1. A **10 m** deep braced excavation with **30 m X 40 m** plan dimensions is to be made in a sandy soil with coefficient of hydraulic conductivity as **2×10^{-2} cm/sec**. The sandy soil layer is followed by hard rock at **20 m** depth and ground water table is located at 4 m depth below ground level. Determine the number of pumps required to bring the ground water table down to **1 m** below the excavation level for construction of foundation system. Consider that for the well point dewatering system, discharge capacity of each pump is **15000 lt.hour**.

2. A plate load test was conducted at the soil surface on a **30 cm X 30 cm** square plate. The results obtained are as follows,

Load (kg)	500	1000	1500	2000	2500	3000
Settlement (mm)	1.25	2.50	3.75	5.00	7.50	15.00

   Compute the following for a square footing of size **3 m X 3 m** with a factor of safety**3.0**,

   (a) Allowable bearing capacity if the deposit is deep sandy strata.
   (b) Allowable bearing capacity if the deposit is deep clayey strata.
   (c) Expected settlements with allowable bearing capacities from (a) and (b).

3. A cantilever sheet pile wall is required to be designed to retain **5.5 m** deep cohesionless soil strata with unit weight **γ = 17 kN/m^3** and friction angle **ϕ = 30^0**. Determine the total depth of penetration required for complete anchorage and draw the net earth pressure diagram for the full height of the sheet pile wall.

4. A closed end tapered pile of **1.0 m** base diameter with **1^0** taper angle has been driven into dense sand with uniform submerged weight of **11 kN/m^3**. The angle of shearing resistance of sand decreases from **40^0** to **35^0** at **20 m** depth. Calculate the ultimate capacity of pile of **20 m** length using IS code method.

5. For cyclic pile load test on a 300 mm diameter pile, the observed field test data is mentioned as follows,

Load (tons)	5.0	10.0	20.0	30.0	40.0	50.0	60.0
Total settlement (mm)	2.5	4.0	9.5	16.5	27.0	40.5	61.0
Net settlement (mm)	0.5	1.25	3.75	8.0	14.0	21.0	31.0

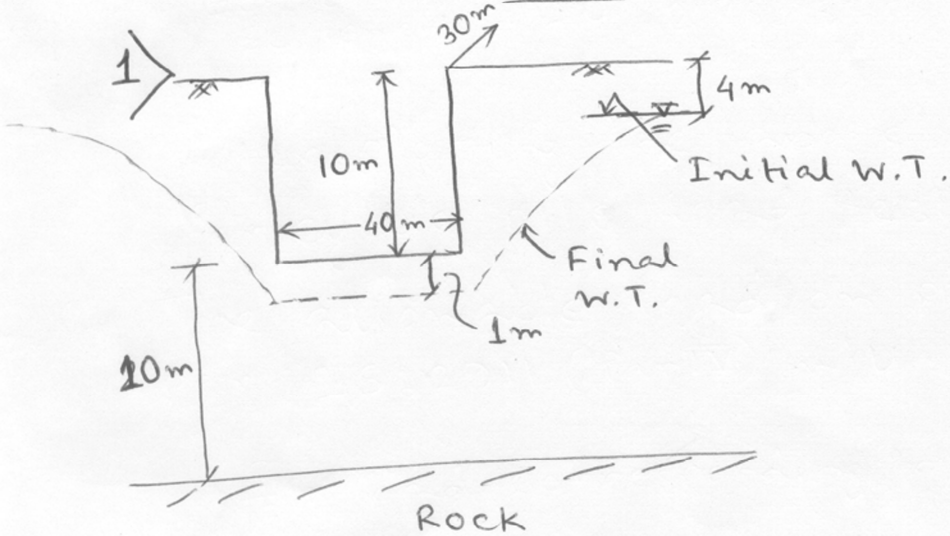
Calculate the allowable load for the pile using IS: 2911 (Part-IV)

6. A group of **36** piles are arranged in a square grid fashion. Diameter of each pile is 600 mm and the c/c distance of piles is **2.4 m** and length of each pile is **15 m**. The entire pile-raft/cap is placed at **3 m** below ground level. Soil is stiff clay with unit cohesion = **105 kN/m^2** from surface and then to **13 m** below ground surface and then unit cohesion = **145 kN/m^2** from **13 m** to **28 m** below ground level which is followed by a hard rock strata. If working load on the whole group is **21000 kN**, compute the factor of safety of the system. Calculate the consolidation settlement of the group. Given, α **= 0.4** and **mv = 8x10^{-5} m^2/kN**.

