Module-III

Deep foundation :—

If Df > B, we called it is deep foundation.
Deep foundation basing on the mechanism from which the foundation gets its bearing capacity.
Shape & material.

Types of deep foundation :—

There are 3 types :
Pile foundation
Pier foundation
Well foundation

Pile foundation :—

Piles are long & slender members that are driven into ground or cast in situ in the above hole.
They are used in multistorage building & bridges in a group.

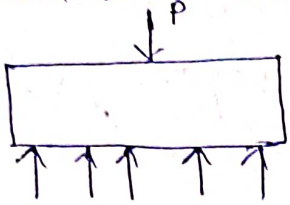
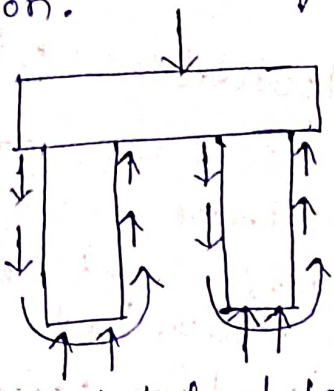
Types of pile foundation :—

Basing on different criteria piles are classified as follows :

Basing on function or load transfer piles :—
(i) Friction Pile
(ii) End bearing pile
(iii) friction + end bearing pile

Basing on construction or installation :—
(i) Pre- cast pile
(ii) Cast-in situ
(a) Bored pile
(b) Driven pile

Difference between Deep & Shallow foundation :—

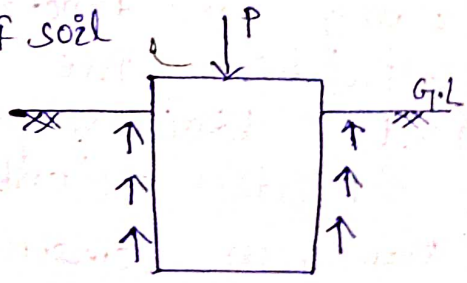
Shallow Foundation	Deep Foundation
1// $D_f \leq B$ Where, D_f = Depth of foundation B = Width of foundation.	1// $D_f > B$
2// Vertical compressive load by bearing capacity q_f of foundation soil. 	2// Vertical compressive load by bearing capacity & skin friction. 
3// Horizontal load by friction develop at the soil foundation interface.	3// Horizontal load by lateral earth pressure develop at the soil foundation interface.
4// Moments by redistribution of bearing pressure.	4// By converting them to axial compaction & uplift pressure.

(i) Friction pile :—

→ The friction pile transfer the entire load 'P' to the surrounding soil. The surrounding soil supports the load due to the skin friction develop between the soil & pile surface.

→ Unit skin friction $= \frac{\text{Skin friction}}{\text{Unit area of pile surface}}$

$=$ Shear strength of soil



→ Unit skin friction is denoted as 'r_f'.

→ Load taken by friction pile

$= \pi d L r_f$

$$\boxed{r_f = \alpha \cdot C_u}$$

→ Frictional Piles are used to transfer loads to the soil surrounding pile length.

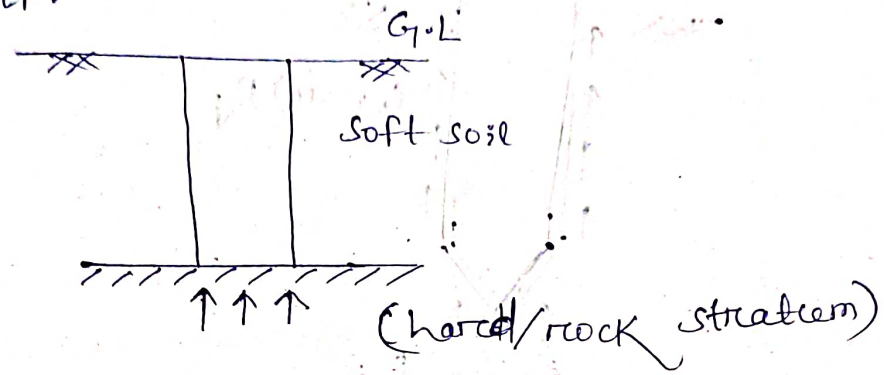
→ The ultimate load bearing capacity

$$\boxed{Q_{up} = A_s \times r_f}$$

where,
As = Surface area of pile
α = Adhesion factor

(ii) End bearing Pile :—

- End bearing piles are used to transfer load through pile based to a hard stratum of soil surface through soft soil.
- The hard stratum support the load by its bearing capacity q_f.



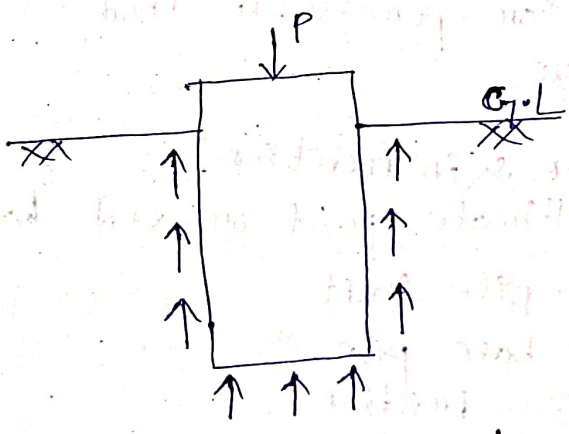
- The ultimate bearing capacity,

$$Q_{up} = A_p \times r_p$$

where,
A_p = Area of base pile
r_p = Unit end bearing i.e. load carried by unit base area of Qs.

(iii) Combination of friction pile & end bearing pile :—

Generally a pile behaves as a friction pile & end bearing pile.



Classification based on construction :—

) Precast Piles are made up steel RCC :—

) Compaction Pile :—

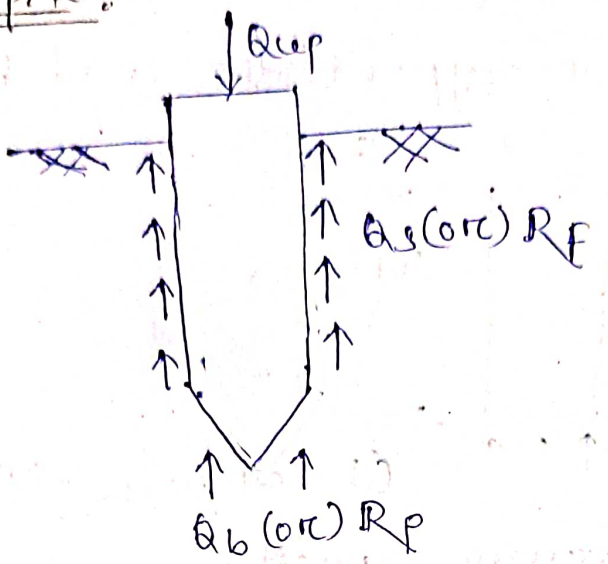
Compaction piles are used to compact loose granular soil. Thus increasing their bearing capacity. The pile tube driven to compact the soil is gradually taken out & sand is filled in its place. Thus forming

a load pile.

