THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY (CIVIL) – LEVEL 06
Final Examination 2008/2009

078

CEX6230 – GEOTECHNICS

Time allowed: Three Hours
Date: Sunday, 05th April, 2009 Time: 1330-1630

Answer five questions. All questions carry equal marks.

1. A point on the Mohr's circle of stress represents σ_n and τ, acting on a certain plane. This plane is determined relative to a pre-determined reference plane. During a Direct Shear Test, test samples are made to `shear' along the horizontal plane, passing through the centre of the sample.

 a) A Direct Shear Test is performed on a compacted lateritic soil (SC – SM). The initial normal stress corresponding to 10kg load is 41.3kPa. Assuming $\phi' = 46^0$, plot the Mohr's circle of stress corresponding to `before loading' situation. Use the graph sheet provided. (4 points)
 b) Show principal stresses and principal stress directions corresponding to `before loading' situation. (4 points)
 c) The sample attained its peak strength at σ_{nf} = 50.4kPa and τ_f = 52.8 kPa. Plot the Mohr's circle of stress corresponding to this state of stress. Candidates may use the same graph sheet, (5 points)
 d) State the principal stresses corresponding to peak strength. Measure or compute their respective directions, measured with reference to the horizontal plane. (4 points)
 e) Compute p' and q corresponding to `before loading' and peak strength situations. (2 points)
 f) Discuss why you cannot join the two stress points with a straight line. (1 point)

2. The total settlement of a shallow footing is expressed as: $S = S_I + S_c + S_s$. The suffixes stand for immediate, primary consolidation and secondary compression, respectively. Figure Q2 shows a 1.2mx1.2m square pad footing to be founded on a sandy soil, which is overlain by a normally – consolidated clay.

 Sand: E = 10,000 kPa
 Clay: E_u = 5,000 kPa, ν = 0.5, e_0 = 0.8, C_c = 0.32, C_r = 0.09

 a) Determine the depth and breadth of the influence zone, based on a 5% stress level. (3 points)
 b) Compute average vertical stresses you would use to estimate settlements in sand and clay. (3 points)
 c) Compute the immediate settlement of the sand stratum. (6 points)
 d) Compute the consolidation settlement. (6 points)
 e) State whether the settlement is acceptable. If not, state your recommendations. (2 points)

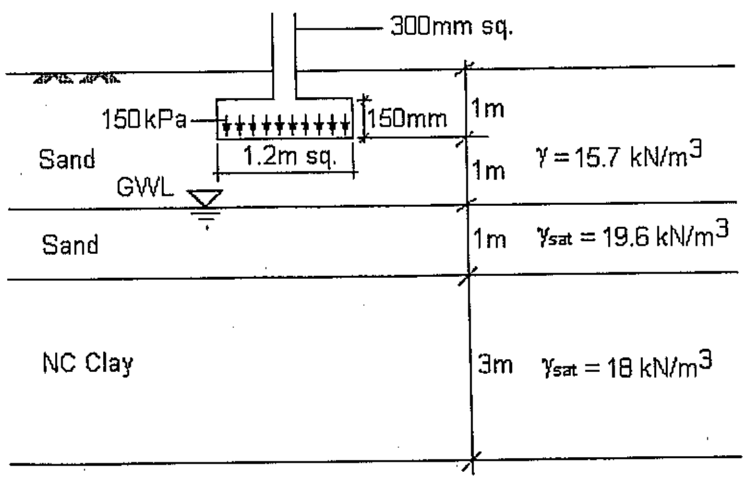


Figure Q2

3. Figure Q3 shows a flow net, which models seepage though an embankment dam. The elevations of points B, C, D and E, measured from datum AD are 10m, 6.25m, 2.75m and 0m, respectively.

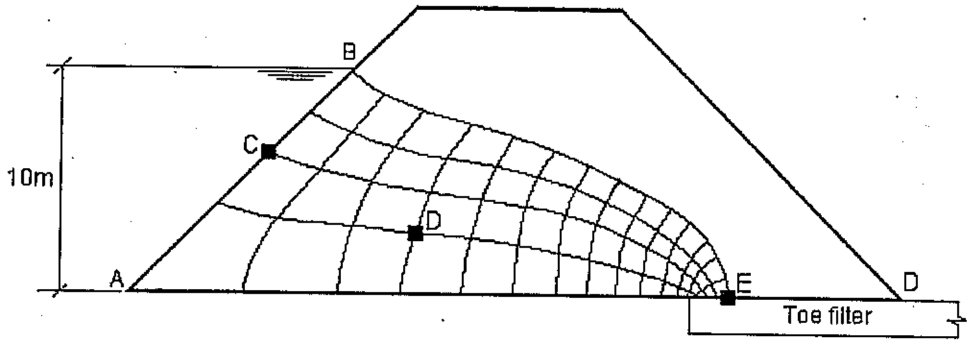


Figure Q3

a) Compute the total head at points B, C and E. (3 points)

