تابع مراجعة
mid-Term
[illegible] قسم رابع انشاءات

Piled foundation

Types of piles according to the method of installation:

1) Bored piles (Replacement piles)
2) Driven piles (Displacement piles)
3) Screw piles (Semi driven-semi bored)
4) Continious flight auger piles (Semi driven-semi bored)

Choice of suitable R.C. pile :

Problem condition	Suitable R.C. pile
Square piles	Driven
Circular piles	Driven or Bored
Precast piles	Driven
Cast in place piles	Driven or Bored
Large diameter piles (Φ>60cm)	Bored
Adjacent buildings beside the site	Bored
The soil profile contains a hard layer (Rock,Very dense sand,very stiff clay ,Very stiff silt , Gravel)	Bored

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Pile Axial Capacity

The maximum axial force (Compression or tension) that can be carried safely by a single pile .

يمكن تحديد قدرة تحمل الخازوق الواحد بالطرق الآتية :

1) Structural formula:

$$Q_{all} = A_{pile} \times F_{co}$$

Q_{all} : allowable compression capacity of single pile. (N)

A_{pile} : Cross sectional area of pile. (m.m.)

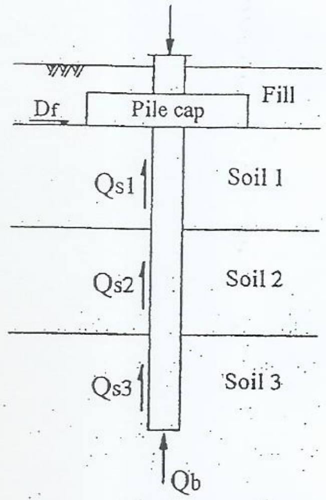
F_{co}: axial compressive strength of concrete. ($4 - 5\ N/m.m^2$)

2) Statical formula:

2-a) Compression Capacity:

$$Q_{ult.} = Q_b + \Sigma Q_{si}$$

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



$Q_{ult.}$: ultimate single pile capacity. (KN)

Q_b : bearing resistance force. (KN)

Q_s : Side friction resistance force. (KN)

Q_{all} : allowable single pile capacity. (KN)

End bearing resistance (Q_b):

$$Q_b = (C*N_c + q * N_q) \times A_b \qquad (C\text{-}\Phi soil)$$

A_b : Cross sectional area of pile base. (m^2)

C : Cohesion strength of bearing soil. (KN/m^2)

$N_c = 9$

q : effective stress at pile tip. (KN/m^2)

N_q = factor depends on $\bar{\Phi}$. جدول ٤-٥

Driven piles $\bar{\Phi} = \frac{\Phi+40}{2}$

Bored piles $\bar{\Phi} = \Phi-3$

Note:

For C- Soil ⟶ $N_q = 0$

For Φ- Soil ⟶ $C = 0$

Side friction resistance (Qs):

$$Q_s = (C_a + K_{HC} \cdot P_o \cdot \tan\delta) \times A_s \qquad (\text{C-}\Phi\text{soil})$$

A_s : Side area of the pile. (m^2)

Ca : Adhesion strength of soil. (KN/m^2)

Ca —
- 0.35 Csoil (Bored piles)
- (جدول ٤ - ٤) (Driven piles)

K_{HC} : (جدول ٤ - ٦) . معامل الضــغط الجـــانبى للتربــــة فــى حالـة الخـازوق المحمـل بأحمــال ضـغط .

IF NOT GIVEN :

Take $K_{HC} = 1.0$ (Bored piles or Driven piles)

Po : الضــغط الفعـــال عنـد منتصـــف الطبقـــة الـــتى يتـــم حسـاب الQs لها .

δ : زاويــة الاحتكـــاك بيـــن الخـازوق و التربــــة.

$\delta = \frac{3}{4}\Phi$ or Given

Note:

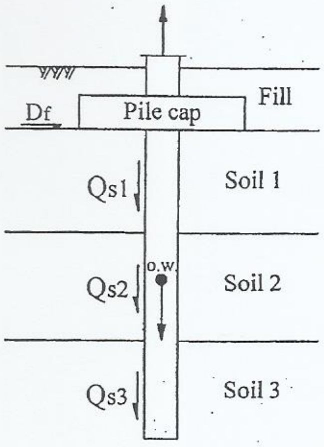
For C- Soil ⟶ $\delta = 0$

For Φ- Soil ⟶ $Ca = 0$

2-b) Tension Capacity:

$T_{ult.} = Q_s + o.w.$

$T_{all.} = \frac{Q_s}{F.O.S} + o.w.$



$$Q_s = (C_a + K_{HT} \cdot P_o \cdot \tan\delta) \times A_s \qquad (\text{C-}\Phi\text{soil})$$

K_{HT} : . معامل الضــغط الجـــانبى للتربــــة فــى حالـة الخـازوق المحمـل بأحمــال شـد .