******** END ********

END Sem Exam Solution

1)



For well point dewatering system, Steady ~~stad~~ pumping rate in unit time is calculated as,

$$Q = \pi k \frac{H^2 - h^2}{2 \cdot 3 \log_{10}\left(\frac{R}{r}\right)}$$

Let $R = 10r$ (influence area).

& given, $k = 2\times10^{-2}$ cm/s, $H = (20-4) = 16$ m

$h = (10-1) = 9$ m

$$\therefore\ Q = \pi \times 2\times10^{-4} \frac{(16)^2 - (9)^2}{2 \cdot 3 \log_{10}(10)} \text{ m}^3/\text{sec.}$$

$$Q = 0{\cdot}047807 \text{ m}^3/\text{sec.} = 172105{\cdot}2 \text{ lt/hour.}$$

$\therefore$ Number of Pumps reqd. $= \dfrac{172105 \cdot 2}{15000} \simeq 12$ Ans.

2) From graph,

$$Q_{ult} = 2750 \text{ kg.}$$

for $S_p = 6.5$ mm

$$\therefore q_{ult} = \frac{2750}{(0.3)^2} \text{ kg/m}^2$$

$$= 30555.56 \text{ kg/m}^2$$

(a) For footing size 3m × 3m.

using F.S. = 3.0,

$$q_{all} = \frac{30555.56 \times (3)^2 (3.0)}{3 \times (3)^2 (0.3)} \text{ kg/m}^2$$

$$= 10185.20 \text{ kg/m}^2$$

in sand

(b) $q_{all} = 10185.2 \text{ kg/m}^2$ in clay also.

(c) In sand,

foundation settlement.

