Q1 (25%):

Determine the allowable bearing capacity of the pile group (Q_{all}), shown In the figure if, $D = 0.3m$, $Fs = 2$
$X_1 = 4.57m$, $X_2 = 17.72m$, $C_{U1} = 50.3\ kN/m^2$,
$\gamma_{sat}1 = 17.6kN/m^3$, $C_{U2} = 85.1kN/m^2$, $\gamma_{sat} = 19.02\ kN/m3$
The distance between piles C-C , d=0.889m

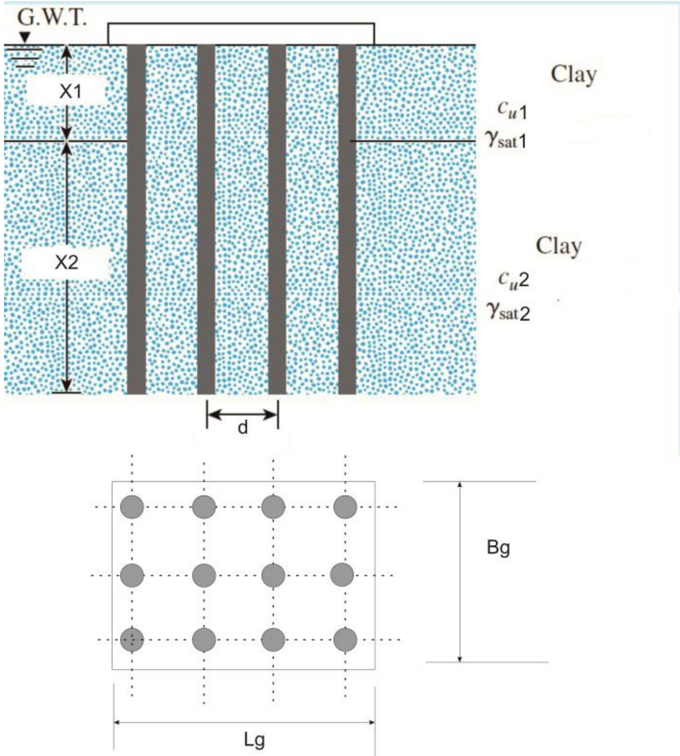


Table 11.10 Variation of α (interpolated values based on Terzaghi, Peck and Mesri, 1996)

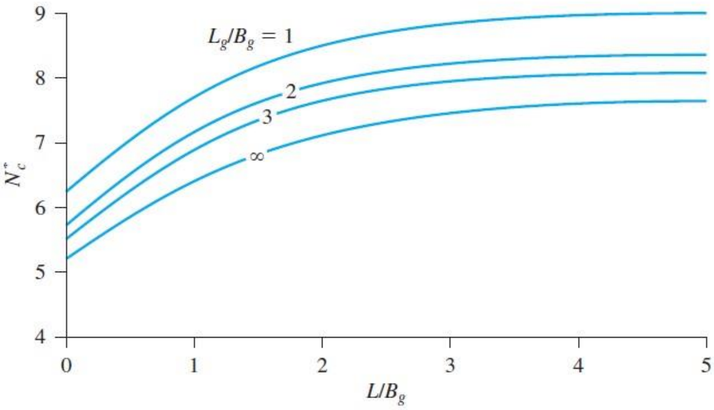
$\frac{c_u}{p_a}$	α
≤ 0.1	1.00
0.2	0.92
0.3	0.82
0.4	0.74
0.6	0.62
0.8	0.54
1.0	0.48
1.2	0.42
1.4	0.40
1.6	0.38
1.8	0.36
2.0	0.35
2.4	0.34
2.8	0.34

Note: p_a = atmospheric pressure $\approx 100\ kN/m^2$

Hint:

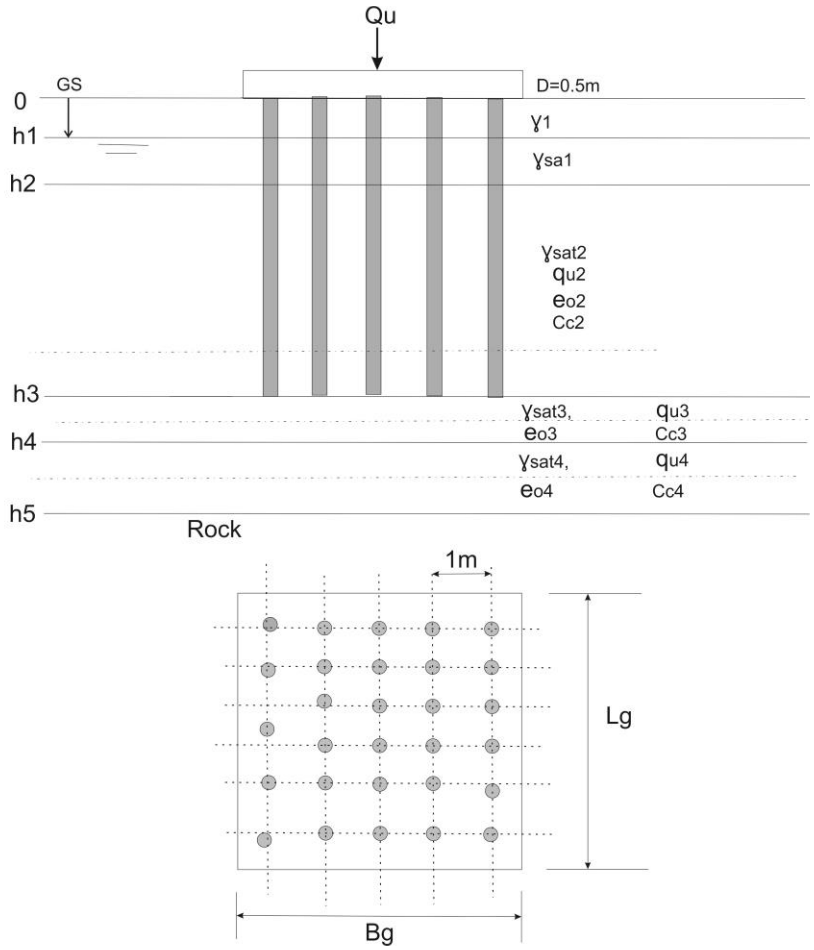
$$\sum Q_u = n_1 n_2 [9 A_b C_u + \sum \alpha C_u P(\Delta L)]$$

$$\sum Q_u = L_g B_g C_u N_C^* + \sum 2(L_g + B_g) C_u \Delta L$$



Q2 (25%):

Compute the consolidation settlement of the pile group shown in the figure if,
$\gamma_1 = 16kN/m^3$, $\gamma_{sat1} = 20kN/m^3$
$\gamma_{sat2} = 21kN/m^3$, $q_{u2} = 100kN/m^2$,
$e_{o2} = 0.7$, $C_{C2} = 0.13$,
$\gamma_{sat3} = 19kN/m^3$, $q_{u3} = 110kN/m^2$,
$e_{o3} = 0.95$, $C_{C3} = 0.15$,
$\gamma_{sat4} = 20kN/m^3$, $q_{u4} = 150kN/m^2$,
$e_{o4} = 0.8$, $C_{C4} = 0.12$.
The distance is measured from ground Surface to interface of each layer
$h_1 = 2m$, $h_2 = 4m$, $h_3 = 15m$, $h_4 = 17m$
$h_5 = 20m$ and the diameter of each pile is $D = 0.5m$, and $Q_U = 2500\ kN$



Hint: use

$$S_f = \frac{C_c}{1+e_o} H_o \log_{10}\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right)$$

Q3 (25%):

Estimate the ultimate bearing capacity of the pile shown in the figure, if it penetrated a clay layer of thickness $L_1 = 5m$ and continued in deep sandy layer to a depth of $L_2 = 7m$. The diameter of the pile $D = 0.5m$, $C_u = 40kN/m^3$, $\gamma_1 = 16\ KN/m^3$, $\gamma_2 = 18\ KN/m^3$, $\emptyset = 30^\circ$, k = 1.5

Table 11.10 Variation of α (interpolated values based on Terzaghi, Peck and Mesri, 1996)