(جدول ٤ - ٦)

IF NOT GIVEN :

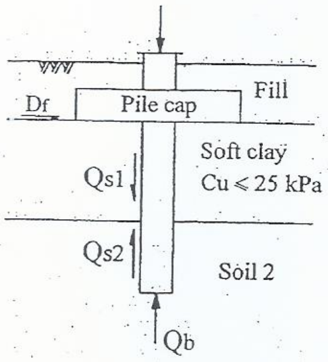
Assume $K_{HC} = K_{HT}$

Negative Skin Friction:

Compression Capacity:

$$Q_{ult.} = Q_b + Q_{s2} - Q_{s1}$$

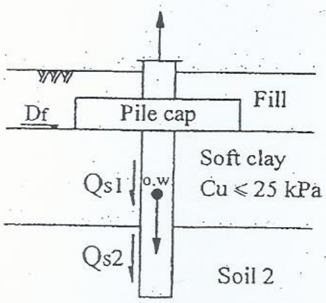
$$Q_{all.} = \frac{Q_b + Q_{s2}}{F.O.S} - Q_{s1}$$



Tension Capacity:

$$T_{ult.} = Q_{s2} + o.w.$$

$$T_{all.} = \frac{Q_{s2}}{F.O.S} + o.w.$$



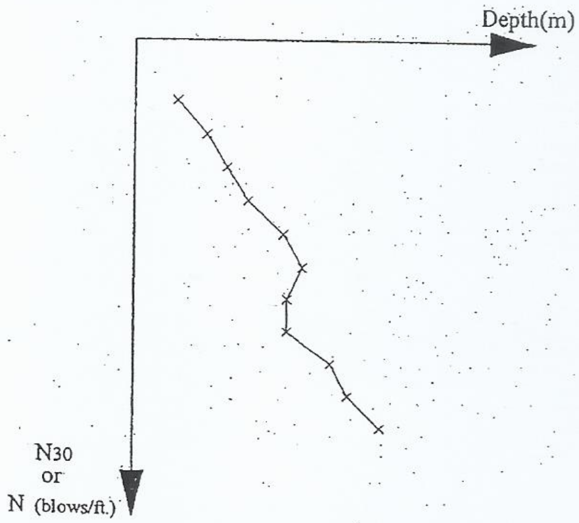
3) S.P.T.: (Pile capacity from results of standard penetration field test)

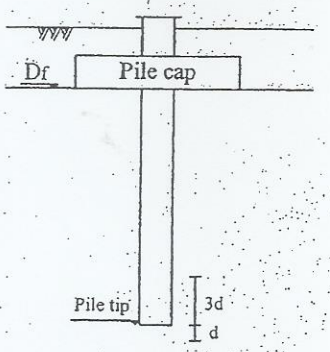
Given:

Depth(m)	✓	✓	✓	✓	✓	✓	✓
N30	✓	✓	✓	✓	✓	✓	✓

Solution:

1) Sketch the distribution of N30 with depth.





2) Calculate pile Capacity

a) Compression Capacity

1) For Driven piles

$$Q_{all.} = 90\ N_b(\pi R^2) + \overline{N}(2\pi RL)$$

Q_{all} : allowable single pile capacity. (KN)

R : Pile radius. (m)

L : Pile length. (m)

N_b : Average value of N_{30} in the distance **3d** above pile tip and **d** below pile tip.

$\overline{N}$: Average value of N_{30} along the pile length subjected to friction.

d : Pile diameter. (m)

2) For Bored piles

$$Q_{all.\,bored} = 0.5\ Q_{all.\,driven}$$

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b) Tension Capacity

1) For Driven piles

$$T_{all.} = \overline{N}(2\pi RL) + O.W. \quad (KN)$$

2) For Bored piles

$$T_{all.} = 0.5 * \overline{N}(2\pi RL) + O.W. \quad (KN)$$

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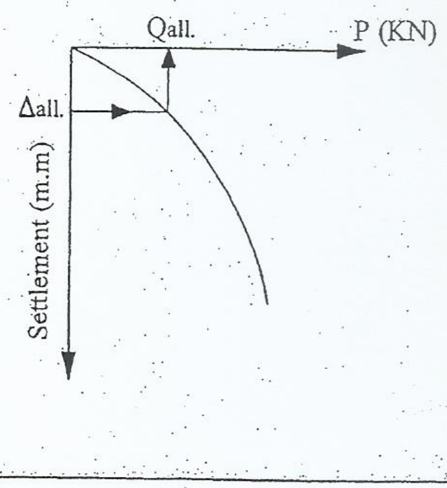
4) Pile load test:

يمكـن تحديـد قـدرة تحمـل الخـازوق باحـدى الطـريقتين التـاليتين:

a) From Δall:

Δall.: Given allowable settlement.



b) From modified Chen method:

Given:

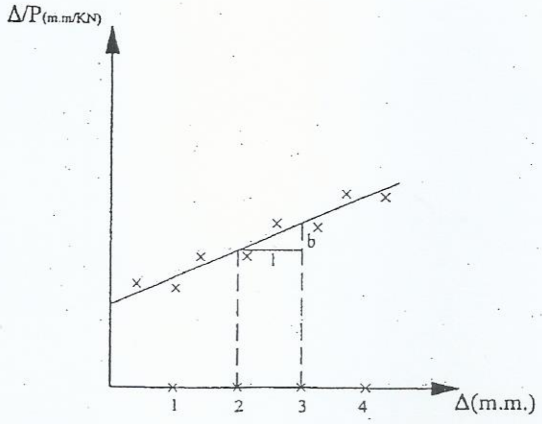
P(KN)	✓	✓	✓	✓	✓	✓	✓
Δ(m.m.)	✓	✓	✓	✓	✓	✓	✓

Solution:

1) Calculate Δ/P.

