Type of piles and Pile design

Piles

Type of piles and pile design

Prepared by civil eng/ Aras Bashir Amin

Piles:

1) Design of piles:

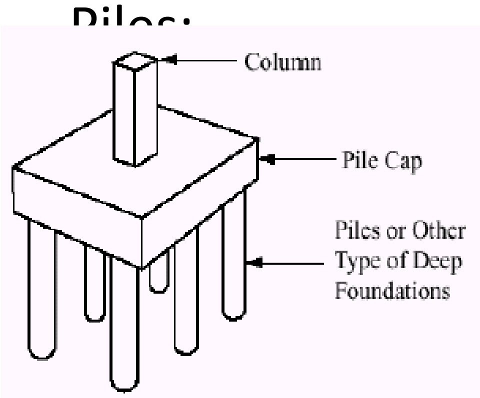
2) Bearing Capacity of piles:

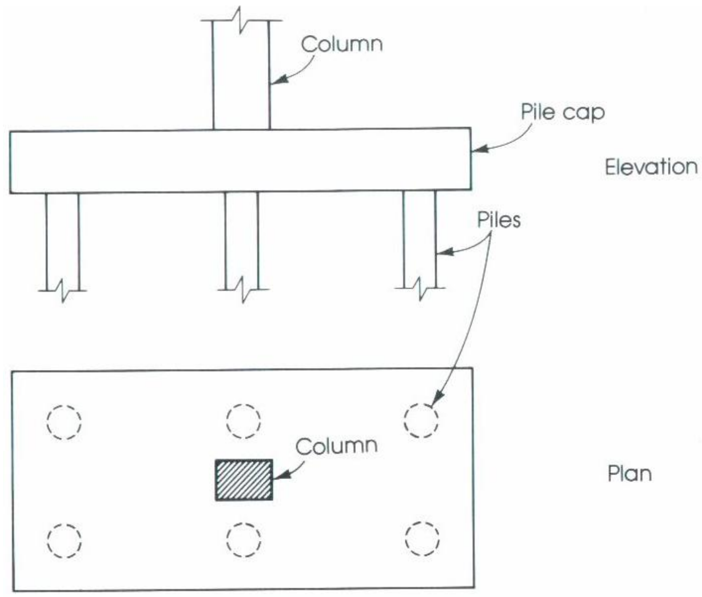
3) Determination settlement:

4) Short and Long pile:

5) Design of piles cap:

Piles:





Main reasons For use piles:

1) In case of the top layers are as weak that they could not bear the structure , the piles transfer loads to a good layer at reasonable depth.

عندما تكون الطبقات السطحية ضعيفة بحيث لا تستطيع تحمل أحمال المنشأ تقوم الخوازيق بنقل الحمل إلي الطبقات العميقة الأقوى.

2) In order to resist uplift pressure.

3) In case of structure in water.

في حالات المنشآت المائية.

4) In order to densify the soil as in case of short stone piles.

Types of piles:

1)With respect to the method of transform loads:

A) End Bearing piles.

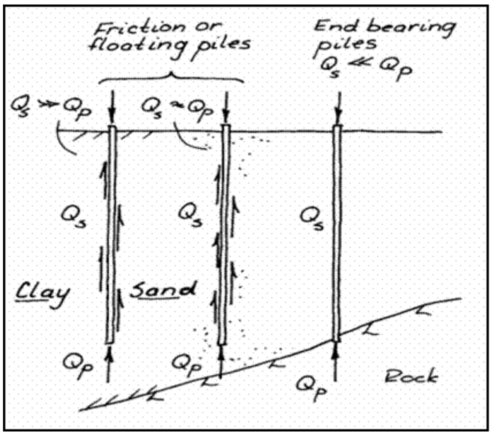
خوازيق ارتكاز: وهذا النوع ينقل الحمل إلى التربة بالمقاومة المتولدة عند نقطة ارتكازه أو قاعدته (Qb).

B) Friction piles.

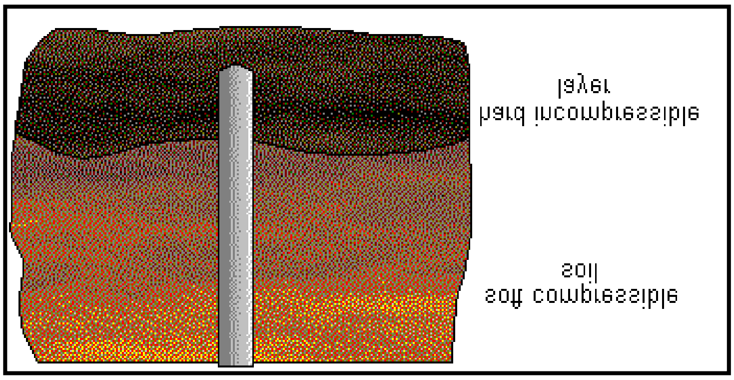
خوازيق احتكاك: وهذا النوع ينقل الحمل أساسا بمقاومة الاحتكاك على سطحه (Qs).

C) End Bearing + Friction piles.

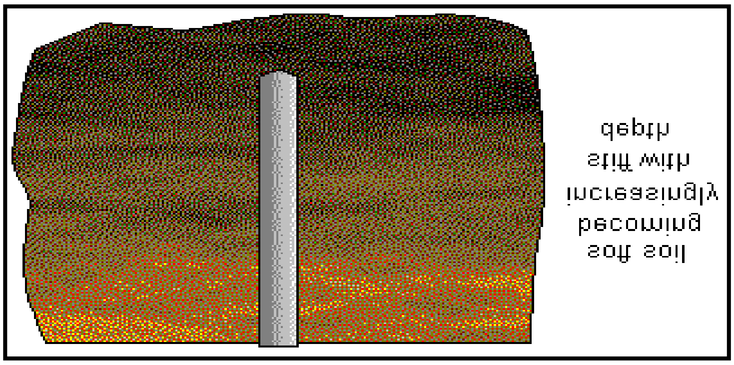
وهذا النوع ينقل الحمل جزئيا بواسطة الاحتكاك على سطحه وجزئيا بمقاومة الارتكاز عند قاعدته (Qb+Qs).



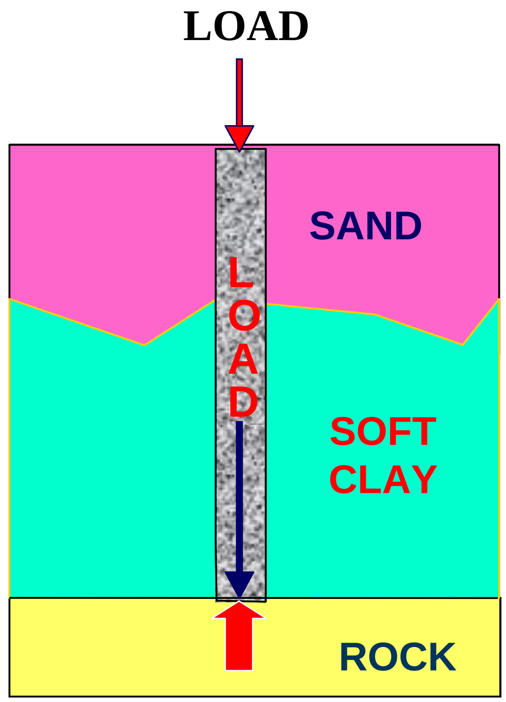
End bearing piles

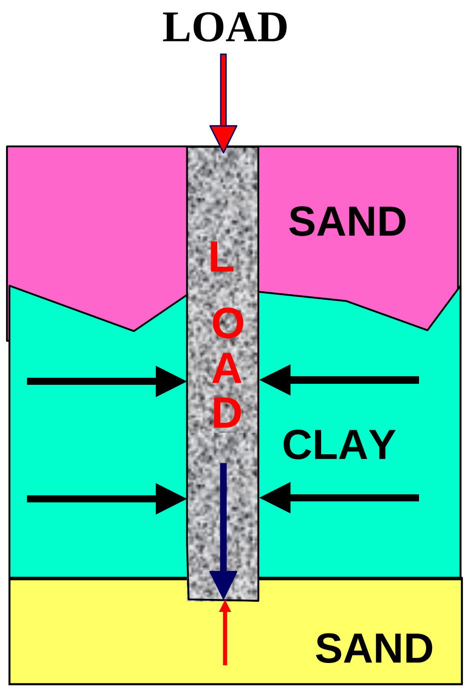


Friction piles



END BEARING PILE **FRICTION PILE**



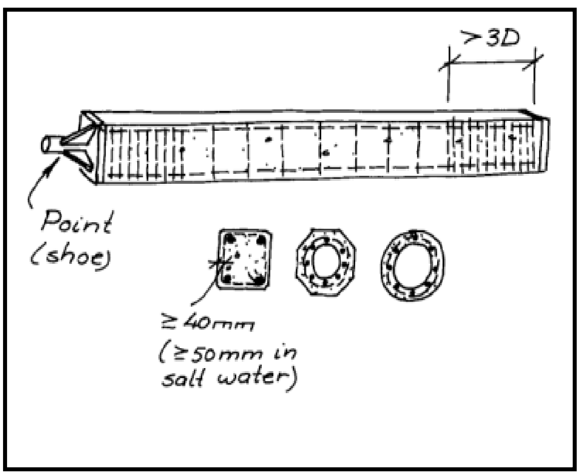


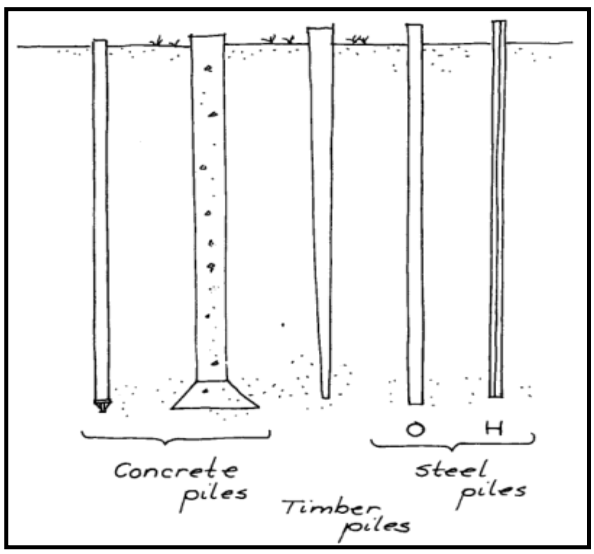
End bearing - Friction

2) With respect to Material:

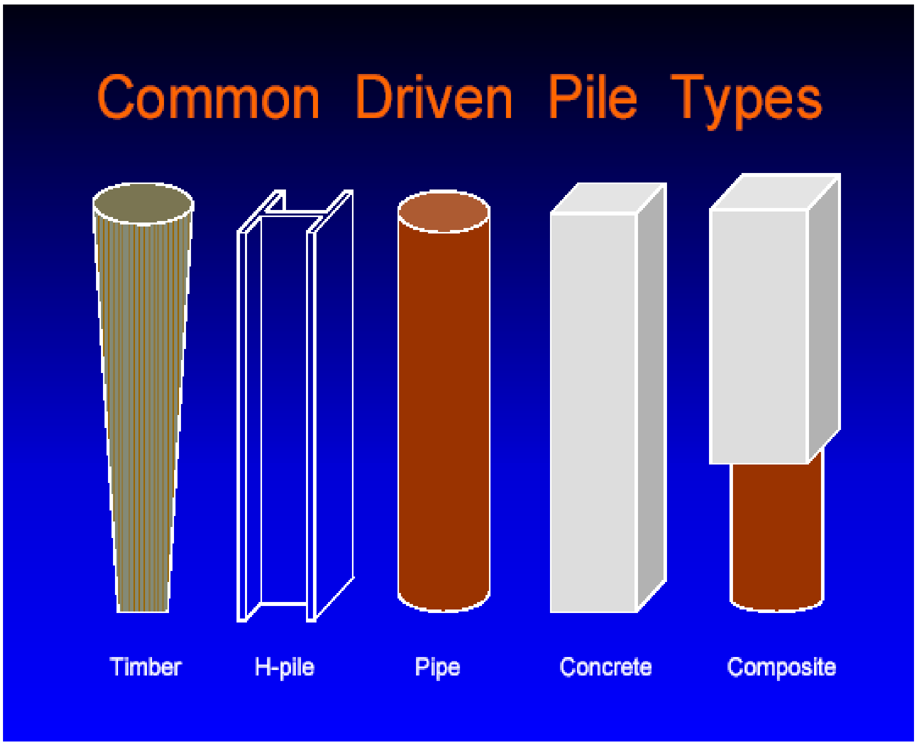
تصنع الخوازيق من الخرسانة أو الحديد أو الخشب أو أكثر من مادة من هذه المواد.

The main types of materials used for piles are wood, steel and concrete.





Materials used for piles

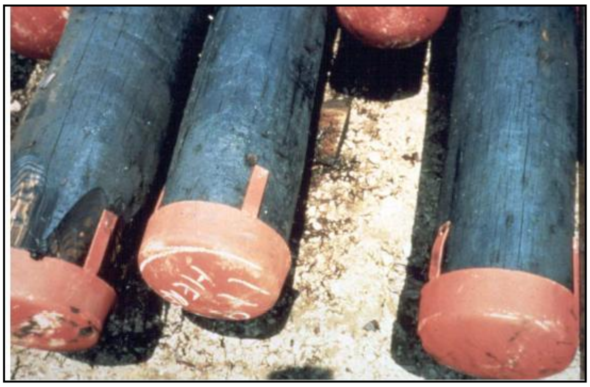


A) Timber piles:

خوازيق خشب:

تستخدم في الأعمال المؤقتة.

Use in temporary works.



Length: 9 → 15 m

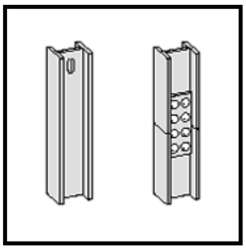
Max load: 45 Ton

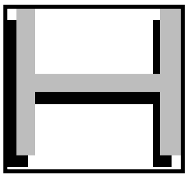
B) Steel piles:

خوازيق حديد:

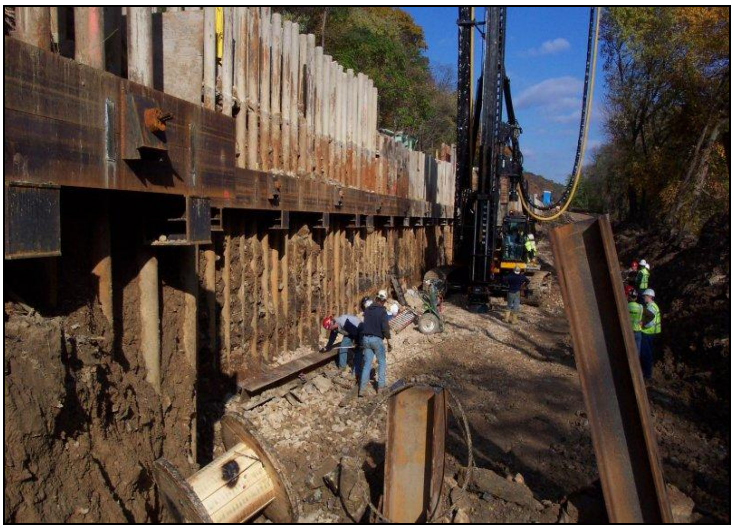
تستخدم عندما يخترق الخازوق طبقات قوية.

Use when the pile cross hard layers.





