3) Field Method :

a) Pile Load Test :

→ This method is suitable for dense sand because in clays there is case of remoulding whereas in loose saturated sand liquefaction may occur.

→ The load on test pile is applied through jacking mechanism & settlement of pile is recorded.

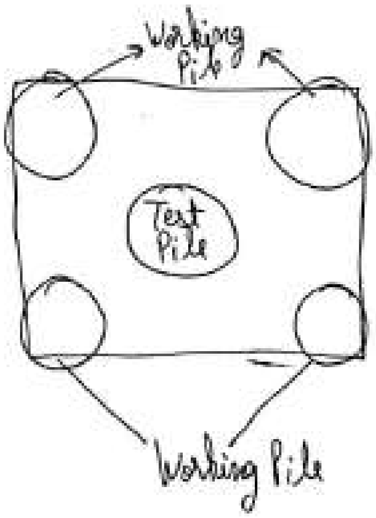
→ It is most reliable insitu test on piles

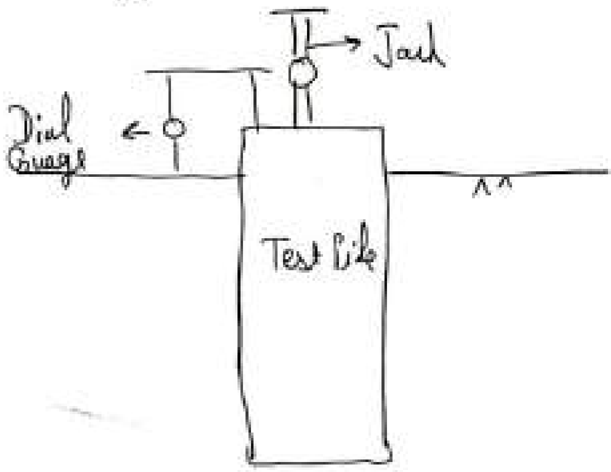
→ Load on test pile is applied through jacking ~~mech~~ mechanism & settlement of pile is recorded.

→ Load settlement curve is plotted in which shear failure is represented by progressive settlement or by sudden settlement at faster rate.

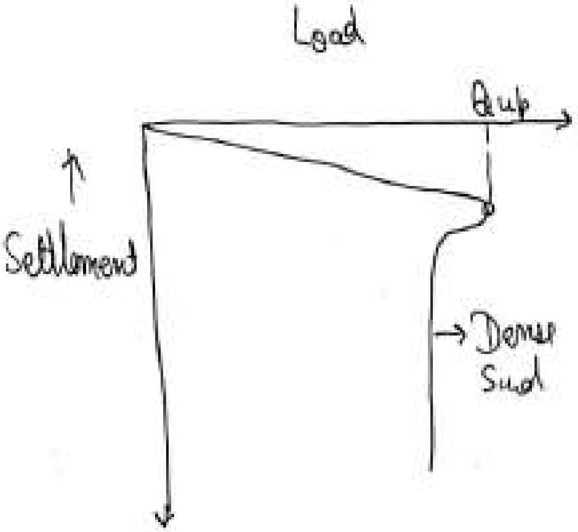
→ Test pile is a pile which is especially bored for the purpose of conducting test & will not be the part of foundation in future.

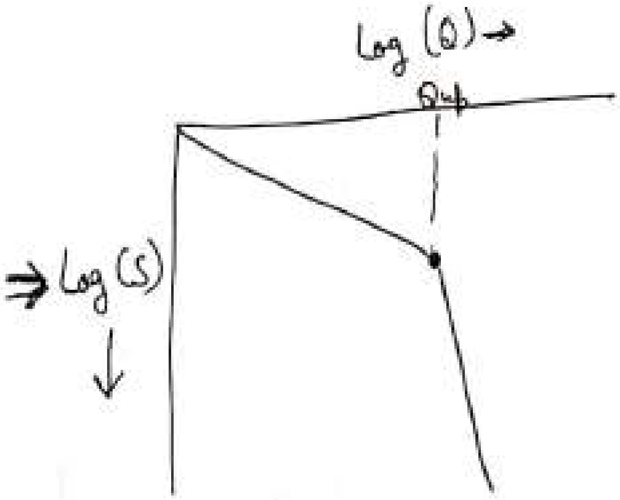
→ While working pile is a pile which is a part of foundation and is being used for the purpose of testing at present.