(ii) Tension or Uplift pile :—

Tension piles anchor down the structure subjected to uplift due to hydrostatic pressure or due to overturning moment.

Design of pile :—



$$Q_{up} = Q_s + Q_b$$

$$Q_{up} = R_f + R_p$$
$$= A_s \cdot \tau_f + A_p \tau_p$$
$$= (\pi d L)\tau_f + A_p \cdot \tau_p$$

$$Q_{up} = (\pi d L)\alpha \cdot C_u + \left(\frac{\pi}{4} d^2\right) \times (N_c \cdot C_p)$$

($\alpha = m$)
$C_u = C = \bar{C} = C_p$

For pile foundation
$N_c = 9$

Allowable load 'or' permissible load

$$= \frac{Q_{up}}{F}$$

R_f = Ultimate skin friction.
R_p = Total ultimate point or end bearing resistance.
A_s = Area of pile shaft.
A_p = Area of base pile.
τ_f = Unit skin friction.
τ_p = Unit end bearing.
L 'or' L_f = Depth of fill or soil which is moving vertically.
$C = C_u = \bar{C}$ = Unit cohesion $= \frac{q_u}{2}$
$N_c = 9$, for deep foundation

For Cohesive Soil :—

$Q_{up} = A_s \cdot \eta_f + A_p \eta_p$

$Q_{up} = (\pi d L)\eta_f + \frac{\pi}{4} d^2 \times (N_c \cdot c_p)$

Ultimate bearing capacity of pile acting individually,

$Q_{ug} = n \cdot Q_{up}$

$\Rightarrow Q_{ug} = Q_{up} \quad (n = 1)$

Ultimate bearing capacity of pile acting as a group,

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

where,

η_g = Efficiency of group pile

A group of 9 piles with 3 piles in a row was driven into soft clay extending from ground level to a great depth. The diameter & length of piles were 30 cm & 10 m respectively. The unit cohesion is 70 KN/m2. If the piles were spaced at 90cm c/c. Compute the allowable load on the pile group on the basis of shear failure criteria for a F.O.S of 2.5. Neglect bearing at the tip of pile. Take $m = 0.6$ for shear mobilization around its soil.

Given data :—

$n = 9$

$d = 30\,cm$

$L = 10\,m$

Cohesive soil

C (or) C_u (or) $\bar{C} = 70\ KN/m^2$

$S = 90\,cm$

F.O.S = 2.5

Adhesion factor m (or) $\alpha = 0.6$

Width of foundation

$B = 2S + d$

$= 2 \times 90 + 30$

$= 210\,cm$

Piles acting individually

$Q_{ug} = Q_{up} = n \cdot Q_{up}$

$= 9 \times [R_f + R_p]$

$= 9 \times [A_s \, r_f + A_p r_p]$ ($r_p = 0$)

$= 9 \times [A_s \cdot r_f]$

$= 9 \times [\pi d L \times \alpha \times c_u]$

$= 9 \times [\pi \times 30 \times 10 \times 0.6 \times 70]$

$= 3562.57 \text{ KN}$ ——— (3)

Pile acting as a group ($r_p = 0$)

$Q_{ug} = A_s r_f + A_p r_p$

$= 4BL \times r_f$

$= 4BL \times \alpha \times c_u$

$= 4 \times 2.10 \times 10 \times 1 \times 70$

$= 5880 \text{ KN}$ ——— (ii)

★ **Note:—**
For grouping action the adhesion factor = $\alpha = 1$

Lesser of (i) & (ii)
i.e., 3562.57 KN
Allowable load or safe load

$Q_a \text{ (or) } Q_s = \frac{3562.57}{FOS} = \frac{3562.57}{2.5}$

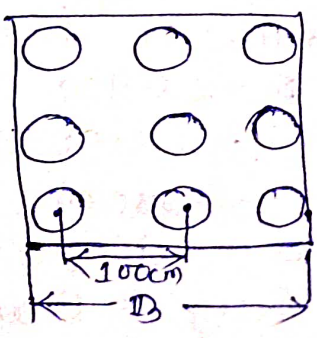
$= 1425.028 \text{ KN}$

Ans

Q A square group of 9 piles are driven into soft clay extending to a large depth, the diameter & length of the piles were 30 cm & 9 m respectively. If the unconfined compression strength of clay is 9 ton/m² & the pile spacing is 100 cm c/c. What is the capacity of the group. Assume F.O.S of 2.5, Adhesion factor = 0.75.

Sol) Given data:—

$n = 9$
clay
$d = 30 \text{ cm}$
$l = 9 \text{ m}$
$q_u = 9 \text{ ton/m}^2$



S = 100 cm

F.O.S = 2.5

Adhesion factor, $\alpha = 0.75$

width of foundation

$B = 2S + d$

$= 2 \times 100 + 30 = 230 \text{ cm} = 2.3 \text{ m}$

$C_u = \frac{q_{ult}}{2} = \frac{9}{2} = 4.5 \text{ t/m}^2$

Pile taken as individually,

$Q_{ug} = Q_{cun} = n \times Q_{up} = 9 \times [R_f + R_p]$

$= 9 \times [A_s \cdot r_f + A_p \cdot r_p]$

$= 9 \times [(\pi d L) \times (\alpha \times C_u) + \frac{\pi}{4} \times d^2 \times C \cdot N_c]$

$= 9 \times [\pi \times 0.3 \times 9 \times 0.75 \times 4.5 + \frac{\pi}{4} \times 0.3^2 \times 4.5 \times 9]$

$= 283.4 \text{ t}$

Pile acting as group

$Q_{ug} = \{A_g \cdot r_f + A_{pg} \cdot r_p\}$

$= 4BL \cdot C + B^2 \times N_c \cdot C$

$= 4 \times 2.3 \times 9 \times 4.5 + (2.3)^2 \times 9 \times 4.5$

$= 586.8 \text{ t}$

Safe load,

$Q_s = \frac{283.4}{F.O.S} = \frac{283.4}{2.5} = 113.36 \text{ tone}$ Ans

In a 16 piles group the pile diameter is 45 cm & c/c spacing of the square group is 1.5m is $C = 50 \text{ KN/m}^2$. Determine the wheather the failure would occur width the pile acting individually or a group neglect the end bearing at the deep of the pile all piles are 10m long. Take $m = 0.7$ for shear mobilisation around the each pile.