$$S_f = S_p \left[\frac{B(b_p + 0.3)}{b_p(B + 0.3)}\right]^2$$

$$= 6.5 \left[\frac{3(0.3 + 0.3)}{0.3(3 + 0.3)}\right]^2$$

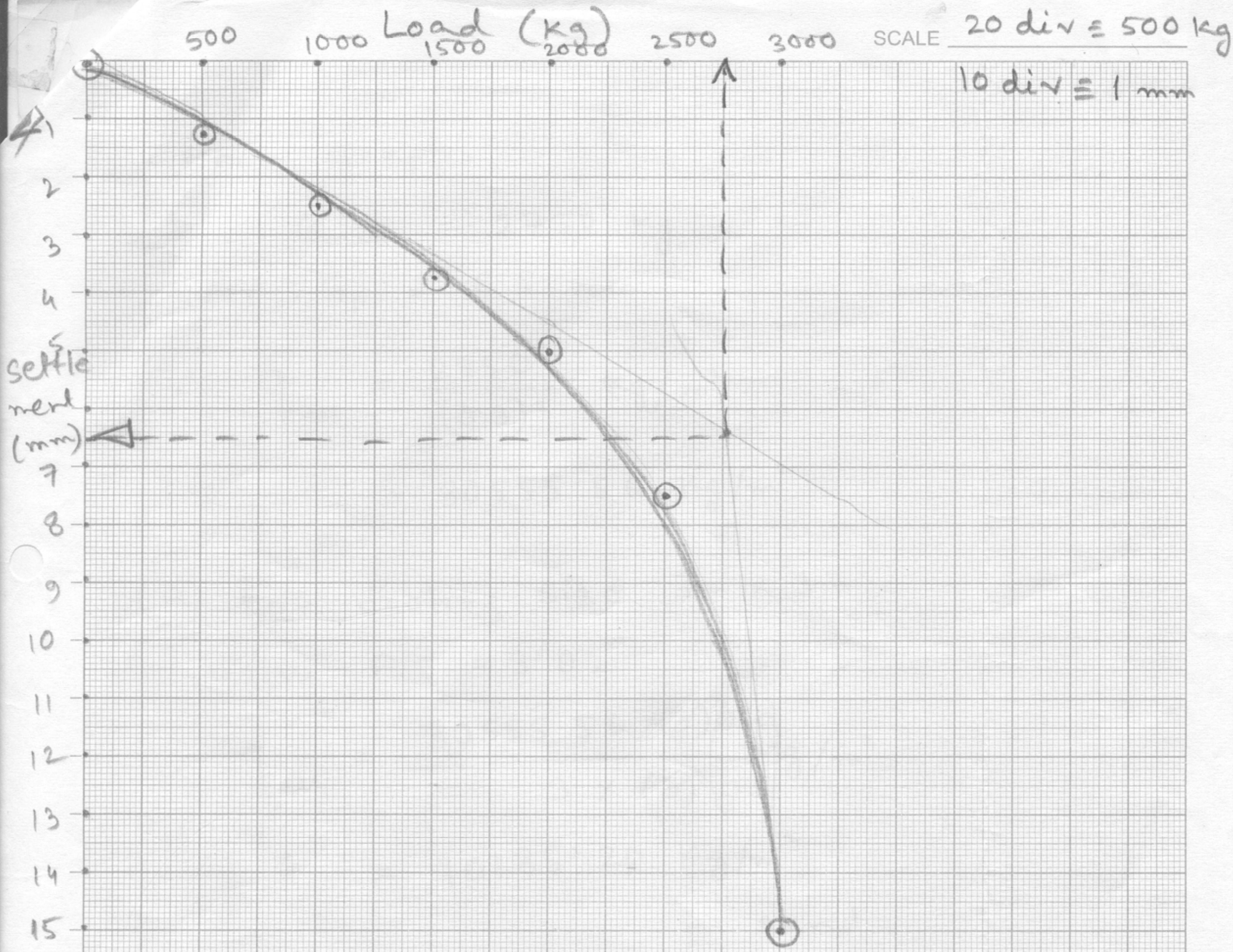
$$= 21.49 \text{ mm.}$$

and in clay,

$$S_f = S_p \times \frac{B}{b_p}$$

$$= 6.5 \times \frac{3}{0.3} \text{ mm}$$

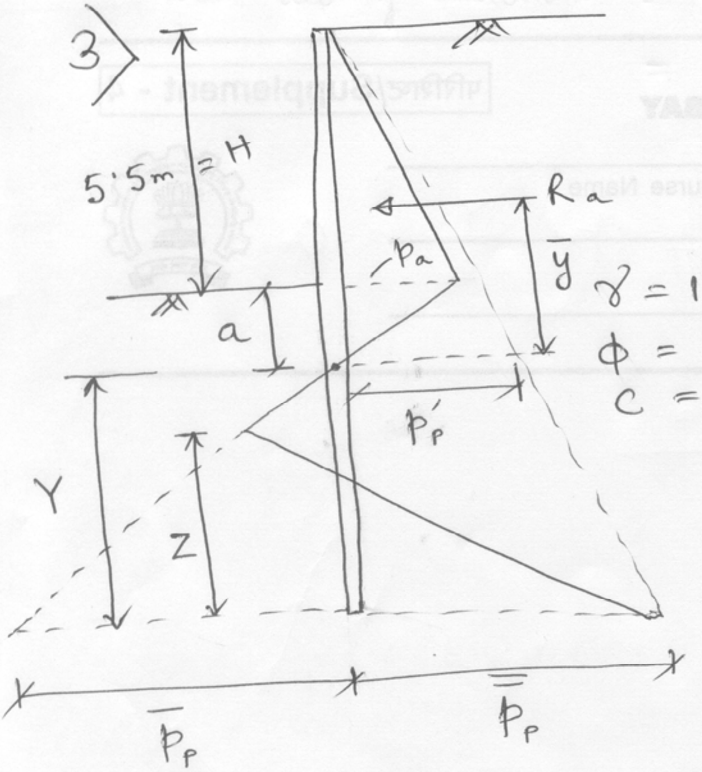
$$= 65 \text{ mm}$$ Ans.