→ This test is conducted for rest period of 3 day after the installation in sandy soil.





$$Q_{safe} = \frac{Q_{up}}{F.O.S} \quad \left[\text{Generally } F.O.S = 2.5 \text{ to } 3\right]$$

- → Most Accurate Method & recommended by IS Code
- → The loaded pile in this method becomes waste, hence it is called destructive test.

Imp IS Code Guidelines: (For allowable load on single Pile)

1) The allowable load on pile may be taken as 50% of Ultimate load at which total settlement of pile is 10% of its diameter.

(or)

2) The allowable load on pile may be taken as 2/3 rd of ultimate load at which total settlement is 12 mm

(or)

3) Allowable load on pile may be taken as 2/3 rd of ultimate load at which net plastic settlement is 6 mm.

b) <u>Cyclic load</u>: It is carried out to determine the skin friction & end bearing ~~tak~~ seperately for a pile load. It is generally an initial test.

c) <u>Standard Penetration Test</u>:

Let 'N' is SPT number at the base of Pile.

$\bar{N}$ = Average SPT numbers along the side of pile.

As per Meyerhoff, Ultimate bearing capacity for driven / displacement pile is given as:

$$Q_{up} = q_b A_b + q_s A_s$$

$$\boxed{Q_{up} = 400 N A_b + 2\bar{N} A_s}$$ in kN (where A_b & A_s are in m^2)

For Non-displacement Pile (H-Piles):

$$Q_{up} = Q_{eb} + \frac{Q_{sf}}{2}$$

$$\boxed{Q_{up} = 400 N A_b + \bar{N} A_s}$$

For Bored Pile:

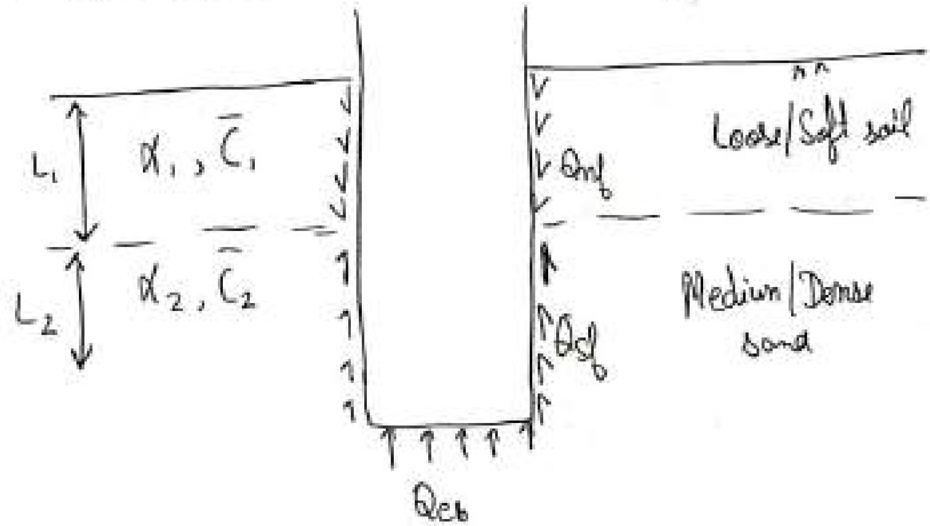
$$(Q_{up})_{Bored} = \frac{1}{3}(Q_{up})_{driven}$$

$$\boxed{Q_{up} = \frac{1}{3}(400 N A_b + 2\bar{N} A_s)}$$

→ In case of boring or displacement piles are found, as due to boring the adjoining soils get displaced or disturbed

Negative Skin Friction:

- → It is the phenomenon in which soil surrounding to the piles settles more than the settlement of pile.
- → It is usually a downward shear drag action on a pile due to downward sinking of surrounding soil relative to piles.
- → This condition occurs when a pile penetrates a compressible soil stratum that can consolidate.
- → The Capacity of pile is unaffected by down drag, it does serve to increase the stress & increase settlement in the pile.
- → This cond. occurs when surrounding soil is loose/soft.