b) Compute the pressure head at D, hence compute the seepage pore pressure at D. (4 points)

c) Determine the point at which maximum hydraulic gradient occurs. You may indicate this point on a sketch. Explain how you would compute the maximum hydraulic gradient. (4 points)

d) Discuss the benefits of having a toe filter in preventing piping. (4 points)

e) Considering a Coefficient of Permeability of 5×10^{-4} cm/s, determine the discharge per meter length. (5 points)

4.

a) Explain the process by which a soil mass develops an active Rankine state of plastic equilibrium. (4 points)

b) A row of anchored sheet piles is driven in to a horizontal layer of sand (refer Figure Q4) having γ_{sat} = 19.2kN/m^3 and $\phi = 30^0$. The sheet pile wall is meant to retain a 8m sand fill with γ = 17.5kN/m^3 and $\phi = 30^0$. The steel rod anchors are tied to the wall 1.2m below the surface of retained material. These anchors are placed 2m apart, along the wall. Using the method of 'free earth support' and allowing for a factor of safety of 2 on passive pressure developed:

i) Compute active and passive pressure distributions, with depth. (6 points)

ii) Compute required total length of sheet piles. (5 points)

iii) Compute the force in each anchor. (5 points)

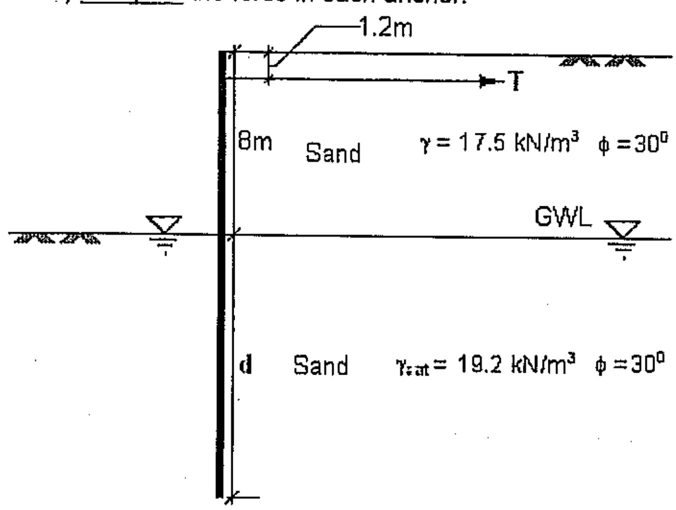


Figure Q4

5. Cylindrical soil samples are used to determine stress-strain behavior of soils. These samples are subjected to axial loads, with or without applying a confining stress. These samples are tested under drained or undrained conditions.

a) List the different types of axi-symmetric loading tests that are performed under undrained conditions. (3 points)

b) Out of the tests listed by you in Q5(a), which test is done without any pore water pressure measurements. (1 points)

c) Stress-strain behavior observed during an undrained triaxial loading test is expressed using the plots: Deviatoric Stress, $(\sigma_1 - \sigma_3)$ versus Axial Strain, ε_1 and Excess Pore Water Pressure, u versus Axial

Strain, ε_1. Sketch these variations as observed for a Normally Consolidated (NC) clay soil and an Over Consolidated (OC) clay soil. Compare the trends observed for both soil types. Name the axes and state all units of measurement. (6 points)

d) Sketch on p, p′ – q space the total stress path and the effective stress path observed for a Normally Consolidated (NC) clay soil, subjected to undrained triaxial loading. (4 points)

e) Show on the same sketch Mohr-Coulomb failure line on p′ – q space. Indicate its gradient and intercept using shear strength parameters ϕ' and c'. (2 points)

f) Using the sketch obtained in Q5(e) above, explain why short-term stability is critical than long-term stability when a NC Clay is subjected to a loading. (4 points)

6. Figure Q6 shows a pad footing carrying a column load of 700kN. The eccentricity, e = 0.23m. The load is transferred to the footing via a 300mm x 300mm square column.

a) Compute the Factor of Safety against ultimate bearing failure. (6 points)

b) Compute allowable bearing capacity based on a limiting settlement of 25mm. Average SPT N values are as follows: Above footing level = 8, below footing level = 20. (6 points)

c) Re-calculate Q6(a) and Q6(b) if groundwater table is 0.5m below the footing level. (8 points)

