059

THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY (CIVIL) – LEVEL 06
Final Examination 2007/2008

CEX6230 – GEOTECHNICS

Time allowed: Three Hours

Date: Friday, 28th April, 2008 | Time: 0930-1230

Answer five questions. All questions carry equal marks.

1. Figure Q1 shows a soil element of a normally consolidated clay soil located at a depth of 8m from the ground-surface. A surcharge fill of 2m height is to be placed to enhance the elevation. It is required to check whether soil element A is safe when the surcharge is applied.

   a) State the assumptions that enable you to relate stresses σ_v, σ_h, τ_{vh} and τ_{hv} to principal stresses σ_1 and σ_2. Subscripts \`v' and \`h' refers to vertical and horizontal directions, respectively. (3 points)

   b) Compute principal stresses σ_1, σ_2, σ_1' and σ_2' for soil element A, prior to excavation. (4 points)

   c) Compute p, p' and q for stresses computed in 1(b) above. Plot these values on the graph sheet provided to you. (4 points)

   d) Assuming that the horizontal stress σ_h remains unchanged during loading, compute p and q for soil element A, at end of excavation. Plot the total stress path on the same graph sheet. (2 points)

   e) Plot the Mohr-Coulomb failure line on p – q space, on the same graph sheet (2 points)

   f) Sketch the Effective Stress Paths corresponding to short-term and long-term conditions, on the same graph sheet. (2 points)

   g) Comment on short-term and long-term safety, due to placement of fill. If the loading is found to be unsafe, how would you ensure safe construction? (3 points)

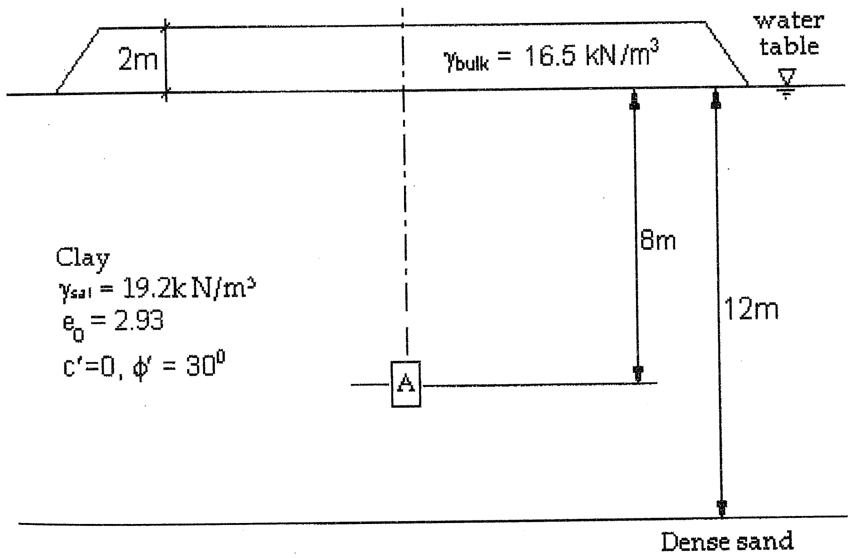

Figure Q1

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2.

   a) Table Q2(a) gives typical values observed for various coarse grained materials. Summarise the findings stated in this table. Generalise your conclusions to explain shear strength of granular materials. Candidates may draw from their knowledge and experience gained on the subject (8 points)

   b) Figure Q2(b) presents the results normally obtained during a conventional triaxial loading test

      i) Name the three tests represented by Fig: A, Fig: B and Fig: C. (3 points)

      ii) Describe the line X-X' shown in Fig: A (3 points)

      iii) Describe the line Y-Y' shown in Fig: C (3 points)

      iv) Explain why line Z-Z' shown in Fig: C is always horizontal. (3 points)

Table Q2(a): Typical values of ϕ' (Leonards)

Size of grains	State of Compaction	ϕ' Rounded grains Uniform gradation	ϕ' Angular grains Well graded
Medium sand	Very loose	$28^0 - 30^0$	$32^0 - 34^0$
	Moderately dense	$32^0 - 34^0$	$36^0 - 40^0$
	Very dense	$35^0 - 38^0$	$44^0 - 46^0$
Sand 35% & Gravel 65%	Loose	-	39^0
	Moderately dense	37^0	41^0
Sand 20% + 80% Gravel	Loose	34^0	-
	Dense	-	45^0
Blasted rock fragments		$40^0 - 45^0$	