P(KN)	✓	✓	✓	✓	✓	✓	✓
Δ(m.m.)	✓	✓	✓	✓	✓	✓	✓
Δ/P(m.m/KN)	✓	✓	✓	✓	✓	✓	✓

2) Draw graph Δ/P vs Δ.



3) $Qult. = \dfrac{1}{1.2\,b}$ (KN)

4) $Qall. = \dfrac{Qult}{F.O.S}$ (KN)

Pile Group

1) Pile group capacity:

$Qult_g = Ge * n * Qult_s$

$Qall_g = Ge * n * Qall_s$

$Qall_g = \dfrac{Qult_g}{F.O.S}$

$Qult_g$: ultimate capacity of pile group. (KN)

$Qall_g$: allowable capacity of pile group. (KN)

n. : number of piles under pile cap

Ge. : Group efficiencey

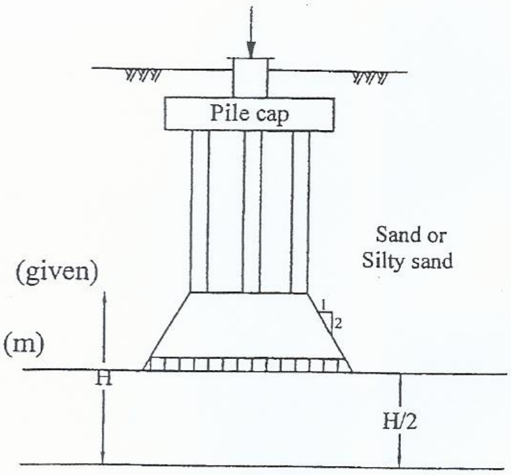
- Ge = 1 (for piles bearing on sandy soil)
- Ge (use chart 4-22) (for piles bearing on clayey soil)

2) Settlement of pile group:

2-1) Cohesionless soil (sand):

a)

$$Sg = 1/E * \Delta\sigma * H$$



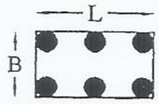
Sg :Settlement of pile group. (m)

E: Modulus of Elasticity of the sand compressible layer. (KN/m^2) (given)

H : thickness of the sand compressible layer below the pile group (m)

H = 1.5 B اذا كانت الطبقة ممتدة نفرض

$$\Delta\sigma = \frac{Pcol. \text{ or } Qall.g}{(L+H/2) * (B+H/2)} \quad (KN/m^2)$$



Pier dimensions

L,B : pier dimensions

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b)

$$Sg = So \sqrt{\frac{B}{d}}$$

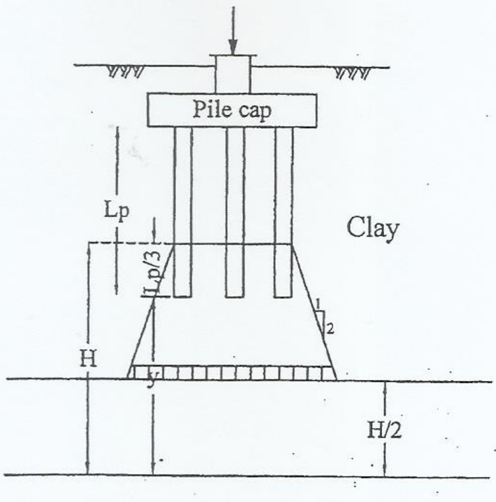
So :Settlement of single pile . (m) (given)

B : minimum pier width. (m)

d : pile diameter or width. (m) (given)

2-2) Cohesive soil (clay):

$$Sg = mv * \Delta\sigma * H$$



mv: Coefficient of volume change. (m^2/KN) (given)

$$\Delta\sigma = \frac{Pcol. \text{ or } Qall.g}{(L+H/2) * (B+H/2)} \quad (KN/m^2)$$

L,B : pier dimensions

$$H = Lp/3 + y \quad (m)$$

Lp/3 من H = 1.5 B اذا كانت الطبقة ممتدة نفرض

2) Group action (G_A):

$$\text{Group action } (G_A) = \frac{\text{Settlement of pile group (Sg)}}{\text{Settlement of single pile (So)}}$$

Piles arrangement: **See pile group notes**

Lateral pile capacity: **See pile group notes**

PILED FOUNDATIONS

Advice the most suitable pile type for the following conditions:

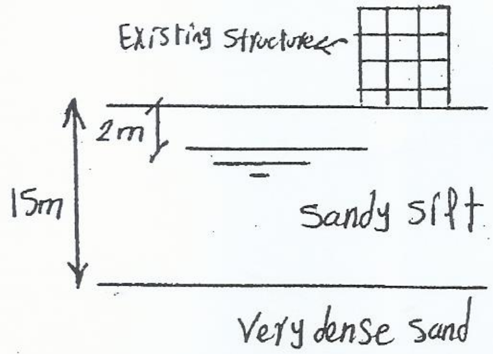
1- Offshore platform with water depth of 20 m.
2- Foundation of an extension building of a hospital where the soil consists of 15 m sandy silt followed by very dense sand and the ground water table lays 2.0 m below ground surface.
3- Foundation of road bridge where the subsoil consists of dense sand and the ground water table lays just at ground surface

1)

Use steel pipe pile for the offshore platform.