Steel Pile – H piles:

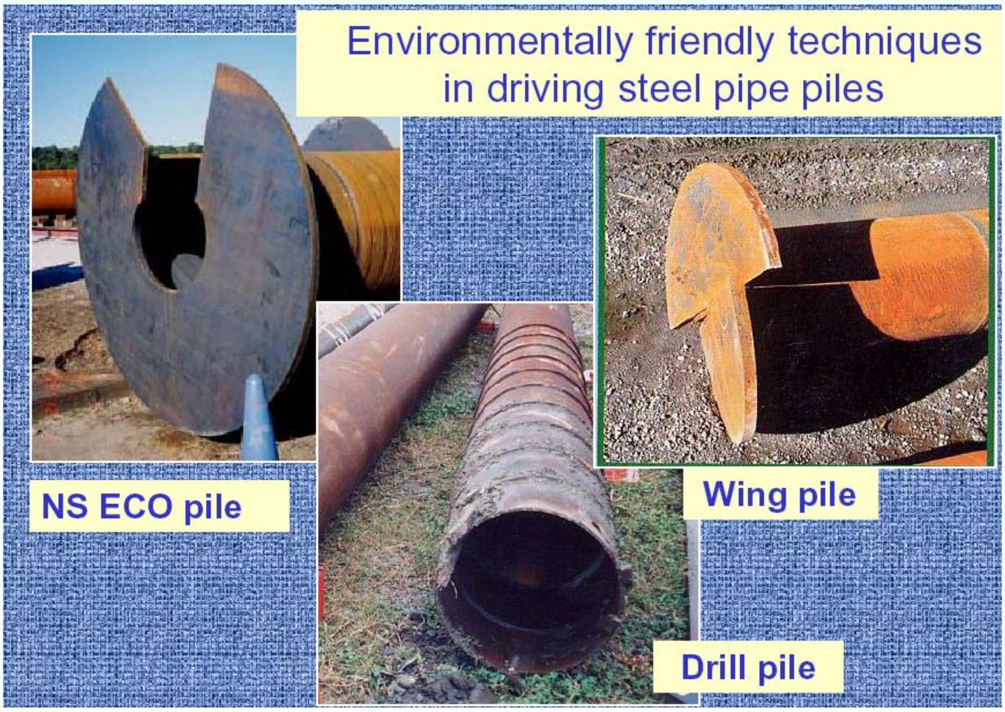


Steel Pipe Pile (Tube piles)

Steel Pipe Pile

Steel Pipe Pile

NS ECO pile has a one-round spiral wing at the end of the pile of which diameter is 1.5 to 2.0 times of its shaft diameter, i.e. the shaft diameter is 1200mm, then the spiral wing diameter is 2400mm so that its end bearing area is quite large and effective to increase its bearing capacity.



Length: 12 → 50 m

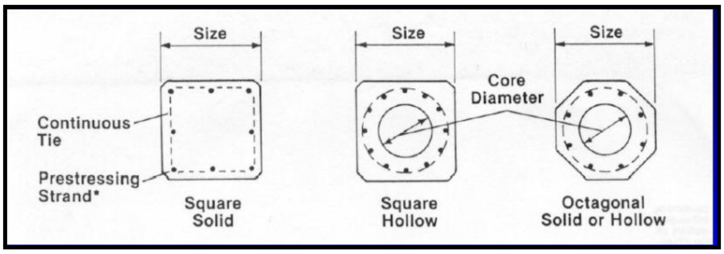
Max load: 35 → 100 Ton

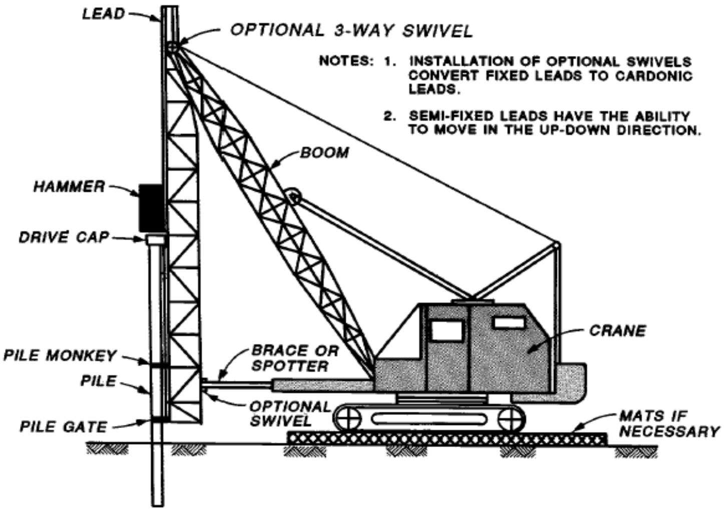
C) Concrete piles:

C-1) Pre cast: Driven

C-2) Cast in place: Driven , Bored

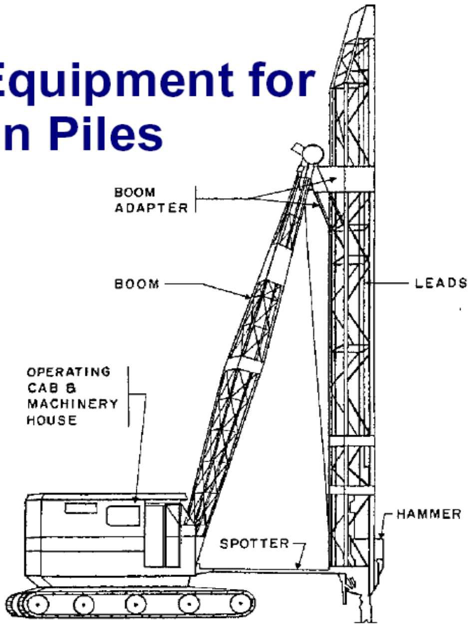
مصبوب في الموقع :بالحفر والصب




LEAD
OPTIONAL 3-WAY SWIVEL
NOTES: 1. INSTALLATION OF OPTIONAL SWIVELS CONVERT FIXED LEADS TO CARDONIC LEADS.
2. SEMI-FIXED LEADS HAVE THE ABILITY TO MOVE IN THE UP-DOWN DIRECTION.
BOOM
HAMMER
DRIVE CAP
CRANE
PILE MONKEY
BRACE OR SPOTTER
PILE
OPTIONAL SWIVEL
PILE GATE
MATS IF NECESSARY

Installation Equipment for Driven Piles

- Pile Driving Rigs
- Pile Hammers
- Hammer Accessories
  - Leaders
  - Cushion Material
- Predrilling, Jetting and Spudding



Hammer & Cushion

Leads

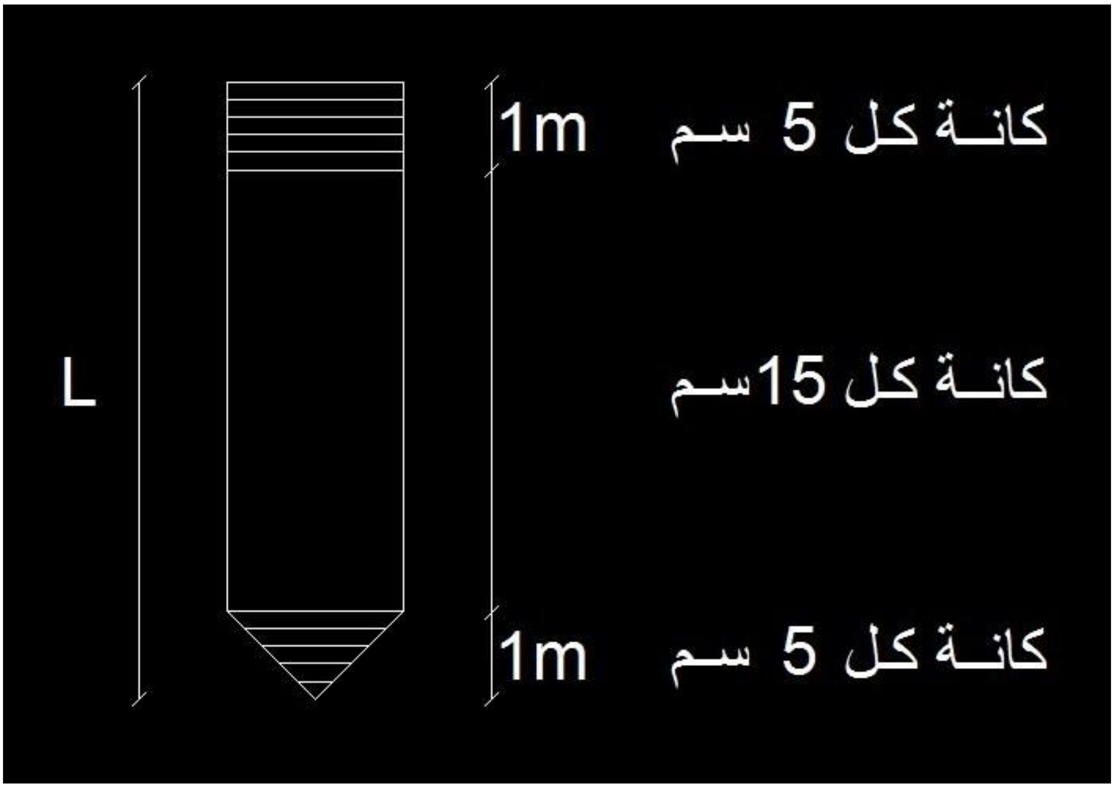
Pile & Cushion

Template

C-1) Pre c

يتطلب تسليح الأجهادات الناتجة عن المناولة والنقل.

Handling stresses.



If $\frac{L}{D} \leq 30 \rightarrow A_S = 1.25\ \%\ A_C$

If $30 < \frac{L}{D} < 40 \rightarrow A_S = 1.5\ \%\ A_C$

If $\frac{L}{D} > 40 \rightarrow A_S = 2\ \%\ A_C$

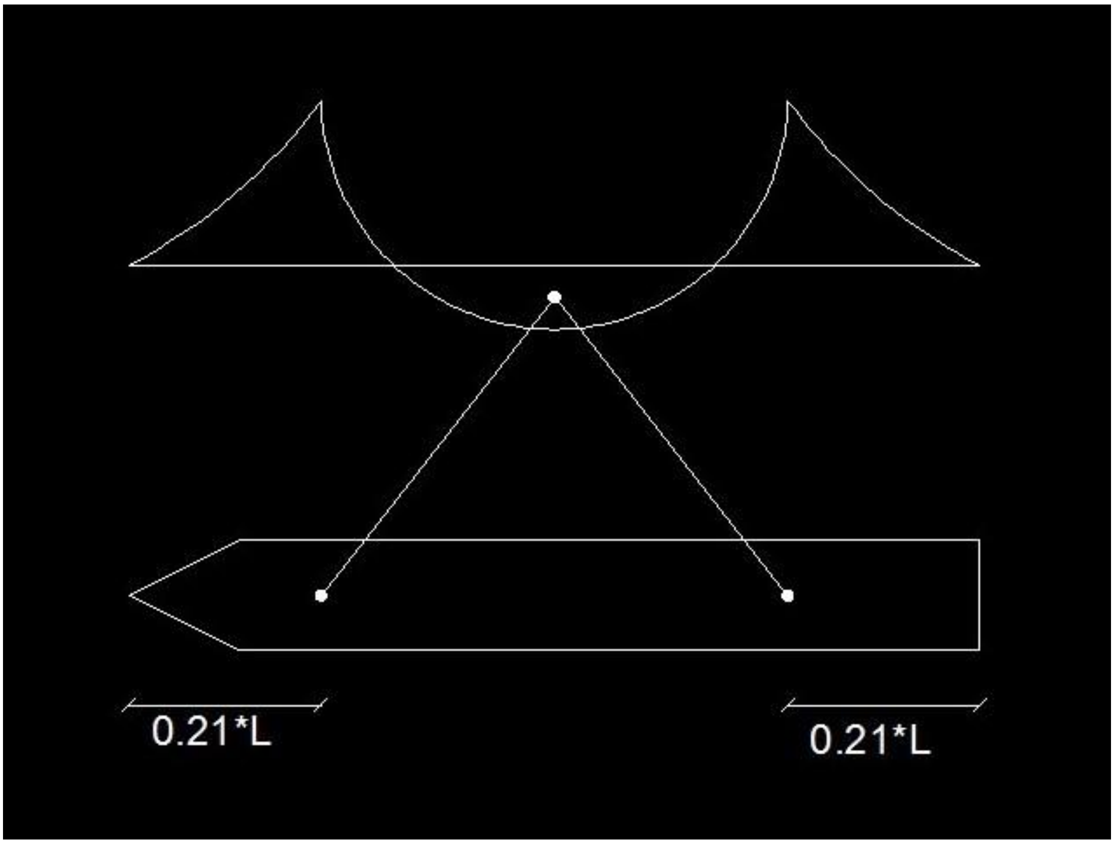
حيث أن:

L → طول الخازوق

D → قطر الخازوق

عملية رفع الخازوق:

هناك طريقتين:



C-2) Cast in place:

Types of Cast in place pile:

C-2-1) Simplex piles. , C-2-2) Frankie piles.

C-2-3) Vibro piles. , C-2-4) Raymod piles.

C-2-5) Strausse piles.

1) Design of piles:

هناك طريقتين:

١- استخدام اختبار الاختراق القياسي:

Use standard penetration test (S.P.T):

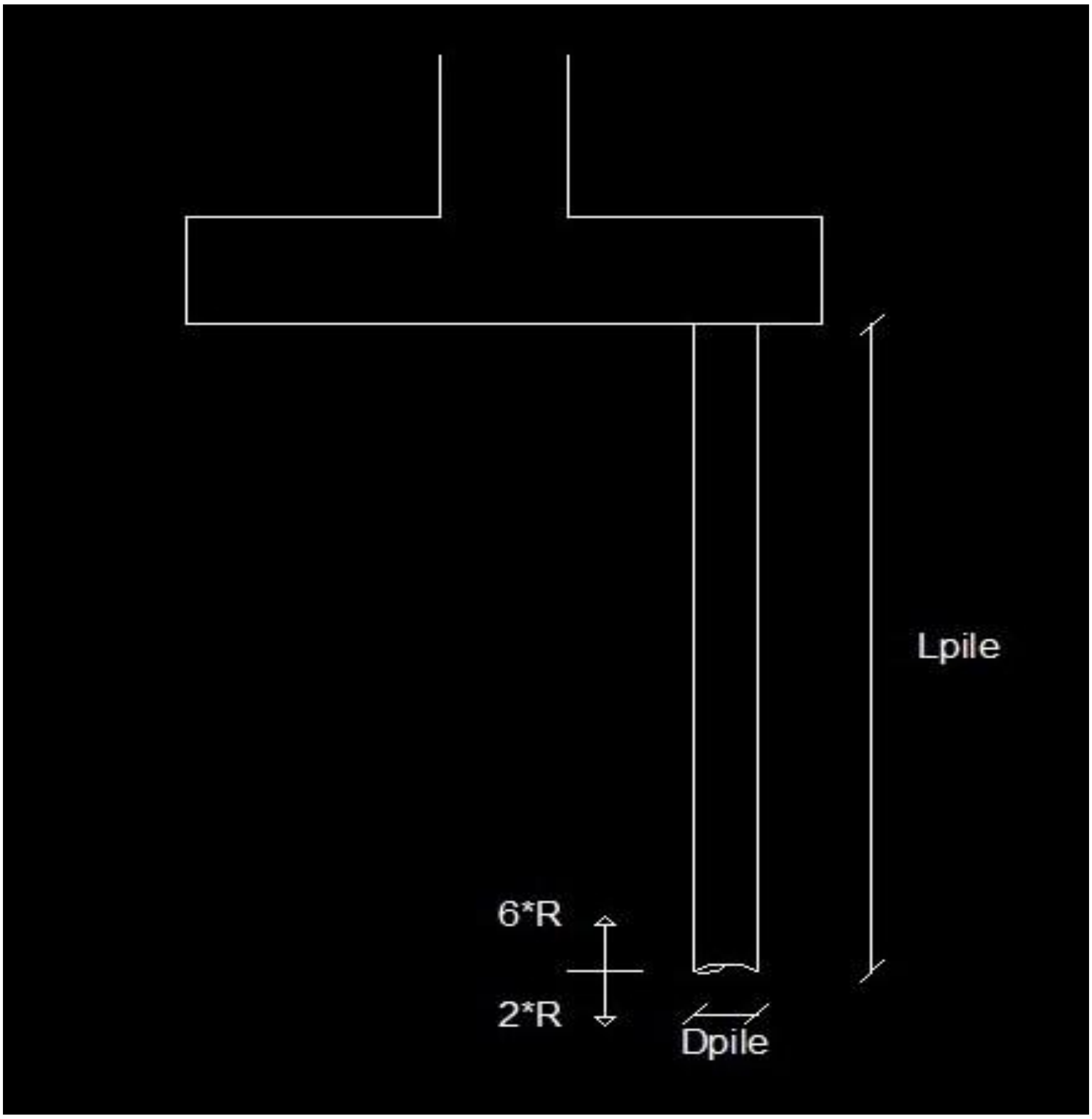
٢- استخدام اختبار المخروط الإستاتيكى:

Use cone penetration test (C.P.T):

سيتم دراسة الطريقة الأولي فقط

٣- استخدام اختبار الاختراق القياسي:

Use standard penetration test (S.P.T):



Assume:

D_{pile} = … cm

L_{pile} = … m

$Q_{all} = 45*N*\frac{\pi(Dpile)^2}{4} + \frac{\bar{N}}{3} * \pi * D_{pile} * L_{pile} = ...$ KN

حيث أن:

$Q_{all} \rightarrow$ حمل تشغل الخازوق.