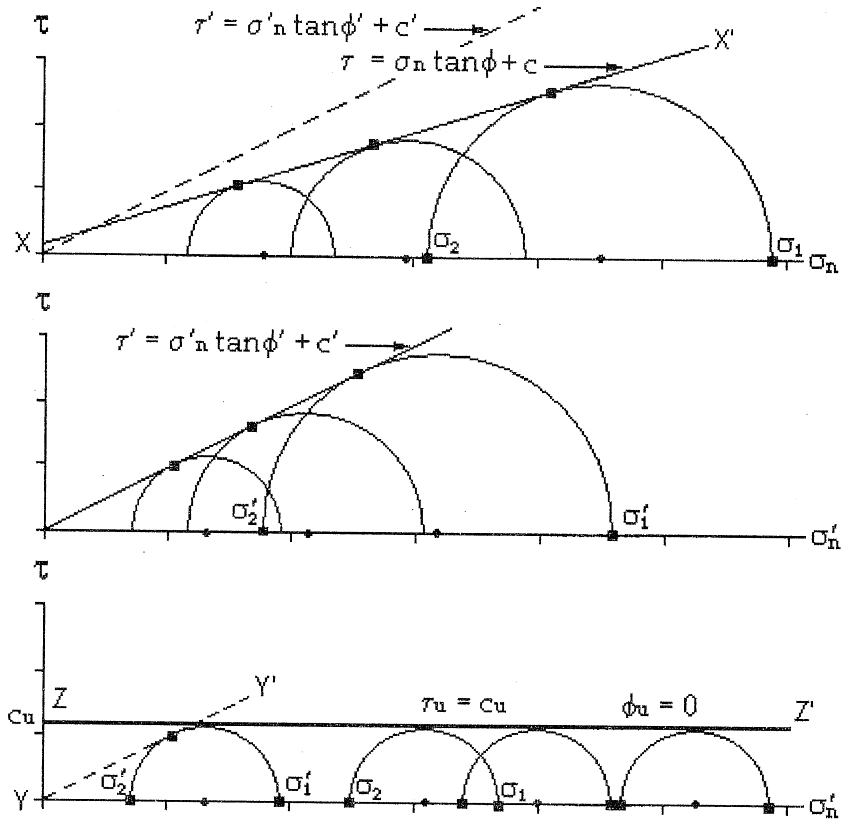

Fig: A

Fig: B

Fig C

Figure Q2(b)

3. Descriptive Question

a) Figure Q3(a) shows a design chart used in the design of shallow foundations. Draw a flow diagram to show how this chart is used. Explain how independent variables shown in this chart is found. (5 points)

b) Figure Q3(b) shows a shallow foundation with the groundwater table located at the base of footing. Explain the influence of ground water table on the Safe Bearing Capacity, which satisfies a limiting total settlement of 25mm. (5 points)

c) Figure Q3(c) shows a square footing carrying an axial load and a bending moment. Compute the eccentricity of loading and the effective width B′ used in the design. (5 points)

d) The Ultimate Bearing Capacity of a shallow rectangular footing is expressed as:

$q_{ult} = cN_c\left[1 + 0.3\frac{B}{L}\right] + \gamma DN_q + 0.4\gamma BN_\gamma$. Using this equation derive the expressions for q_{ult} based on total stresses if undrained loading takes place. (5 points)

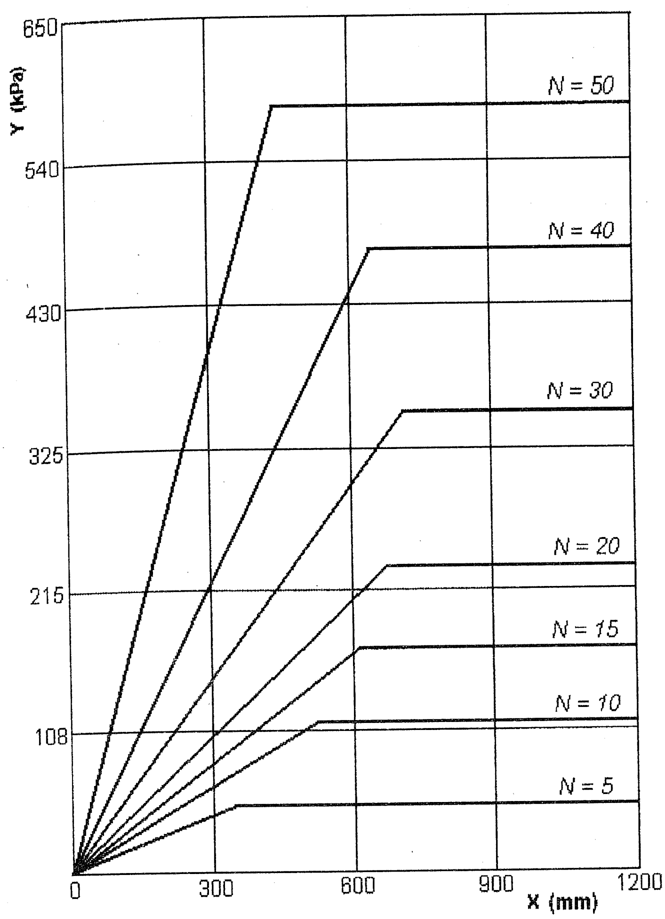

Figure Q3(a)