2)

Use R.C. bored pile with bentonite slurry.



Reason:-

1) We can't use driven pile due to the presence of existing buildings.

2) We use bentonite slurry to prevent boiling of the sand, and to prevent ground water from seepage into boring. → منع دخول الماء داخل الحفر + منع حدوث boiling

3)

Use large diameter bored pile with bentonite slurry.

Reason:-

1) Foundation of road bridge → High load value

2) G.W.T. at ground surface → Bentonite slurry

Evaluate the following statements (right or wrong) and comment on your evaluation ***(Any answer without comments is not accepted)***:

1. Driven piles are the most suitable piling technique in city centers.
2. Bentonite slurry is used to stabilize the drilling hole during construction of large diameter bored piles in sandy soil.
3. Pile load tests (static and/or dynamic) should be applied at least on 50 % of working piles.
4. Pile skin friction is fully mobilized at small settlement.
5. The structural loads are carried completely by the piles of a piled raft foundation.
6. The settlement of shallow foundation is generally larger than the settlement of deep foundation.
7. Bored piles with casing causes less disturbance of the surrounding soil.
8. Screw piles is not bored piles .
9. Enlarged pile base reduces the pile capacity.
10. Post grouting increases pile capacity.
11. Soil investigation is not necessary for the design of deep foundations.
12. Allowable pile load is determined only from the ultimate load by applying a factor of safety.
13. Settlement of pile group is bigger than the settlement of the corresponding single pile under the same pile load.
14. Hammering and lifting process should be considered in the design of the precast piles.
15. During the construction of bored piles using casing,the casing should be lifted after full casting of concrete.

16. In C.F.A. piles the excavated volume of soil is equal to the pile volume.
17. The density of bentonite slurry is less than that of water.
18. Excavation of bored piles is achieved in one stage.
19. The negative skin friction increases the axial compression capacity of piles.
20. The site investigation depth is the same for both piled foundations and raft foundations.
21. During the construction of bored piles using drilling mud, the drilling mud should be removed before pouring the concrete.
22. Drilling mud used in the construction of bored piles is bentonite slurry only.
23. Large diameter piles are those piles which have diameter larger than 60 cm.
24. The most suitable construction technique for large diameter piles is driven piles technique.
25. The capacity of pile group is usually greater than the sum of the single pile capacity.
26. Pile load test can judge the quality of the pile concrete in an indirect manner.
27. Load transformation from pile to soil occures by end bearing at pile tip.
28. Bored piles often have square section.
29. For a soil profile incorporates a layer of very dense sand, the most suitable type of piles to be constructed through this soil is the driven piles.
30. The settlement of pile group can be estimated in sandy soil by the summation of the single pile settlement.
31. Driven piles are replacement piles.
32. For bored piles with bentonite slurry, Mud cake increases the pile capacity.
33. Single pile capacity is affected by construction technique.
34. In C.F.A. piles, Reinforcement cage is installed before concrete casting.

35. C.F.A. piles are the most suitable construction technique in squeezing soil.
36. For a cohesionless soil side friction along pile sides for a pile under axial compression load differs in value from that along a pile side under tension load, considering the same load value and the same soil.
37. Driven piles are suitable piling technique in city centers beside historical buildings.
38. Bored piles are the most suitable piling technique in off-shore structure
39. Pile integrity test is a quick and economic way to determine ultimate pile capacity.
40. Pile skin friction is mobilized under relatively small displacements where pile base resistance needs relatively large displacements to be mobilized.
41. In a pile group under tension loads, the own weight of soil between the piles can govern the pullout resistance of the pile group.
42. In a pile group that is connected with a rigid pile cap and subjected to horizontal load, the horizontal loads are distributed equally among all piles.
43. Settlement of pile group under vertical compression load is smaller that the settlement of the single pile under average load.

Answer :-

1- (X) We don't use driven piles in city centers to avoid damage in adjacent buildings, due to the vibration effect of driving.

2- (X) Temporary casing is preferred than Bentonite slurry in cohesionless soil and vice-versa, But Bentonite slurry (or water) is used in case of high ground water table.