$\frac{c_u}{p_a}$	α
$\leq$ 0.1	1.00
0.2	0.92
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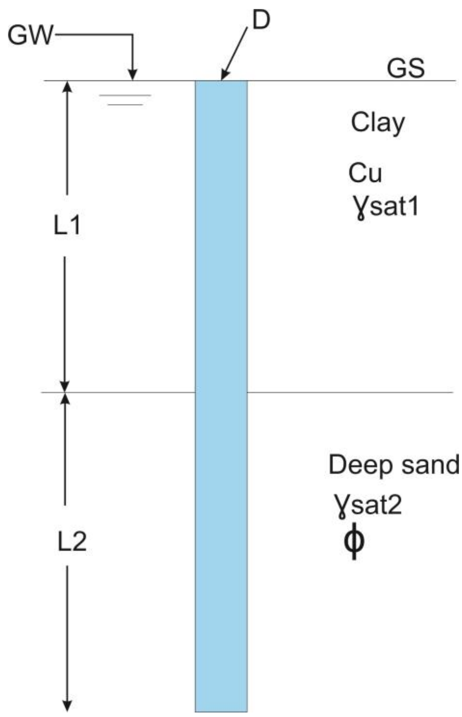
1.0	0.48
1.2	0.42
1.4	0.40
1.6	0.38
1.8	0.36
2.0	0.35
2.4	0.34
2.8	0.34

Note: p_a = atmospheric pressure $\approx 100\ kN/m^2$

Soil friction angle, ϕ (deg)	N_q^*
20	12.4
21	13.8
22	15.5
23	17.9
24	21.4
25	26.0
26	29.5
27	34.0
28	39.7
29	46.5
30	56.7
31	68.2
32	81.0
33	96.0
34	115.0
35	143.0
36	168.0
37	194.0
38	231.0
39	276.0
40	346.0
41	420.0
42	525.0
43	650.0
44	780.0
45	930.0



Hint:

$Q_b = qN_qA_b$

$0.5\ P_{atm}N_q(tan\emptyset)A_b$

$\boldsymbol{Q_s = PL\alpha C_U}$

Q4 (25%):

Choose one or more of correct answers in between brackets:

1- The friction coefficient (f) in sand is allowed to increase to:- (5D, 10D, 15D, 20D, 25D).
2- If $\emptyset = 25^{\circ}$, the lateral earth pressure coefficient (k_a) equals to:- (0.405, 0.035, 0.305, 0.33, 0.25).
3- The common pile cross sections are:-(square, circular, triangle, rectangle, octagonal).
4- Piles may be made of (Timber, Steel, Concrete, class, water, carton, oil).
5- The pile's tip or end should be rest on:- (rock, dense sand, soft clay, collapse soil).

Q5 (25%):

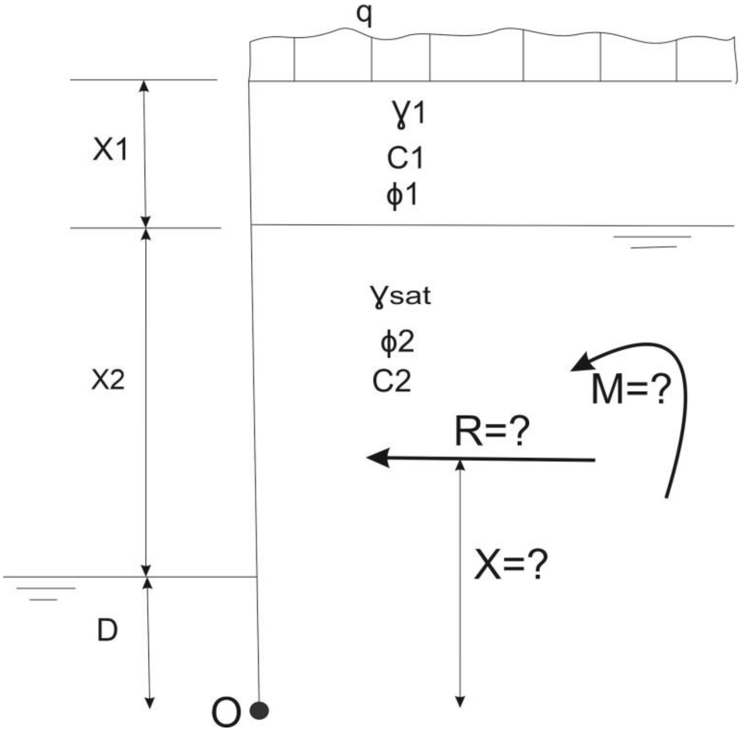
Estimate :-

1- The resultant (R), and
2- It distance (X)from the point of rotation (O).
3- The moment (M) about the point of rotation (O).