N → number of average blows from S.P.T. tests through depth of 3D above and below pile tip.

القيمة المتوسطة لعدد الدقات في تجربة الاختراق القياسي في طبقة التربة المؤثرة علي حمل الارتكاز و الممتدة لمسافة (2R) أسفل قاعدة الخازوق و (6R) أعلا نقطة الارتكاز.

$\bar{N}$ → average number of blows from S.P.T. tests throughout the pile length subjected to shear.

متوسط عدد الدقات في تجربة الاختراق القياسي علي طول الخازوق داخل الطبقة أو الطبقات غير متماسكة الحبيبات.

$D_{pile} \rightarrow$ pile diameter.

قطر الخازوق.

$L_{pile} \rightarrow$ pile length.

طول الخازوق.

Example: 1

For the inspection of soil Design of piles Use standard penetration test (S.P.T)

Solution

Assume:

D_{pile} = 40 cm

L_{pile} = 12 m

$Q_{all} = 45*N*\frac{\pi(Dpile)^2}{4} + \frac{\bar{N}}{3} * \pi * D_{pile} * L_{pile}$

$N = \frac{31+33}{2} = 32$

$\overline{N} = \frac{3+4+5+25+31}{5} = 13.6$

$Q_{all} = 45*32*\frac{\pi(0.4)^2}{4} + \frac{13.6}{3}*\pi*0.4*12 = 249.4$ KN

$Q_{all} = 25$ T

2) Bearing Capacity of piles:

Methods of Calculation Bearing Capacity of piles:

1) Static formula.

2) Dynamic formula.

3) Field tests.

4) Pile loading test.

سيتم دراسة الطريقة الأولي فقط.

1) Static formula:

For pure clay:

1) Compression:

الخوازيق المعرضة لأحمال ضغط:

$Q_{ult} = C * N_{C} * \frac{\pi(D)^2}{4} + C_a * \pi * d*L$

$Q_{all} = \frac{Qult}{F.O.S}$

End Bearing $= C * N_{C} * \frac{\pi(D)^2}{4}$

Friction $= C_a * \pi * d * L$

حيث أن:

$Q_{ult} \rightarrow$

قدرة تحمل الخازوق.

$Q_{all} \rightarrow$

حمل الآمان للخازوق.

C →Cohesion of soil at pile tip.

متوسط تماسك التربة حول الطرف السفلي للخازوق.

d → pile diameter.

قطر الحازوق.

L → pile length.

طول الخازوق.

F.O.S → Factor of Safety.

معامل الأمان.

F.O.S = 3 if (D.L+L.L)

F.O.S = 2.5 if (D.L+L.L+WIND+EAETHQUAKE)

N_C → Bearing capacity factor (6→9)

معامل قدرة التحميل.

$N_C = 6$ if $d > 100$ cm

$N_C = 7$ if $50 < d < 100$ cm

$N_C = 9$ if $d < 50$ cm

C_a → adhesion

متوسط إلتصاق التربة علي سطح الخازوق.

$C_a = \frac{2}{3} * C$

OR

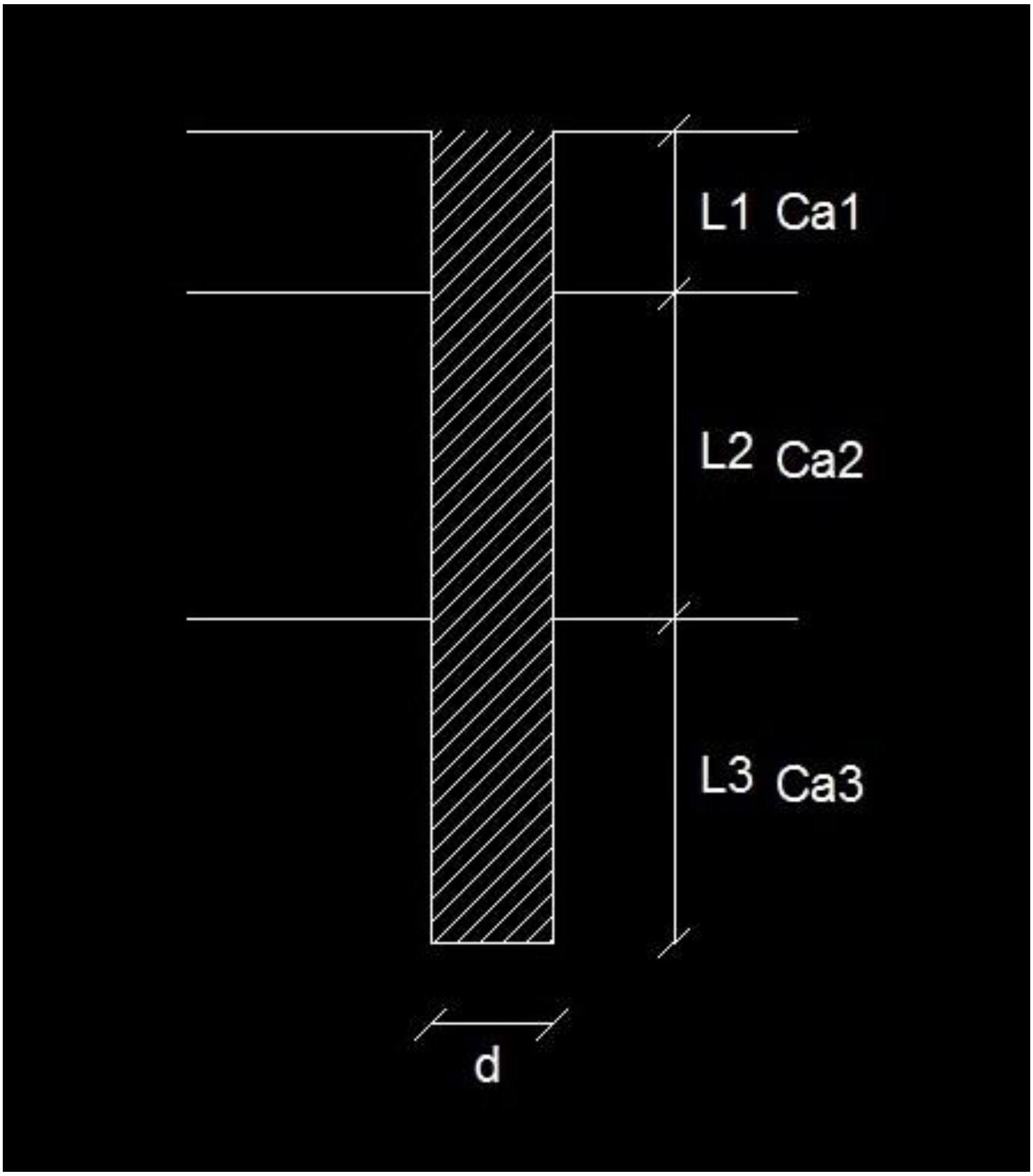
$C_a = 0.3 – 0.4\ (C_u)$ $Cu \leq 100$ kPa For bored piles.

$C_a = 0.6 – 0.8\ (C_u)$ For driven piles.

OR

For driven Piles Ca could be directly taken as mentioned in the following table:

Pile Type	Cohesion C_u (kN/m^2)	Adhesion Ca (kN/m2)
Timber or concrete	0-12.5 12.5-25 25-50 50-100 100-200	0-12.5 12.5-24 24-37.5 37.5-47.5 47.5-65
Steel	0-12.5 12.5-25 25-50 50-100	0-12.5 12.5-23 23-35 35-36



في حالة وجود عدد من الطبقات نضرب C_a لكل طبقة * طول الخازوق في هذه الطبقة:

$C_{a1} * L_1 + C_{a2} * L_2 + C_{a3} * L_3$

2) Tension:

الخوازيق المعرضة لأحمال الشد:

$T_{ult} = C_a * \pi * d * L + W_p$

$T_{all} = \frac{tult}{F.O.S}$

حيث أن:

$T_{ult} \rightarrow$

أقصي حمل شد يتحمله الخازوق.

$T_{all} \rightarrow$

حمل الشد الآمان الذي يتحمله للخازوق.

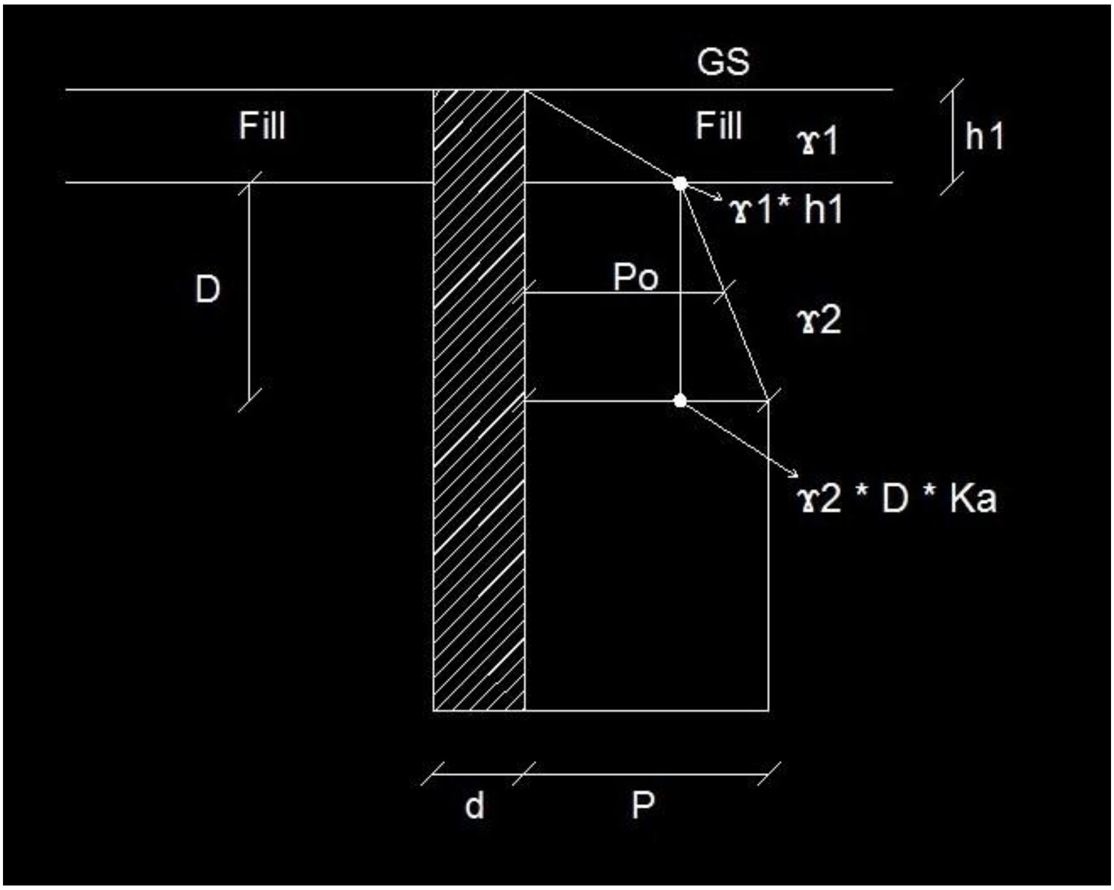
$W_p \rightarrow$ Weight of pile.

وزن الخازوق.

$W_p = \frac{\pi * (d^2)}{4} * L * \gamma_c$

$\gamma_c = 2.5$

For Cohesion Less Soil (Sand):



1) Compression:

الخوازيق المعرضة لأحمال ضغط:

$Q_{ult} = P*N_q*\frac{\pi*(d^2)}{4} + K_{HC}*P_o*\tan\delta*\pi*d*L$

$Q_{all} = \frac{Qult}{F.O.S}$

End Bearing = $P*N_q*\frac{\pi*(d^2)}{4}$

Friction = $K_{HC}*P_o*\tan\delta*\pi*d*L$

حيث أن:

D = 20*d

العمق الذي يظل بعده الضغط الجانبي ثابت ولا يزيد.

$P = \gamma_1*h_1 + \gamma_2*h_2$

P $\rightarrow$

الضغط الجانبي علي عمق D من سطح طبقة الرمل.

$K_a = \frac{1-\sin\emptyset}{1+\sin\emptyset}$

$N_q \rightarrow$ Bearing capacity factor function of $\emptyset$

معامل قدرة التحميل.

To get N_q from table:

$\emptyset$	25	30	35	40	
Displacement pile	15	30	75	150	
Bored pile	7	15	37	75	Nq

If $\emptyset = 0$, $N_q = 0$

$\emptyset^* = \emptyset - 3^o$ (For bored piles)

$\emptyset^* = \frac{\emptyset+40^o}{2}$ (For driven piles)

$K_{HC} \rightarrow$ Coefficient of lateral pressure.

$K_{HC} = 0.7 \rightarrow 1.5$ (For bored piles) Take = 1

$K_{HC} = 1 \rightarrow 1.5$ (For driven piles) Take = 1.5

قيم المعاملات (K_{HC}) & (K_{Ht}) طبقا للكود المصرى :

K_{Ht}	K_{HC}	نوع الخازوق
0.50 – 0.30	1.0 - 0.50	خازوق ذو قطاع H
1.0 – 0.6	1.5 - 1.0	خازوق إزاحة
1.3 – 1.0	2.0 – 1.5	خازوق إزاحة متغير القطاع
0.6 – 0.3	0.9 – 0.4	خازوق إزاحة باستخدام النفاثات
1.0 – 0.4	1.5 – 0.7	خازوق تثقيب اعتيادى (قطر أقل من ٠,٦٠ متر)

$P_o \rightarrow$

متوسط قيمة الضغط الجانبي خلال الطول.