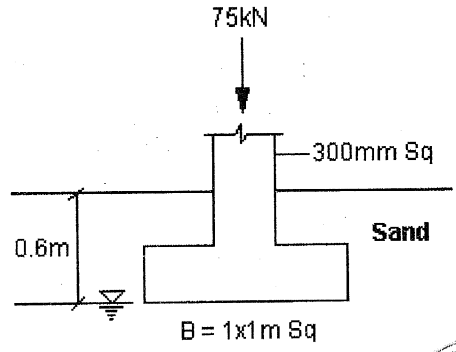

Figure Q3(b)

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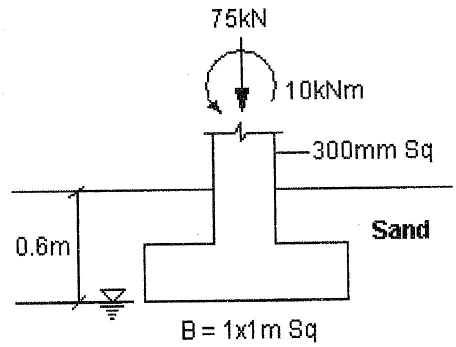


Figure Q3(c))

4. Figure Q4 shows a single row of sheet piles driven in to a permeable soil layer with $k = 6.5 \times 10^{-4}$ cm/s.

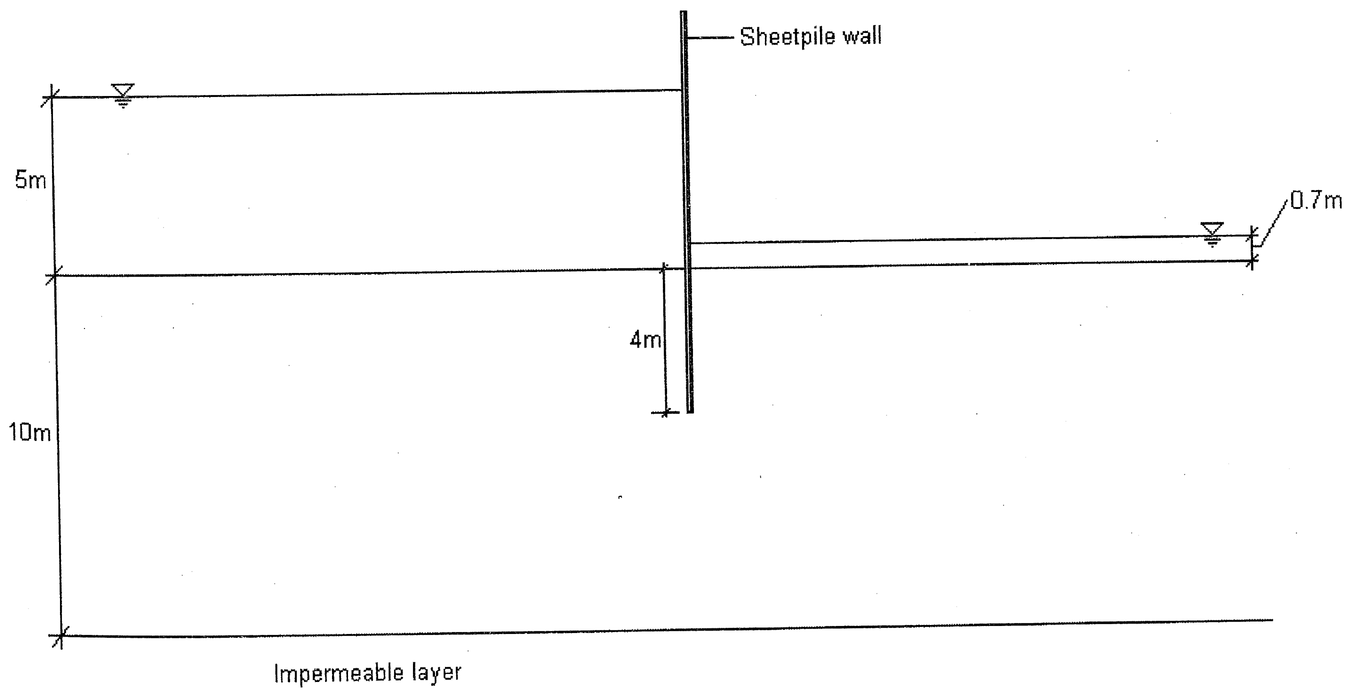


Figure Q4

a) Draw the flow net for the configuration shown in Page 10; attach it to your answer script. (5 points)

b) List the rules that you have considered in drawing this flow net. (4 points)

c) Compute the seepage flow per meter run of sheet piles (4 points)

d) Assuming a suitable unit weight of soil, compute the Critical Hydraulic Gradient (2 points)

e) Show the point where you expect the maximum hydraulic gradient that may lead to subsequent piping. (2 points)

f) Determine whether the structure is safe against piping. (3 points)

5. Figure Q5 shows a normally consolidated clay stratum overlain by a sand stratum. A developer wishes to raise its elevation by placing a controlled fill to a 4m height. This adds a uniform vertical stress of 85kPa to both strata. The unit weights of the two soil types are: for sand γ_{bulk} = 16.5kN/m^3, γ_{Sat} = 18.5kN/m^3; for clay γ_{Sat} = 21kN/m^3. 1–D Consolidation Test yields the following properties: C_c=0.4, C_r=0.08, $c_v = 1.3\times10^{-6}$ m^2/min; initial void ratio is 1.05.