Q_{nf} → negative skin friction

Ultimate load carrying Capacity:

$$Q_{up} = Q_{eb} + Q_{sf} - Q_{nf}$$

For Clay: $Q_{nf} = \alpha_1 \bar{C}_1 (\pi d L_1)$

For Sand: $Q_{nf} = \frac{1}{2} K \gamma L_1 \tan\delta (\pi d L_1)$

Q_{sf} → skin friction
Q_{nf} → negative skin friction
α → adhesion factor b/w soil & pile
C → Cohesion

Revise:

For sand: q_s

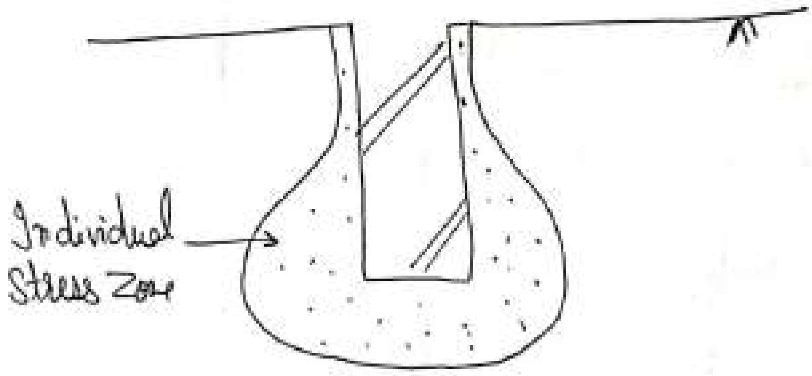
$q_s = \frac{1}{2} k \gamma L \tan\delta \, A_s$