Hence $Q_{ult} = 2750$ kg (using double-tangent method)

for $S_p = 6.5$ mm

3)



$\gamma = 17 KN/m^3$

$\phi = 30°$

$C = 0$

$$K_a = \frac{1 - \sin 30°}{1 + \sin 30°} = \frac{1}{3}$$

$$K_p = \frac{1}{K_a} = 3$$

$$p_a = K_a \gamma (5'5)$$

$$= \frac{1}{3} \times 17 \times 5'5 \quad KN/m^2$$

$$= 31'17 \quad KN/m^2$$

$$a = \frac{p_a}{\gamma (K_p - K_a)} = \frac{31'17}{17\left(3 - \frac{1}{3}\right)} = 0'69 \ m.$$

$$\therefore \bar{y} = \left(0'69 + \frac{5'5}{3}\right)$$

$$= 2'523 \ m.$$

$$p_p' = \gamma (H + a) K_p - \gamma a K_a$$

$$= \left[17 (5'5 + 0'6) 3 - 17 \times 0'69 \times \frac{1}{3}\right] KN/m^2$$

$$= 307'19 \quad KN/m^2$$

$$R_a = \frac{1}{2} \times p_a \times H = \frac{1}{2} \times 31'17 \times 5'5 \quad KN/m$$

$$= 85'72 \ KN/m$$

$$\bar{p}_p = \gamma (K_p - K_a) Y = 17\left(3 - \frac{1}{3}\right) Y = 45'33 Y \ KN/m^2$$

$$\bar{\bar{p}}_p = p_p' + \gamma (K_p - K_a) Y$$

$$= (307'19 + 45'33 Y) \quad KN/m^2$$

Now, $\sum F_H = 0$

$$\therefore R_a + (\bar{p}_p + \bar{\bar{p}}_p)\frac{Z}{2} - \bar{p}_p \cdot \frac{Y}{2} = 0$$

$$\text{or,} \quad Z = \frac{\bar{p}_p Y - 2R_a}{\bar{p}_p + \bar{\bar{p}}_p}$$

$$\text{or,} \quad 85{\cdot}72 + (45{\cdot}33Y + 307{\cdot}19 + 45{\cdot}33Y)\frac{Z}{2} - 45{\cdot}33\frac{Y^2}{2} =$$

$$\text{or,} \quad 85{\cdot}72 + 90{\cdot}66\frac{YZ}{2} + 307{\cdot}19\frac{Z}{2} - 45{\cdot}33\frac{Y^2}{2} = 0 \qquad \text{— (1)}$$

<u>And</u>, Taking moment about bottom of sheet pile,

$\sum M = 0$

$$\therefore R_a(\bar{y} + Y) + \frac{Z}{3}(\bar{p}_p + \bar{\bar{p}}_p)\frac{Z}{2} - \bar{p}_p\left(\frac{Y}{2}\right)\left(\frac{Y}{3}\right) = 0$$

$$\text{or,} \quad 6R_a(Y + \bar{y}) + Z^2(\bar{p}_p + \bar{\bar{p}}_p) - \bar{p}_p Y^2 = 0$$

$$\text{or,} \quad 6 \times 85{\cdot}72(2{\cdot}523 + Y) + Z^2(45{\cdot}33Y + 307{\cdot}19 + 45{\cdot}33Y$$