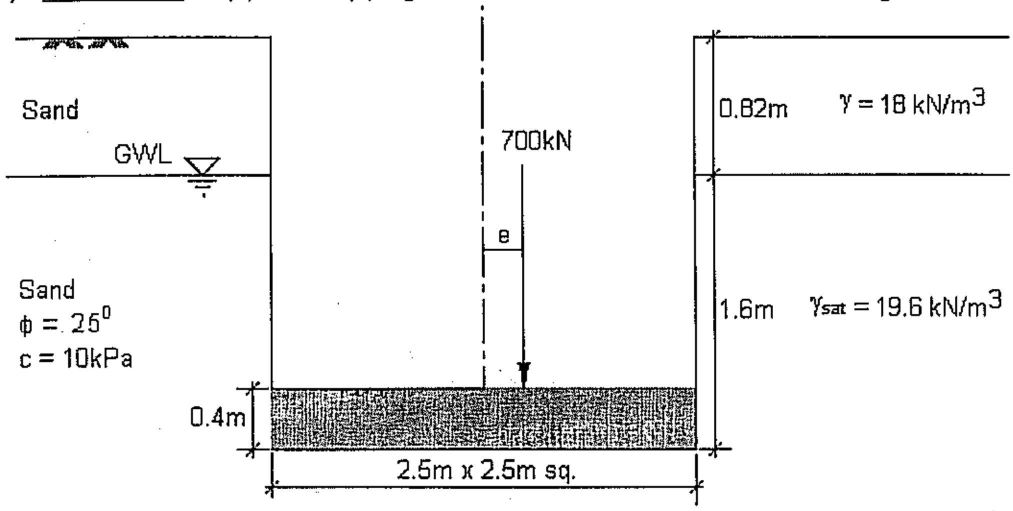


Figure Q6

7.

a) Table below shows A_f values for different soil types.

i) Define A_f. (4 points)

ii) Explain how you would determine A_f. (4 points)

Soil type	A_f
Normally Consolidated	½ to 1
Compacted sand clay	¼ to ¾
Lightly over-consolidated clays	0 to ½
Compacted clay - gravel	-¼ to ¼
Heavily over-consolidated clays	-½ to 0

b) Figure Q7 shows a chart that expresses Stability Number $N_s = \frac{c'}{F_c \gamma H}$ for critical circular failure types.

i) Explain the term $\frac{c'}{F_c}$. (3 points)

ii) This chart is developed assuming that $F_\phi = 1$. Explain how you would use this chart when $F\phi \neq 1$. (3 points)

iii) An earth-embankment levee with a slope angle $\beta = 50^0$ is submerged to a height of 20m. γ_{sat} = 19kN/m^3; c' = 60kPa; $\phi' = 20^0$. Determine the factor of safety. You may consider the same factor of safety with respect to cohesion and friction. (6 points)