3- (X) يتم اختبار خازوق كل ،، خازوق في الموقع

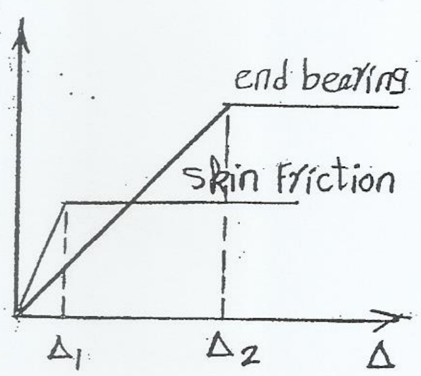
4- (✓) A small pile settlement value is needed to mobilize skin friction

For example :- for large diameter bored piles

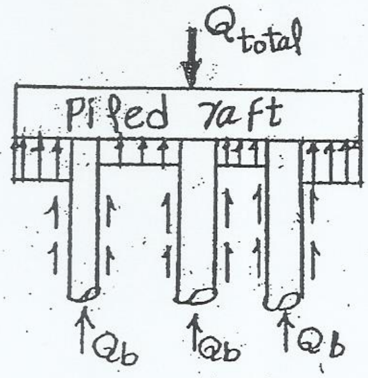
Δ_1 = 1% pile diameter

Δ_2 = 5% pile diameter (c-soil)

15 m.m. (ϕ-soil)



5- (X) The piles carry the major part of loads, and the minor part of loads is carried by the soil in contact with raft.

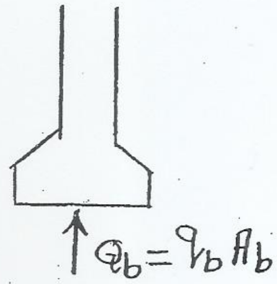


6- (✓) Specially when compressible soil layers are present at shallow depth.

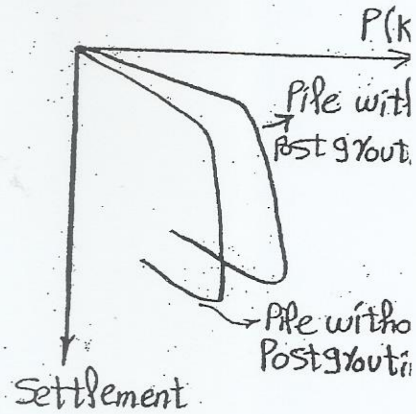
7- (✓) Because the casing separates the auger from the surrounding soil.

8- (X) They are semi bored - semi driven piles.

9- (X) Enlarged base increases the end bearing capacity.



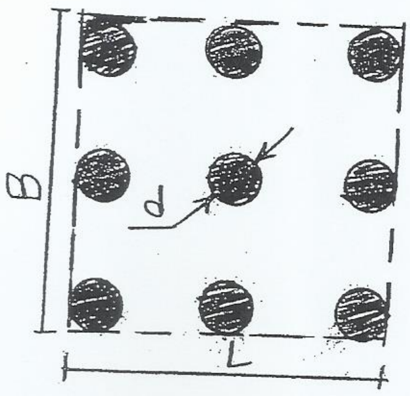
10- (✓) Piles with post grouting has higher load capacity and less settlement.



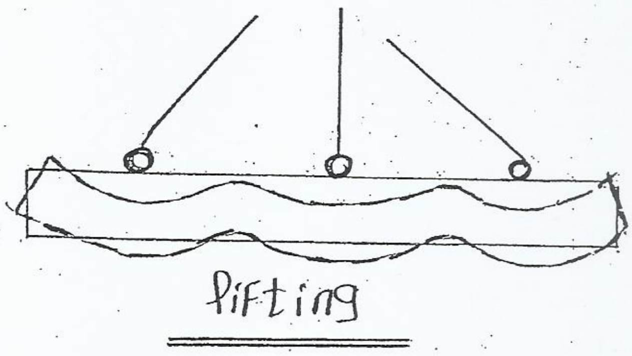
11- (X) soil investigation is very important for deep foundations to determine the most suitable piling technique and the safe pile length.

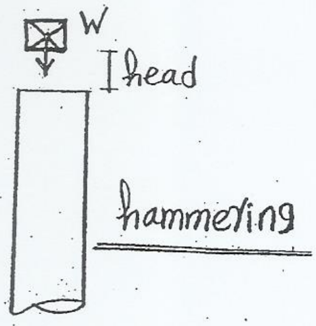
12- (X) Q_{all} may be determined at a specified allowable pile settlement.

13- (✓) Because the pile group dimensions are larger ($B \gg d$), and as the foundation dimensions increase the zone of soil affected by stresses increases.



14- (✓) To consider the pile deflection during the lifting process, and the effect of hammering on the pile during installation.





15 – (X) The casing should be lifted by a rate less than that of lifting the tremie pipe.

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16 – (X) $V_{excavated} < V_{pile}$

والفرق في الحجم يزاح لأسفل

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17 – (X) $\gamma_{bentonite} \simeq 1.1\ t/m^3 > \gamma_w = 1\ t/m^3$

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18 – (X) Excavation of bored pile is achieved by several stages due to the limited height of the auger or the bucket يتم الحفر على مراحل (١-٣)م