$\delta \rightarrow$ Pile-Soil friction angle

زاوية الاحتكاك بين الخازوق و التربة.

$\delta = \frac{3}{4} * \emptyset$ (for concrete and timber pile).

$\delta = 20^o$ (for steel pile).

2) Tension:

الخوازيق المعرضة لأحمال الشد:

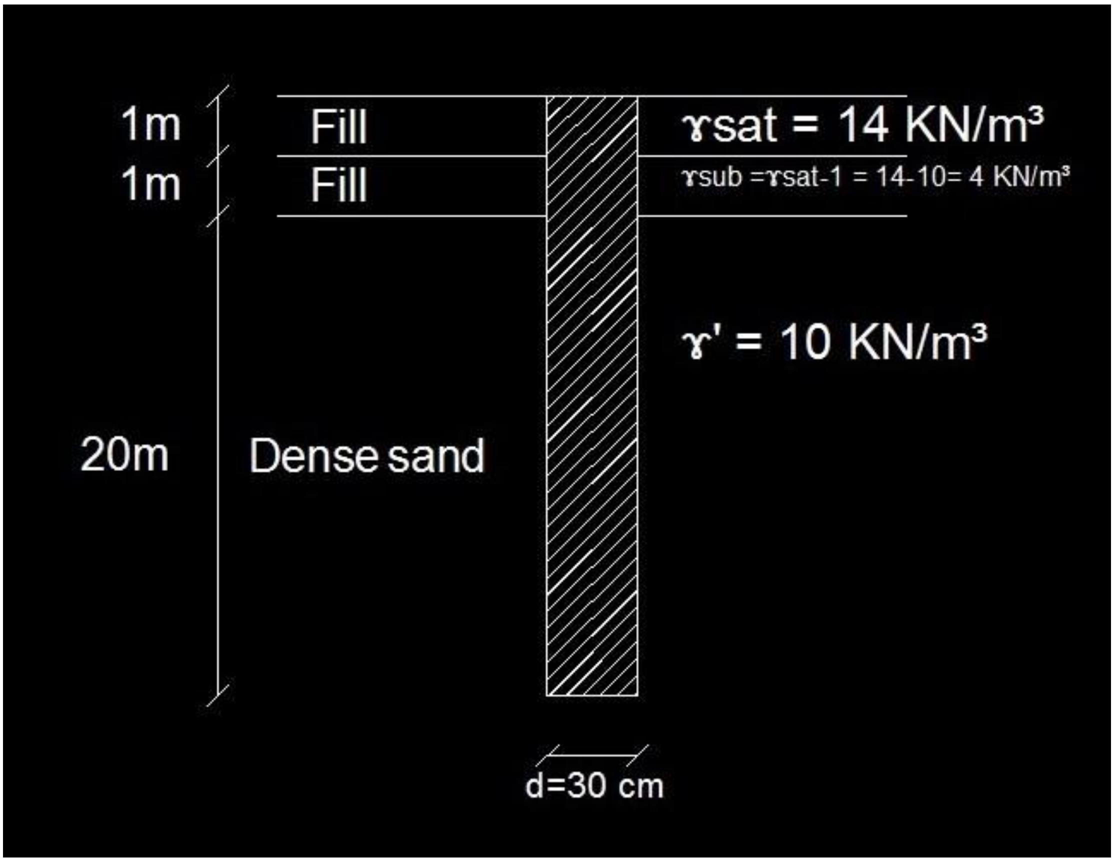
$T_{ult} = K_{Ht} * P_o * \tan\delta * \pi * d + W_p$

$T_{all} = \frac{tult}{F.O.S}$

Example: 2

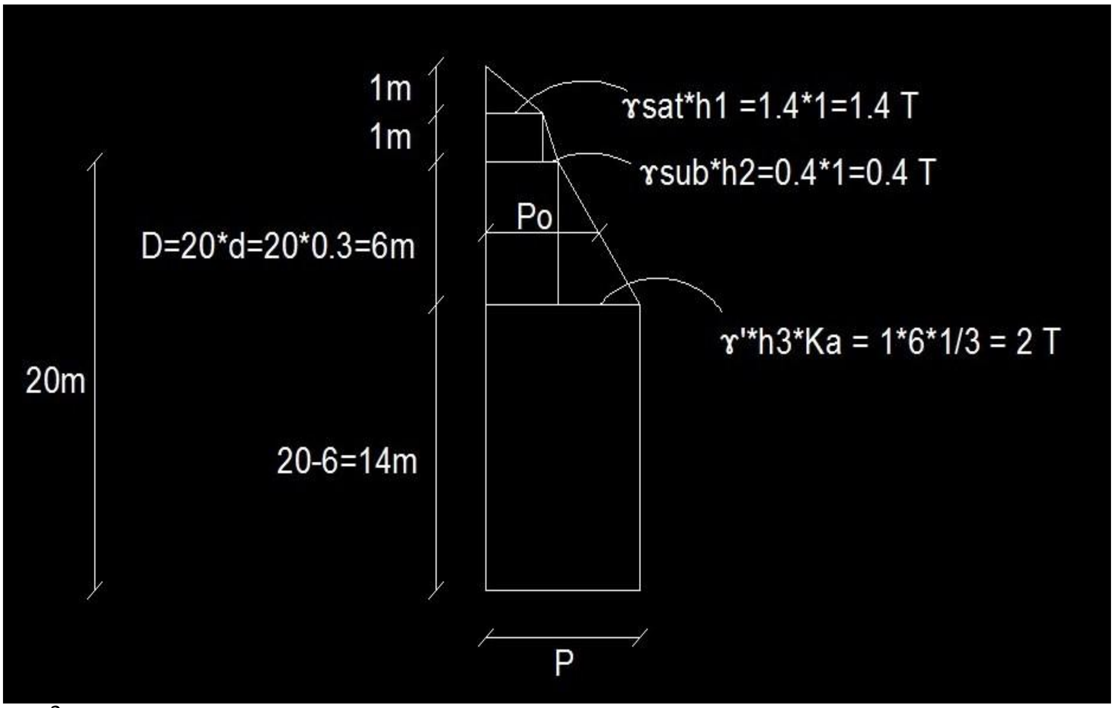
Given : $\emptyset = 30^o$, d= 30 cm , $K_{Ht} = 1$, $K_{Hc} = 1.5$, F.O.S = 3

Req : Determine the allowable Max Load for Driven pile shown in case of Compression & Tension .



Solution

100 kN / m^2 = 10 t / m^2 = 1 kg / cm



2

For Cohesion Less Soil (Sand):

$D = L*d = 20*0.3 = 6$ m

1) Compression:

$Q_{ult} = P*N_q*\frac{\pi*(d^2)}{4} + K_{HC}*P_o*\tan\delta * \pi * d * L$

$K_a = \frac{1-\sin\emptyset}{1+\sin\emptyset} = \frac{1-\sin 30}{1+\sin 30} = 0.33$

$\delta = \frac{3}{4} * \emptyset = \frac{3}{4} * 30 = 22.5$

$\emptyset = 30^o \rightarrow N_q = 30$ from table

$P = 1.4 + 0.4 + 2 = 3.8$ T

$P_{o1} = (\frac{1.4 + 0.4 + 3.8}{2}) * 6 = 16.8$ T

$P_{o2} = 3.8*14 = 47.6$ T

$P_{To} = 47.6 + 16.8 = 64.4$ T

تم ضرب قيمة ال P_o في الطول L لكل جزء فلا يتم وضع قيمة الطول L في المعادلة.

$Q_{ult} = 3.8*30*\frac{\pi*(0.3)^2}{4} + 1.5*64.4*\tan 22.5* \pi*0.3$

$= 45.77$ Ton

$Q_{all} = \frac{Qult}{F.O.S} = \frac{45.77}{3} = 15.26$ Ton

2) Tension:

$T_{ult} = K_{Ht}*P_o*\tan\delta * \pi * d + W_p$

$= 1*64.4**\tan 22.5* \pi*0.3 + 3.89 = 29$ Ton

$K_{Ht} = 1$, $L = 22$

$W_p = \frac{\pi*(d^2)}{4} * L * \gamma_c$

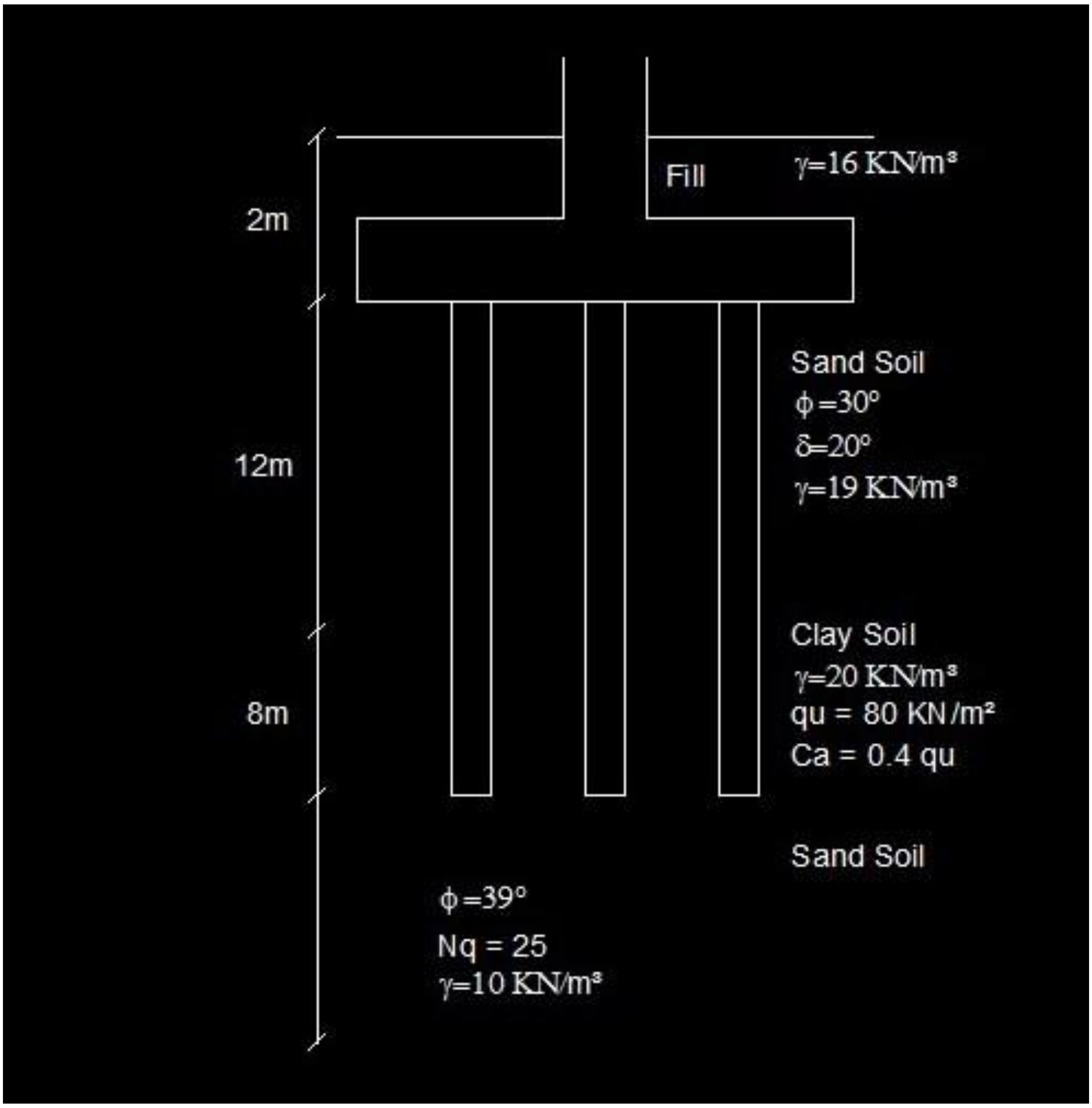
$W_p = \frac{\pi*(0.3)^2}{4} * 22 * 2.5 = 3.89$

$T_{all} = \frac{tult}{F.O.S} = \frac{29}{3} = 9.67$ Ton

Example: 3

Given : d= 40 cm , $K_{Ht} = 1$, $K_{Hc} = 1$, F.O.S = 3 , No. of piles = 12

Req : Determine the safe Load capacity of the pile group.



Solution

For Clay Soil:

∵ Pile Rested on Sand Soil:

∴ end Bearing = 0

$Q_{ult(1)} = C_a * \pi * d*L$

$C_a = 0.4* q_u = 0.4 * 80 = 32\ KN/m^2$

$Q_{ult(1)} = 32* \pi * 0.4*8 = 321.7\ KN$

For Sand Soil:

Sand (1):

طبقة الرمل العلوية:

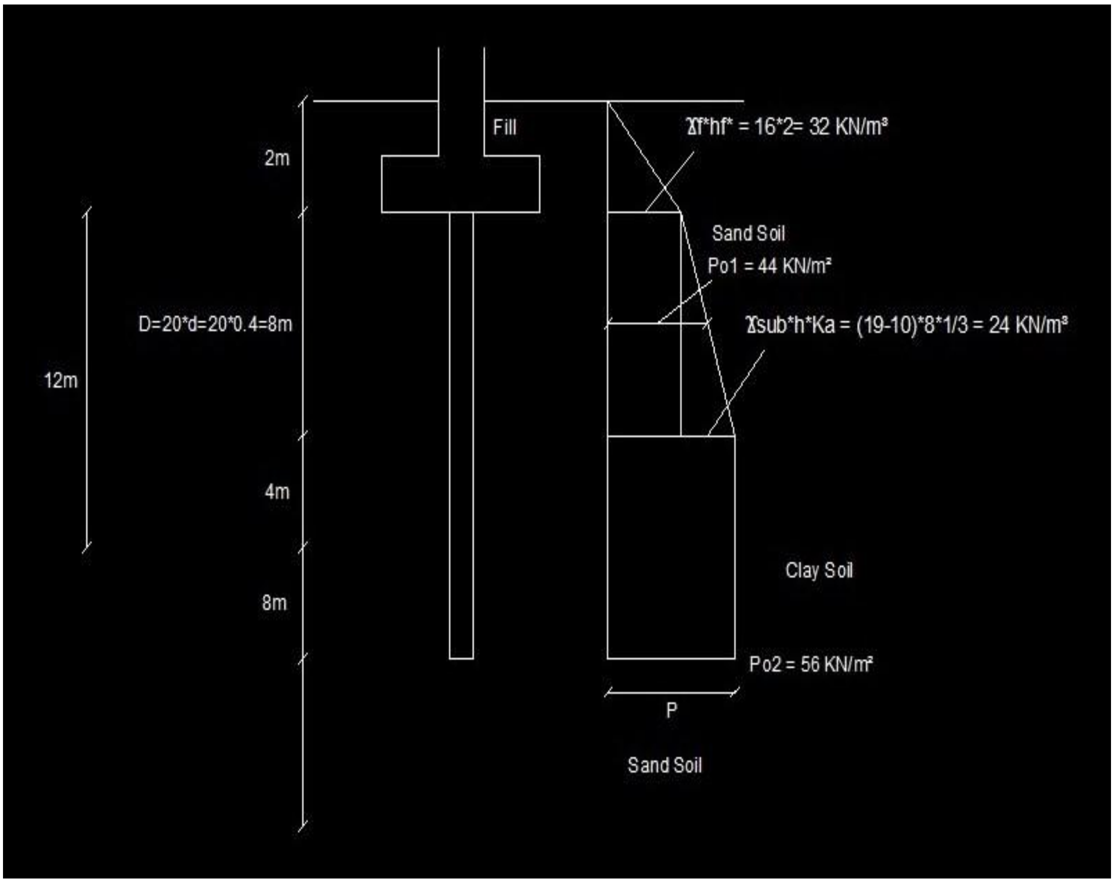
Friction only:

D = L*d = 20*0.4 = 8 m

$Q_{ult} = K_{HC} *P_o *\tan\delta * \pi * d * L$

$K_a = \frac{1-\sin\emptyset}{1+\sin\emptyset} = \frac{1-\sin 30}{1+\sin 30} = 0.33 = 1/3$

$\gamma_{sub} = \gamma - \gamma_w = 19 - 10 = 9\ KN/m^3$



$P_{o1} = \frac{32+56}{2} = 44\ KN/m^2$

$P_{o2} = 56\ KN/m^2$

$Q_{ult(2)} = 1*\{(8*44)+(4*56)\}*\tan 20*\pi*0.4$

$= 263.45\ KN$

Sand (2):

طبقة الرمل السفلية:

End Bearing only:

$Q_{ult(3)} = P*N_q*\frac{\pi*(d^2)}{4}$

$Q_{ult(3)} = 56*25*\frac{\pi*(0.4)^2}{4} = 176\ KN$

$Q_{ult(TOTAL)} = Q_{ult(1)} + Q_{ult(2)} + Q_{ult(3)}$

$=321.7 + 263.45 + 176 = 761.15\ KN$

$Q_{all} = \frac{Qult}{F.O.S} = \frac{761.15}{3} = 253.72\ KN$

$Q_{all(group)}$ = No. of piles * Q_{all} = 12*253.72

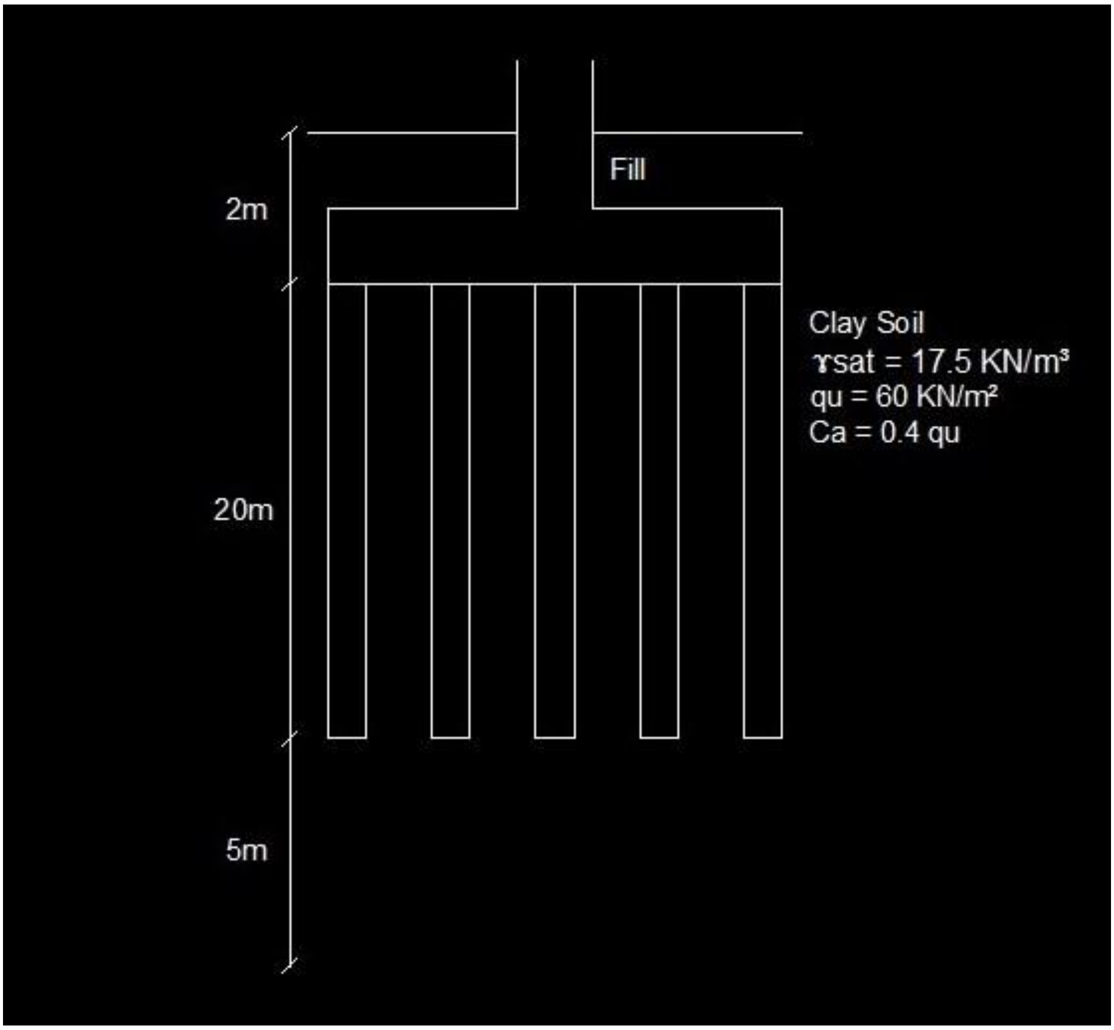
= 3044.64 KN = 304.46 Ton

Example: 4

Given : d= 40 cm , F.O.S = 3 , No. of piles = 16 ,

Friction pile.

Req : Determine the safe Load capacity of the pile group.



Solution

For Clay Soil:

∵ Pile Friction:

∴ end Bearing = 0

$Q_{ult(F)} = C_a * \pi * d*L$

$C_a = 0.4* q_u = 0.4 * 60 = 24$ KN/m^2

$Q_{ult(F)} = 24* \pi *0.4*20 = 603.2$ KN = 60.3 Ton

$Q_{all} = \frac{Qult}{F.O.S} = \frac{603.2}{3} = 201.1$ KN

$Q_{all(group)}$ = No. of piles * Q_{all} = 16*201.1

= 3217.1 KN = 321.7 Ton

3) Determination piles settlement:

For settlement of a single pile is considered to be the sum of three components:

هبوط الخازوق المفرد: يتم حسابه باعتبار هبوط الخازوق عند طرفة العلوي هو حاصل جمع ثلاثة مقادير هي:

1.The elastic compression of pile shaft (S_s):

الهبوط نتيجة لانفعال جذع الخازوق تحت إجهادات التحميل:

2.The settlement caused by load transferred at the pile tip (S_{pp}):

الهبوط نتيجة لإنتقال حمل الارتكاز Q_b إلي التربة S_{pp}.

3.The settlement caused by load transferred along the pile shaft (S_{ps}):

هبوط الخازوق نتيجة لإنتقال حمل الاحتكاك Q_f من جذع الخازوق إلي التربة S_{ps}.

The total settlement is then equal to:

$$S_o = S_s + S_{pp} + S_{ps}$$

1.The elastic compression of pile shaft (Ss) :

$$S_s = (Q_b + \alpha_f * Q_f) * \frac{L}{A * Ep}$$

In which:

حيث أن:

Qb → Bearing load at pile tip.

حمل الإرتكاز المنقول للتربة عند طرف الخازوق السفلي.

Qf → Friction load transmitted by pile shaft.

حمل الإحتكاك المنقول للتربة عن طريقة جهود الإحتكاك علي سطح جذع الخازوق.

L →Pile length.

طول الخازوق.

A → Pile cross-sectional area.

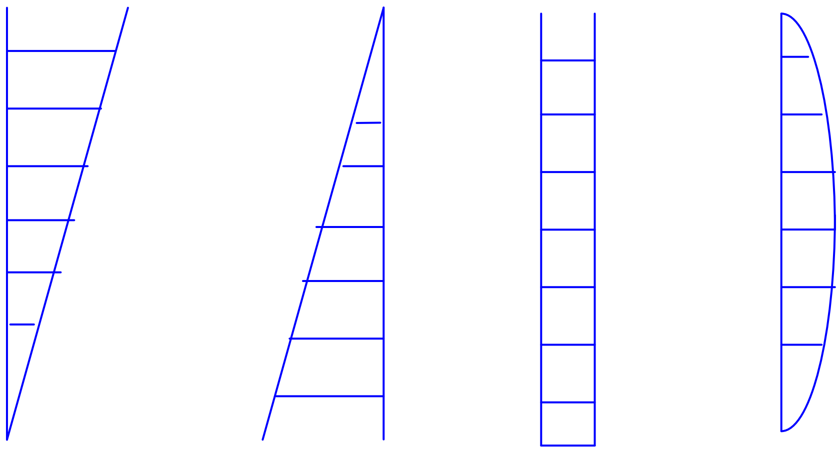
مساحة مقطع الخازوق.

E_p → Elastic modulus for pile material.

معامل المرونة لمادة الخازوق.

α_f → Skin friction distribution coefficient.

معامل يتوقف علي منحني توزيع جهود الإحتكاك علي إمتداد طول الخازوق.



$\alpha_f = 0.33$ $\alpha_f = 0.67$ $\alpha_f = 0.5$ $\alpha_f = 0.5$

Skin friction distribution Coefficient (α_f)

2- Settlement caused by load transferred at the pile tip (S_{pp}):

$$S_{pp} = \frac{C_b\, Q_b}{d.q}$$

In which:

C_b → Factor according to table 9.1.

معامل يعتمد علي نوعية التربة وعلي أسلوب تنفيذ الخازوق.

Q_b → Bearing load at pile tip.

حمل الإرتكاز المنقول للتربة عند طرف الخازوق السفلي.

d → pile diameter.

قطر الخازوق.

q → Ultimate end bearing capacity.

الجهد الأقصى لسعة التحميل عند نهاية الخازوق.

Bearing stratum under pile tip assumed to extend at least 10 pile diameters below tip and soil below tip is of comparable or higher stiffness.

ويشترط أن تكون طبقة ارتكاز الخازوق ممتدة تحت طرف الخازوق لمسافة تساوى عشرة أمثال قطره على الأقل وأن تكون الطبقات التى تليها ذات مقاومة تتساوى مع أو تزيد عن مقاومة الطبقات المنشأة بها الخوازيق.

Table 9.1 Values of C_b:

Soil Type	Driven piles	Bored Piles
Loose to dense sand	0.02-0.04	0.09-0.18
Soft to stiff clay	0.02-0.03	0.03-0.06
Loose to dense silt	0.03-0.05	0.09-0.12

3- Settlement caused by load transferred along the pile shaft (S_{ps}):

$$S_{ps} = \frac{C_s\, Q_f}{L_o \,.\, q}$$

In which:

حيث أن:

C_s → Factor from the following relation:

معامل.

$$C_s = (0.93 + 0.16\sqrt{\frac{L_o}{d}}).C_b$$

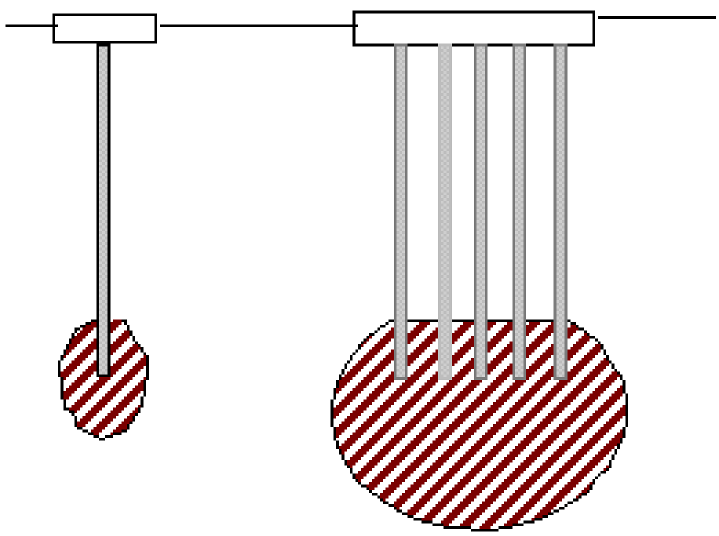
Lo → Embedded pile length.

طول جذع الخازوق المدفون بالتربة.

q → Ultimate end bearing capacity.

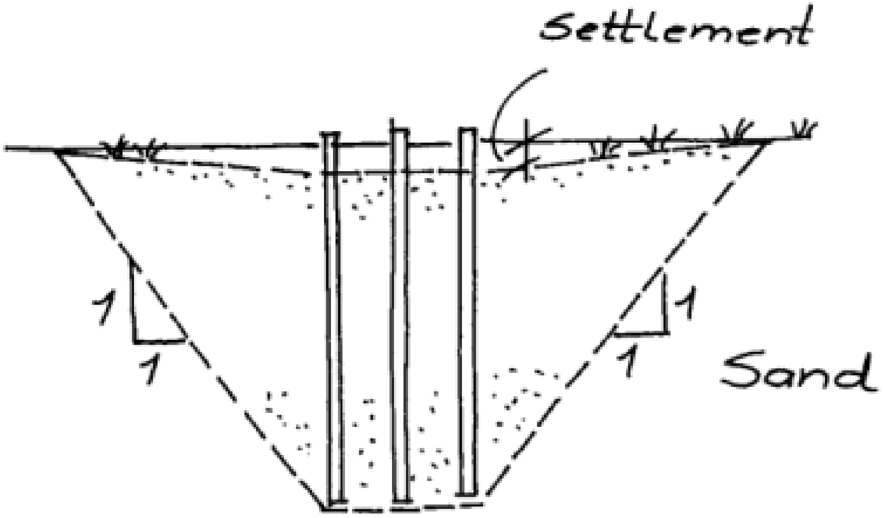
الجهد الأقصى لسعة التحميل عند نهاية الخازوق.

Settlement of pile groups:



a) single pile

b) pile group



Settlement of pile groups according to Egyptian code:

$$S_g = S_o * \sqrt{\frac{b}{d}}$$

In which:

حيث أن:

b → pile group width.

المقياس الأدنى (الطول الأصغر) لمجموعة الخوازيق بالمسقط الأفقي.

d → pile diameter.

قطر الخازوق.

So → Single pile settlement estimated or determined from load tests.

مقدار هبوط الخازوق المفرد مقدر من الصيغة السابق ذكرها أو المحددة من تجارب التحميل.