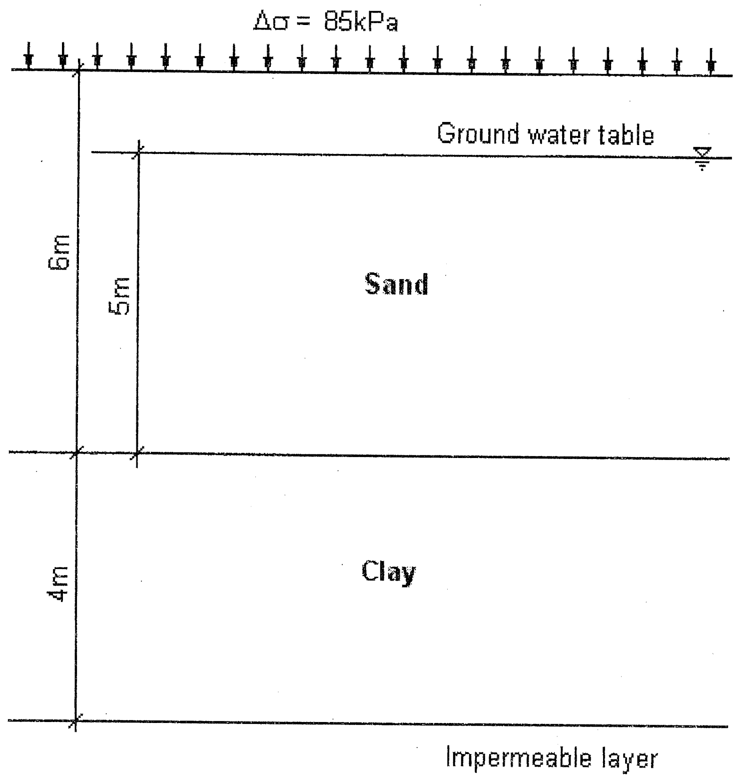


Figure Q5

a) Compute the anticipated total settlement. (4 points)

b) Plot the variation of σ'_v with depth, and u with depth, for the clay layer, before placing the compacted fill. Show on the same plot, the principal values you have computed. (4 points)

c) Plot the variation of σ'_v with depth, and u with depth, for the clay layer, immediately after placing the compacted fill. Show on the same plot, the principal values you have computed. (2 points)

d) Compute the settlement 5 years after placing the compacted fill. (4 points)

e) Compute the elastic settlement of the sand layer. E_s = 26MN/m^2; ν = 0.32. State any assumptions you have made. (6 points)

6. A square column foundation (refer Figure Q6) carries a load of 500kN, and a moment of 50kNm.

a) Compute the Ultimate Bearing Capacity for the footing and determine whether it satisfies a Factor of Safety of 3.0. (6 points)

b) Determine the Factor of Safety, if groundwater rises by 1m. (4 points)

c)

i) Compute the stress distribution with depth, below the footing, along the centerline, at depths shown in Table Q6. (6 points)

ii) Determine whether 10% of the incremental stress $\Delta\sigma_v$ occurs within the clay strata. (2 points)

iii) Compute the height of clay stratum you would use to determine the consolidation settlement (2 points)

Table Q6

Depth (m) measured from founding level	m	n	I_z	$\Delta\sigma_v$ (kPa)
0				
0.4				
0.8				
1.2				
2.4				
4.8				
6.0				