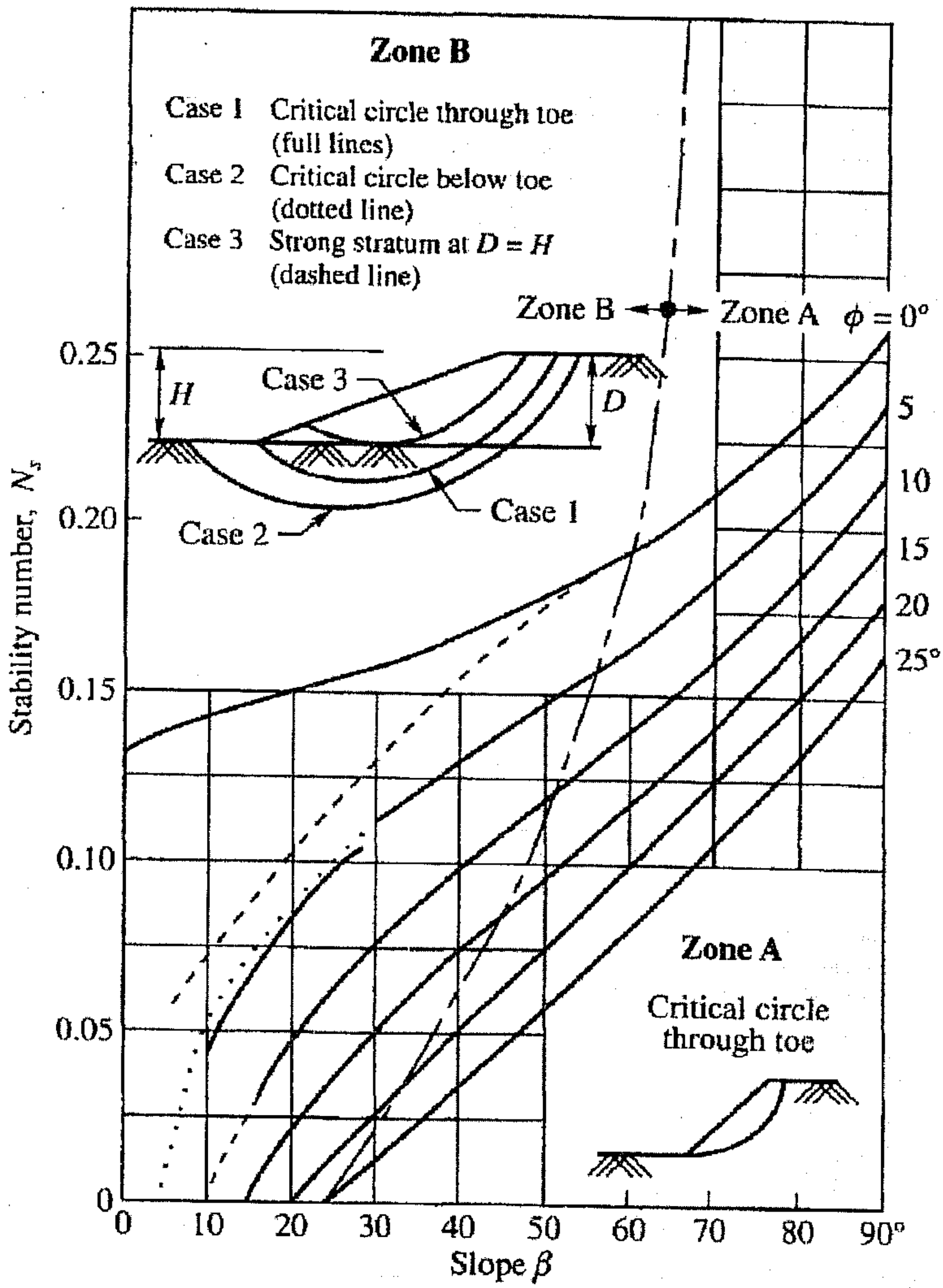


Figure Q7: Taylor's stability numbers for circles passing through the toe and below or above the toe (Taylor, 1937)

8.

a) Sketch load – settlement behaviour as observed during a pile load test. Explain how you would use these observations to design a pile foundation. (5 points)

b) A 350mm diameter pile is to support a load of 175kN while maintaining a factor of safety of 3 (refer Figure Q8). Estimate the required pile length. (10 points)

End resistance: $q_u = cN_c + K_s.\gamma D.N_q$

Skin Friction: $F_u = C_a + K_s.\gamma D.\tan\delta$ [for cohesionless soils]

$F_u = \alpha C_u$ [for cohesive soils]