Given data:-

$n = 16$

$C = 50 \text{ KN/m}^2$

$S = 1.5 \text{ m}$

α (or) $m = 0.7$

$d = 45 \text{ cm} = 0.45 \text{ m}$

$L = 10 \text{ m}$

Width of foundation,

$B = 2s + d$

$= 3 \times 1.5 + 0.45 = 4.95\ m$

Pile taken as individually,

$Q_{ug} = Q_{un} = n \times Q_{up}$

$= 16\,[A_s \cdot r_f + \cancel{A_p \cdot r_p}^{\,0}]$

$= 16\,[\pi d L \times \alpha \times C_u]$

$= 16\,[\pi \times 0.45 \times 10 \times 0.7 \times 5]$

$= 7916.81\ KN$ ——— (i)

Pile acting as group,

$Q_{ug} = [A_g \cdot r_f + \cancel{A_{pg} \cdot r_p}^{\,0}]$

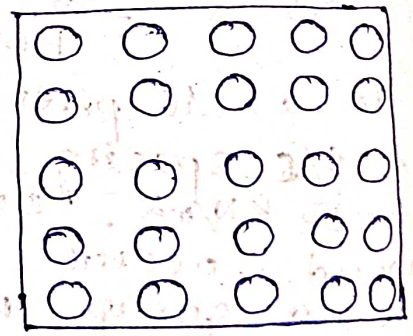
$= 4BL \times C$

$= 4 \times 4.95 \times 10 \times 50 = 9900\ KN$ ——— (ii)

From eq^n (i) & eq^n (ii) the allowable load bearing capacity is 7916.81 KN

Ans

Q An end pile group has to be proportion in uniform pattern in soap clay with equal spacing in all direction, Assuming any value of C. Determine the optimum value of spacing of piles in the group. Take $n = 25$, $m = 0.7$ neglect the end bearing effect assume that each pile is circular in section.



Sol^n:-

Let us consider the length of the pile is $-N$.

C/c spacing of each pile $= S$

Dia. of the pile $= d$

Width of each pile $= b = 4s \times d$

Pile acting load carried by pile acting individually.

$Q_{un} = n \times Q_{up}$

$= n\,[A_s \cdot r_f + \cancel{A_p \cdot r_p}^{\,0}]$

$= 25\,[\pi d L \times \alpha \times C_u]$

$= 25\,[\pi \times d \times L \times 0.7 \times C_u]$

$= 55 L d C$ ——— (i)

Pile acting load carried by group action,

$$Q_{ug} = Q_{up} = [A_g \cdot r_f + A_{pg} \cdot \cancel{r_p}^{0}]$$

$$= 4BL \times C$$

$$= 4 \times (4S+d) L \times C$$

$$= 4\, CL\, (4S+d) \quad \text{———— (ii)}$$

Equating eqn (i) & (ii)

$$55\, \cancel{L} d \cancel{C} = 4 \cancel{C} \cancel{L} (4S+d)$$

$$\Rightarrow 55d = 4(4S+d)$$

$$\Rightarrow 55d = 16S + 4d$$

$$\Rightarrow 51d = 16S$$

$$\Rightarrow S = \frac{51d}{16}$$

$$\Rightarrow S = 3.18\, d$$

Spacing should be 3.18 times the dia of the piles.

Ans

Types of formula for calculating allowable load :—

1) Static formula
2) Dynamic formula

Dynamic formula :—

- This formula are best suited for coarse grain soil.
- Dynamic formula is applicable pre-cast pile where which are driven to ground by hammering.

Engineering News Formula :—

$$\boxed{Q_a = \frac{WH}{F(S+C)}}$$

Where,

Q_a = Allowable load.

H = Height of fall in cm.

F = factor of safety = 6,

S = Penetration per blow in cm.

C = Empirical constant.

W = Weight of hammer in Kg.

C = 2.5 for drop hammer & 0.25 for single & double acting steam hammer.

Q A wooden pile is being driven with a drop hammer weighing 20 KN & having a free fall of 1 m. The penetration in the last blow is 5 mm. Determine the load carrying capacity of pile according to Engg. news formula.

Sol^n Given data:—

Drop hammer

F.O.S = 6

C = 2.5

W = 20 KN

S = 5 mm = 0.5 cm

H = 1 m = 100 cm

By Engg. news formula,

$$Q = \frac{WH}{F(S+C)} = \frac{20 \times 100}{6 \times (0.5+2.5)} = 111.1 \text{ KN}$$

Ans

(2) Hilley's formula:—

→ I.S code formula

→ Allowable load

$$Q_f = \frac{\eta_h \cdot WH \cdot \eta_b}{S + C/2}$$

where,

Q_f is known as ultimate load on pile,

η_h = Efficiency of hammer.

η_b = Efficiency of hammer blow.

W = Weight of hammer in Kg.

H = Height of drop hammer in cm.

S = Penetration per blow in cm.

C = Total elastic compression.

$$\eta_h = \frac{W + e^2 P}{W+P} - \left\{\frac{W - e \cdot P}{W+P}\right\}^2$$

when $W < e \cdot P$

$$\eta_b = \frac{W + e^2 P}{W+P}$$

when, $W > e \cdot P$

e = Co-efficient of restitution.

A reinforced concrete pile weighing 30 KN (inclusive of helmet & dolly) is driven by a drop hammer weighing 40 KN & having an effective fall of 0.8 m. the average set for blow is 1.4 m, the total temporary elastic compression is 1.8 cm. Assuming the co-efficient of restitution 0.25 & F.O.S of 2. Determine the ultimate bearing capacity & allowable load for pile.

Given data :—

$W = 40$ KN

$P = 30$ KN

$L = 1.8$ m

F.O.S = 2

$e = 0.25$

$S = 1.4$ m

$\eta_h \cdot H = 0.8$ m $= 80$ cm

$e \cdot P = 0.25 \times 30 = 0.75$ $\quad W > e \cdot P$

$$\eta_h = \frac{W + e^2 P}{W + P}$$

$$= \frac{40 + (0.25)^2 \times 30}{40 + 30} = 0.598$$

$$Q_f = \frac{\eta_h \cdot WH \cdot \eta_h}{S + C/2}$$

$$= \frac{0.8 \times 40 \times 0.598}{1.4 + \frac{1.8}{2}} = 8.32 \text{ KN}$$

Ans

Settlement of footing :—

Clay may be considered in, settlement :

$$\boxed{S = S_i + S_c + S_s}$$

Where,

S_i = Immediate settlement.