If $x_1 = 2m,\ x_2 = 6m,\ D = 2m$

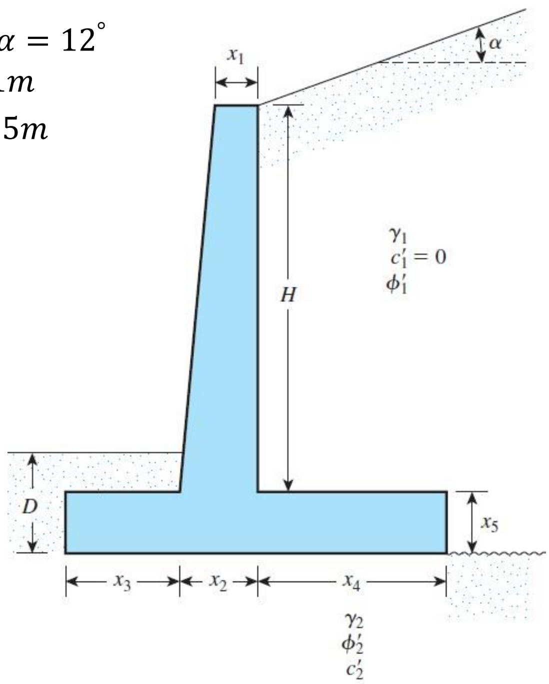
$\gamma_1 = 16\frac{kN}{m^3}, \emptyset_1 = 10\ \ C_1 = 25\ kN/m^3$

$\gamma_{sat} = 20\ KN/m^3\ ,\ \emptyset = 30^{\circ}\ , C_2 = 0$



Q6 (25%):

A full design is required for the retaining wall
Shown in the figure, if $H = 11m$ $\gamma_{Cr} = 23.5\ kN/m^3$, $\alpha = 12^{\circ}$
$x_1 = 0.3m,\ x_2 = 0.7m, x_3 = 1.7m, x_4 = 3.8m, x_5 = 1m$
$\gamma_1 = 16.\frac{5kN}{m^3}, \emptyset_1 = 32^{\circ}, \gamma_2 = 17.5 = kN/m^3, D = 1.75m$



Good Luck

Examiner	**Head of Department**
Prof. Dr Najah M. L. Al Maimuri	Dr. Riyadh Abdulabas Ali Al-Sultani

Solutions

Ans1:

$L_g = 3 * 0.889 + 2 * 0.3 = 3.267m$, $B_g = 2 * 0.889 + 2 * 0.3 = 2.378m$

$\frac{L_g}{B_g} = 1.37$, $\frac{L}{B_g} = \frac{4.57+13.72}{2.378} = 7.7$, $N_c = 8.7$

Step1: Using sing pile bearing capacity:

$$\sum Q_u = n_1 n_2 [9A_b C_u + \sum \alpha_1 C_{u1} P(\Delta L_1) + \sum \alpha_2 C_{u2} P(\Delta L_2)]$$

$A_b = \frac{\pi * 0.3^2}{4} = 0.07m2,$ $P = \pi(0.3) = 0.942m, C_{u1} = 50.3KN/m2, \alpha_1 = 0.68,$

$C_{u2} = \frac{85.1KN}{m2}, \Delta L_1 = 4.57m, \Delta L_2 = 13.72m,$ $\alpha_1 = 0.68$

$$From\ the\ table\ \frac{0.8 - 8.5}{0.85 - 1} = \frac{0.54 - \alpha_2}{\alpha_2 - 0.48}, \quad \alpha_2 = 0.494$$

$$\sum Q_u = 3 * 4[9 * 0.07 * 85.1 + \sum [0.68 * 50.3 * 0.942 * 4.57m] + (0.494 * 85.1 * 0.942 * 13.72)] = 643.3 + 147.2 + 543.3 = 8{,}930KN$$