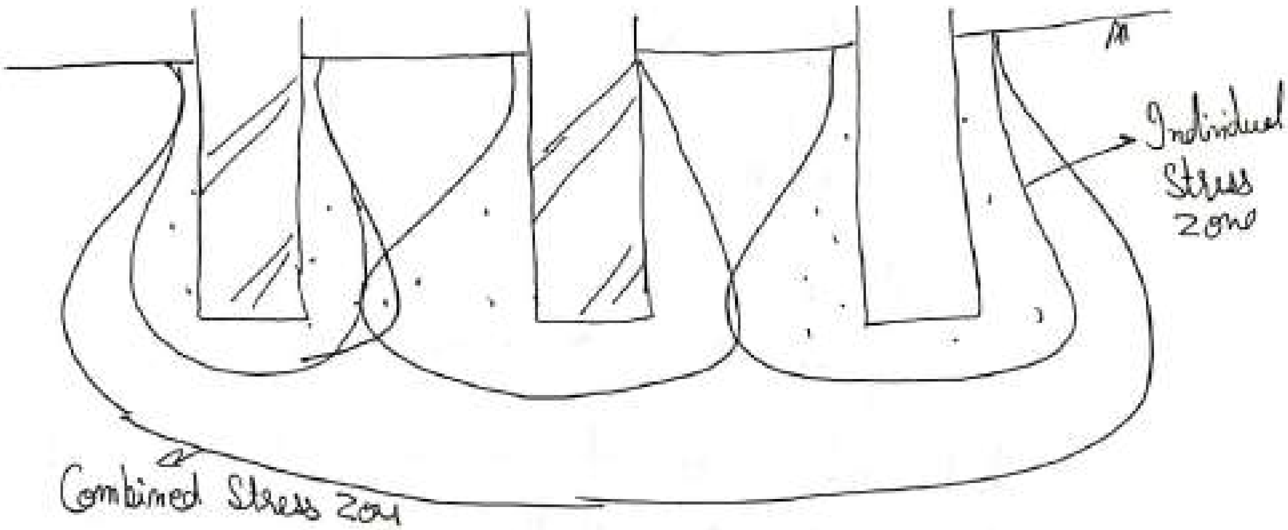
For Clay

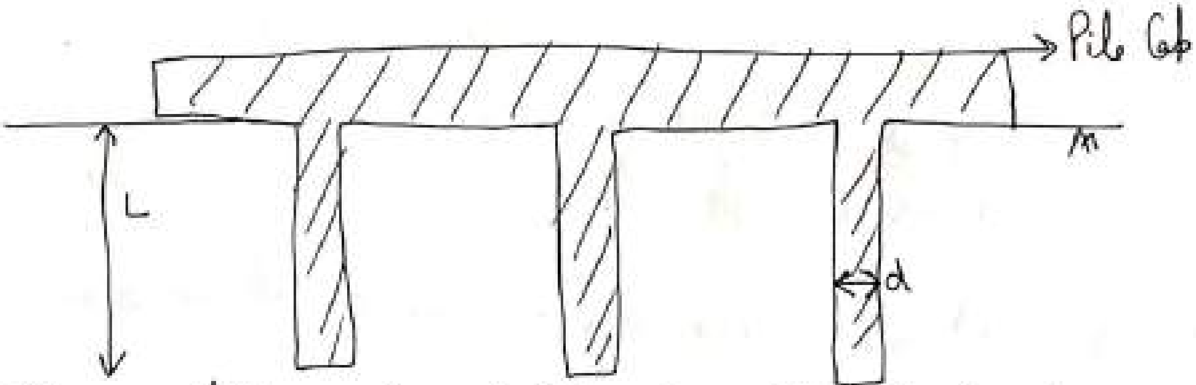
$q_s = \alpha \bar{C} (A_s)$

Group Action of Piles:

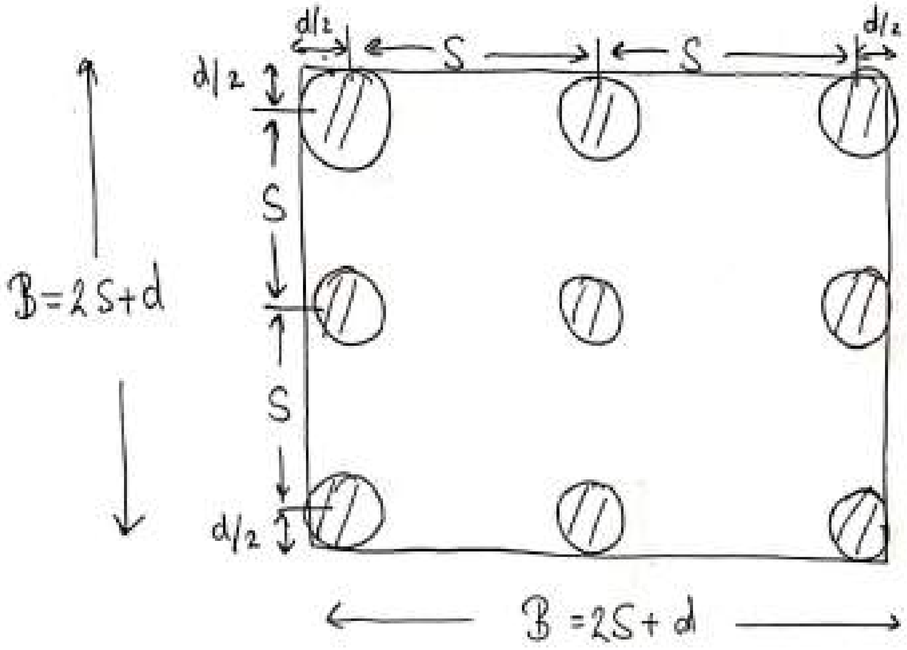
→ The pile spacing mainly controls the behaviour of pile groups. The spacing should not be too small so that the upheaval of ground surface takes place during driving into dense or in-compressible material.







Pile Cap is a thick concrete mat that rests on piles that have been driven into soft or unstable ground to provide stable foundation.