S_c = Consideration settlement.

S_s = Settlement due to secondary consolidation of clay.

$$S_i = q \cdot B \left(\frac{1 - \mu^2}{E_s}\right) I_w$$

$$S_c = C \frac{C_c}{1 + e_0} H \log_{10} \left(\frac{\bar{\sigma_0} + \Delta\bar{\sigma}}{\bar{\sigma_0}}\right)$$

$$= 0.009 (w_L - 10)$$

Where, q = Intensity of contact pressure.
B = Least lateral dimension of footing.
μ = Poission Ratio.
E_s = Modulus of elasticity of soil.
I_w = Influence factor.
C = Correction factor.
C_c = Compression index.
e_0 = Initial void ratio.
H = Thickness of compressible layer.
$\overline{\sigma_0}$ = Effective initial over burden pressure.
$\Delta\overline{\sigma}$ = Vertical stress increment due to footing.

Q A footing 3m × 1.5m in a plant transmits a pressure of 160 KN/m² on a cohesive soil having $E = 8 \times 10^4$ KN/m² & $\mu = 0.48$. Determine the immediate settlement at the centre. Assuming the footing to be
(a) Flexible ($I_w = 1.52$)
(b) Rigid ($I_w = 1.22$)

Soln:- Given data:—
Size of footing = 3m × 1.5m
Pressure, $q = 100$ KN/m²
$B = 1.5$ m.
$L = 3$ m
$\mu = 0.48$
$E = 8 \times 10^4$ KN/m²

(a) $I_w = 1.52$
For flexible footing immediate settlement

$$S_i = q \cdot B \left(\frac{1-\mu^2}{E_s}\right) I_w$$

$$= 160 \times 1.5 \left(\frac{1-0.48^2}{8\times10^4}\right) \times 1.52$$

$$= 3.51 \times 10^{-3}$$

$$= 3.51 \text{ mm}$$

(b) $I_w = 1.22$
For rigid footing immediate settlement

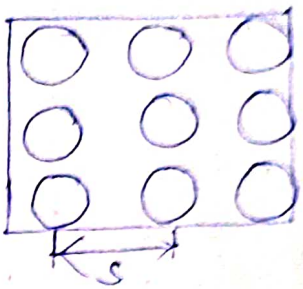
$$S_i = q \cdot B \left(\frac{1-\mu^2}{E_s}\right) I_w$$

$$= 160 \times 1.5 \left(\frac{1-0.48^2}{8\times10^4}\right) \times 1.22 = 2.82 \times 10^{-3}$$

$$= 2.82 \text{ mm} \quad \text{(Ans)}$$

200 mm diameter & 8 m long piles are used as foundation for a column in uniform deposite of medium clay (unconfined compressive strength = 100 KN/m², Adhesion factor = 0.91 there are 9 piles arranged in a square pattern 3×3 for group efficiency 1.0 Find the spacing betⁿ the piles neglect bearing.

Given data:—



$d = 200\ mm = 0.2\ m$

$L = 8\ m$

$n = 9$

Square pattern

$S = ?$

$B = 2S + d$

$q_u = 100\ KN/m^2$

α (or) $m = 0.91$

$\eta_g = 1.0$

$C_u = \frac{q_u}{2} = \frac{100}{2} = 50\ KN/m^2$

Piles acting as individually,

$Q_{un} = n \times Q_{up}$

$= n \times \{A_s \cdot f_f + A_p \cdot f_p\}$ ($f_p \to 0$)

$= n \times \{\pi dL \times \alpha \times C_u\}$

$= 9 \times (\pi \times 0.2 \times 8 \times 0.91 \times 50)$

$= 2058.3\ KN$

Piles acting as group,

$Q_{ug} = Q_{up}$ ($f_p \to 0$)

$= [A_s \cdot f_f + A_p \cdot f_p]$

$= 4BL \times C$

$= 4 \times (2S + d) \times 8 \times 50$

$= 3200\ (S + 0.1)$

Efficiency, $(\eta) = \frac{Q_{ug}}{Q_{un}}$

$\Rightarrow \frac{Q_{ug}}{Q_{up}} = 1$

$\Rightarrow Q_{ug} = Q_{up}$

$\Rightarrow 3200\ (S + 0.1) = 2058.37$

$\Rightarrow 3200\ S + 320 = 2058.37$

$\Rightarrow 3200\,S = 1738.37$

$\Rightarrow S = 0.543$

$\Rightarrow S = 54.3\,cm$

Group action in pile settlement :—

→ The settlement of a group of friction pile can be computed on the assumption that the clay counted between the top of the pile & there lower hard point is in compressible.

→ The soil below this level is divided into no. of layers & the $\bar{\sigma}_p$ & $\Delta\bar{\sigma}$ are calculated at the middle of each layer then the settlement of each layer is calculated from their following expression,

$$p = \frac{H \times C_c}{1+e_0} \log_{10} \frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}$$

where,

H = Thickness of the layer

e_0 = Initial void ratio

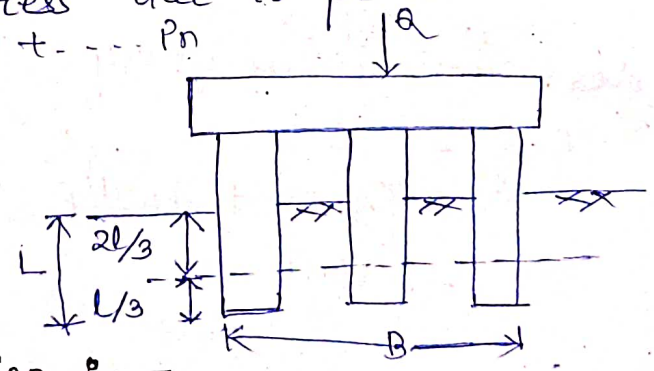
$\bar{\sigma}_0$ = Initial stress at the centre of the layer.

$$\bar{\sigma} = \gamma \times Z$$

Z = Depth of the centre of layer below the ground.

$\Delta\bar{\sigma}$ = Additional stress due to pile.