Step2: Using Pile group bearing capacity

$$\sum Q_u = L_g B_g C_u N_C^* + \sum 2(L_g + B_g) C_u \Delta L +$$

$$\sum Q_u = L_g B_g C_u N_C^* + \sum 2(L_g + B_g) C_{u_1} \Delta L_1 + \sum 2(L_g + B_g) C_{u_2} \Delta L_2$$

$$\sum Q_u = 3.267m * 2.378m * 85.1 * 8.7 + \sum 2(3.267m + 2.378m) 50.3 * 4.57 + \sum 2(3.267m + 2.378m) 85.1 * 13.72 = 13{,}181KN$$

$$\sum Q_U = 5751.879 + 2{,}595.24 + 13{,}181.88 = 21{,}529$$

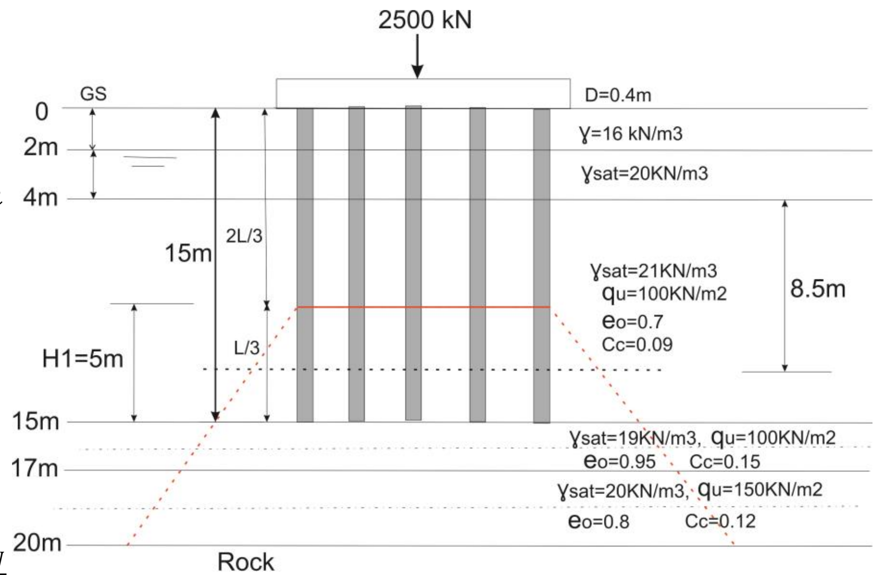
Take the minimum $8{,}930KN$

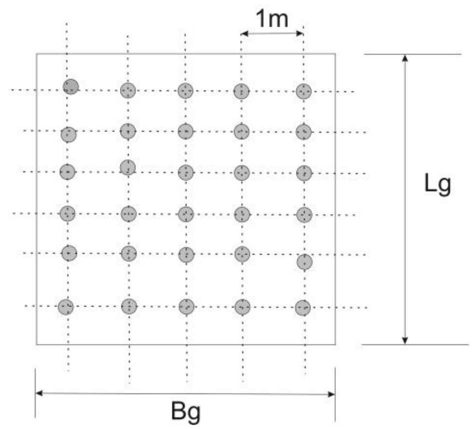
Take $Q_{all} = \frac{8930}{2} = 4{,}465KN$

Ans2:

Settlement of pile croup

$L_g = 5 * 1m + 2D = 6m, B_g = 4 * 1 + 2D = 5m$





Layer 1:

Settled layer $(\frac{L}{3} = \frac{15}{3} += 6m$

$H1 = 5m$

$S1 = \frac{C_c H}{1+e_o} \log \frac{\sigma + \Delta\sigma}{\sigma}, \qquad s1 = \frac{C_c H}{1+eo} \log \frac{Po + \delta p}{po}$