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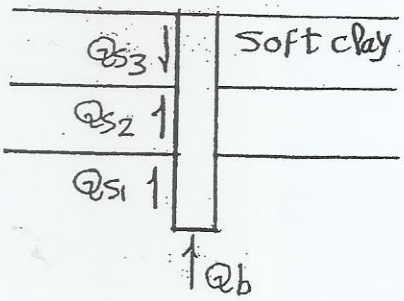
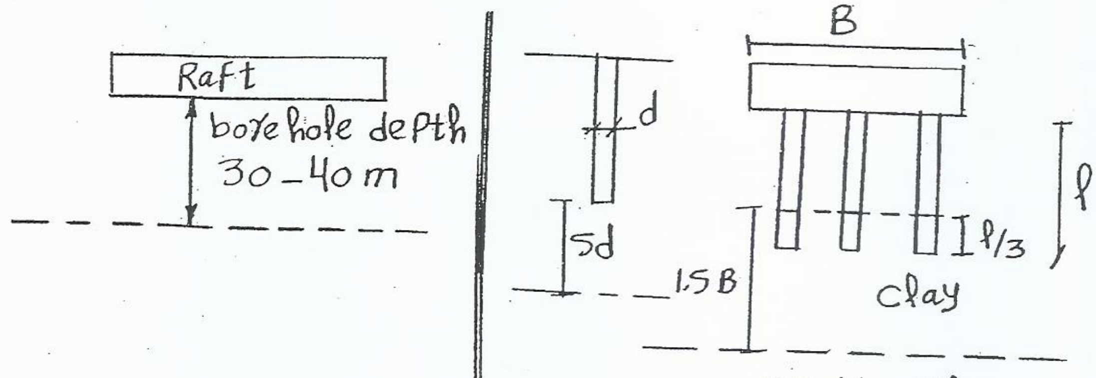
19 – (X) The negative skin friction decreases the pile capacity.

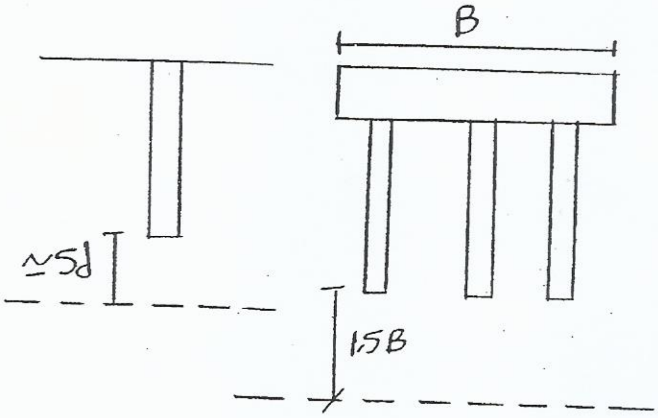
$Q_{ult.} = Q_b + Q_{s_1} + Q_{s_2} - Q_{s_3}$



20- (X)



Friction Piles

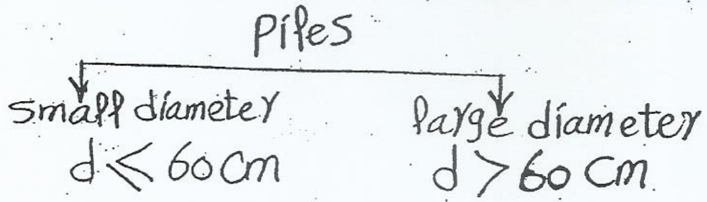


End bearing Piles

21- (X) يتم صب الخرسانة بواسطة ال tremie pipe
من أسفل لأعلى ، فتزيح الخرسانة ذات الكثافة
الأعلى البنتونيت خارج الحفرة

22- (X) Drilling mud may be:-
1) water , 2) Bentonite suspension
3) Polymer solution

23- (✓)



24 - (X) Large diameter Piles are bored Piles because we can't use driven Piles as we need a large driving energy.

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25 - (X) $Q_{ultg} = G_e \, n \, Q_{ults}$

G_e may be :- >1 or <1 or $=1$

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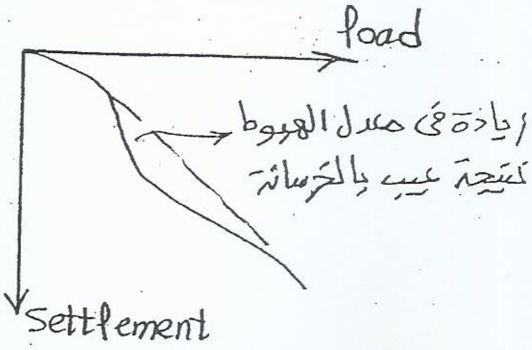
26 - (✓)



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27 - (X) By both bearing and side friction.

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28 - (X) Bored Piles always have a circular section.

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29 - (X) We use bored Pile because driven Pile may fail to Penetrate the very dense sand layer.

30 - (X) $S_g = S_o \sqrt{\frac{B}{d}}$ $\neq n * S_o$

S_o - single pile settlement

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31 - (X) Driven piles are displacement piles.

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32 - (X) الـ Mud cake تلغي (تقلل) الإحتكاك على جانب الخازوق.

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33 - (✓) عملية الدق في الـ driven piles تؤدي إلى دمك التربة المحيطة للخازوق أي تحسن خواص هذه التربة، أما في حالة الـ bored piles فإن سنون الـ Auger تسبب disturbance للتربة المحيطة.

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34 - (X) يتم صب الخرسانة ثم سحب الماكينة لأعلى، ثم انزال شبكة حديد التسليح داخل الخرسانة قبل تصلدها.

