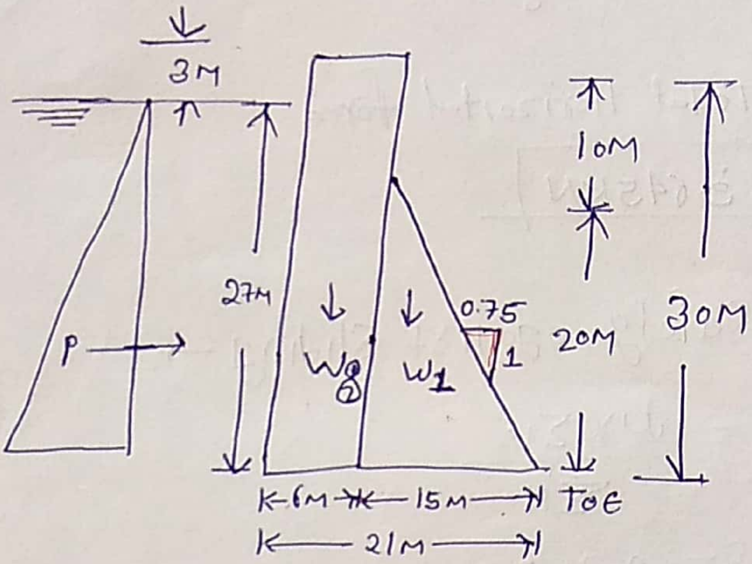
⑥ Check the Stability of the gravity dam shown in figure. For Reservoir full condition.

Assume $\mu = 0.70$ Unit weight of concrete $w_c = 24 KN/M^3$

unit wt of water $w = 10 KN/M^3$

And $q = 1400 KN/M^2$.



Step ① weight of the Dam →

$$\boxed{W = W_1 + W_2}$$

$W_1 \Rightarrow \frac{1}{2} \times 20 \times 15 \times 24$

$\boxed{W_1 = 3600 KN}$

$C.G = \frac{2}{3} \times 15 = 10M$ from toe

$W_2 = 6 \times 30 \times 24 = 4320 KN$

$C.G = 15 + \frac{B}{2} = 15 + \frac{6}{2} = 18M$ from toe

ΣV = Total Vertical force

$\Sigma V = 3600 + 4320 = 7920 KN$

Water pressure →

$$P = \frac{WH^2}{2}$$

$$= \frac{10 \times (27)^2}{2}$$

$$\boxed{P = 3645 KN}$$

$$C.G = H/3 = \frac{27}{3} = 9m \text{ from base.}$$

ΣH = Total Horizontal force

$$\boxed{\Sigma H = 3645 KN}$$

(a) factor of safety against sliding →

$$F_S = \frac{\mu \times \Sigma V}{\Sigma H}$$

$$F_S = \frac{0.7 \times 7920}{3645}$$

$$\boxed{F.S = 1.52}$$

(b) Shear friction factor →

$$S.F.F = \frac{\mu \Sigma V + b \times q}{\Sigma H}$$

$$= \frac{0.7 \times 7920 + 21 \times 1400}{3645}$$

$$\boxed{S.F.F = 9.58}$$

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(c) factor of safety against overturning →

$$\Sigma M_R = 3600 \times 10 + 4320 \times 18$$

$$\Sigma M_R = 113760 \text{ KN-M}$$

And $$\Sigma M_o = 3645 \times 9$$

$$\Sigma M_o = 32805 \text{ KN-M.}$$

$$F_o = \frac{\Sigma M_R}{\Sigma M_o} = \frac{113760}{32805}$$

$$\boxed{F_o = 3.47}$$

(d) Maximum Stress

Reservoir full condition →

Taking the moments of all the forces about toe.

$$\Sigma M = 3600 \times 10 + 4320 \times 18 - 3645 \times 9$$

$$\boxed{\Sigma M = 80955 \text{ KN-M}}$$

And $$\Sigma M = \Sigma V \times \bar{x}$$

$$\bar{x} = \frac{\Sigma M}{\Sigma V} = \frac{80955}{7920}$$

$$\boxed{\bar{x} = 10.22 M}$$

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eccentricity $e = \frac{B}{2} - \bar{x}$

$e = \frac{21}{2} - 10.22$

$\boxed{e = 0.28M}$

Vertical stress at

toe = f_{yd} or $(P_n)_{toe}$

$(P_n)_{toe} = \frac{\Sigma V}{b}\left(1 + \frac{6e}{b}\right)$

$= \frac{7920}{21} \times \left(1 + \frac{6 \times 0.28}{21}\right)$

$(P_n)_{toe} = 407.31 KN/M2$

Principal stress at toe

$\sigma_d = (P_n)_{toe} \times Sec^2\phi_d$

$\sigma_d = 407.31 \times (1 + \tan^2\phi_d)$

$\sigma_d = 407.31 \times (1 + (0.75)^2) = 636.42 KN/M^2$

Shear stress at toe.