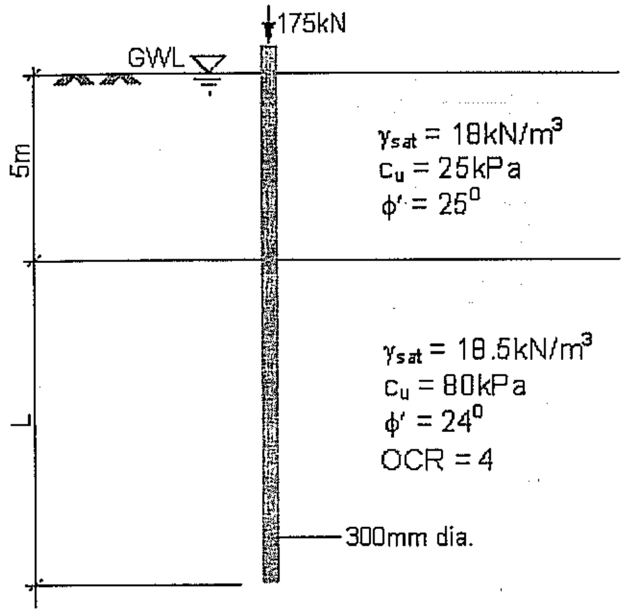
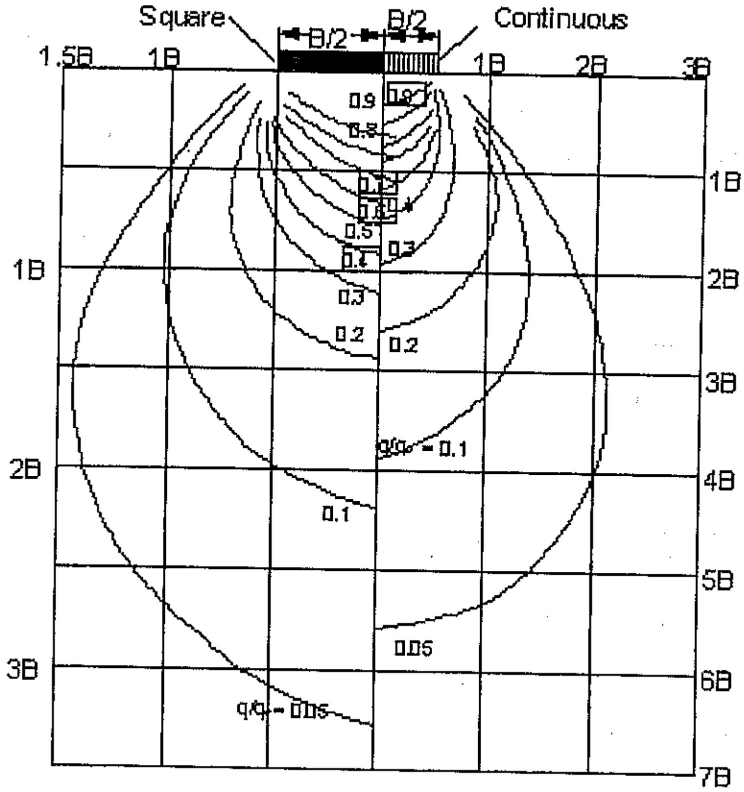
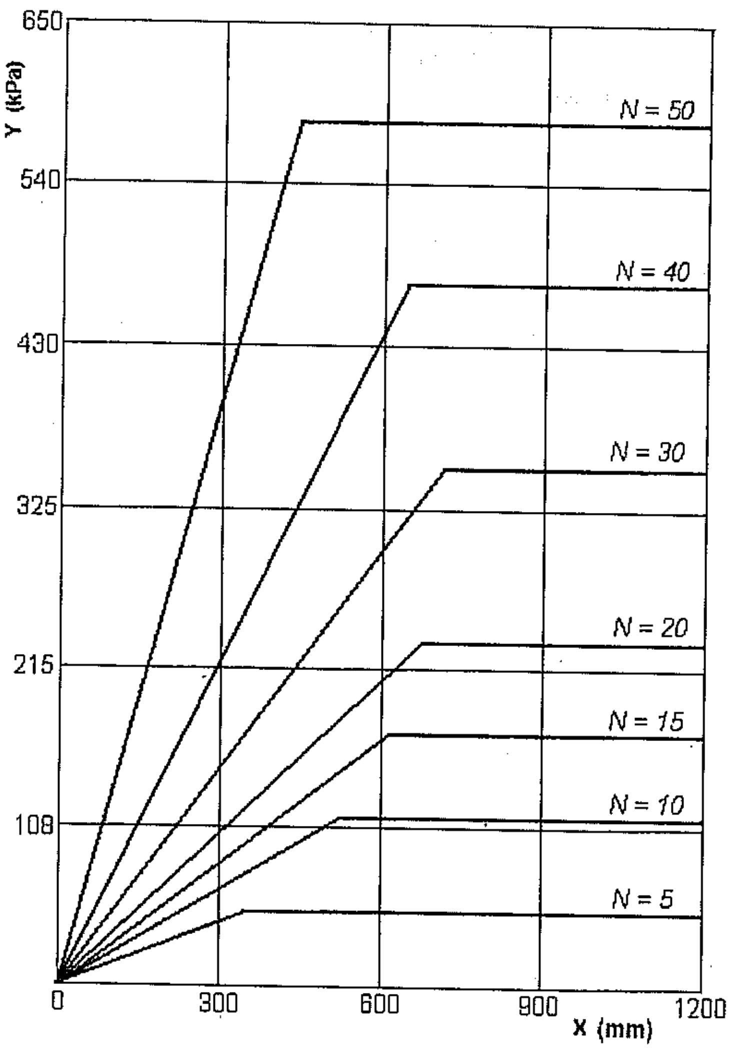