Total settlement = $P_1 + P_2 + P_3 + \dots P_n$



Negative Skin Friction :—

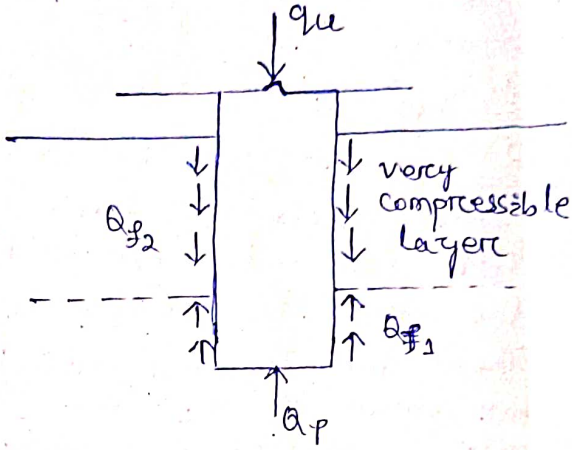
→ Negative skin friction is downward drag on a pile due to the downward movement of compressible soil relative to the pile. This downward dragon force is known as negative skin friction.

→ It developes in the case of very loose sand & soft soil.

This happens when the surrounding compressible soil has been filled before two days of pile construction. The compressible soil (loose soil) consolidates or settles move downward by the skin friction develops on the perimeter of piles forcing the pile to move downward.

Negative skin friction may also develop by the lowering of the ground water.

$$Q_u = Q_p + Q_{f_1} - Q_{f_2}$$



Pile is moving in downward direction & the resistance act in upward direction.

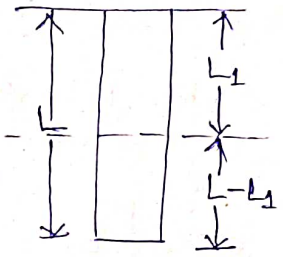
Here, Q_{f_2} → Negative skin friction

For single pile :—

(1) For cohesive soil,

$\phi = 0$

$$Q_{fN} = P \cdot L_1 C_a$$
$$= P \cdot L_1 \alpha \cdot C_u$$



where,

P → Perimeter of the pile

L_1 → Length of the pile in negative skin friction.

α → Adhesion factor.

C_u → Undrained cohesion on the compressible layer.

(2) For Cohesionless soil,

$$Q_{fN} = \frac{1}{2} P L_1 \gamma \cdot K \cdot \tan\phi$$

where,

K → Co-efficient of lateral earth pressure.

Group pile :—

$$Q_{fNg} = C_u L_1 P_g + \gamma L_1 A_g$$

Where,

P_g = Perimeter of pile

γ = Unit weight of soil

A_g = Area of the pile group.

C_u = Undrained cohesion

$$F.O.S = \frac{Q_u \text{ (Single) or } Q_{ug} \text{ (group pile)}}{\text{working load} + Q_{fN} \text{ or } Q_{fNg}}$$

Group action of piles:—

Efficiency of pile group in clay:—

$$\text{Group Efficiency} = \eta_g = \frac{Q_{ug}}{Q_{un}}$$

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

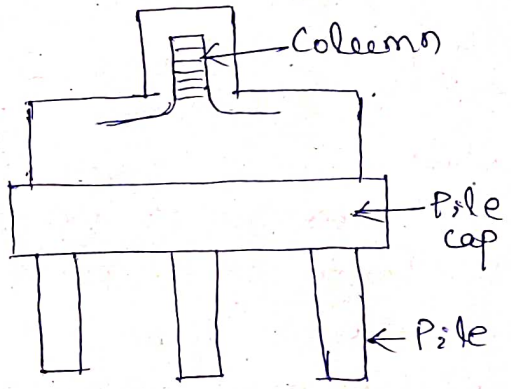
Piles in the group acts in two way depending on the spacing i.e. C/C distance.

(1) They act as a group.
(2) They act as an individually.

→ When several closely spaced piles are group together it is reasonable to expect that the soil pressure develop in the soil is resistance will overlap. Then the bearing capacity of pile group may or may not be equal to the sum of bearing capacity of individual piles constituting a group.

'η_g' depends upon the following factors.

(i) Pile dia & length of matter.
(ii) Spacing of pile.
(iii) No. of pile in a row & no. of rows.



Ultimate bearing capacity of a group:—

Ultimate bearing capacity of pile acting individually,

$$Q_{un} = n \times Q_{up}$$

$$Q_{ug} = \eta_g \times (n \times Q_{up})$$

where,

Q_{up} = Ultimate load carried by each friction pile.
Q_{ug} = Load carrying capacity by group of friction piles.
η_g = Efficiency of pile group also called as reduction factor.
n = No. of piles in the group.

Special type of bored pile :-

Under reamed Pile foundation :-

An under reamed pile is a special type of bored pile which is provided with bulb or pedestral at the end It is nominally reinforced concrete pile having one or more enlargement bulbs.

When the pile has one bulb it is known as single under reamed pile while the pile with more than one bulb, is known as multi under reamed pile.

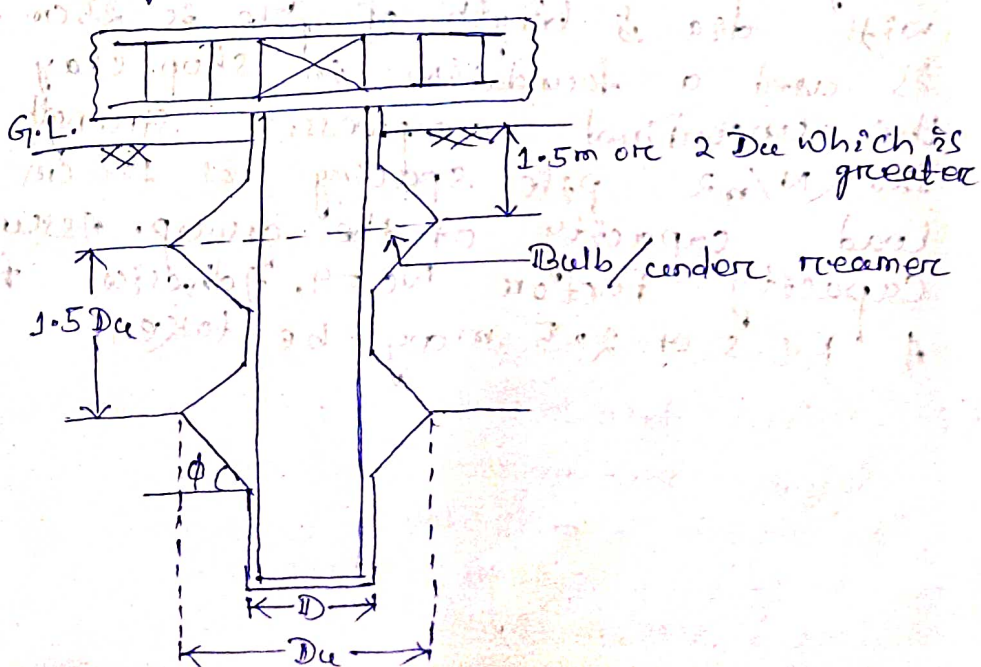
Construction :-

The under reamed pile is constructed by making a hole in the ground by means of a hand operated auger.