Example: 5

Given : d= 80 cm , L= 25 m , Qall = 200 Ton ,

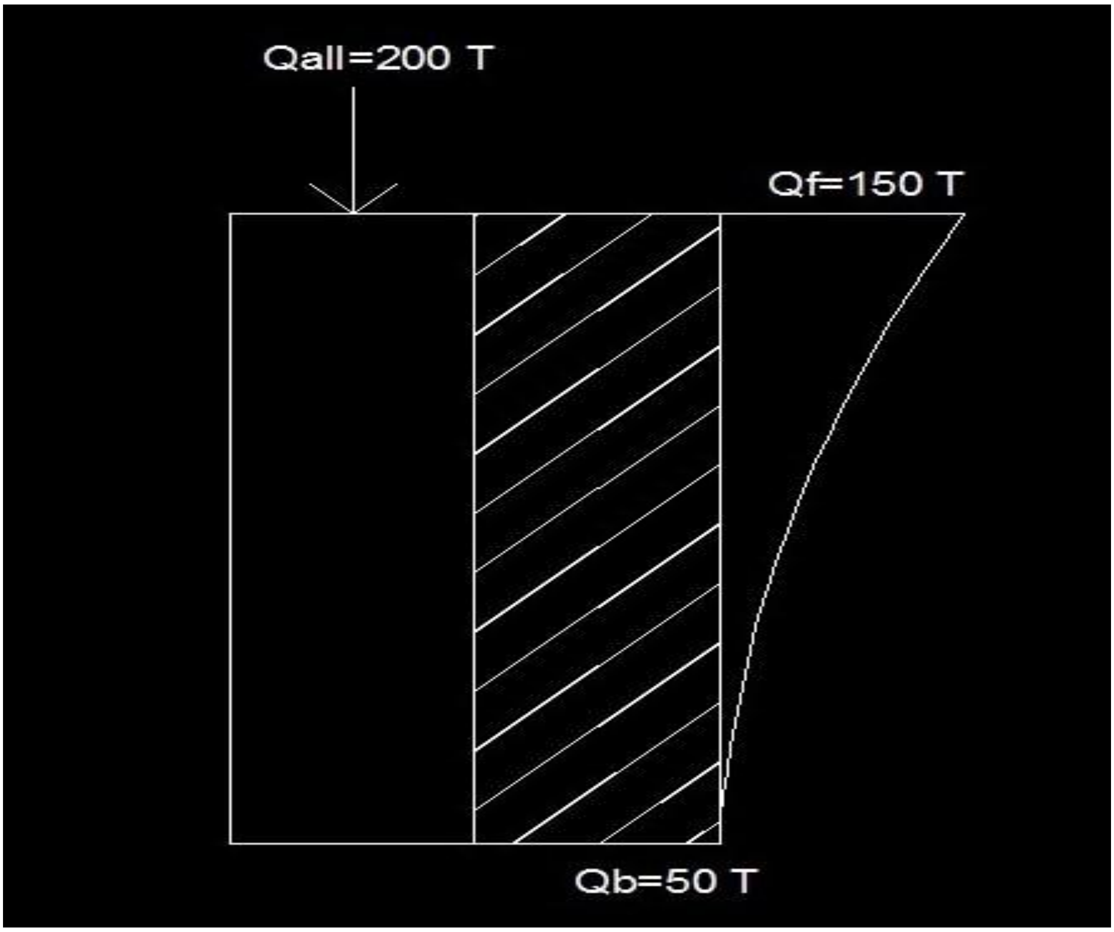
E_p = 2000000 t/m^2 , b = 5.6 m , Soil Type is Loose to dense sand , Bored Piles

Req : Determine the settlement of a single pile & the Settlement of pile groups.

Solution

For settlement of a single pile:

$$S_o = S_s + S_{pp} + S_{ps}$$



$S_s = (Q_b + \alpha_f * Q_f) * \frac{L}{A*Ep}$

$A = \frac{\pi*(d)^2}{4} = \frac{\pi*(0.8)^2}{4}$ = 0.5 m

α_f = 0.5 from chart

$S_s = (50 + 0.5*150)*\frac{25}{0.5*2000000} = 0.00313$ m

$S_{pp} = \frac{Cb*Qb}{d*q}$

d = 0.8 m , Q_b = 0 T

C_b = 0.09 From table

$q = \frac{Qb}{A} = \frac{0}{0.5} = 0$

$S_{pp} = \frac{0.09*0}{0.8*0} = 0$

$S_{ps} = \frac{Cs*Qf}{Lo*q}$

$C_s = (0.93+0.16\sqrt{\frac{Lo}{d}})*C_b$

L_o = 18 m , d = 0.8 , C_b = 0.09 , q = 300

$C_s = (0.93+0.16*\sqrt{\frac{18}{0.8}})*0.09 = 0.15$

$S_{ps} = \frac{0.15*150}{18*300} = 0.0042$ m

$S_o = S_s + S_{pp} + S_{ps}$

$= 0.00313 + 0 + 0.0042 = 0.0073$ m

For Settlement of pile groups:

$S_G = S_o\sqrt{\frac{b}{d}} = 0.0073*\sqrt{\frac{5.6}{0.8}} = 0.02$ m

4) Short and Long pile:

Elastic versus rigid behavior:

$T = \sqrt[5]{\frac{E*I}{\eta}}$

حيث أن:

T → relative stiffness factor

E → modulus of elasticity of pile

I → pile inertia

$I = \frac{\pi*(D)^4}{64}$

η for clayey or silty soil:

q_{un} (KN/m^2)	25	50	100
η(KN/m^3)	600	1600	3700

η for sand soil:

Relative Density (Dr)	35	65	85	100
η(KN/m^3)	4300	12300	18000	22200

For submerged soil ''η'' is reduced to half the above values. Besides, ''η'' must be reduced to 0.25 the above values if pile spacing in the direction of loading is three times the pile diameter (3D), no reduced if spacing = 8D, values for another spacing values shall be calculated by interpolation.

If $\frac{L}{T} < 2$ → the pile is considered short rigid pile

If $\frac{L}{T} > 4$ → the pile is considered long flexible pile

حيث أن:

L → pile length (embedded length)

For Short Rigid Piles:

1) Fixed headed piles:

1.1.) Piles in sandy soil:

$P_u = 1.5 * \gamma * L^2 * D * K_P$

حيث أن:

γ → effective unit weight

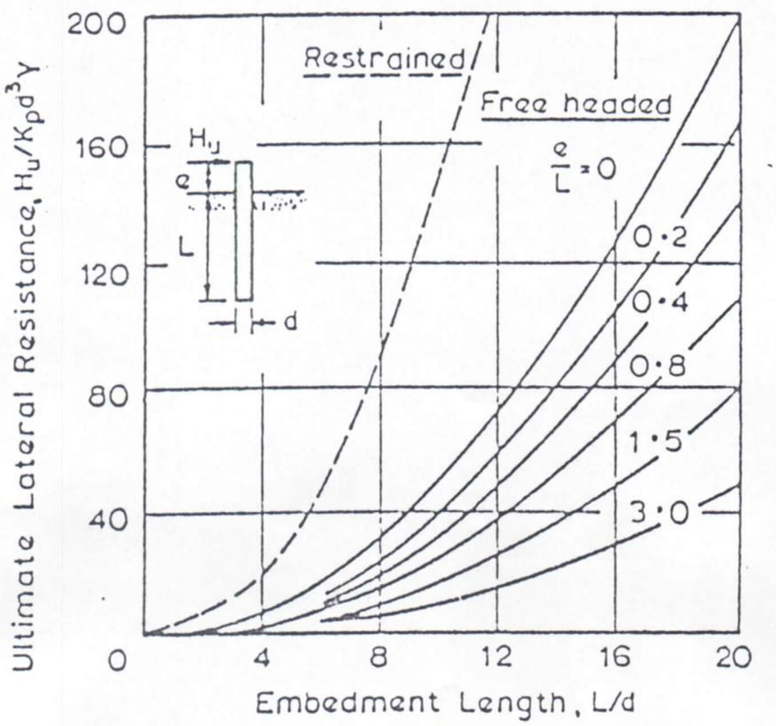
$\gamma = \gamma_{sub}$ under water

L → pile length

D → pile diameter

K_P → passive coefficient

To get K_P from chart



(a)

Fig. (2-a) Ultimate lateral resistance of short piles in cohesionless soils (after Broms, 1964)

1.2.) piles in clay soil:

$P_u = 9*c_u*D*(L-1.5*D)$

حيث أن:

$c_u \rightarrow$ undrained shear strength of soil

2) Free headed piles:

2.1.) Piles in sandy soil:

$P_u = \frac{0.5*D*(L)^3*Kp*Ɣ}{H+L}$

حيث أن:

$L \rightarrow$ is the embedded length of pile

$H \rightarrow$

سمك الردم

Take H=2m

2.2.) piles in clay soil:

$P_u = \frac{(Lo)^2-2*L'*Lo+(0.5*(L')^2)}{L+H+(1.5*D)} * 9 * Cu * D$

حيث أن:

$L' = L - 1.5*D$

$L_o = \frac{(H+\frac{2}{3}*L)}{2*H+L} * L$

For Long Flexible Pile

1) Fixed headed piles:

1.1.) Piles in sandy soil:

$P_u = \frac{2*\text{Mult resisting}}{H+\{0.54*\left(\frac{Pu}{(\gamma'*D*Kp)}\right)\}}$

حيث أن:

M_{ult} → is the moment of resisting of the pile section including its reinforcement.

1.2.) piles in cohesive soil:

$P_u = \frac{2*\text{Mult resisting}}{H+\{1.5*\left(\frac{Pu}{(9*Cu*D)}\right)\}}$

The maximum induced ultimate moment in pile = $0.85*P_u*\eta$

The maximum deflection at pile top

$= 0.88*P_{service} * \frac{(T)^3}{E*I}$

2) Free headed piles:

2.1.) Piles in sandy soil:

$P_u = \frac{\text{Mult resisting}}{H+\{0.54*\left(\frac{Pu}{(\gamma'*D*Kp)}\right)\}}$

حيث أن:

M_{ult} → is the moment of resisting of the pile section including its reinforcement.

2.2.) piles in cohesive soil:

$P_u = \frac{\text{Mult resisting}}{H+\{1.5*\left(\frac{Pu}{(9*Cu*D)}\right)\}}$

The maximum induced ultimate moment in pile = $0.77*(P_u*\eta+M_{OU})$

The maximum deflection at pile top

$= 2.4 * \frac{Pservice*(\eta)^3}{E*I} + \frac{1.55*Mo*(\eta)^2}{E*I}$

حيث أن:

$M_o \rightarrow$ is any induced acting moment on the free pile head

$P_u = \frac{Rection}{no.of\ pile}$

Reaction = $\sqrt{(Fx)^2 + (Fy)^2}$

From INTERACTION Diagrams:

$K = \frac{Mu}{Fcu*(R)^3}$

Get ρ

$A_s = \boldsymbol{\rho} * (fcu * 10^{-4}) * \pi * (R)^2$

حيث أن:

$R \rightarrow$

نصف قطر الخازوق

Example: 5

Given : D= 80 cm , L= 25 m , E_p = 2000000 t/m^2 , piles in clay soil , q_{un} = 50 KN/m^2 , C_u = 5 t/m^2 , F_x = 327.7 ,

F_y = 73.34 , No. of piles = 11 ,

F_{cu} = 30 N/mm^2 , Pile Rested in cohesive soil

Req : Determine the pile is Short or Long pile.

Solution

$T = \sqrt[5]{\frac{E*I}{\eta}}$

$I = \frac{\pi*(D)^4}{64} = \frac{\pi*(0.8)^4}{64} = 0.02\ m^4$

for clayey soil:

η = 1600 = 1600 /2 = 800 KN/m^3 = 80 t/m^3

$$T = \sqrt[5]{\frac{2000000*0.03}{80}} = 3.47 \text{ m}$$

L = 25 – 2 = 23 m

$$\frac{L}{T} = \frac{23}{3.47} = 6.63 > 4$$

∴ the pile is considered long flexible pile

For long flexible pile (Fixed headed)

$$P_u = \frac{2*\text{Mult resisting}}{H+\{1.5*\left(\frac{Pu}{(9*Cu*D)}\right)\}}$$

Take H = 3

C_u = 5 t/m^2

$$P_u = \frac{\text{Rection}}{\text{no.of pile}}$$

$$\text{Reaction} = \sqrt{(Fx)^2 + (Fy)^2}$$

$$= \sqrt{(327.7)^2 + (73.34)^2} = 336 \text{ T}$$

$$P_u = \frac{336}{11} = 30.55 \text{ T}$$

$$30.55 = \frac{2*\text{Mult}}{3+\{1.5*\left(\frac{30.55}{(9*5*0.8)}\right)\}}$$

$2M_{ult}$ = 130.54

M_{ult} = 65.27 m.t

From INTERACTION Diagrams:

$$K = \frac{Mu}{Fcu*(R)^3} = \frac{65.27*10^7}{30*(400)^3} = 0.34$$

ρ = 4

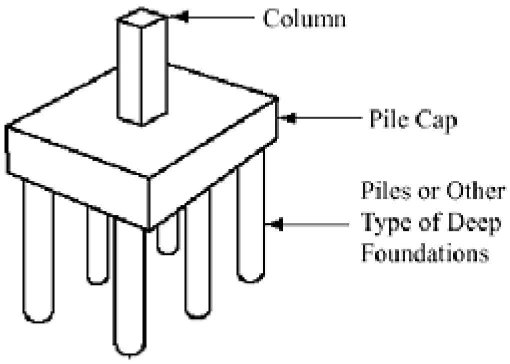
$A_s = \boldsymbol{\rho} * (fcu * 10^{-4}) * \pi * (R)^2$

$= \mathbf{4} * (30 * 10^{-4}) * \pi * (40)^2$

= 60.32 cm

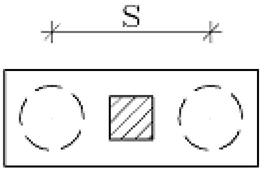
Use 20 y 25

5) Design of piles cap:

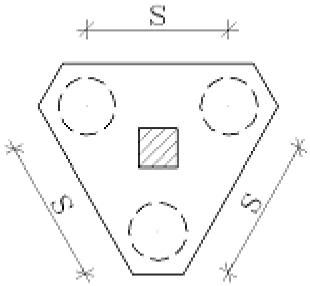


Pile caps are thick slabs used to tie a group of piles together to support and transmit column loads to the piles.