$\sigma = 2 * 17 + 2 * 10 + 8.5 * 11 = 147.5 \frac{kN}{m2}$

$\Delta\sigma 1 = \frac{2500}{(5+2.5)(6+2.5)} = 39.2 KN/m2$

$S1 = \frac{0.09*5}{1+0.7} log \frac{147.5+39.2}{147.5} = 0.027m = 27mm$

Layer2

H=2m

$S2 = \frac{C_c H}{1+e_o} log \frac{\sigma + \Delta\sigma}{\sigma},$

$\sigma = 2 * 17 + 2 * 10 + 11 * 11 + 1 * 9 = 184 \frac{kN}{m2}$

$\Delta\sigma = \frac{2500}{(5+6)(6+6)} = 18.9 KN/m2$

$S2 = \frac{0.15*2}{1+0.95} log \frac{184+18.9}{184} = 0.0065m = 6.5mm$

Layer3

H=3m

$S3 = \frac{C_c H}{1+e_o} log \frac{\sigma + \Delta\sigma}{\sigma},$

$\sigma = 2 * 17 + 2 * 10 + 11 * 11 + 2 * 9 + 1.5 * 10 = 208 \frac{kN}{m2}$

$\Delta\sigma = \frac{2500}{(5+8.5)(6+8.5)} = 12.77 KN/m2$

$S3 = \frac{0.12*3}{1+0.8} log \frac{208+12.77}{208} = 0.0051m = 5.1mm$

$S = s1 + s2 + s3 = 27 + 6.5 + 5.1 = 38.6mm > 25 \; not \; okay$

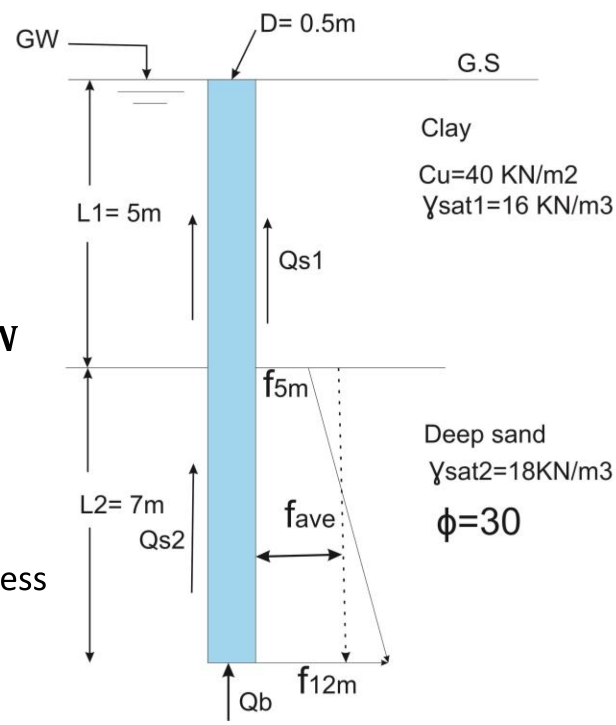
Ans3:

$Q_b = qN_qA_b$

$Q_b = (5*6+7*8)*56.7*\frac{\pi(0.5)^2}{4} = 957$ kN

$\leq 0.5\, P_{atm}N_q(tan\emptyset)A_b = 0.5*100*56.7*tan30*\frac{\pi(0.5)^2}{4} = 321\ kN$

Take $Q_b = 321KN$



Layer1

$\boldsymbol{Q_{s1} = PL\alpha C_U}$

For $\boldsymbol{C_U = 40KN/m2, \quad \alpha = 0.74, \quad L_1 = 5m}$

$\boldsymbol{Q_{s1} = \pi(0.5)*5m*0.74*40KN/m2 = 232KN}$

Layer2

$Q_s = PLf$

$L^{'} = 15D = 15*0.5 = 7.5m$ > 7m sand layer thickness

$f \ = k\sigma\tan(0.8\emptyset)$

$f_{5m} = 1.5*(6*5)\tan(0.8*30) = 20KN/m2$

$f_{12m} = 1.5(6*5+7*8)\tan(0.8*30) = 57.4KN/m2$

$K_{ave} = \frac{f_{5m}+f_{12m}}{2} = 38.7KN/m2$

$Q_{s2} = PL^{'}f_{ave}$

$Q_{s2} = (\pi*0.5)*7m*38.7KN/m2 = 425.5\ kN$

$Q_U = 321+232+425.5 = 978.5\ KN$

Ans4

1- **15D**
2- **0.405**
3- **Square, Circular, Octagonal**
4- **Timber, Steel, Concrete**
5- **rock, dense sand**

Ans5:

Layer1

At h = 0

$P_a = k_a(\gamma h + q) - 2c\sqrt{k_a}$, for $\emptyset = 10,\ k_a = 0.7$

$P_a = 0.7 * (16 * 0 + 100) - 2 * 25\sqrt{0.7} = 28KN/m2$

At h = 2 m

$P_a = k_a(\gamma h + q) - 2c\sqrt{k_a} = 0.7(16 * 2 + 100) - 2 * 25\sqrt{0.7} = 50KN/m2$