S = Spacing b/w piles
d = diameter of pile

Size of Pile group:

$2 \times 2 \Rightarrow B = S + d$

$3 \times 3 \Rightarrow B = 2S + d$

$4 \times 4 \Rightarrow B = 3S + d$

$5 \times 5 \Rightarrow B = 4S + d$

$m \times m \Rightarrow B = (m-1)S + d$

$A_b = B^2 \Rightarrow$ Base area

$A_s = 4BL \Rightarrow$ Surface area

→ If applied load is large and more no. of piles are used; either piles will act individually or in group depending upon spacing b/w piles.

→ If Centre to centre C/C spacing is (2.5 d to 4d), then soil may get compacted b/w piles and entire wedge of size (B×B) may act as a single pile. Such an action is called group action.

→ In group action, base area & surface area both increases.

→ In group action, the depth of stress zone extends to great depth than in individual action. Therefore settlement due to consolidation in group action will always be grater than the settlement in individual action.

→ Minimum number of piles required for group action is three (3).

→ The pile group may be square, rectangular, traingular, polygonal or ~~circle~~ circular.

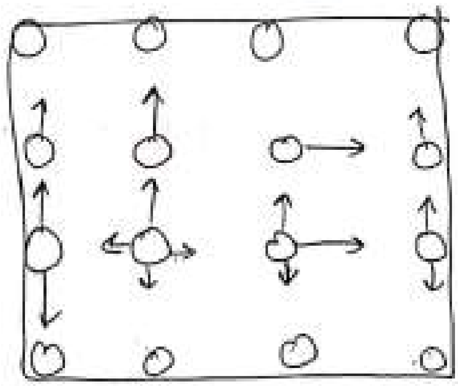
⇒ Minimum spacing b/w piles according to I.S Code:

For loose sand or back filled soil = 2 X Diameter
For end bearing piles = 2.5 X Diameter
For Friction Piles = 3 X Diameter

→ If spacing is governed as mentioned above then usually load carrying capacity of pile group (Q_{ug}) is greater than sum of load carrying capacity of all the piles ($n \cdot Q_{up}$); in case of Sand

→ However in case of clay, it depends upon properties of soil and spacing.

→ When the piles are driven, pile driving mechanism should start from centre pile and centre pile should be driven Ist & proceed radially outwards.
In this process, resistance in pile driving is less hence cheaper.



⇒ **Determination of ultimate load carrying capacity of pile group:**

For pile group $\boxed{\alpha = 1}$

$$Q_{ug} = Q_{eb} + Q_{sf}$$
$$= q_b A_b + q_s A_s$$

$$\left\{ \begin{array}{l} A_b = B^2 \\ A_s = 4BL \end{array} \right\}$$

For Clay:

$$\boxed{Q_{ug} = 9c(B^2) + \bar{C}(4BL)}$$

For Sand:

$$\boxed{Q_{ug} = \gamma L N_q (B)^2 + \frac{1}{2} K \gamma L \tan\delta \cdot (4BL)}$$

$\delta \rightarrow$ friction angle

Allowable load or safe load on Pile group:

Safe load will be minimum of following two:

$$Q_{safe} \rightarrow \left. \begin{array}{l} \dfrac{Q_{ug}}{F.O.S} \\[2ex] \dfrac{n\,Q_{up}}{F.O.S} \end{array} \right\} \text{min. of two}$$

n = no. of pile in group

F = F.O.S (2.5 to 3)

$Q_{up} \rightarrow$ Individual pile load capacity.

⇒ **Group efficiency (η_g):**

It is defined as the ratio of ultimate load carrying capacity of pile group to the ultimate load carrying capacity of all the piles under individual action.

$$\boxed{\eta_g = \frac{Q_{ug}}{n \cdot Q_{up}}}$$

if $\eta_g > 1$; then $Q_{safe} = \frac{n \cdot Q_{up}}{F.O.S}$

For design, η_g should be ≥ 1

⇒ **Group settlement Relation:**

It is defined as the ratio of settlement of pile group to the settlement of individual pile.

$$\boxed{G.S.R = \frac{S_g}{S_i}}$$ {Always greater than 1}

It is always greater than 1 and may be as high as 16.