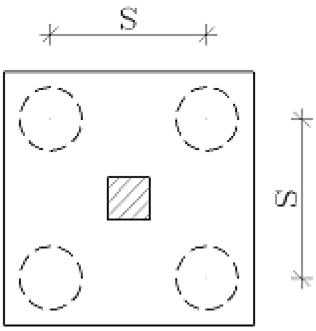
Typical Arrangement of Piles:



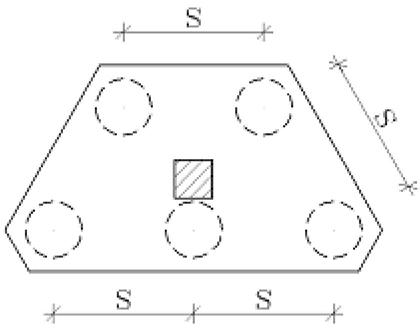
2 Piles



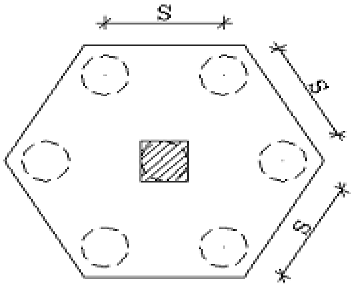
3 Piles

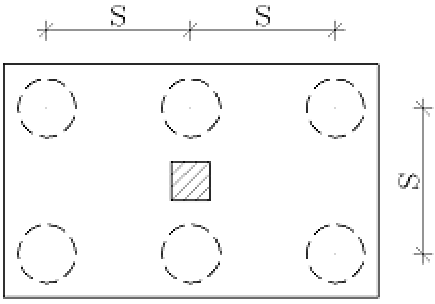


4 Piles

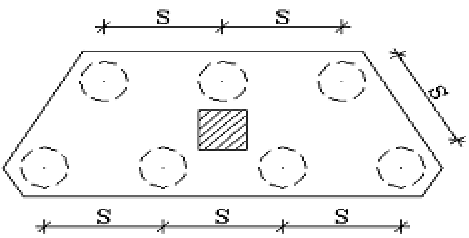


5 Piles

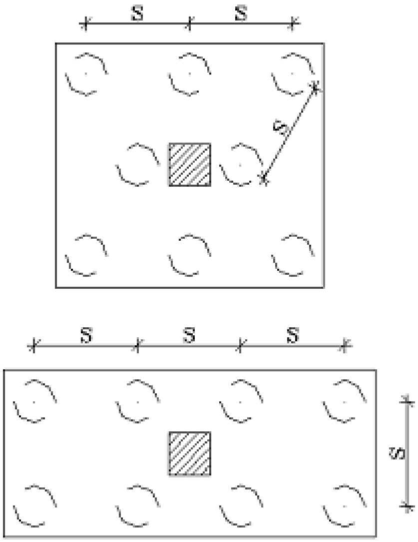




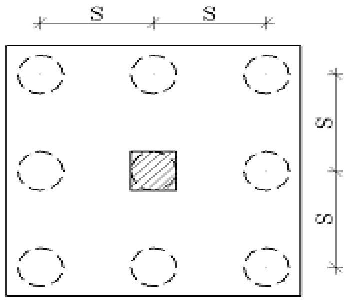
6 Piles



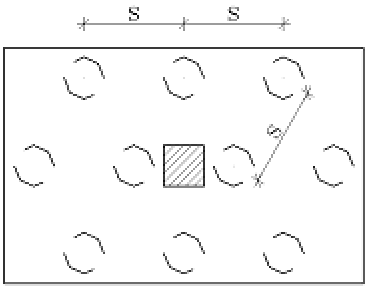
7 Piles



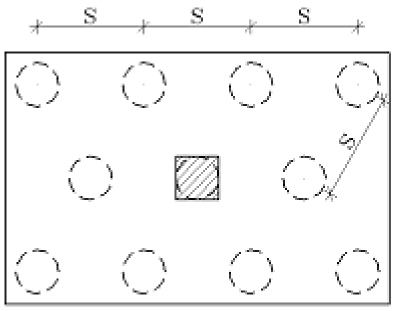
8 Piles



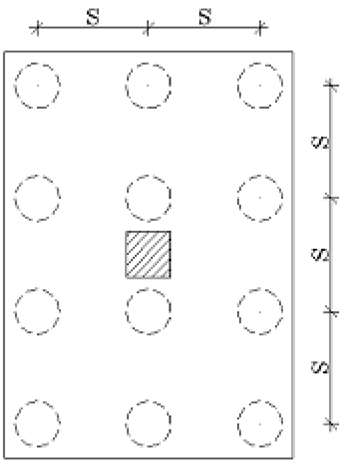
9 Piles



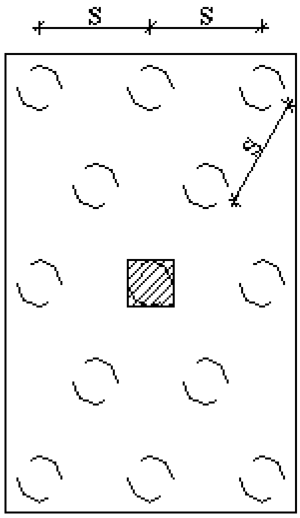
10 Piles



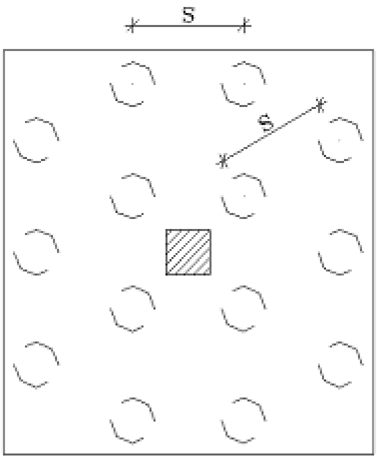
11 Piles



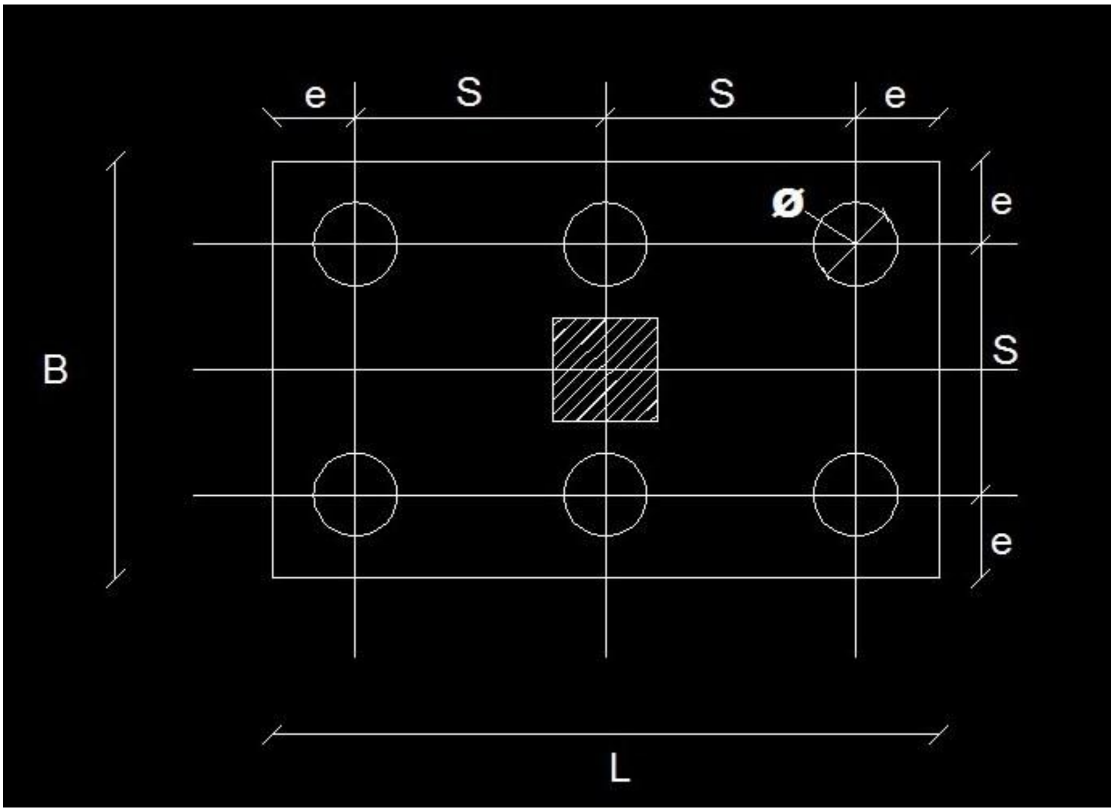
12 Piles



13 Piles



14 Piles



يراعي أن يكون العمود في C.G of pile cap

حتي تكون القاعدة مرتكزة علي العمود

Steps of Design:

1) No.of.pile= $\frac{1.15*p}{Qall} + (1 \rightarrow 2)$ approximated to the nearesr bigger no $\rightarrow$ min 2 piles

2) Draw pile cap and get Dimention:

Thickness of PC = 10 cm

S_{min} = 3*∅ → for friction piles

S_{min} = 2.5*∅ → for bearing piles

S_{max} = 6*∅

e =(1→1.5)*∅

$P_{pile} = \frac{1.1P}{no.of\ piles}$

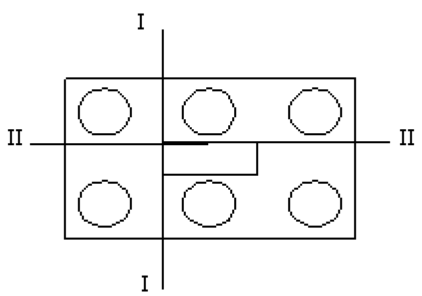
P_u = 1.5* P_{pile}

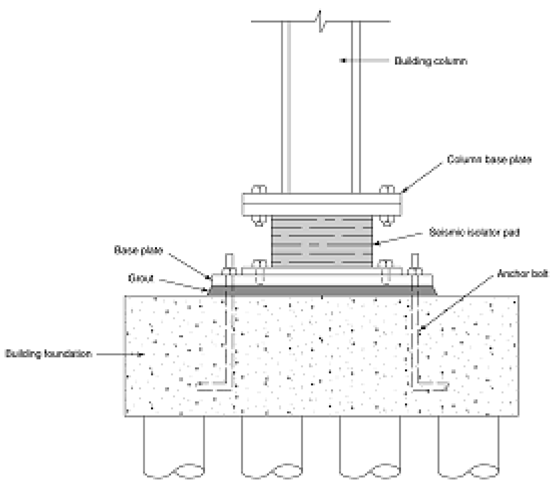
حيث أن:

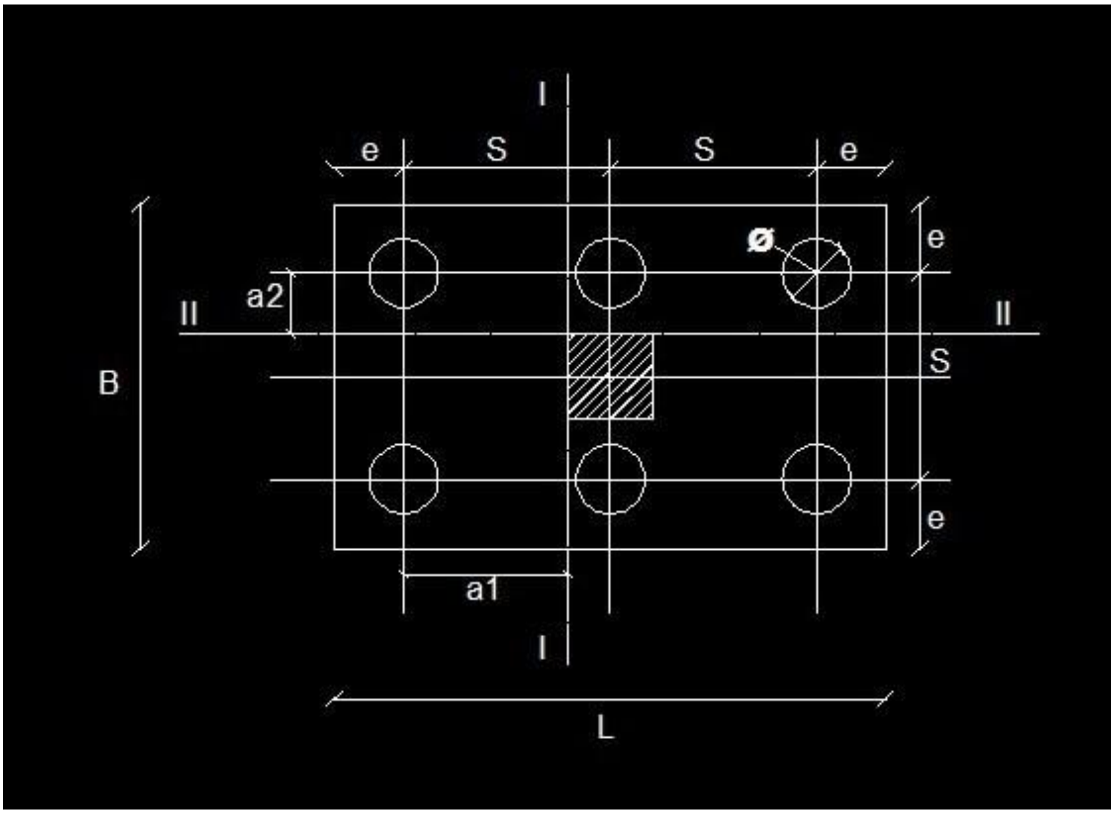
∅ → pile diameter

3) Design for moment:

The critical section for moment is taken at the column face.







M_I = no. of pile*P_u *a_1

No. of piles →

عدد الخوازيق المقابل لل I

M_{II} = no. of pile*P_u *a_2

No. of piles →

عدد الخوازيق المقابل لل II

$d_I = C_1\sqrt{\frac{MuI}{Fcu*B}}$

$d_{II} = C_1\sqrt{\frac{MuII}{Fcu*L}}$

حيث أن:

$C_1 = 5$

Take the bigger of d_I , d_{II}

d_{min} = {(1.5*∅)+10cm}

حيث أن:

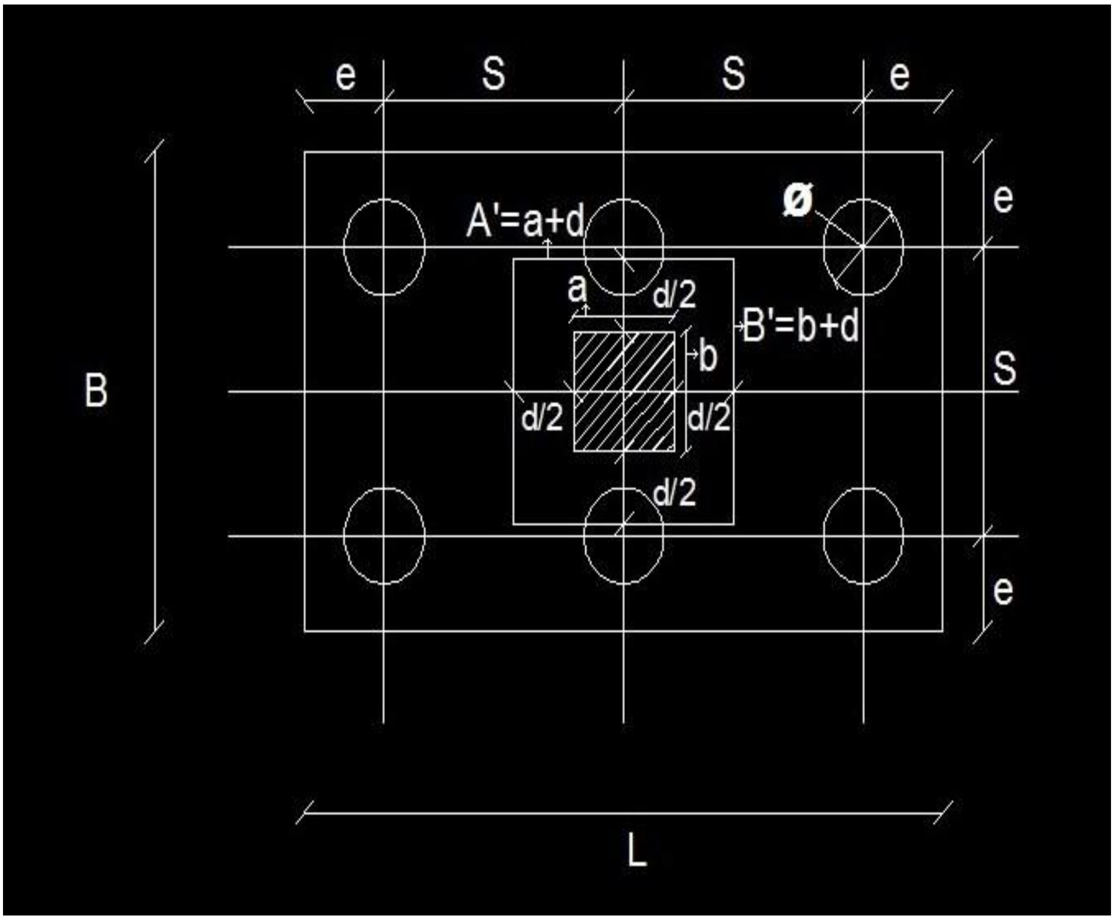
∅ → pile diameter

d_I , d_{II} , d_{min} → depth of pile cap

t = d + cover

cover = (10 to 15 cm)