Figure Q8

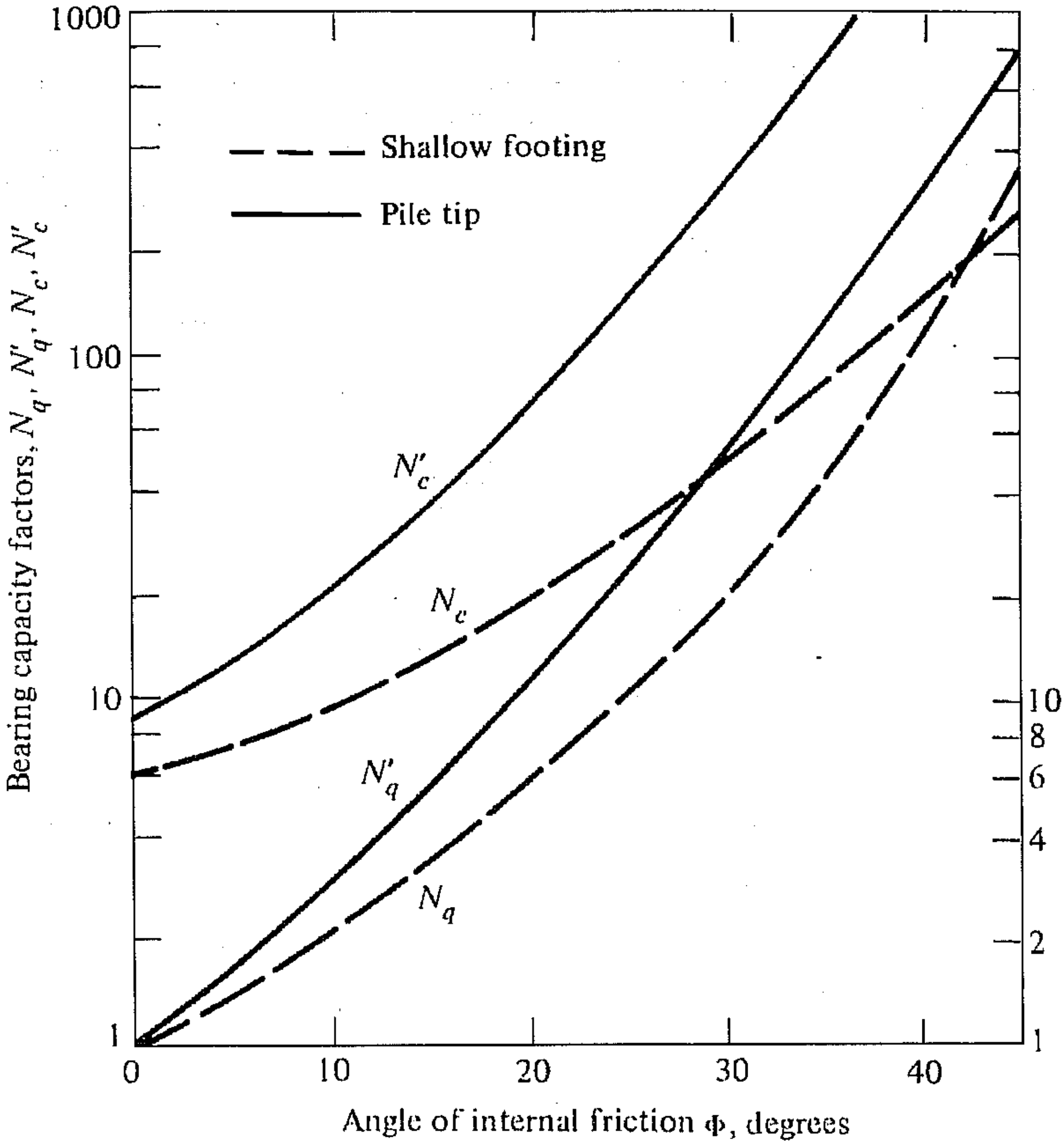
c) Explain the procedure you would use to determine the settlement of a single pile. (5 points)



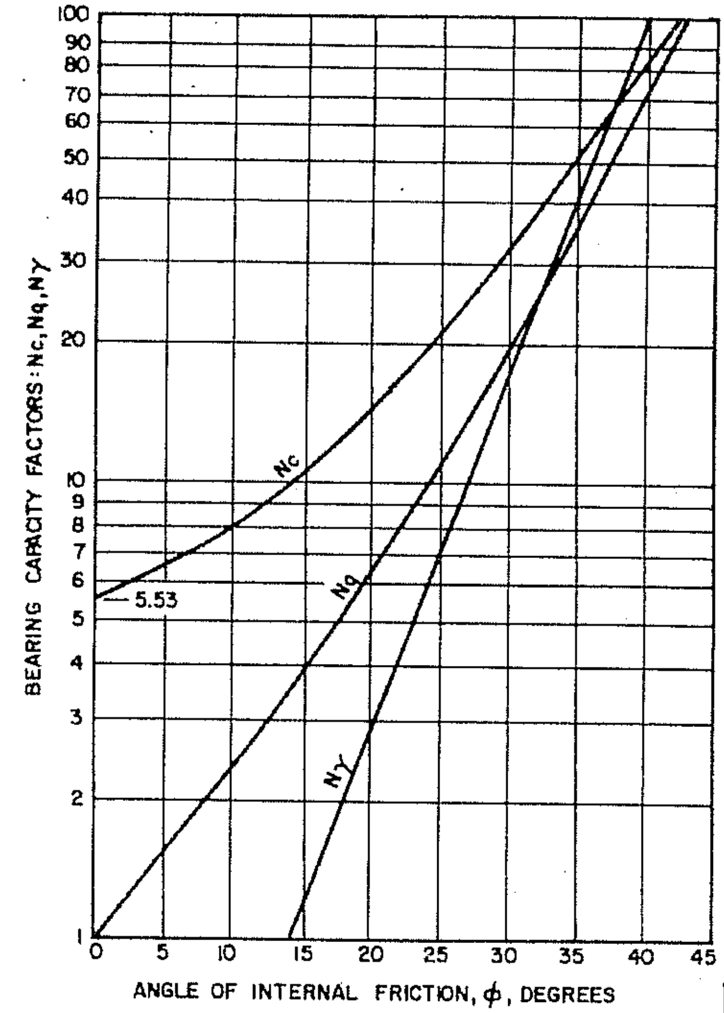
Square
B/2
B/2
Continuous
1.5B
1B
1B
2B
3B
0.9
0.9
0.8
0.5
0.4
0.3
0.3
0.2
0.2
q/q_o = 0.1
0.1
0.05
q/q_o = 0.05
1B
2B
3B
2B
3B
4B
5B
6B
7B