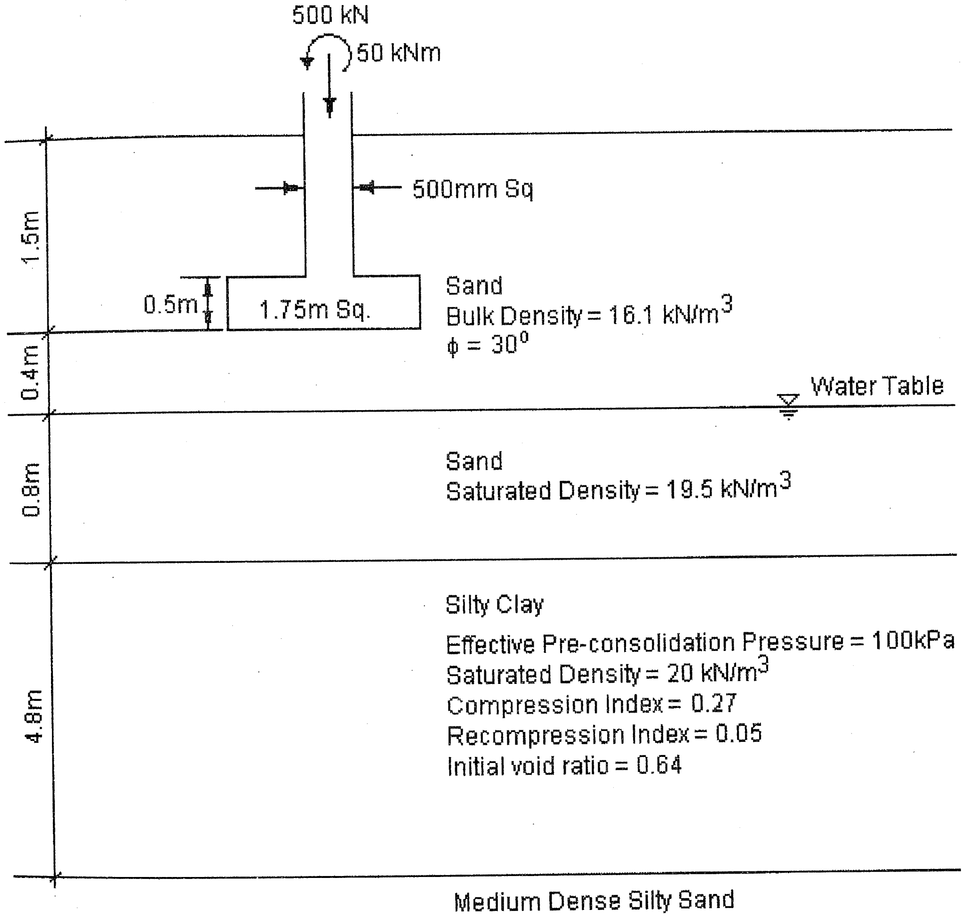


Figure Q6

7.

a) Discuss desirable engineering properties and applications that makes the following pile types suitable:

i) Timber piles (2 points)

ii) Bored cast in-situ reinforced concrete piles (2 points)

iii) Steel H-piles (2 points)

b) Figure Q7(b) shows a cast in-situ reinforced concrete pile in clay. Determine the Ultimate Bearing Capacity of the pile. (9 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]

c) Discuss the factors that contribute to settlement of the pile. (5 points)

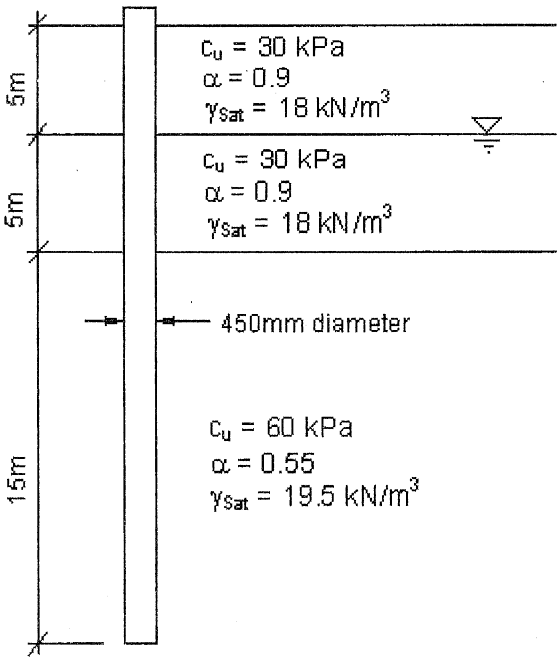


Figure Q7(b)

