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Examples of sheet Pile

Calculation of Maximum Bending Moment

The nature of the variation of the moment diagram for a cantilever sheet-pile wall is shown in Figure 4.9b. The maximum moment will occur between points E and F ' . Obtaining the maximum moment (Mmax) per unit length of the wall requires determining the point of zero shear. For a new axis z' (with origin at point E) for zero shear

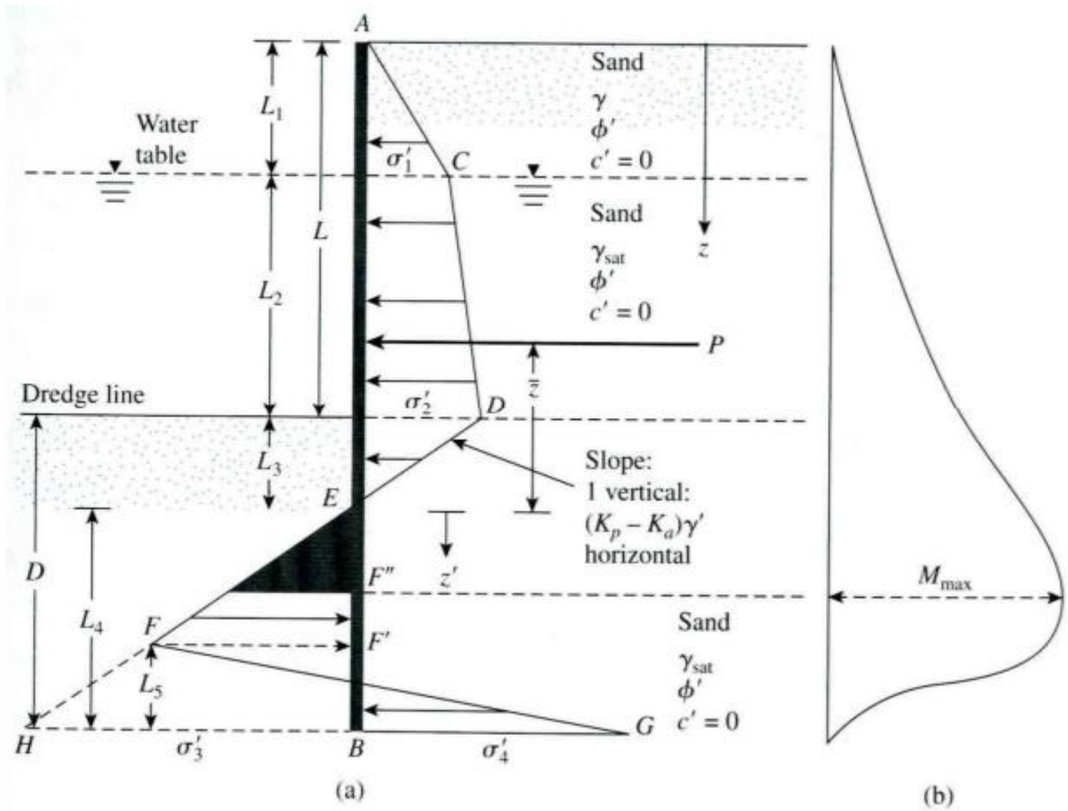


Figure 4.9 Cantilever sheet pile penetrating sand: (a) variation of net pressure diagram; (b) variation of moment

$$P = \tfrac{1}{2}(z')^2(K_p - K_a)\gamma'$$

Or

$$z' = \sqrt{\frac{2P}{(K_p - K_a)\gamma'}} \tag{4.21}$$

Once the point of zero shear force is determined (point F' in Figure 4.9a), the magnitude of the maximum moment can be obtained as

$$M_{max} = P(\bar{z} + z') - [\tfrac{1}{2}\gamma' z'^2(K_p - K_a)](\tfrac{1}{3})z' \tag{4.22}$$

The necessary profile of the sheet piling is then sized according to the allowable flexural stress of the sheet pile material, or

$$S = \frac{M_{max}}{\sigma_{all}} \tag{4.23}$$

Where:

S = section modulus of the sheet pile required per unit length of the structure

σ_{all} = allowable flexural stress of the sheet pile.