Converse Labarre pile group efficiency:

$$\eta_g = 1 - \frac{\theta}{90}\left[\frac{(n-1)m + (m-1)n}{mn}\right]$$

$$\tan\theta = \frac{d}{s}$$

d = diameter of pile

s = Centre to centre spacing

m = no. of rows

n = no. of pile in a row

Settlement of pile groups:

As the zone of influence of pile group is generally more than the individual pile so settlement of pile group is generally greater than the settlement of individual pile to same loading.

Settlement of pile group in Clays:

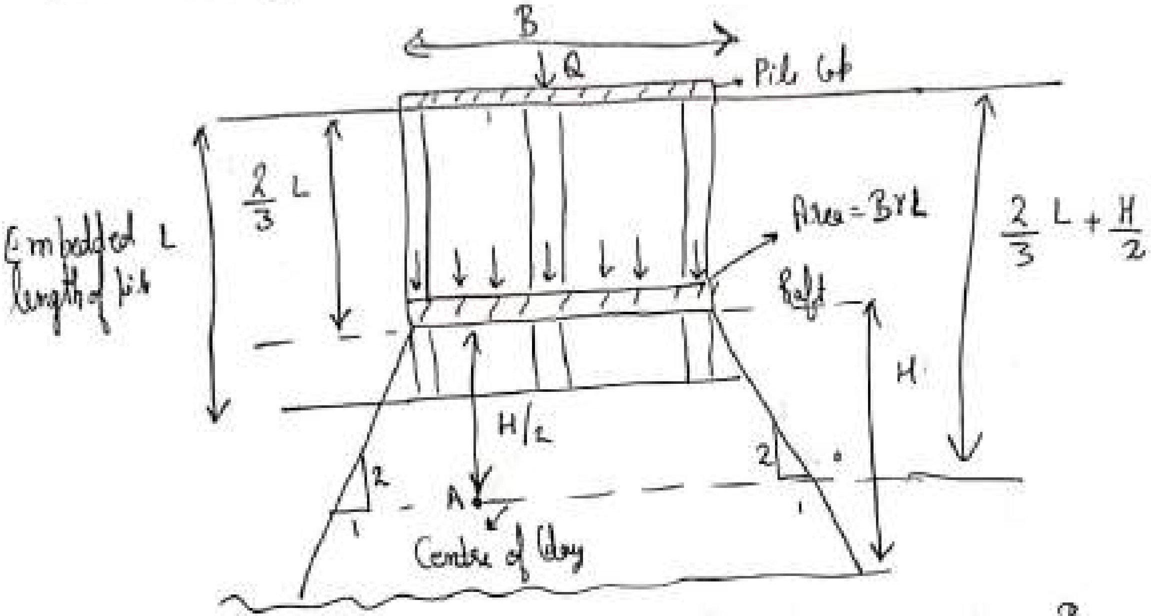
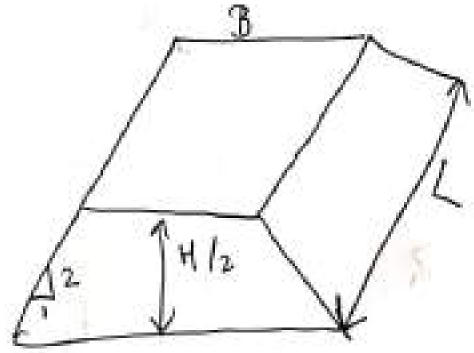


Fig1



Case1: When pile is embedded in Uniform Clay deposit:

Equivalent raft is assumed at depth of 2/3 L from top, where L is embedded length of pile and loading on pile cap is (Q). (Fig1)
Calculation of settlement is done in a similar manner as done in consolidation settlement.