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35 - (X) في الـ C.F.A. piles تستخدم مؤخرات لشك الخرسانة، وبالتالي الـ squeezing soil تضغط على الخرسانة قبل حدوث الشك، فيحدث Necking لقطاع الخازوق.

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36 - (✓)

$Q_s = F_s * A_{side}$

F_s → $K_{HC} P_o \tan\delta$ (Comp. loading) ; $K_{HT} P_o \tan\delta$ (tension loading)

According to ECP $K_{HT} \simeq 0.5 K_{HC}$

37- (X) We don't use driven Piles beside any buildings, to avoid the damage or cracks that may occur in these buildings due to the Vibrations caused by Pile driving

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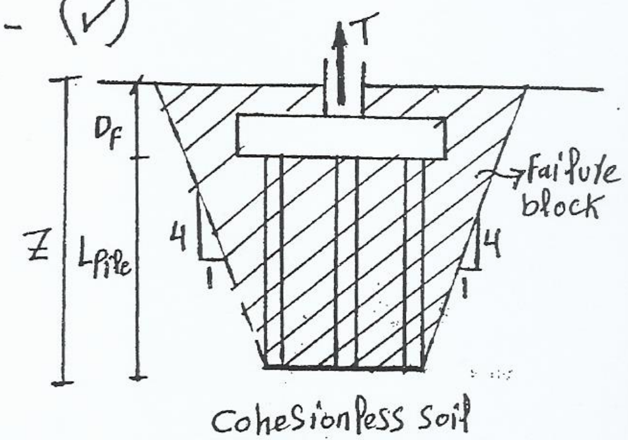
38- (X) Steel driven Piles are the most suitable in off-shore structures.

39- (X) Pile integrity test is used to check the quality of Reinforced Concrete. Also, to check that both Pile length and diameter are the same as the design requirements.

40- (✓). انظر رقم (٤)

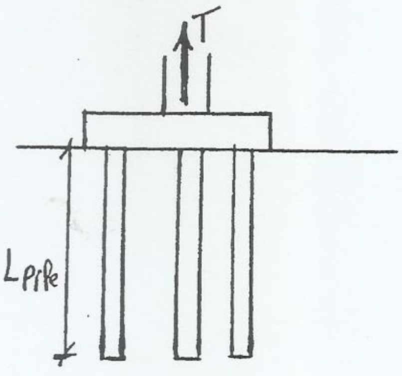
41- (✓)



Cohesionless soil

T= Weight of failure block

$= \gamma_{eff.} * Z * [(L+Z/4)(B+Z/4)]$

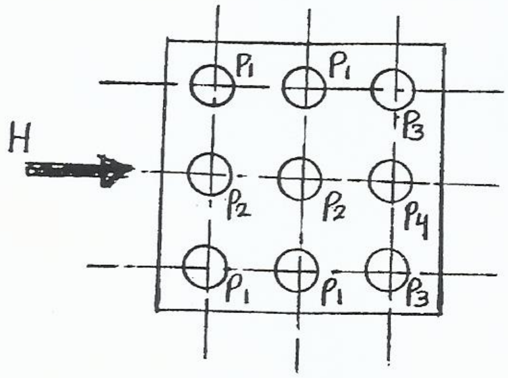


Cohesive soil

$T = \frac{C * A_s}{F.o.S.} + W_p$

و/و الخوازيق + ال Pile cap + التربة المحصورة بين خوازيق المجموعة

42- (X) Piles in the front row carries more loads than other piles.



Hi :- Horizontal load carried by each pile

$H_3 > H_4 > H_1 > H_2$

43- (X) انظر رقم (١٣)

1. Comment on static pile load test using anchors or Osterberg cell as a reaction system.

2. Discuss the quality control of piles using pile (sonic) integrity test through the following points:

   i. Advantages and limitations of the test.
   ii. Phenomena which can be detected by sonic integrity test, and those which can not be detected by sonic integrity test.

3. Explain the factors which affect the lateral capacity of a single pile subjected to horizaontal load. Discuss briefly how to distribute horizaontal loads on each pile in a pile group.

2) Quality control of Piles using Pile integrity test:-

هو أحد الإختبارات الغير متلفة للخوازيق ، و يتم اجراؤه للتأكد من جودة خرسانة الخوازيق المنفذة ، و التأكد أيضاً من أن الخوازيق منفذة بالأطوال و الأقطار المحددة في التصميم .

المميزات :-

١) يمكن اختبار عدد كبير من الخوازيق في زمن قليل وتكلفة منخفضة .