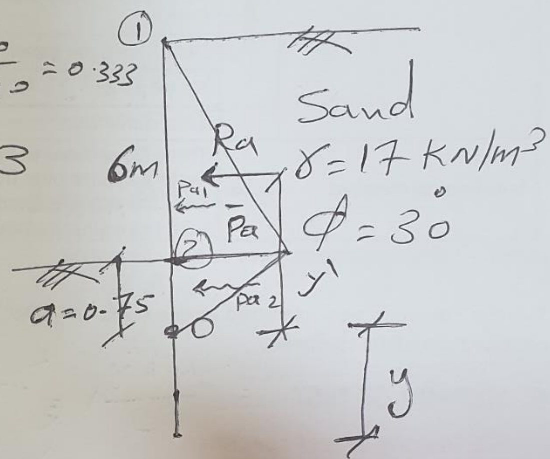
Example 1: Determine the embedent depth (D) and section moduls if $F_p = 17 \frac{MN}{m^2}$

F_p: maximum allwable flexural stress for sheet pile material

Solution

$$K_a = \frac{1-\sin\varphi}{1+\sin\varphi} = \frac{1-\sin 30}{1+\sin 30} = 0.333$$

$$K_p = \frac{1+\sin\varphi}{1-\sin\varphi} = \frac{1+\sin 30}{1-\sin 30} = 3$$



$$\sigma_{h①} = \sigma_v K_a - 2c\sqrt{K_a}$$
$$= \gamma * 0 \times K_a = 0$$

$$\sigma_{h②} = \gamma h K_a - 2c\sqrt{K_a} = 17 \times 6 \times 0.333$$

$$\boxed{\sigma_{h②} = 34\ kPa = \bar{P}_a}$$

$$a = \frac{\bar{P}_a}{C} = \frac{34}{\gamma(K_p - K_a)} = \frac{34}{45.333}$$

$$\boxed{a = 0.75\ m}$$

$$\bar{P}_p = \sigma_p - \sigma_a$$

$$\bar{P}_p = (\gamma' H + \gamma' a)K_p - \gamma a K_a$$
$$= (17(6+0.75)) \times 3 - 17 \times 0.75 \times 0.333$$

$$\boxed{\bar{P}_p = 340\ kPa}$$

(2)

$$R_a = \underbrace{\frac{1}{2} \times 34 \times 6}_{102} + \underbrace{\frac{1}{2} \times 34 \times 0.75}_{12.75}$$

$$\boxed{R_a = 114.75}$$

$$R_a * y' = P_{a_1} * y_1 + P_{a_2} * y_2$$

$$114.75\, y' = 102\left(\frac{6}{3} + 0.75\right) + 12.75\left(\frac{2}{3} \times 0.75\right)$$

$$\boxed{y' = 2.5 \text{ m from point } O}$$

for application the equation (4)

$$\frac{P_p^{-1}}{C} = \frac{340}{45.33} = 7.5 \quad , \quad \frac{8 R_a}{c} = \frac{8 \times 114.75}{45.33} = 20.25$$

$$\frac{6 R_a (2 y' C + P_p^{-1})}{C^2} = 189.85$$

$$\frac{6 R_a y' P_p^{-1} + 4 R_a}{C^2} = 310.4$$

$$y^4 + 7.5 y^3 - 20.25 y^2 - 189.85 y - 310.4 = 0$$

$$y = 5.3 \text{ m}$$

$$D_o = y + a = 5.3 + 0.75 = 6.05 \text{ m}$$

$$D_{design} = 1.3 * D_o = 1.3 * 6.05$$

$$D_{design} = 7.86 \approx 8 \text{ m}$$

$L = H + D = 6 + 8 = 14\ m$

Calculation of maximum Moment.