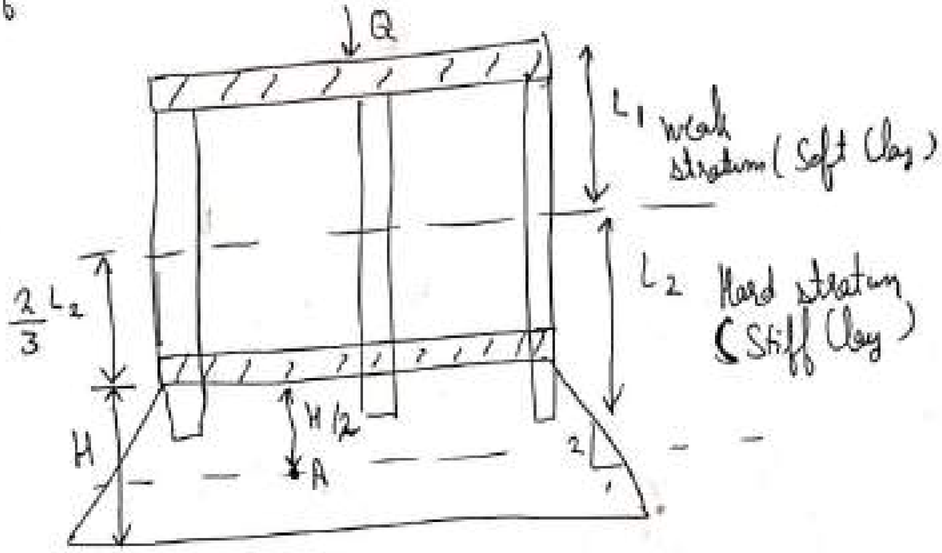
$$\Delta H = \frac{C_c}{1+e_0} \log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right) \cdot H$$

$\gamma \rightarrow$ may be submerged or bulk acdg. to cond. given

$$\bar{\sigma}_0 = \left(\frac{2}{3}L + \frac{H}{2}\right)\gamma \qquad \Delta\bar{\sigma} = \frac{Q}{\left(B+\frac{H}{2}\right)^2}$$

Case 2: Pile are driven into a strong stratum through a layer of weak stratum

In this case equivalent raft is located at a depth of $2/3 L_2$ below the top level of strong stratum where L_2 is the depth of embedded pile in strong stratum.



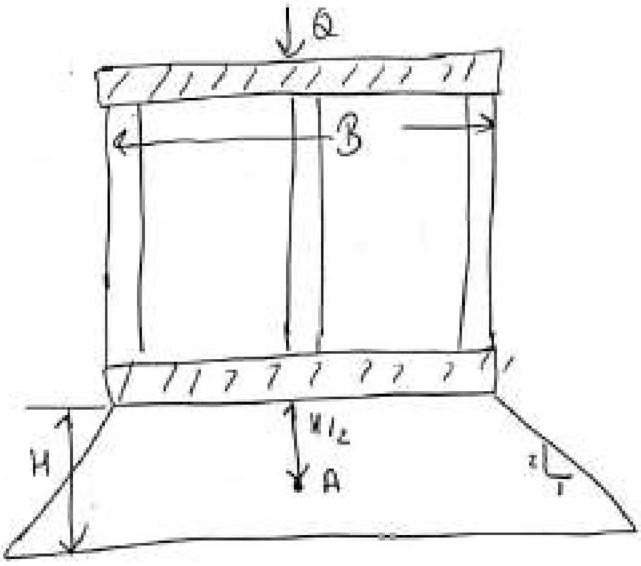
$$\Delta H = \frac{C_c}{1+e_0} H \log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$

where $\bar{\sigma}_0$ is measured at pt. A (mid depth of H)

Case 3: In case of end bearing pile resting on strong stratum and in Bored pile:

In this case equivalent raft is considered at tip of pile.
Here H is measured from the bottom of pile to the bottom hard strata.

$$\Delta H = \frac{C_c}{1+e_0} H \log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$



Settlement of pile group of in Sand :

$$\text{Group settlement Ratio} = \frac{S_g}{S_i} = \left(\frac{4B + 2.7}{B + 3.6}\right)^2$$

S_g = Group settlement at same load of pile group
B = Size of pile group in metre
S_i = Settlement of individual pile calculated from pile load test

Q. A concrete pile, 40 cm diameter is driven 25 m into a soft clay ($C_u = 25\, kN/m^2$, $\gamma = 19\, kN/m^2$). Determine the allowable load. F.O.S = 2.25, $\lambda = 0.16$. Water Table is at Ground Surface.