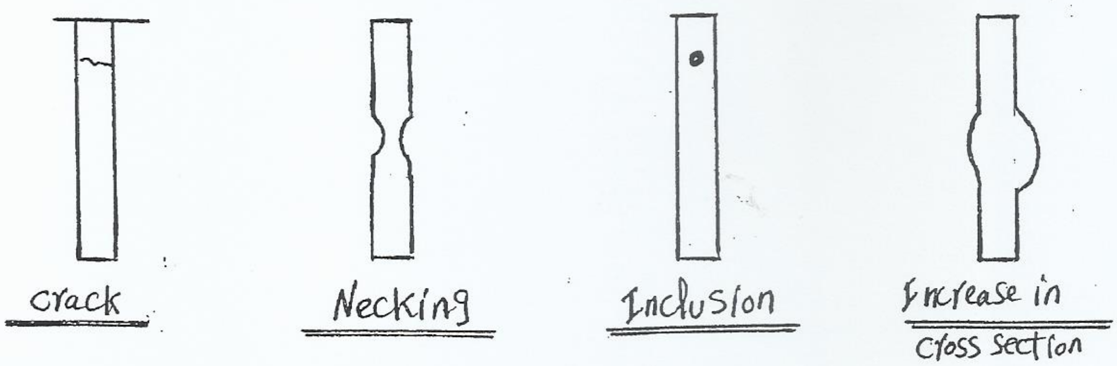
٢) لا يحتاج إلى تجهيزات .

العيوب :-

١) لا يعطي معلومات عن مقاومة الخازوق (ultimate Pile capacity)

٢) لا يعطي معلومات عن الـ defects local مثل سقوط الغطاء الخرساني (cover) في جزء من الخازوق .

Phenomena which can be detected by integrity test:-



Phenomena which cannot be detected by integrity test:-

Gradually increasing diameter

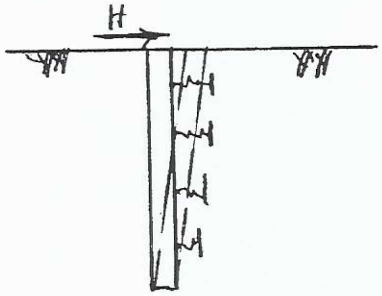
Gradually decreasing Parameter

Curved Pile

Local loss of cover

3) Factors which affect the lateral capacity of a single pile

1) Horizontal subgrade reaction of soil :- K_h

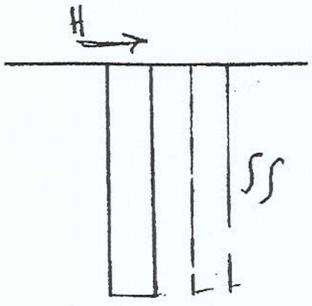


* تعتمد مقاومة الخازوق للأحمال الجانبية على الـ Passive resistance للتربة المحيطة بالخازوق والتي يتم تمثيلها بـ (K_h).

* قيمة (K_h) تعتمد على نوع التربة المحيطة بالخازوق.

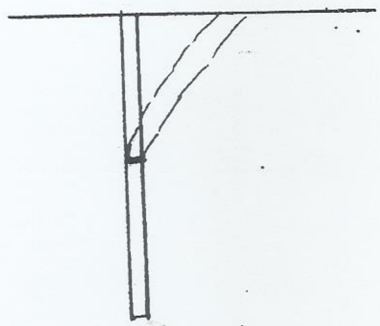
* قيمة K_h ثابتة مع العمق في حالة الـ over consolidated clay ومتغيرة في حالة الـ Normally loaded clay.

2- Pile-Soil relative stiffness :-



Rigid Pile

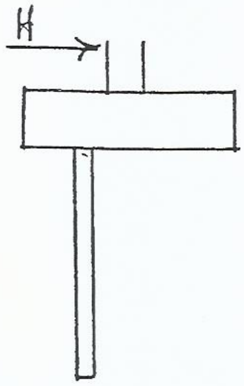
failure in soil



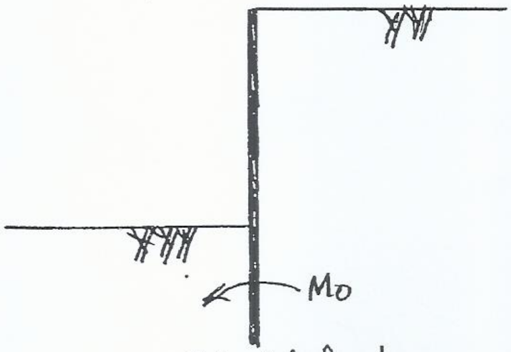
Flexible Pile

يحدث Buckling للخازوق

3 - Pile head condition:-

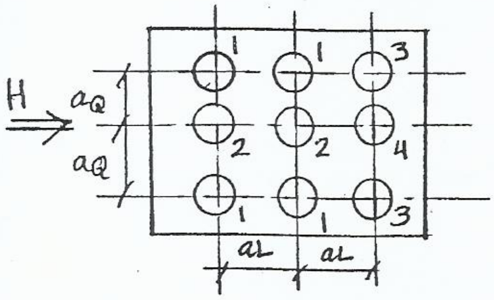


Fixed Pile head



Free Pile head

Distribution of HZ. load in a Pile group:-



$$H_i = \frac{\alpha_i}{\sum \alpha_i} * H_{Total}$$

* يتم ايجاد α_Q , α_L من charts وتعتمد على مكان ال Pile وال Pile spacing .

Pile	$\alpha_L . \alpha_Q$
P_1	$\alpha_L . \alpha_{QA}$
P_2	$\alpha_L . \alpha_{QZ}$
P_3	$1 * \alpha_{QA}$
P_4	$1 * \alpha_{QZ}$