$$R_a = P = \frac{1}{2}(z')^2 \underbrace{(K_p - K_a)\gamma'}_{C}$$

$$R_a = \frac{1}{2}(z')^2\, C$$

$$z' = \sqrt{\frac{2 \times 114.75}{45.333}} = 2.25\ m$$

$$M_{max} = R_a(\bar{y} + z') - \frac{1}{2}\gamma' z'^2 (K_p - K_a)\frac{1}{3} \times z'$$

$$M_{max} = 114.75\,(2.5 + 2.25) - \frac{1}{2} \times 17 \times 2.25^2 \times (3 - 0.333) \times \frac{2.25}{3}$$

$$M_{max} = 459$$

$$S = Z_s = \frac{M_{max}}{\sigma_{all}\,(f_p)} = \frac{459}{175 \times 1000} = 0.002622$$

$$Z_s = 2.622 \times 10^{-3}\ m^3/m \text{ of wall}$$

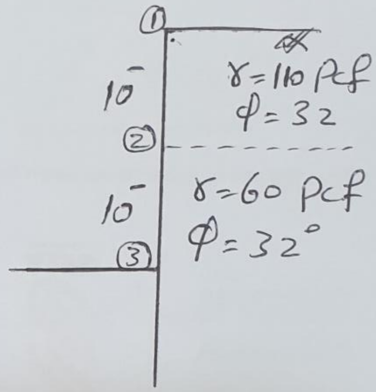
Example 2: Find the length of Sheet pile with Condition shown in figure below? ①

Solution

$$K_a = \frac{1-\sin\varphi}{1+\sin\varphi} = \frac{1-\sin 32}{1+\sin 32}$$

$$K_a = 0.307$$

$$K_p = \frac{1}{K_a} = \frac{1}{0.307} = 3.225$$

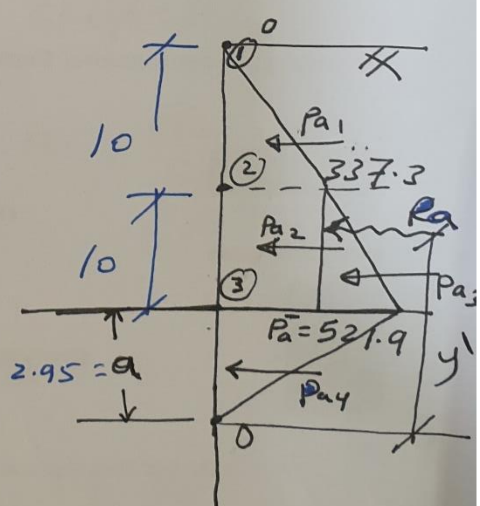


σ_{ha} ① $= 0$

σ_{ha} ② $= 10 * 110 * 0.307 = 337.7$ Kpa

σ_{ha} ③ $= (10 \times 110 + 10 \times 60)\, 0.307 = 521.9$ Kpa

$$\boxed{\bar{P}_a = 521.9}$$



$$C = \gamma'(K_p - K_a)$$

$$= 60(3.255 - 0.307) = 176.88$$

$$\boxed{C = 176.88}$$

$$a = \frac{P_a'}{c} \Rightarrow a = \frac{521.9}{176.88}$$

$$\boxed{a = 2.95}$$

$Pa_1 = \frac{1}{2} \times 10 \times 337.3 = 1687$ @ 16.28 From point o

$Pa_2 = 10 \times 337.3 = 3377$ @ 7.95 From point o

$P_{a3} = \frac{1}{2} \times 10 \times (521.9 - 337.7) = 921$ @ 6.28 from point ⓞ

$P_{a4} = \frac{1}{2} \times 2.95 \times 521.9 = 769.8$ @ 1.96 from point "O"

$\boxed{R_a = \sum P_a = 6753.3}$, $\boxed{y' = 9.12}$

$\bar{P}_p' = (\gamma h_1 + \gamma h_2 + \gamma' a) K_p - a \gamma' K_a$

$= (110 \times 10 + 60 \times 10 + 60 \times 2.95) \times 3.255 - 2.95 \times 60 \times 0.307$

$\boxed{\bar{P}_p' = 6054.5}$

to calculate $Y \rightarrow$ application equation in step(4)

$\frac{\bar{P}_p'}{c} = 34.23$, $\frac{8 R_a}{c} = 305.95$, $\frac{6 R_a (2 y' c + \bar{P}_p')}{c^2} = 12041.5$