$$- 45{\cdot}33Y^3 = 0$$

or, ~~514·32+~~ $1297{\cdot}63 + 514{\cdot}32Y + 307{\cdot}19Z^2$

$$+ 90{\cdot}66YZ^2 - 45{\cdot}33Y^3 = 0 \qquad \text{— (2)}$$

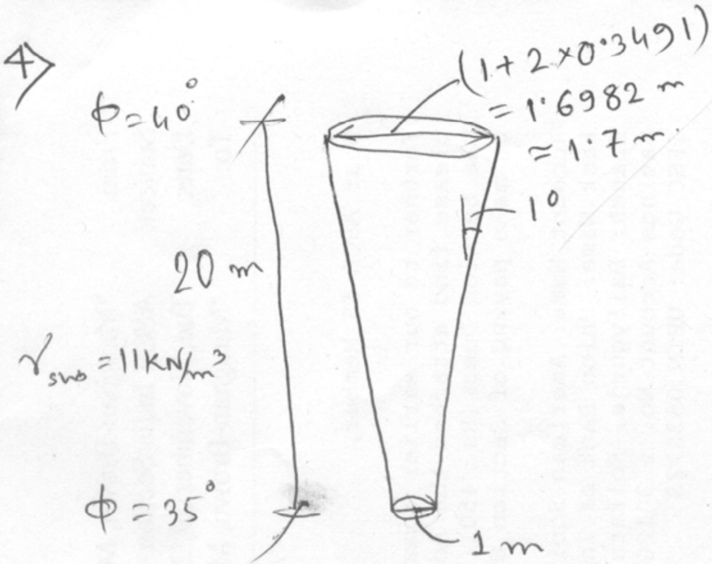
Solving $Y = 4{\cdot}668$ m

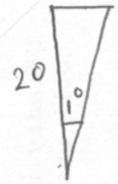
$\therefore Z = 1.12$ m

$\therefore$ Total depth of embedment $= 1.2\,(0.69 + 4.668)$

$= 6.43\ m$

4)





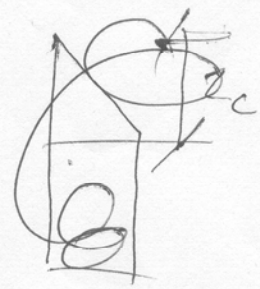
$\frac{x}{20} = \tan 1°$

$\therefore x = 0.3491$ m

Fig. 1 of IS:2911 – Part (sec 1) – 1979

for $\phi = 35°$, $N_q = 57$ (Reattin 2002)

$$Q_u = A_p (P_D \cdot N_q) + \sum_{i=1}^{n} K P_{Di} \tan\delta A_{si}$$



$\phi_{avg} = 37.5°$

$\therefore \beta = K_s \tan\delta = 1.6$ for $\phi_{avg} = 37.5°$

(From Meyerhof 1976 / Poulos 1980)

using β - method.

As per Poulos (1980),

For driven pile, $\phi = 0.75\phi_1 + 10°$

For design, $\phi_1 = \phi_{avg} = 37.5°$ (say)

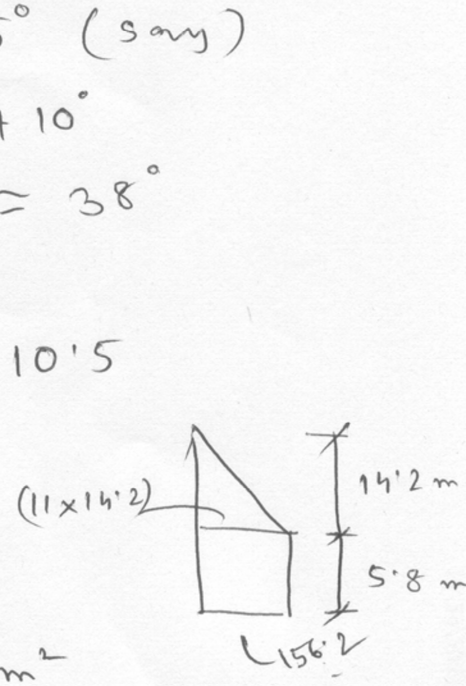
$\therefore \phi = 0.75(37.5) + 10°$

$= 38.125° \simeq 38°$

$\therefore \frac{L_c}{d} = 7 + 2.35(\phi - 36.5°)$

$= 7 + 2.35(38 - 36.5) = 10.5$

$d_{avg} = \frac{1.7 + 1}{2} = 1.35$ m.



$\therefore L_c = 14.175 \simeq 14.2$ m.

$\therefore P_D = (11 \times 14.2) = 156.2$ kN/m²

$\therefore \quad Q_{tip} = \frac{\pi}{4}(1)^2 \times 156.2 \times 57$

$= 6992.7 \text{ KN}$

Now, ~~P_{Di}~~

$Q_f = \left(1.6 A_{si} \sum_{i=1}^{n} P_{Di}\right) F_w$ ← tapering correction factor (As per Nordlund, 1963).