An under reamer is then lowered in the clean hole. The under reamer is placed down & rotated. Under pressure the plates open up & due to rotary action, the soil is cut & fall in the bucket. When the bucket is full the under reamer is pulled out & clean. The under reamer is lowered again & the process is repeated.

After enlarge & it formed the reinforcement cage is lowered & concrete is down. The size of such piles are 27 cm to 37.5 cm shaft diameter & 3 m to 4 m long.

Under reamed piles are considered usefull in loose soil & filled up soil in black cotton soil, which excessive shrinkage & swelling.



$\phi = 30°$ to $40°$

$D_u = 3\ D$

$\phi = 40° - 50°$

$D_u = 2.5\ D$

$\phi = 50° - 60°$

$D_u = 2\ D$

Q A 30 cm diameter concrete pile is driven into a homogeneous consolidated clay having $C_u = 40\ KN/m^2$, $\alpha = 0.7$ if the embedded length of pile is 10 m. Estimate the safe load F.O.S = 2.5.

Sol^n:- Given data:-

$d = 30\ cm = 0.3\ m$

$C_u = 40\ KN/m^2$

$\alpha = 0.7$

$L = 10\ m$

F.O.S = 2.5

Safe load = ?

$$\text{Safe load} = \frac{\text{Ultimate load}(Q_u)}{\text{F.O.S}}$$

$$Q_u = A_s \cdot \pi_f + A_p \cdot \pi_p$$

$$= (\pi d L)(\alpha \cdot C_u) + \left(\frac{\pi}{4} d^2\right)(CN_c)$$

$$= (\pi \times 0.30 \times 10)(0.7 \times 40) + \left(\frac{\pi}{4} \times 0.3^2\right)(40 \times 9)$$

$$= 289.3\ KN$$

$$Q_{safe} = \frac{289.3}{2.5} = 115.72\ KN$$ Ans

Q A group of a pile arranged in a square pattern with dia & length of pile is 25 cm & 10 m respectively, is used a foundation in shop clay deposite taking the unconfined compressive strength of clay is 120 KN/m2. pile spacing is 100 cm c/c. Find the load capacity of the group. Assume the bearing capacity Factor $N_c = 9$; Adhesion factor $\alpha = 0.9$. A F.O.S of 2.5 may be taken.

Sol^n:- Given data:-

Square pattern

Diameter, $d = 25\ cm$

Length, $L = 10\ m$

$S = 100\ cm$ c/c

Load capacity = ?

$N_c = 9$

$\alpha = 0.75$

F.O.S = 2.5

Compressive strength of clay, $q_u = 120\ KN/m^2$

$$C_u = \frac{q_u}{2} = \frac{120}{2} = 60\ KN/m^2$$

Piles acting as a individually,

$$Q_{un} = n\{A_s \cdot r_f + A_p \cdot r_p\}$$

$$= n\{\pi dL \times \alpha \times C_u\} + \frac{\pi}{4} d^2 \times C N_c$$

$$= 9\{\pi \times 0.25 \times 30 \times 0.75 \times 60 + \frac{\pi}{4} \times (0.25)^2 \times (60 \times 9)\}$$

$$= 3419.42\ KN$$

Piles acting as group,

$$Q_{ug} = 4BL \times C + B^2 \times N_c \times C$$

$$= 4 \times 2.25 \times 30 \times 60 + (2.25)^2 \times 9 \times 60$$

$$= 8133.8\ KN$$

$Q_{min} = 3419.42$

$$Q_{safe} = \frac{3402}{2.5} = 1360.8$$

401

b) Design of friction pile group to carry a load of 3000 KN including the weight of pile cap at a side where the soil is uniform clay to a depth of 20 m alternate by a rock. Average unconfined compressive strength of the clay is 70 KN/m² the clay may be assumed to be of normal sensitivity & normally loaded with a liquid limit 60 % & FOS of 3. If requires again shear failure.

Sol:- Given data:-

$Q_{ug} = 3000\ KN$

Depth = 20 m

$q_u = 70\ KN/m^2$

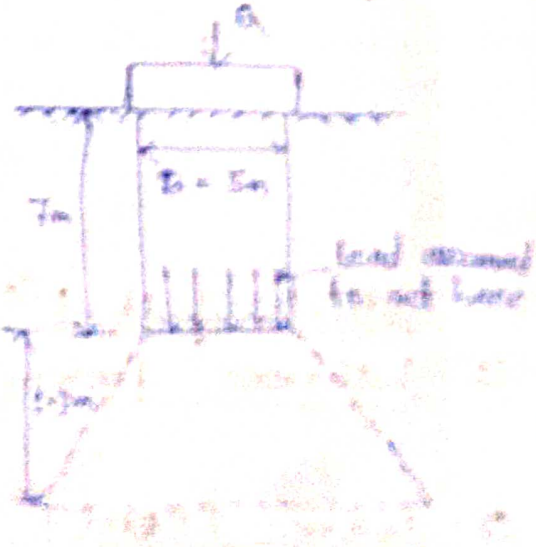
$W_L = 60\%$

F.O.S = 3

$$C_u = \frac{q_u}{2} = \frac{70}{2} = 35\ KN/m^2$$

Permissible value of

$$C_u = \frac{25}{3} = 11.67\ KN/m^2$$



Let the length of the pile is 10 m & dia = 0.5 m & the total no. of piles = n

Considering pile acting as individually

$Q_{gen} = n \times Q_{cap}$

$= n \{A_s \cdot f_y\}$

$= n \{\pi dL \times \alpha \times C_u\}$

$\Rightarrow 3000 = n \times \{\pi \times 0.5 \times 10 \times 1 \times 35\}$

$=$

$\Rightarrow n = 16$ nos.