$\frac{6 R_a y' * \bar{P}_p' + 4 R_a}{c} = 77498.6$

$y^4 + 34.23 y^3 - 305.94 y^2 - 12041.5 y - 77498.6 = 0$

$\boxed{y = 20.14}$

$D = a + y \Rightarrow \boxed{D = 23}$

$$D_{design} = 1.3 \times D = 1.3 \times 23$$

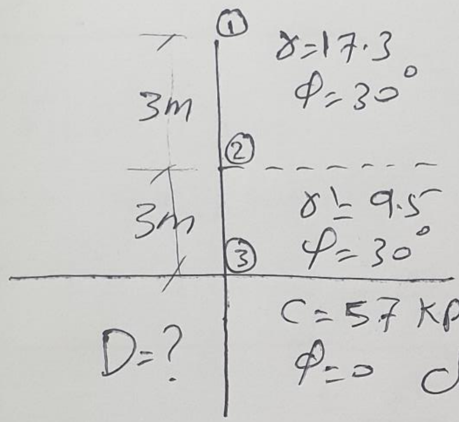
$$\boxed{D_{design} = 29.9}$$

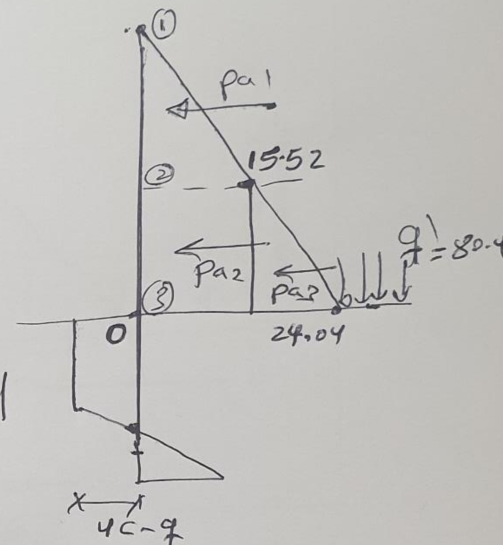
$$L = H + D \Rightarrow L = 20 + 29.9$$

$$\boxed{L \approx 50\,m}$$

Example 3: find depth of embedment if:

1- 30% increase in embedment depth
2- S.F=1.5 for passive (cohesion)





Solution

$$K_a=\frac{1-\sin\phi}{1+\sin\phi}=\frac{1-\sin 30}{1+\sin 30}=0.299$$

$$K_p=\frac{1}{K_a}=5.385$$

$$\sigma h_{a_{①}}=0 \quad , \quad \sigma h_{a_{②}}=3\times17.3=15.52\text{ Kpa}$$

$$\sigma h_{a_{③}}=\left[(3\times17.3)+(3\times9.5)\right]\times0.229=24.04\text{ Kpa}$$

$$q'=(3\times17.3)+(3\times9.5)=80.4\text{ Kpa}$$

$$\boxed{q'=80.4\text{ Kpa}}$$

$P_{a_1}=\frac{1}{3}\times3\times15.52\Rightarrow P_{a_1}=23.28$ @ 4m from point "O"

$P_{a_2}=3\times15.52=46.56$ @ 1.5 m from point "O"

$P_{a_3}=\frac{1}{2}\times3\times(24.04-15.52)=12.78$ @ 1m from point "O"

$R_a = \Sigma p_a \Rightarrow \boxed{R_a = 82.62 \text{ kpa}}$

$R_a \times y' = \Sigma p_{a1} \times 4 + p_{a2} \times 1.5 + p_{a3} \times 1$

$\boxed{y' = 2.13 \text{ m}}$

to Find $D = ?$

use equation (2)

$4c - q' = 4 \times 57.0 - 80.4 \Rightarrow \boxed{4c - q' = 149.6}$

$$\frac{R_a(12c\, y' + R_a)}{2c + q'} = 656.36$$

$149.6\, D^2 - 165.241\, D - 656.36 = 0$

$\boxed{D = 2.72 \text{ m}}$

$D_{design} = 1.3 \times D = 1.3 \times 2.72$

$\boxed{D_{design} = 3.6 \text{ m}}$

2) $C = \frac{c}{S.F} = \frac{57.0}{1.5} = 38.39$ kpa

$4c - q' = (4 \times 38.39) - 80.04 = 73.16$ Kpa

$$\frac{R_a(12\bar{y}c + R_a)}{2c + q'} = 559.21$$

$73.16 D^2 - 165.24 D - 559.21 = 0 \Rightarrow D = 4.2$ m

Homework No.4: Cantilever sheet pile in clay soil.