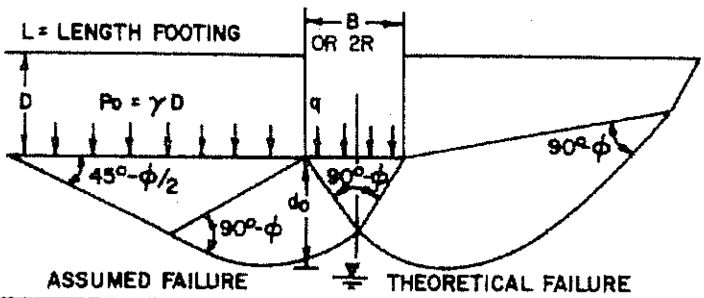


650
540
430
325
215
108
0
300
600
900
1200
Y (kPa)
X (mm)
N = 50
N = 40
N = 30
N = 20
N = 15
N = 10
N = 5



1000
100
10
1
Shallow footing
Pile tip
N'_c
N_c
N'_q
N_q
10
8
6
4
2
1
0
10
20
30
40
Bearing capacity factors, N_q, N'_q, N_c, N'_c
Angle of internal friction Φ, degrees





ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN d_o BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES c, ϕ, γ

ULTIMATE BEARING CAPACITY = q_{ult}

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma D N_q$

$q'' = \gamma \frac{B}{2} N_\gamma$

$q_{ult} = cN_c + \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c\,(1 + .3\frac{B}{L}) + \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING: $R = B/2$

$q_{ult} = 1.3\,cN_c + \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIONLESS FOUNDATION SOILS ($c = 0$)

CONTINUOUS FOOTING:

$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

$q_{ult} = cN_c + \gamma D$

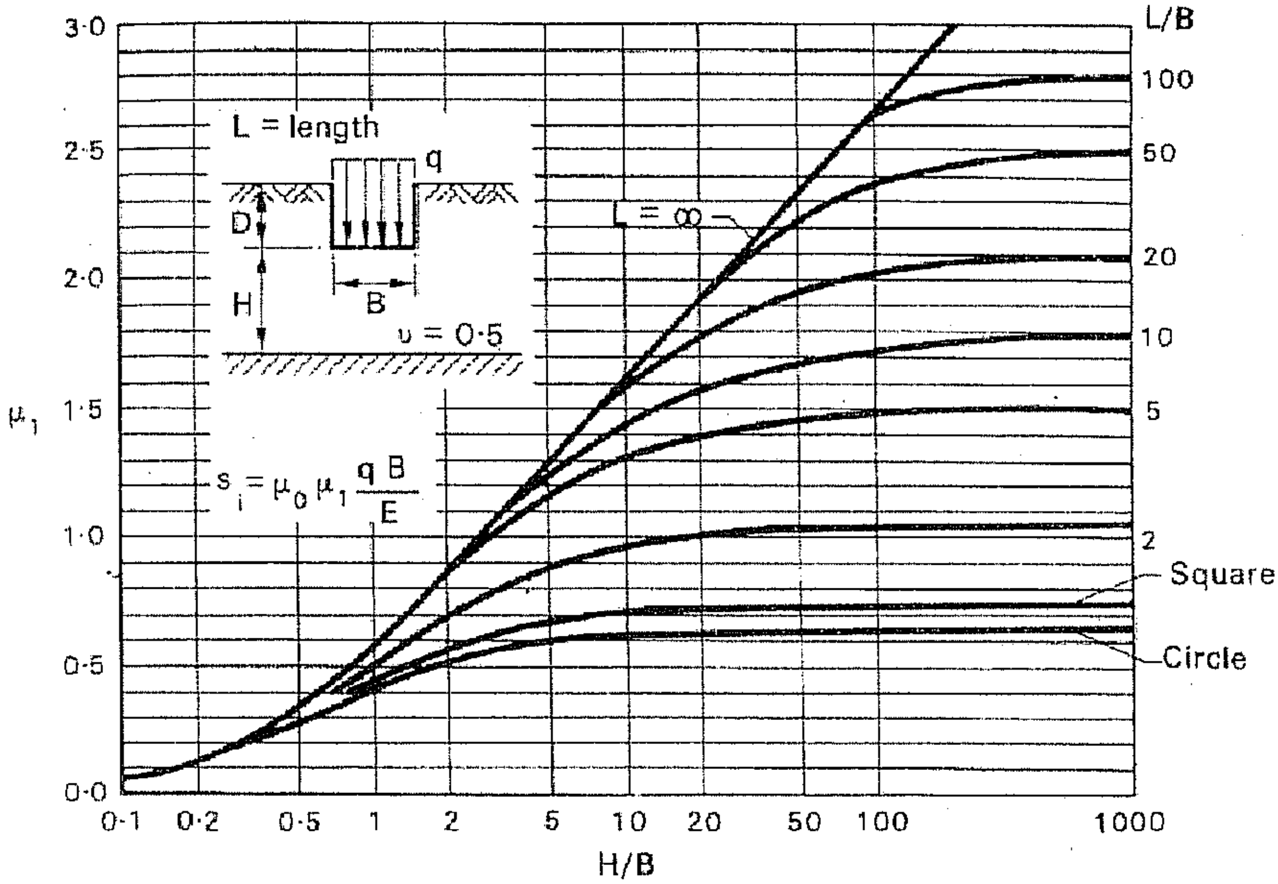
SQUARE OR RECTANGULAR FOOTING:

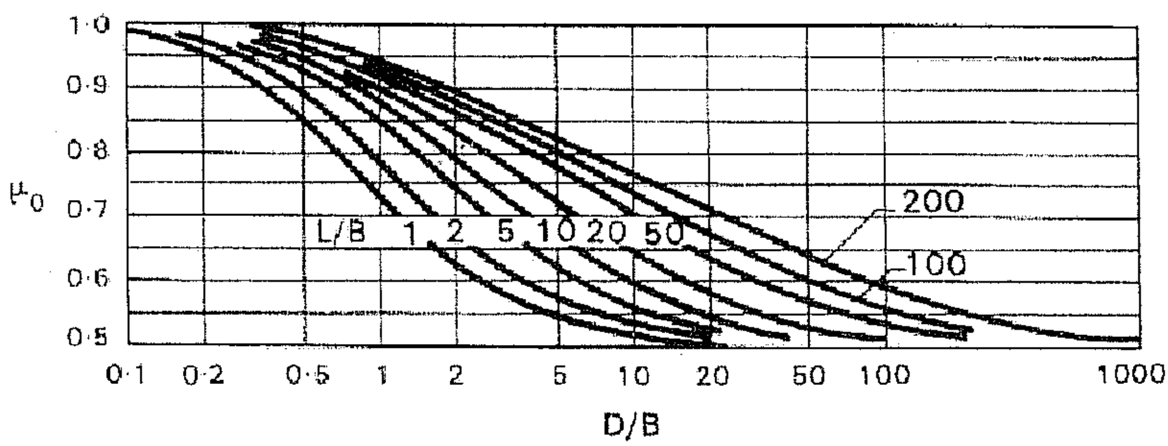
$q_{ult} = cN_c\,(1 + .3\frac{B}{L}) + \gamma D$

CIRCULAR FOOTING:

$q_{ult} = 1.3\,cN_c + \gamma D$

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads


L = length
q
D
H
B
υ = 0·5
$s_i = \mu_0 \mu_1 \frac{q B}{E}$
L = ∞
L/B
100
50
20
10
5
2
Square
Circle
μ_1
3·0
2·5
2·0
1·5
1·0
0·5
0·0
0·1 0·2 0·5 1 2 5 10 20 50 100 1000
H/B


μ_0
1·0
0·9
0·8
0·7
0·6
0·5
L/B 1 2 5 10 20 50
200
100
0·1 0·2 0·5 1 2 5 10 20 50 100 1000
D/B