Efficiency of pile in group:—

(1) Labarre formula:—

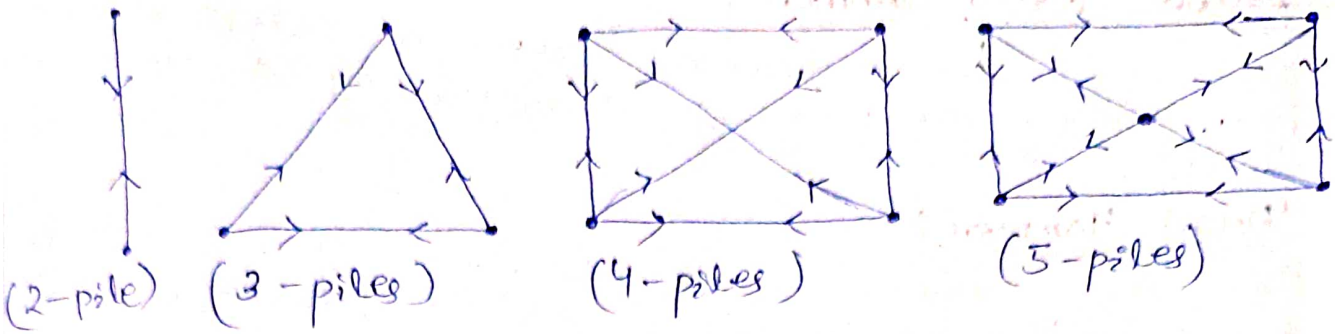
$$\eta_g = 1 - \frac{\theta}{90}\left[\frac{(n-1)m + (m-1)n}{mn}\right]$$

(2) Seiler Keercey Formula:—

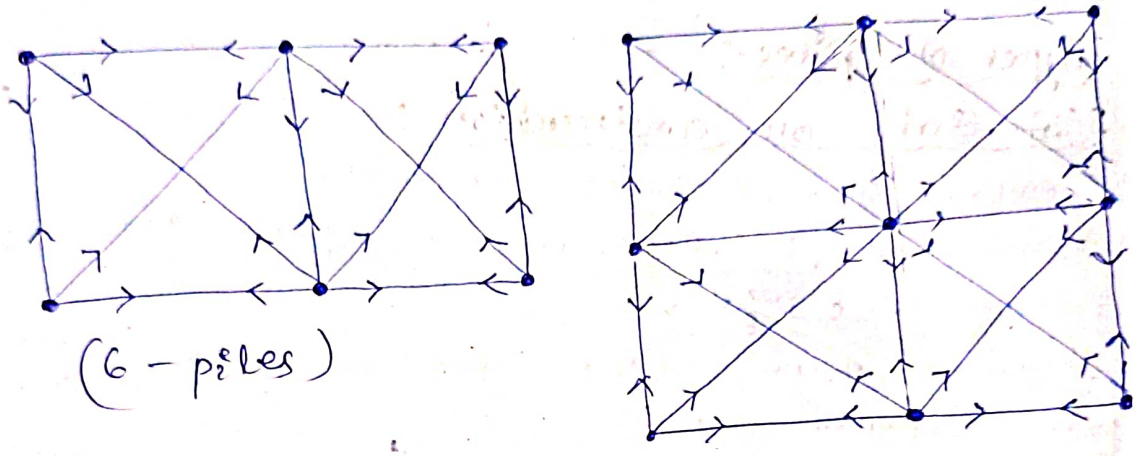
$$\eta_g = \left[1 - 0.479\left(\frac{s}{s^2 - 0.093}\right)\left(\frac{m+n-2}{m+n-1}\right)\right] + \frac{0.3}{m+n}$$

Feld's Rule :—

According to this rule, the value of each pile is reduced by 1/16 on account of the effect of the nearest pile in diagonal or a straight row.



(2-pile) (3-piles) (4-piles) (5-piles)



(6-piles) (9-piles)

Pile driving / driven pile :—

In driven piles hollow steel casing is driven to ground, then inside casing reinforcement is put if necessary then casing filled with concrete. The casing is either withdrawn or left after filling concrete.

Bored Pile :—

- A bore is first made by drilling reinforcement, then fill with concrete.
- Piles are commonly driven by means of a hammer supported by a crane. The hammer is guided between the two parallel steel member known as leads.

Types of hammer :—

(i) Drop hammer
(ii) Single acting hammer
(iii) Double acting hammer

(i) Drop hammer :—

- If a hammer is raised by inch & allow to fall by gravity on the top of a pile. It is called as drop hammer.

(ii) Single acting hammer:—

→ If the hammer is raised by steam, compressed air but it is allowed to fall by gravity alone is called as single acting hammer.

(iii) Double acting hammer:—

→ The double acting hammer employees steam or air for lifting the ram & for accelerating the downward stroke.

Diesel Hammer:—

→ The diesel hammer is a small, light weight, self contain & self acting type using gasoline for fuel.

Types of Piles:—

Materials or construction:—

(a) Timber, steel, concrete composite.
(b) Based on C/S:- Circular pile, square pile, I-section, Hexagonal pile.
(c) Based on shape:- Under reamed pile cylindrical pile, Tapered pile
(d) Mode of load transfered:— Bearing, friction & tension.
(e) Method of forming:— Pre-cast, Pre-stressed, cast-in-site.
(f) Method of installed:— Driving pile, bored pile, vibrated pile & Jetted pile.

Well foundation:—

Basics of well foundation:—

Well foundation for the most common type of deep foundation for bridges in India.

Types of Well:—

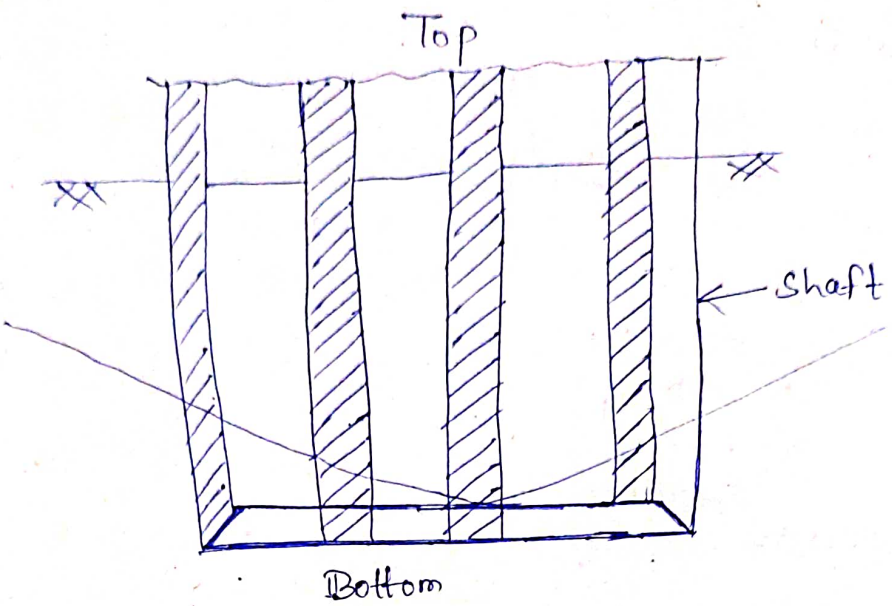
(1) Open or caisson well.
(2) Box well or floating caisson
(3) Pneumatic well.