Find:

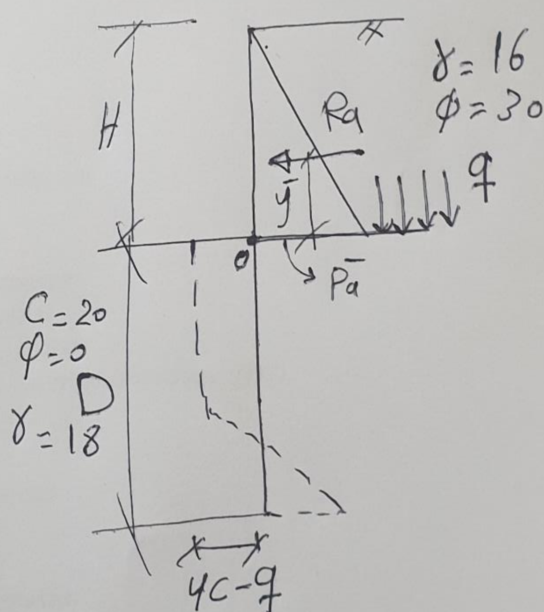
1- K_a and K_p

2- Active earth pressure along depth H of the Sheet pile

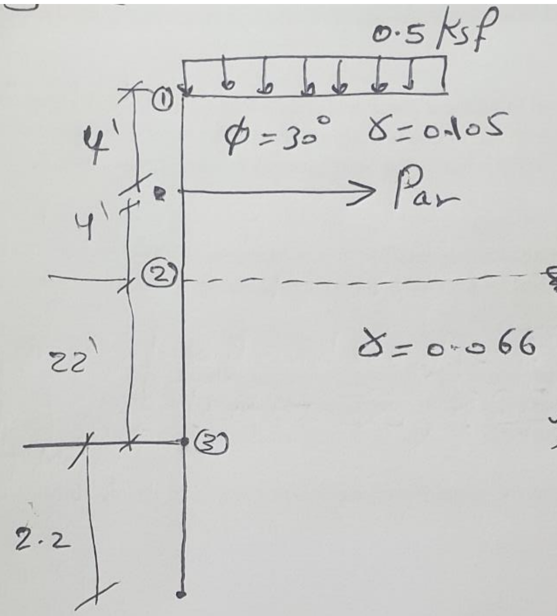
3- find R_a and $\bar{y}$ to point "O"

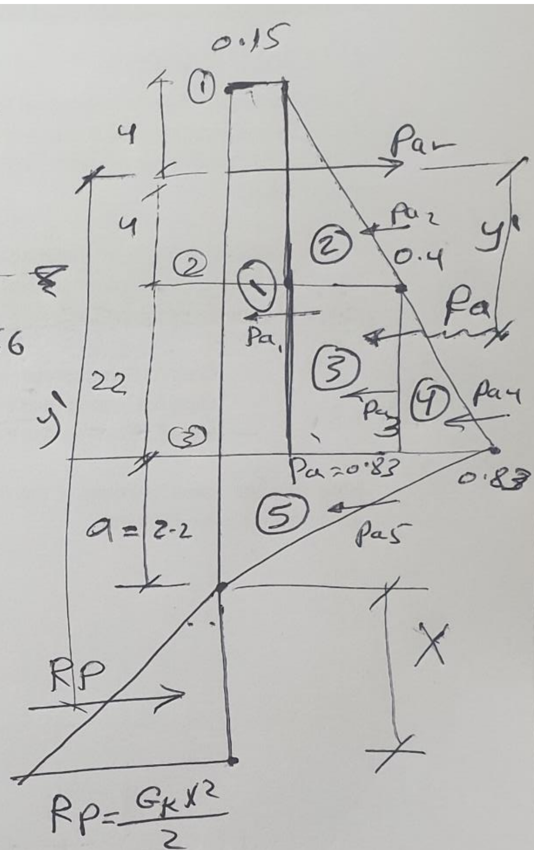
4- Find $\bar{q}$ along H

4) Find D



Example 5: compute the embedment depth of sheet pile shown in figure below.