Layer2

At h = 2m

$P_a = k_a(\gamma h + q) = 0.33 * (16 * 2 + 100) = 43.5KN/m2$

At h = 10

$P_a = 0.33 * 10 * 10$ = 33KN/m2

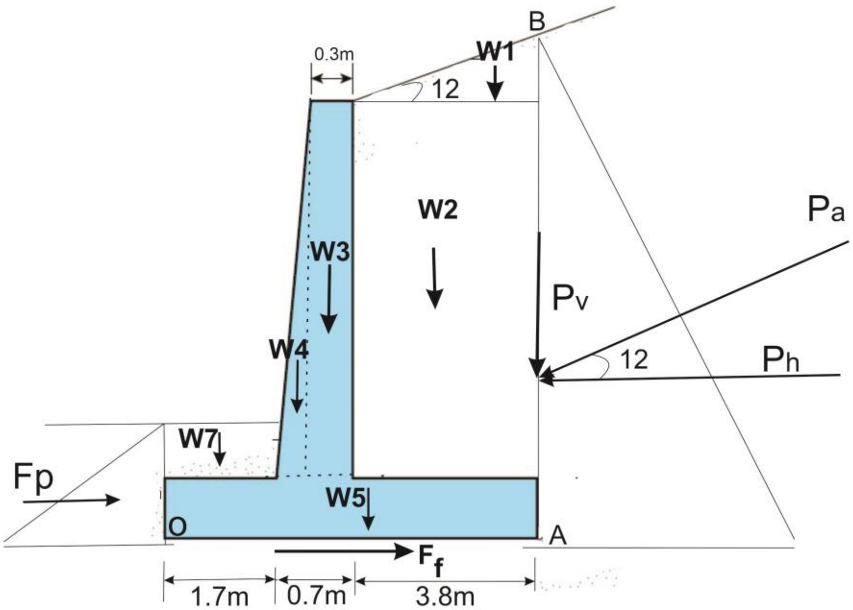
$\boldsymbol{R = 56 + 22 + 348 + 452 - 80 = 798KN}$

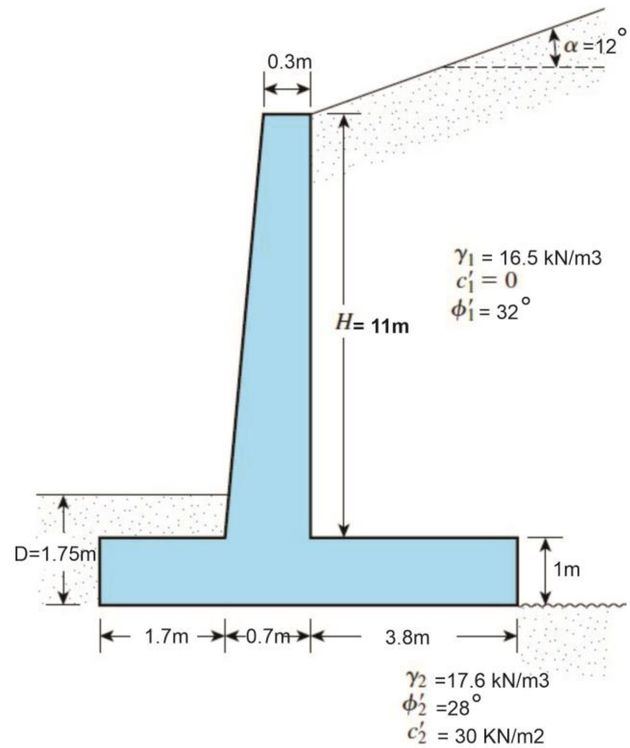
$\boldsymbol{798X = 56 * 9 + 22 * 8.66 + 348 * 5 + 452 * 2.66 - 80 * 0.66}$

$\boldsymbol{X = 4.491m}$

$$\boldsymbol{M = 798 * 4.491 = 3,584\ KN.m\ \ , Counterclockwise}$$

Ans6:





$k_a = \tan^2(45 + \frac{\emptyset}{2}) = tan^2\left(45 - \frac{32}{2}\right) = 0.3$

$AB = 11 + 3.8\tan(12) = 11.8m$

$P_a = \frac{k_a\gamma h^2}{2} = \frac{0.3*16.5*11.8^2}{2} = 344KN/m,\ P_h = 344\cos(12) = 337KN/m,$