For tapering $= 1^\circ$

& $\phi_{avg} = 37.5^\circ$

$F_w \simeq 4.2$

with $A_{si} = \pi(1) \times 20 \text{ m}^2$

$= 20\pi \text{ m}^2$

$\therefore \quad Q_f = 1.6 \times 20\pi \times 4.2 \sum_{i=1}^{n} P_{Di}$

$= 422.23 \sum_{i=1}^{n} P_{Di}$

$= 422.23 \left[\frac{(156.2 \times 5.8) + (\frac{1}{2} \times 14.2 \times 156.2)}{20}\right]$

$= 42539.25 \text{ KN}$

$\therefore \quad Q_{ult} = (6992.7 + 42539.25) \text{ KN}$

$= 49532 \text{ KN}$

As

5)

Load (tons)	5·0	10·0	20·0	30·0	40·0	50·0	60·0
Total (mm) Settlement	2·5	4·0	9·5	16·5	27·0	40·5	61·0
Net (mm) Settlement	0·5	1·25	3·75	8·0	14·0	21·0	31·0
Elastic (mm) Settlement	2·0	2·75	5·75	8·5	13·0	19·5	30·0

After plotting the above field test data for cyclic pile load test,

The allowable load on pile of 300 mm dia as per IS:2911 (Part IV) will be least of the followi

(i) $\frac{2}{3}$ x load corresponding to 12 mm total settlement

$= \frac{2}{3} \times 23 = 15.33$ tons.

(ii) 50% of the load corresponding to the total settlement 10% of pile diameter (i,e. 30 mm)

$= \frac{1}{2} \times 42 = 21$ tons.

(iii) $\frac{2}{3}$ x load corresponding to 6 mm net settlement $= \frac{2}{3} \times 25 = 16.67$ tons.

(iv) Structural capacity of pile in direct compression (Assuming M20 concrete was used)

$\sigma_{cc} = 5\ N/mm^2$ ∴ capacity $= 5 \times \frac{\pi}{4} (300)^2$ N

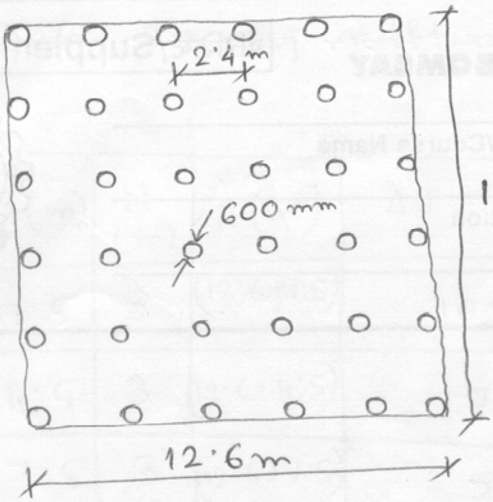
$= 353429.17$ N

$\simeq 35.343$ tons.

∴ Allowable load on the pile = 15·33 tons.

Ans

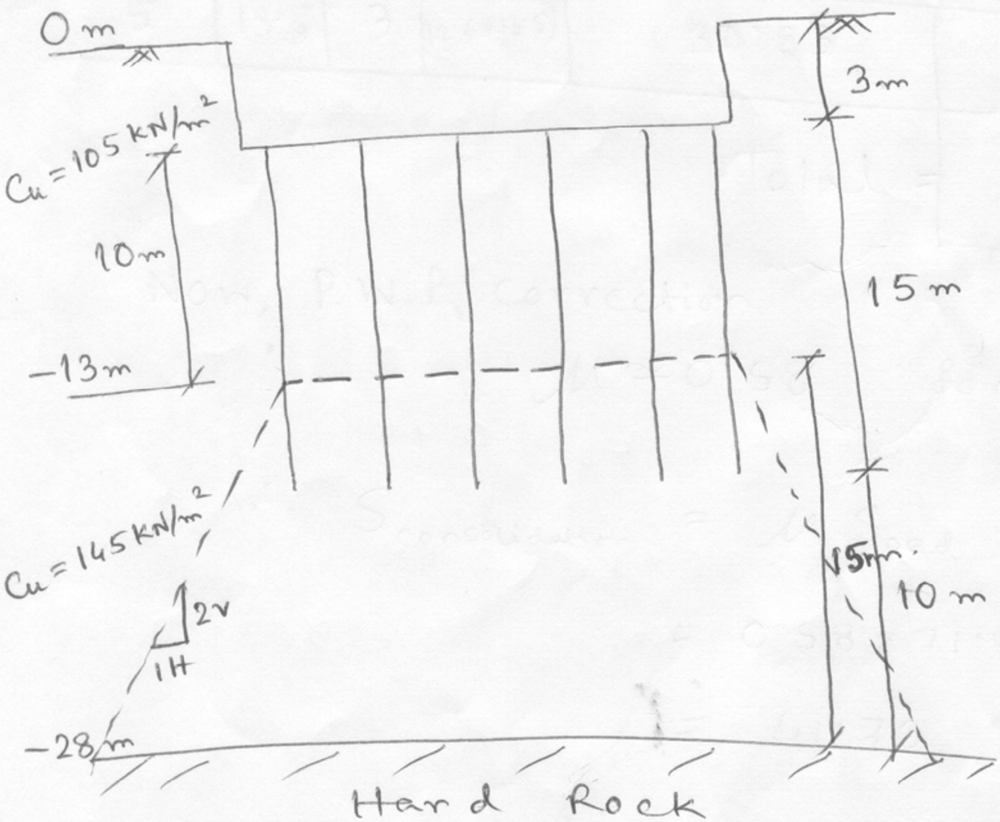
6)