$$K_a = \frac{1 - \sin\varphi}{1 + \sin\varphi} = 0.297$$

$$K_p = \frac{1}{K_a} = 6.1$$

$$\sigma h_{a①} = q\,K_a = 0.5 \times 0.297 = 0.15 \text{ ksf}$$

$$\sigma h_{a②} = (q + \gamma H)\,K_a = (0.5 + 8 \times 0.105)\,0.297 = 0.4 \text{ ksf}$$

$$\sigma h_{a③} = (q + \gamma_1 H_1 + \gamma_2 H_2)\,K_a = (0.5 + 8 \times 0.105 + 22 \times 0.066)$$

$$\sigma h_{a③} = 0.4 \text{ ksf}$$

$$\boxed{\bar{P}_a = 0.83 \text{ ksf}}$$

$$G_K = \gamma'(K_p - K_a) = 0.066\,(6.1 - 0.297) = \cancel{0.}$$

$$\boxed{G_K = 0.38}$$

$$a = \frac{\bar{P_a}}{G_k} = \frac{0.83}{0.38} = 2.2\ ft$$

$$\boxed{a = 2.2\ ft}$$

$Pa_1 = 0.15 \times 30 = 4.5$ @ $\frac{30}{2} - 4 = 11'$ about anchor

$Pa_2 = \frac{1}{2} \times 8\,(0.4 - 0.15) = 1$ @ $\frac{2}{3} \times 8 - 4 = 1.33'$

$Pa_3 = 22 * (0.4 - 0.15) = 5.5$ @ $11 + 4 = 15'$

$Pa_4 = \frac{1}{2}\,(0.8 - 0.4) * 22 = 4.73$ @ $18.67'$

$Pa_5 = \frac{1}{2} \times 2.2 \times 0.83 = 0.913$ @ $26.73'$

$Ra = \Sigma pa \Rightarrow \boxed{Ra = 16.6\ kps}$

$$\bar{y} = \frac{(4.5 * 11) + (1 \times 1.33) + (15.5 \times 15) + (4.73 \times 18.67) + 0.913 \times 26.73}{Ra = 16.6}$$

$$\boxed{\bar{y} = 14.8}$$

$h_3 = 22 + 4 = 26'$

to Find X solve the equation (3)