$P_V = 344sin12 = 71.5KN/m,\ W1 = 3.8*0.8*16.5 = 19.76KN/m,$

$W2 = 3.8*11*16.5 = 689.7KN/m,\ w3 = 0.3*11*23.5 = 77.55KN/m,$

$W4 = \frac{0.4*11}{2}*23.5 = 51.7KN/m,\ W5 = 6.2*1*23.5 = 145.7KN/m$

$F_p = \frac{k_p\gamma D^2}{2} + 2DC\sqrt{kp} = \frac{3*16.5*1.75^2}{2} + 2*1.75*30\sqrt{3} = 181.8KN/m,\ W7 = 0.7*1.7*$ 16.5 =19.6KN/m

$d1 = 4.93m, d2 = 4.3m, d3 = 2.25m, d4 = 1.96m, d5 = 3.1m, d7 = 0.85m, d_h = 3.93m,$ $d_V = 3.8m.$

Factor of safety against overturning moment

Force,	**KN/m**	Distance (d), m	$M_R, KN.m$	M_O, KN.m	FS
W1	19.76	4.93	97.4168		
W2	689.7	4.3	2965.71		
W3	77.55	2.25	174.4875		

W4	51.7	1.96	101.332		
W5	145.7	3.1	451.67		
W7	19.6	0.85	16.66		
Pv	71.5	3.8	271.7		
Ph	337	3.93		1,324	
Pp	181.8	0.583	106		
$\sum F_V$	1075.5		$\sum 4185$	$\sum 1324$	3.1

Factor of safety against sliding

$F_R = \sum V tan(k1\emptyset) + CB + P_p$, $\sum V = 1,095\ KN/m$

$F_R = 1075 \tan(0.5 * 28) + 6.2 * 30 + 181.8 = 635.8KN/m$

$FS = \frac{F_R}{P_h} = \frac{635.8}{337} = 1.9$ < 2.5 the retaining wall need some proportioning

Factor of safety for beneath Soil

1. **Eccentricity analysis**

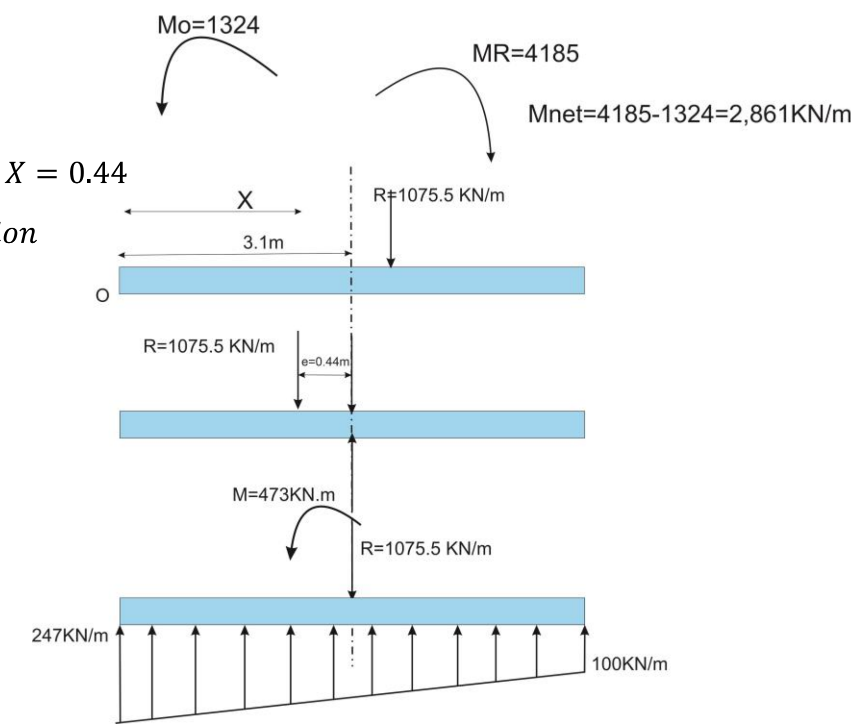
$RX = \sum M_o$

$1075.5R = 4185 - 1324$, $X = 2.66m$, $e = \frac{B}{2} - X = 0.44$

$< \frac{B}{6} = \frac{6.2}{6} = 1.033m\ OK\ no\ negative\ soil\ reaction$

$q = \frac{\sum V}{B} \mp \frac{6M}{B^2} = \frac{1075.5}{6.2} \mp \frac{6*473}{(6.2)^2} = 173.4 \mp 73.8$

$q_A = 100KN/m2$, $q_o = 247KN/m2$



2. B.C of Sub soil

$$q = CN_C + qN_q$$