$S = 2{\cdot}4\ m$

$d = 0{\cdot}6\ m$

$\therefore S = 4d > 3d$



Group efficiency $E_g = 1 - \theta \cdot \frac{(n-1)m + (m-1)n}{90\,mn}$

here, $\theta = \tan^{-1}\left(\frac{d}{s}\right) = \tan^{-1}\left(\frac{1}{4}\right) = 14{\cdot}036^{\circ}$

$n = m = 6$ $\quad \therefore E_g = 0{\cdot}74$

For single pile capacity

$q_b = cN_c = 145 \times 9 = 1305 \text{ KN/m}^2$

$f_s = \alpha Cu_{avg} = 0.4 \left[\frac{105 \times 10 + 145 \times 5}{15} \right] = 47.33 \text{ KN/m}^2$

$\therefore Q_{ult} = A_b q_b + A_s f_s$

$= \left\{ \frac{\pi}{4} (0.6)^2 \times 1305 \right\} + \left\{ \pi (0.6)\, 15 \times 47.33 \right\}$

$= 369 + 1338.2$

$= 1707.2 \text{ KN}$

For pile group capacity

$Q_{ult} = \left\{ (12.6)^2 \times 1305 \right\} + \left\{ 4 \times 12.6 \times 15 \times 47.33 \right\}$

$= 207181.8 + 35781.48$

$= 242963.28 \text{ KN}$

Now, group efficiency, $E_g = 0.74$

$\therefore Q_{ult_{group}} = 0.74 \times 36 \times 1707.2 \text{ KN}$

$= 45480 \text{ KN} < 242963.28 \text{ KN}$

$\therefore Q_{ult_{group}} = 45480 \text{ KN}$

& Given, working load $= 21000$ KN

$\therefore$ Factor of safety $= \frac{45480}{21000} = 2.166$

Ans (i)

Consolidation settlement of the group

Eq. load on eq. raft $= \frac{21000}{(12.6)^2} = 132.275 \ KN/m^2$

Layer	Z(m)	H (m)	A (m^2)	$\Delta\sigma = \frac{21000}{A}$ KN/m^2	$S_{oed} = m_v \Delta\sigma H \times 1000$ (mm)
1	1.5	3	$(12.6+1.5)^2$	105.63	$8\times10^{-5} \times 105.63 \times 3000$ = 25.35
2	4.5	3	$(12.6+4.5)^2$	71.82	17.24
3	7.5	3	$(12.6+7.5)^2$	51.98	12.47
4	10.5	3	$(12.6+10.5)^2$	39.35	9.44
5	13.5	3	$(12.6+13.5)^2$	30.83	7.40
				Total =	71.90

Now, P.W.P. correction

$\mu \simeq 0.58$ for $\frac{H}{B} = \frac{15}{12.6}$

$\therefore S_{consolidation} = \mu S_{oed}$

$= 0.58 \times 71.90$

$= 41.70 < 75$ mm

$\therefore$ O.K.

Ans