$\tau_d = (P_n)_{toe} \tan\phi_d = 407.31 \times 0.75$

$\boxed{\tau_d = 305.48 KN/M^2}$

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Numericals → Based on Stability Analysis →

(4) (7) check the Stability of u/s and d/s slopes of the given earth dam. Assume the saturated unit weight = 21 KN/M³ and unit weight under Steady Seepage = 20 KN/M³ the $\phi = 25°$ and under $c = 20$ KN/M² and $\delta = 60°$

The area of rectangle plotted are $a_N = 13$ cm² $a_T = 6.6$ cm² and $a_u = 3.0$ cm² with scale 1 cm = 5 M for down stream side $a_N = 14.0$ cm² $a_T = 4.2$ cm² for up stream side with same scale.

The Radius r of the slip circle = 75 cm in both cases.

Solution →

given data →

Saturated unit weight

$\gamma_{sat} = 21$ KN/M³

unit weight Steady Seepage = 20 KN/M³

$\phi = 25°$

Cohesion $c = 20$ KN/M²

$\delta = 60°$

Area of U/S side

$a_N = 13$ cm²

$a_T = 6.6$ cm²

$a_u = 3.0$ cm²

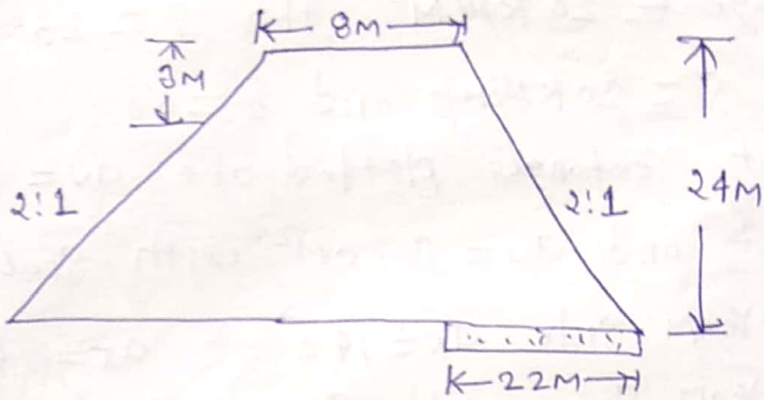
Area of D/S side

$a_N = 14.0$ cm²

$a_T = 4.2$ cm²

Scale = 1 CM = 5 M

Radius r = 75 CM



* Stability of D/S Slope under Steady Seepage →

$$\Sigma N = (a_n \times n^2) \times \gamma = (13 \times (5)^2) \times 20\,kN/m^3$$

$$\Sigma N = 6500\,kN$$

$$\Sigma T = a_T \times n^2 \times \gamma = (6.6 \times (5)^2) \times 20$$

$$\boxed{\Sigma T = 3300\,kN}$$

$$\Sigma U = a_U \times n^2 \times \gamma_w = (3 \times (5)^2 \times 9.81)$$

$$\boxed{\Sigma U = 735.75\,kN}$$

$$L_a = \frac{2\pi r \theta}{360^\circ} = \frac{2 \times \pi \times 75 \times 60}{360^\circ}$$

~~La = [illegible]~~

$$L_a = 78.53\,M$$

factor of safety

$$F_S = \frac{\tan\phi \, \Sigma(N-U) + cLa}{\Sigma T}$$

$$= \frac{\tan 25 \times (6500 - \cancel{3300}\ 735.75) + 20 \times 78.53}{3300}$$

$$F.S = 1.29 < 1.50 \quad (\text{safe})$$

* Stability of U/S Slope under Sudden drawdown →

$a_N = 14.0 \, cm^2$

$a_T = 4.2 \, cm^2$

Scale 1cm = 5m

$\Sigma N = a_N \times n^2 \times \gamma'$

$(\gamma_{sub} = \gamma_{sat} - \gamma_w)$

$\Sigma N = 14 \times (5)^2 \times (21 - 9.8)$

$\boxed{\Sigma N = 3916.80 \, KN}$

$\Sigma T = a_T \, n^2 \times \gamma_{sat}$

$\Sigma T = 4.2 \times (5)^2 \times 21$

$\Sigma T = 2205 \, KN$

$$L_a = \frac{2\pi r \delta}{360^\circ} = \frac{2 \times \pi \times 75 \times 60^\circ}{360} = 78.53 \, M$$

$$F.S = \frac{\tan\phi \, \Sigma N' + c \times L_a}{\Sigma T}$$

$$\cancel{F.S = \frac{\tan 25 \times 14 + 20 \times 78.53}{4.2}}$$

~~F.S =~~

$$F_S = \frac{\tan 25 \times 3916.30 + 20 \times 78.53}{2205}$$

$$\boxed{F.S = 1.54 \text{ Safe}}$$