⇒ For $L \geq 25$ — $\bar{\sigma}_v$ = Mean eff. stress

$$q_s = \lambda(\bar{\sigma}_v + 2\bar{C})$$

$$= 0.16\left(\frac{1}{2} \times 25 \times \underset{\gamma - \gamma_w}{(19-10)} + 2 \times 25\right)$$

$$= 26\, kN/m^2$$

$$Q_{up} = 9C A_b + q_s A_s$$

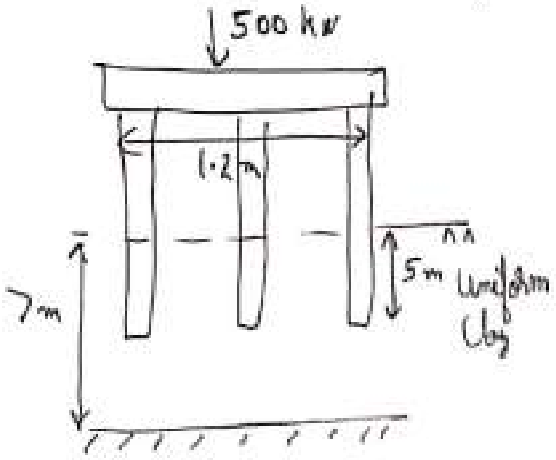
$$= 9 \times 25 \times \frac{\pi}{4}(0.4)^2 + 26 \times \underset{\pi D L}{(\pi \times 0.4) \times 25}$$

$$= 28.3 + 817.4$$

$$Q_{up} = 844.7\, kN$$

$$Q_{safe} = 844.7/2.25 = 375.42\, kN$$

Q. Calculate settlement of pile group for the cond. shown below. (13)



$\gamma_w = 10 \, kN/m^3$; $\gamma_{sat} = 20 \, kN/m^3$

$w_p = 25.25\%$, $e = 1.05$,

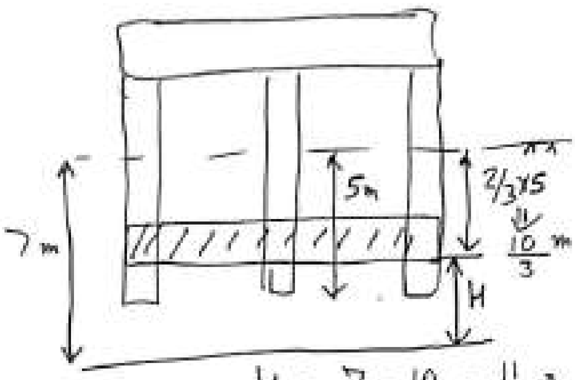
$w_L = 40\%$

The soil is submerged soil.

$\Rightarrow$ $C_c = 0.009(w_L - 10)$

$= 0.009(40 - 10)$

$C_c = 0.27$



$H = 7 - \frac{10}{3} = \frac{11}{3}$ m

$$\Delta H = \frac{C_c H}{1+e_0} \log\left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$$

$$\bar{\sigma}_0 = \gamma_{sub}\left(\frac{2}{3}L + \frac{H}{2}\right)$$

$$= (20-10)\left(\frac{10}{3} + \frac{11}{3} \times \frac{1}{2}\right)$$

$$\bar{\sigma}_0 = 51.6 \, kN/m^2$$

$$\Delta\bar{\sigma}_0 = \frac{Q}{\left(B + \frac{H}{2}\right)^2} = \frac{500}{\left(1.2 + \frac{11}{6}\right)^2} = 54.34 \, kN/m^2$$

$$\Delta H = \frac{0.27}{1+1.05} \times \frac{11}{3} \log\left(\frac{54.34 + 51.6}{51.6}\right) \times 10^3 \, mm$$

$$\Delta H = 150.78 \, mm$$