Check Punching:



$Q_p = p_u - p_{upile}$

A' = (a+ d) = … m

B' = (b + d) = ... m

حيث أن:

a → طول العمود ، b → عرض العمود

d → depth of pile cap

p_{upile} → *parts of the piles inside the column , critical section at d/2 from the column as in shallow footing*

γ_c =1.5

$q_p = \frac{Qp}{2*(A'+B')*d}$ = ... kg/cm^2

$q_{pcu} = \sqrt{\frac{Fcu}{\gamma c}}$ = ... kg/cm^2

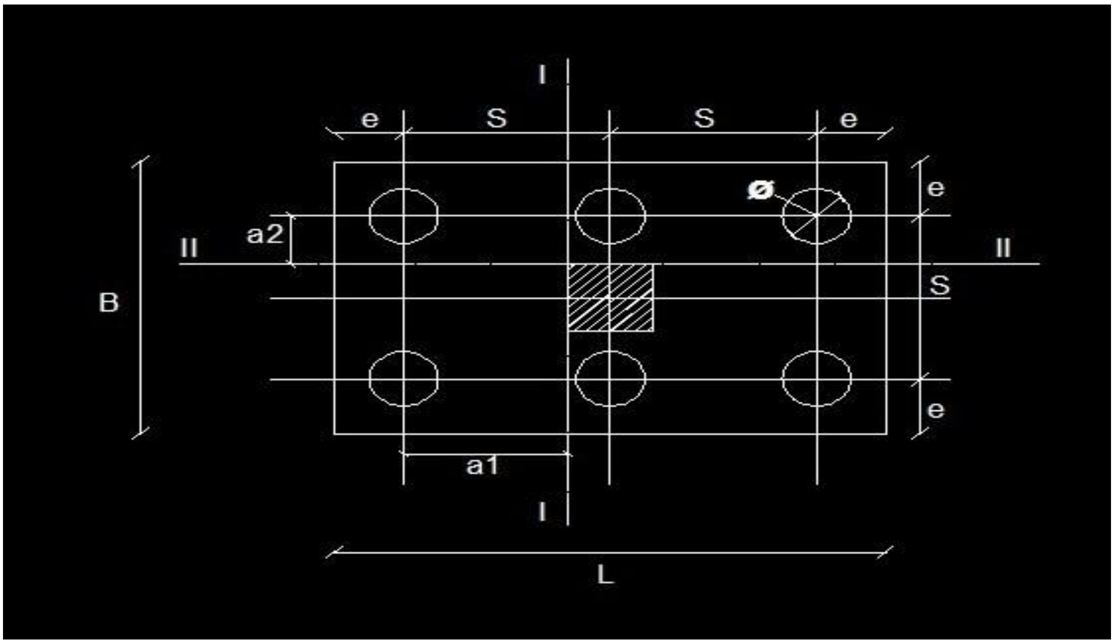
If $q_{pcu} > q_p$ ok safe

If $q_{pcu} < q_p$ un safe → increase depth

t = d + cover

cover = (10 to 15 cm)

Check Shear:



Q_{sh1}= sum no. of piles

No. of piles →

مجموع حمل الخوازيق المقابل لل I

$q_{sh1} = \frac{Qsh1}{B*d}$

$q_{cu} = 0.4 * \sqrt{Fcu}$

if $q_{sh} < q_{cu}$ ok safe

if $q_{sh} > q_{cu}$ not safe increase depth

$d = Q_{sh1} / (q_{cu} * B)$

t = d + cover

cover = (10 to 15 cm)

Q_{sh2}= sum no. of piles

No. of piles →

مجموع حمل الخوازيق المقابل لل II

$q_{sh2} = \frac{Qsh1}{L*d}$

$q_{cu} = 0.4 * \sqrt{Fcu}$

if $q_{sh} < q_{cu}$ ok safe

if $q_{sh} > q_{cu}$ not safe increase depth

$d = Q_{sh1} / (q_{cu} * L)$

t = d + cover

cover = (10 to 15 cm)

Reinforcement of the Cap Pile:

$A_{s1} = M_{ultI} / J*d_I*f_y / B$ - - - - - - - - - -(1)

$A_{s2} = M_{ultII} / J*d_{II}*f_y / L$ - - - - - - - - - -(1)

$A_{s\,min} = (0.15 / 100) * B * d$ - - - - - - - - - -(2)

نأخذ القيمة الأكبر في القيم 1,2

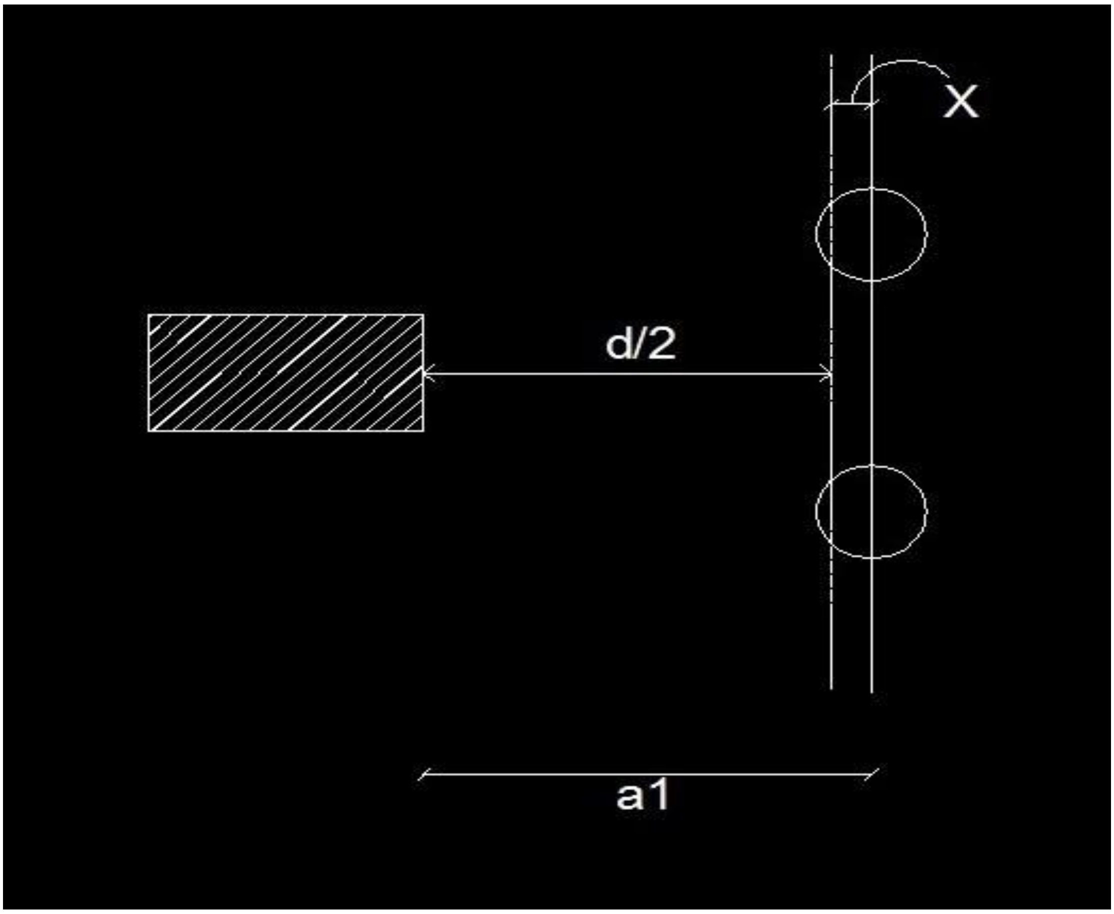
If $A_s \geq A_{s\,min} \rightarrow$ ok

If $A_s < A_{s\,min} \rightarrow$ take $A_s = A_{s\,min}$

في حالة تساوي B=L أبعاد القاعدة والشكل يكون متماثل:

Check Punching:

$Q_p = \frac{Pu*(X+\frac{\emptyset}{2})}{\emptyset}$



حيث أن:

$\varnothing \rightarrow$ pile diameter

$A' = (a + d) = \ldots$ m

$B' = (b + d) = \ldots$ m

حيث أن:

$a \rightarrow$ طول العمود ، $b \rightarrow$ عرض العمود

$d \rightarrow$ depth of pile cap

$\gamma_c = 1.5$

$q_p = \frac{Qp}{2*(A'+B')*d} = \ldots$ kg/cm^2

$q_{pcu} = \sqrt{\frac{Fcu}{\gamma c}} = \ldots$ kg/cm^2

If $q_{pcu} > q_p$ ok safe

If $q_{pcu} < q_p$ un safe $\rightarrow$ increase depth

$t = d +$ cover

cover = (10 to 15 cm)

Check Shear:

$Q_{sh} = Q_P$ * No. of piles

No. of piles $\rightarrow$

عدد الخوازيق المقابل لل II أو I

$q_{sh} = \frac{Qsh}{B*d}$

$q_{cu} = 0.4 * \sqrt{Fcu}$

if $q_{sh} < q_{cu}$ ok safe

if $q_{sh} > q_{cu}$ not safe increase depth

$d = Q_{sh} / (q_{cu} * B)$

$t = d + cover$

cover = (10 to 15 cm)

Reinforcement of the Cap Pile:

$A_s = M_{ult} / J*d*f_y$ - - - - - - - - - -(1)

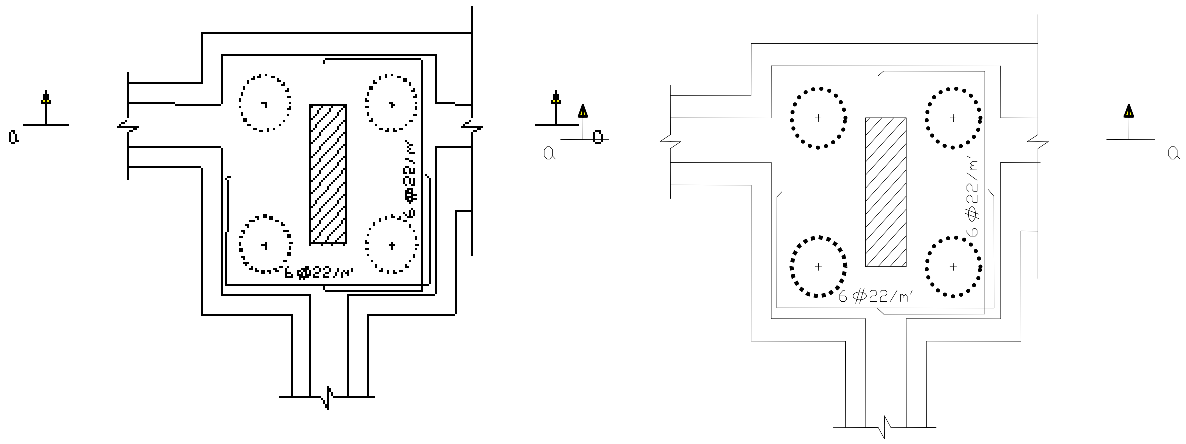
$A_{s\,min} = (0.15 / 100) * B * d$ - - - - - - - - - -(2)

نأخذ القيمة الأكبر في القيم 1,2

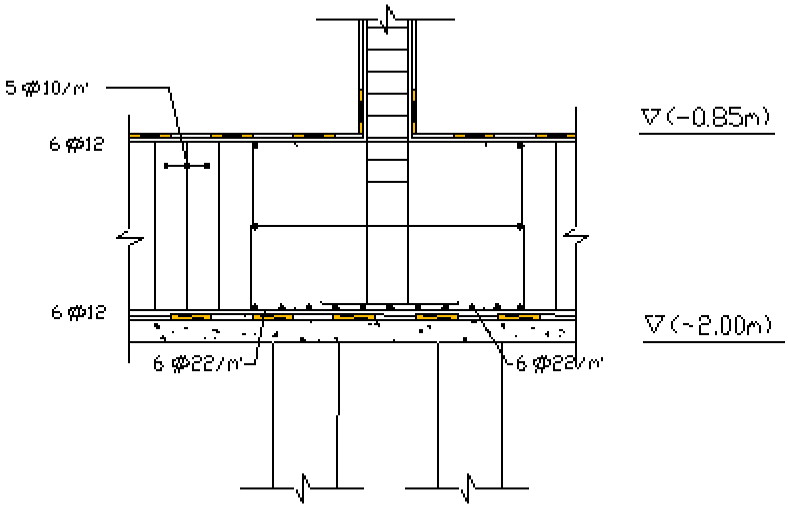
If $A_s \geq A_{s\,min} \rightarrow$ ok

If $A_s < A_{s\,min} \rightarrow$ take $A_s = A_{s\,min}$

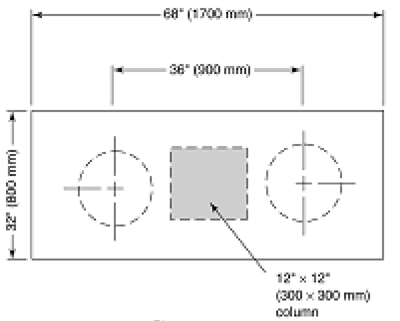
Details of reinforcement:



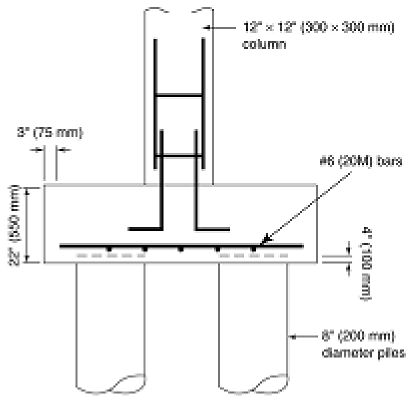
Plane



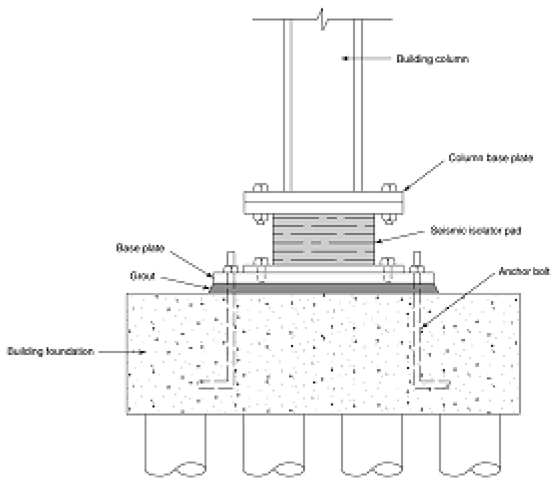
Sec a-a

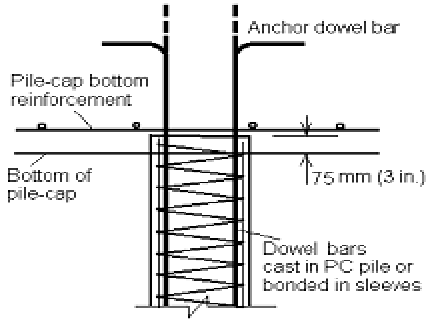


Plan



Elevation





تم بحمد الله