(1) Open or Caisson Well:—

→ When top & bottom portion is open during construction, this can be circular or rectangular type.

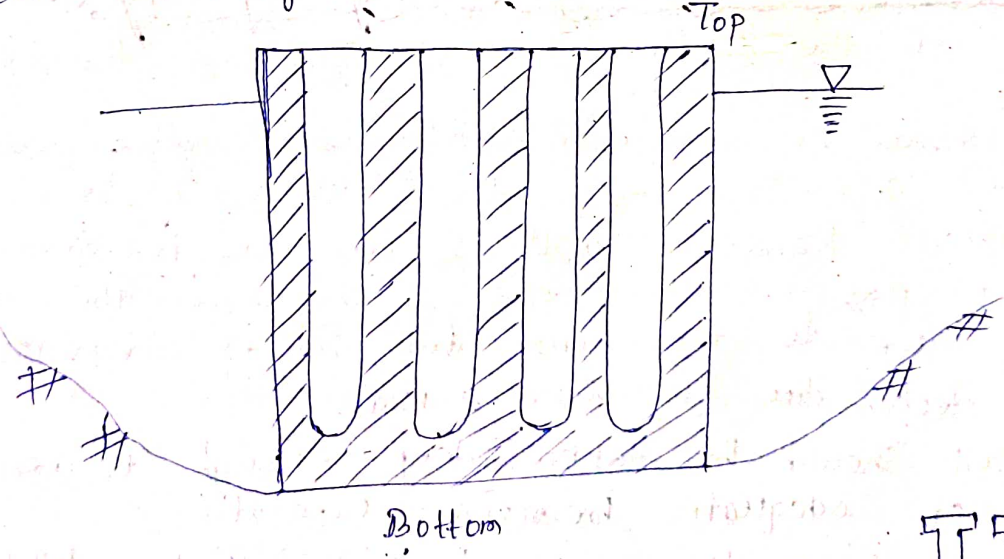
→ Bottom portion filled with concrete. It shrinks into the water upto the required depth shaft is filled with sand.

It is relatively low cost.
In bottom of the surface boulder deposited then it is very difficult to progress the construction.
Concrete sill under the water is not effective.



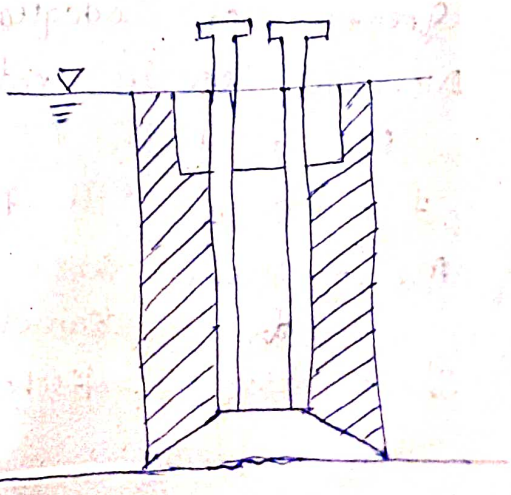
2) Box well or floating caisson :—

In this type of construction of well open at top & closed at bottom.
Bottom is silled up to reach desired length.
Loads are not very heavy. Such type of well is used where bearing stratum is available at shallow depth.



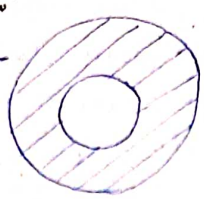
3) Pneumatic Well :—

This type of construction well excavation is done under dry condition.



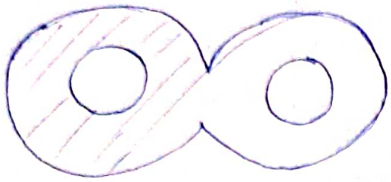
Shape of Well :—

(1) Circular shape :—

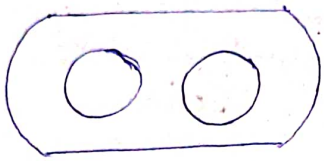


(2) Double - D Well :—

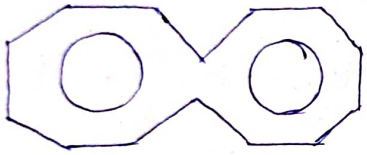
(3) Dumb well :—



(4) Twin Circular :—



(5) Circular double octagonal :—



Depth of well foundation & bearing Capacity :—

Selection of the depth of well is based on the following criteria :

(1) There should be adequate embeded length of well that is called grip land below the lowest scour level. The minimum Rankine depth is required for developing sufficient passive resistance to counteract the overturning moment due to the horizontal forcies acting on the bridge deck due to wind & water.

(2) The well should be taken deep enough to rest on strata of adequate bearing capacity.

Normal scour depth, $d = 0.473 \sqrt[3]{\frac{q}{f}}$ below HFL

$RL = 1.35 \left(\frac{q^2}{f}\right)^{1/3}$

f = Lacy's Silt factor $= 1.76 \sqrt{m_d}$

m_d = mean size of particle in mm 'or' mean diameter in mm.

q = Design discharge in m^3/sec.

The maximum depth of scour at the nose of pier is found to be twice the Lacy's value of normal scour depth.

$$R = 2 \cdot RL$$

R is measured below the high flood level.

Scour level = HFL − R = H.F.L − 2.RL

Estimate the bearing capacity of well foundation :—

According to Terzaghi's & Peck, the ultimate bearing capacity can be determine from the following expression:

$$Qf = Qp + 2\pi R\, fs\, Df$$

$$Qp = \pi R^2 (1.2\, CNc + \gamma Df\, Nq + 0.6\, \gamma R\, Nr)$$

Nc, Nq, Nr = Terzaghi bearing capacity factor

R = Radius of well

f = Depth of well foundation

fs = Average skin friction

Forces acting on well foundation :—

i) Vertical load or forces :—

1) Self weight of well & buoyancy.
2) Live load, dead load & super structure
3) Dead load of pier

ii) Horizontal forces or load :—

1) Braking & tracking import of the moving vehicle.
2) Force due to resistance of bearing
3) Water current force.
4) Wind force
5) Earthquake force
6) Earth pressure
7) Centrifugal force

All the horizontal forces can be replaced by two horizontal forces P & Q & single vertical force 'W'.

Where, P = Resultant of all horizontal forces along the piers.

Centrifugal forces :—

A centrifugal force is transmitted through bearing if the bridge is curved in plan.