$3(h_3 + a) = 3(26 + 2.2) = 84.6$

$$\frac{6 Ra \bar{y}}{G_k} = \frac{6 \times 16.6 + 14.8}{0.38} = 3879.2$$

$$2x^3 + 84.6x^2 - 3879.2 = 0$$

$$\boxed{x = 6.3'}$$

$$D = \overset{x + a}{6.3 + 2.2} = 8.5'$$

$$D_{design} = 1.3 \times D = 1.3 \times 8.5 = 11.0$$

To calculate the value of Par

$$\Sigma fx = 0$$

$$Par + Rp - Ra = 0$$

$$Rp = \frac{1}{2} G_K x^2 = \frac{1}{2} \times 0.38 \times (6.3)^2$$

$$\boxed{Rp = 7.5 \text{ ksf}}$$

$$Par = \overset{Ra}{16.6} - \overset{Rp}{7.5} = 9. \text{ kps}$$

$$y' = h_3 + a + 0.67\,x$$

$$= 26 + 2.2 + 0.67\,(6.3)$$

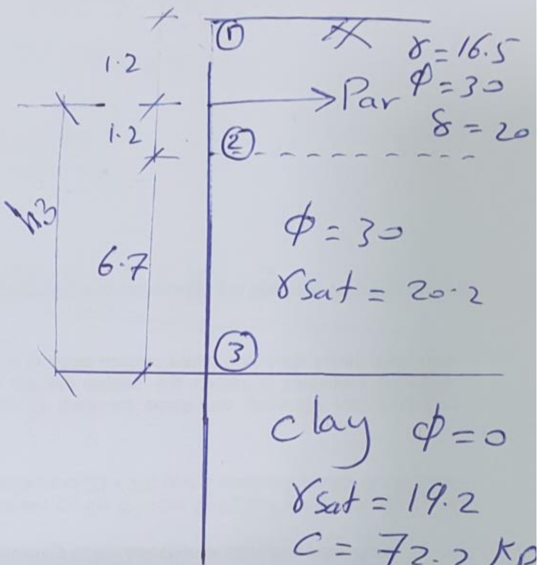
$$y' = ?$$

Example 6: for the anchored sheet pile shown in figure below find:

the embedment depth and anchor –rod force use S.F= 1.5 on cohesive.

①

Solution



1) use columb theory

$K_a = 0.297$

$K_p = 6.1$

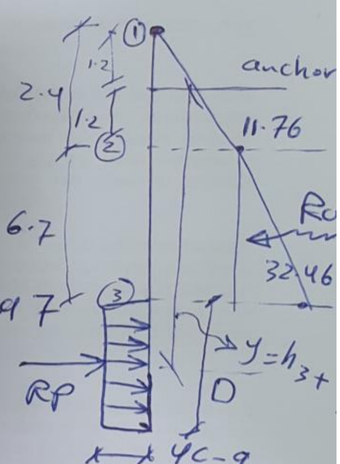
2) Compute Ra

$\sigma h_{a_1} = 0$

$\sigma h_{a_2} = \gamma z K_a - \cancel{2c\sqrt{K_a}}$ 10 تهمل

$\sigma h_{a_2} = \gamma z K_a = 2.4 \times 16.5 \times 0.297$

$\sigma h_{a_2} = 11.76 \text{ KPa}$



$\sigma h_{a_3} = [2.4 \times 16.5 + 6.7(20.2 - 9.81)] \times 0.297$

$\sigma h_{a_3} = 32.46 \text{ KPa}$

$P_{a1} = \frac{1}{2} \times 11.76 \times 2.4 = 14.1 \text{ kN/m}$ @ $2.4 \times \frac{2}{3} - 1.2 = 0.4$

$P_{a2} = 11.76 \times 6.7 = 78.79$ @ $1.2 + \frac{6.7}{2} = 4.55 \text{ m}$

$P_{a3} = \frac{1}{2}[32.46 - 11.76] \times 6.7 = 69.3$ ② $\frac{2}{3}6.7 + 1.2 = 5.67$ m

$R_a = \Sigma P_a = P_{a1} + P_{a2} + P_{a3}$
$= 14.1 + 78.79 + 69.3 =$

$\boxed{R_a = 162.2 \ kN/m}$

$R_a * y' = 14.1 \times 0.4 + 4.55 \times 78.79 + 69.3 \times 5.67$

$\boxed{y' = 4.67 \ m}$

$q' = 16.5 \times 2.4 + (20.2 - 9.81)\ 6.7 = 109.3 \ kPa$

$\boxed{h_3 = 6.7 + 1.2 = 7.9 \ m}$

Compute D

$c = \frac{C}{S.F} = \frac{72.2}{1.5} = 48.13 \ kPa$

$4c - q' = 4 \times 48.13 - 109.3 = 82.7.$

$\frac{2y' R_a}{4c - q'} = \frac{2 \times 4.67 \times 162.2}{82.7} = 18.32$

$D^2 + 2Dh_3 + \frac{2y' R_a}{4c - q'} = 0$

$D^2 + 15.8D - 18.52 = 0 \Rightarrow \boxed{D = 1.1 \ m}$

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$R_p = (4c - q') * D$

$= 82.7 * 1.1 \Rightarrow \boxed{R_p = 1.1\,m}$

Compate Par

$P_{ar} = R_p - R_a$

$= 162.2 - 91 = 162.2 - 91 = 71.2$

$\boxed{P_{ar} = 71.2}$ kN/m