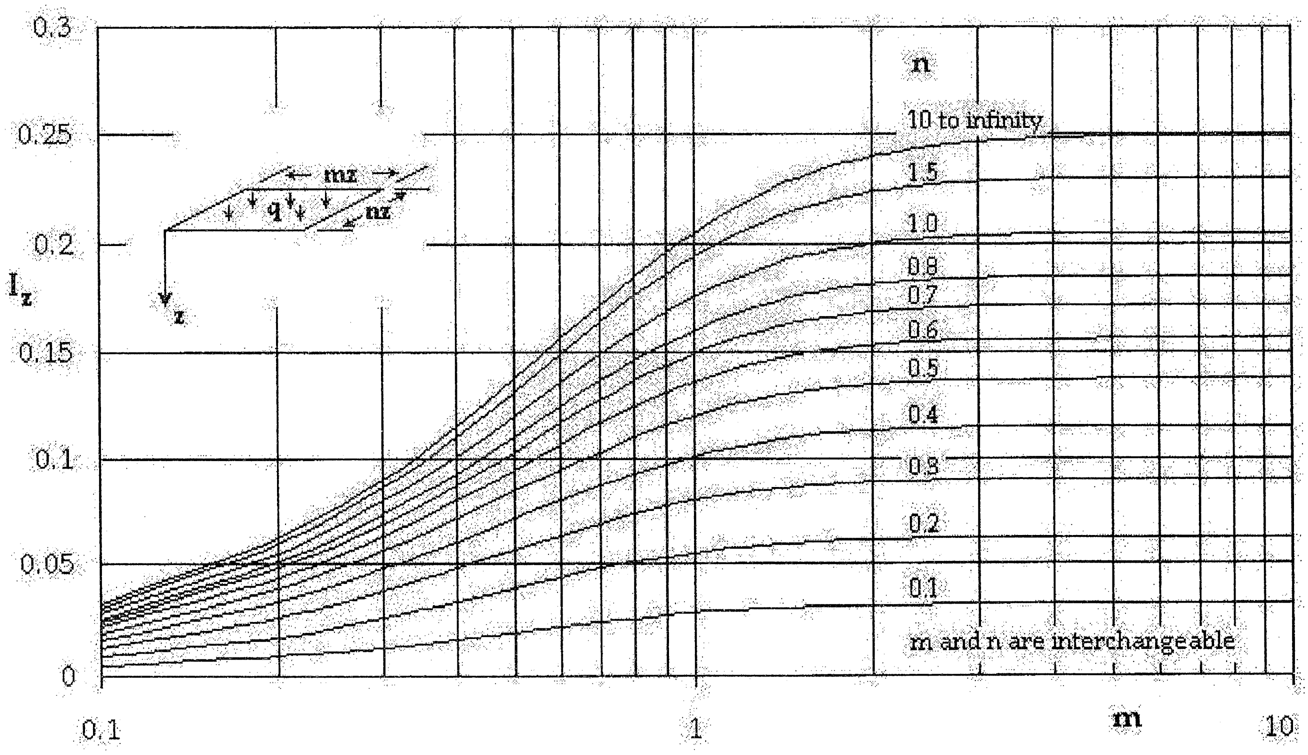
8. A canal 7m deep, with side slopes of 45^0 has been excavated in a soil having the following properties:

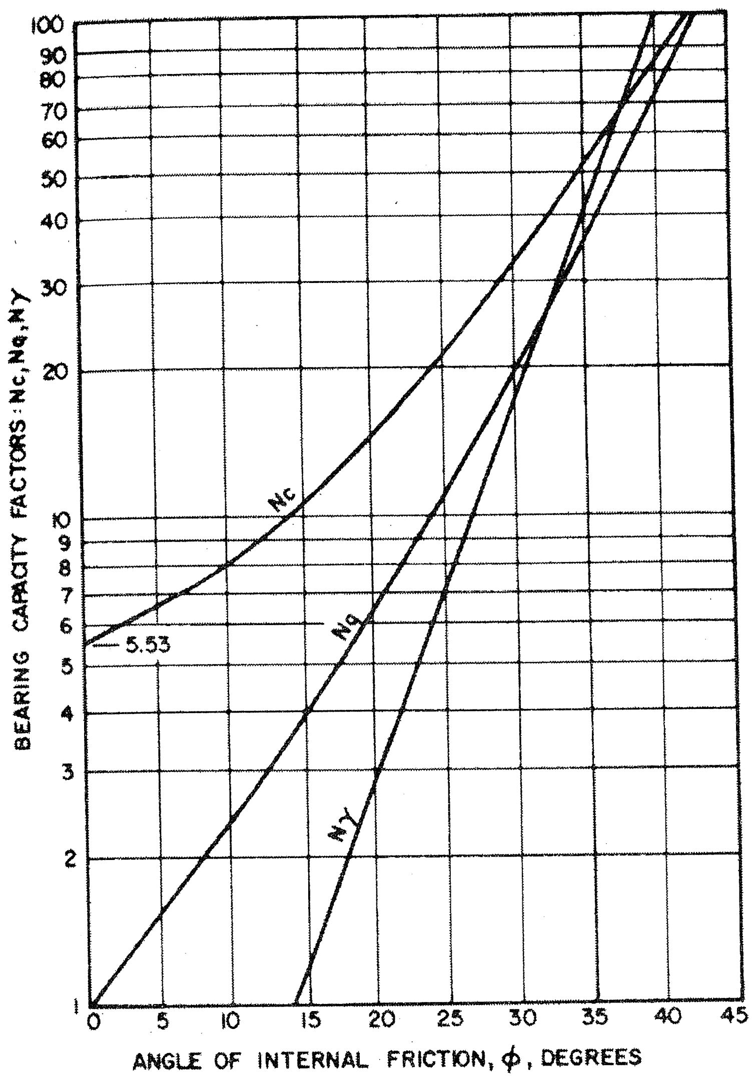
   $c' = 25$ kPa; $\phi' = 20^0$; $e_0 = 0{,}7$; $G_s = 2.7$; $\gamma_w = 9.81$ kN/m^3

   If the same factor of safety is allowed for both cohesion and internal friction, calculate the factor of safety against failure:

   a) When the slope is completely submerged. (12 points)

   b) When the slope is subjected to a sudden complete drawdown. (8 points)





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:

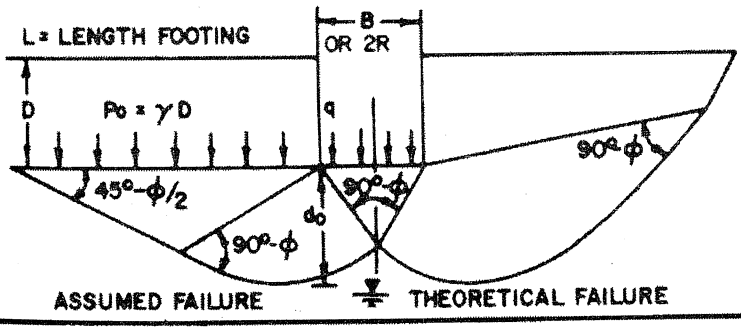
$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

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 (φ = 0)

CONTINUOUS FOOTING:

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

SQUARE OR RECTANGULAR FOOTING:

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

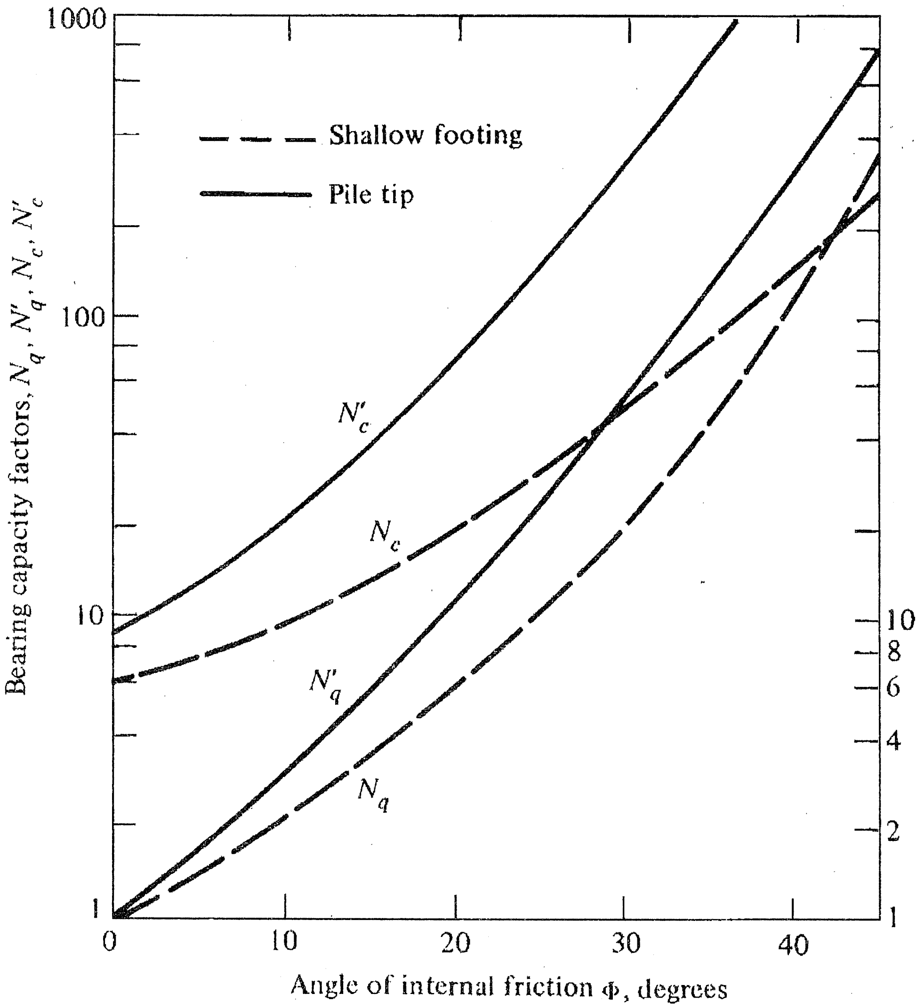
CIRCULAR FOOTING:

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

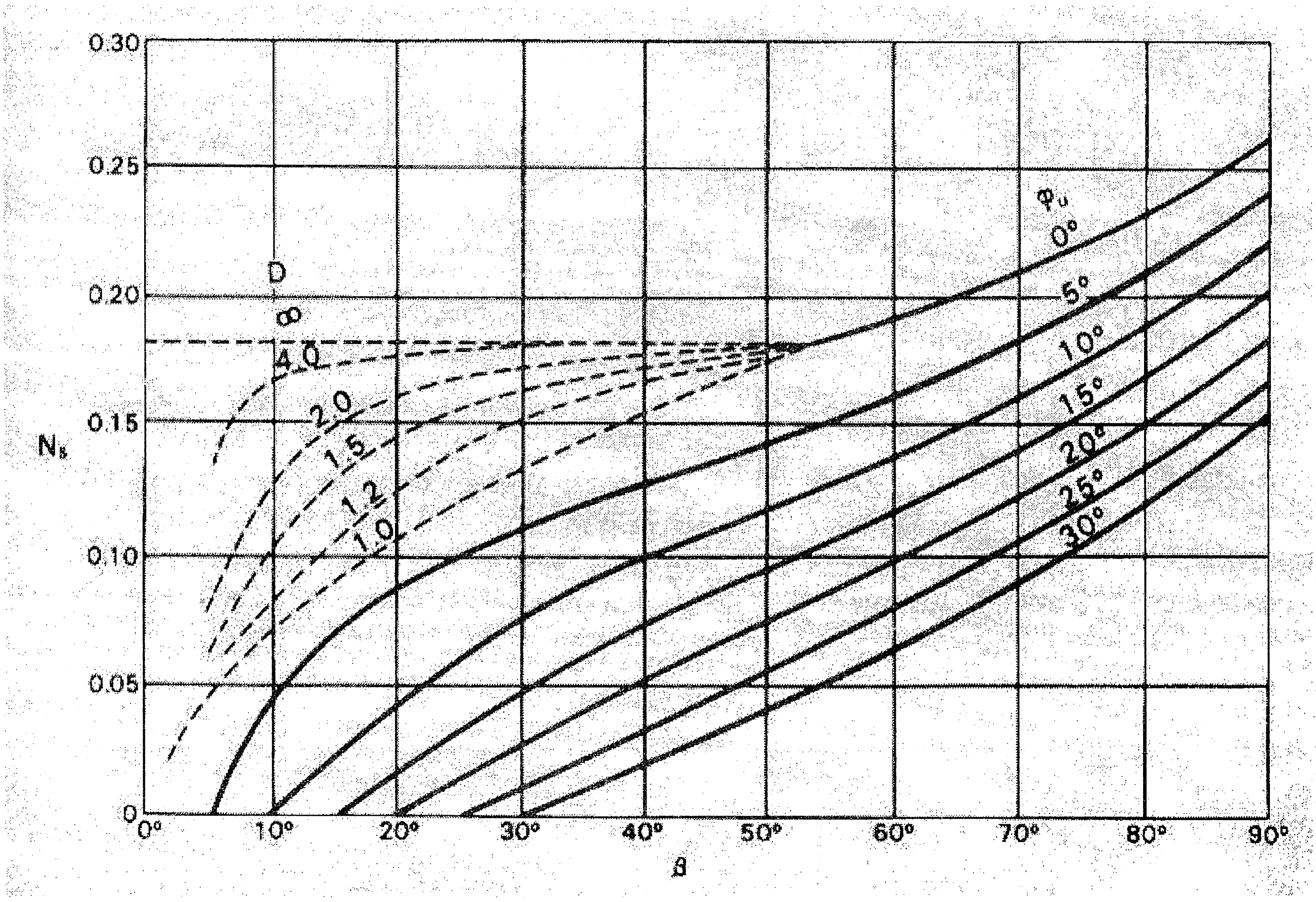
ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_0 > B$.
3. WATER LEVEL LOWER THAN d_0 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

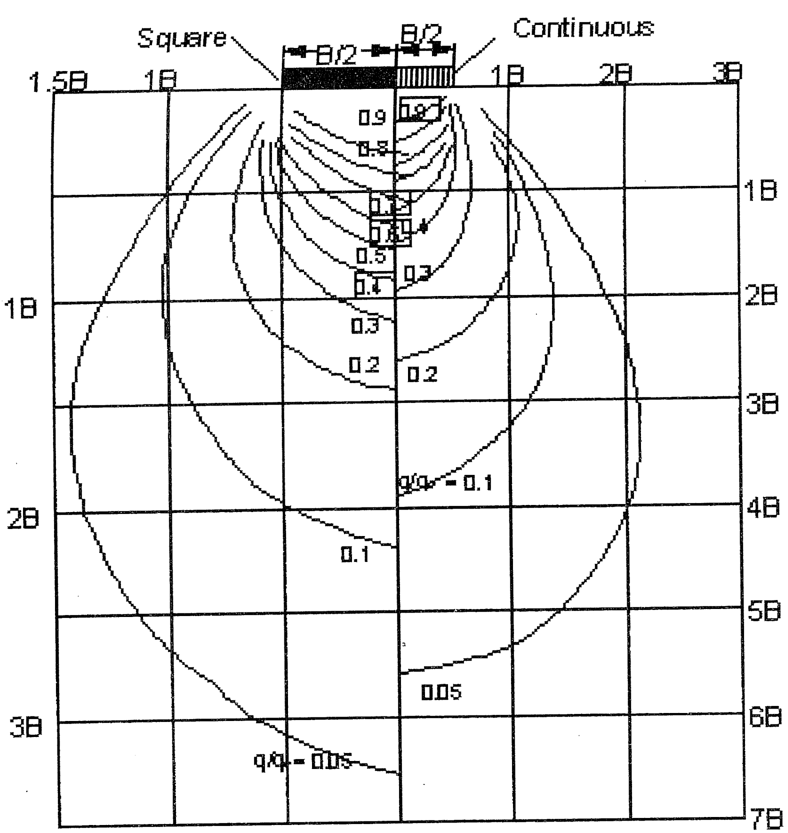
FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads

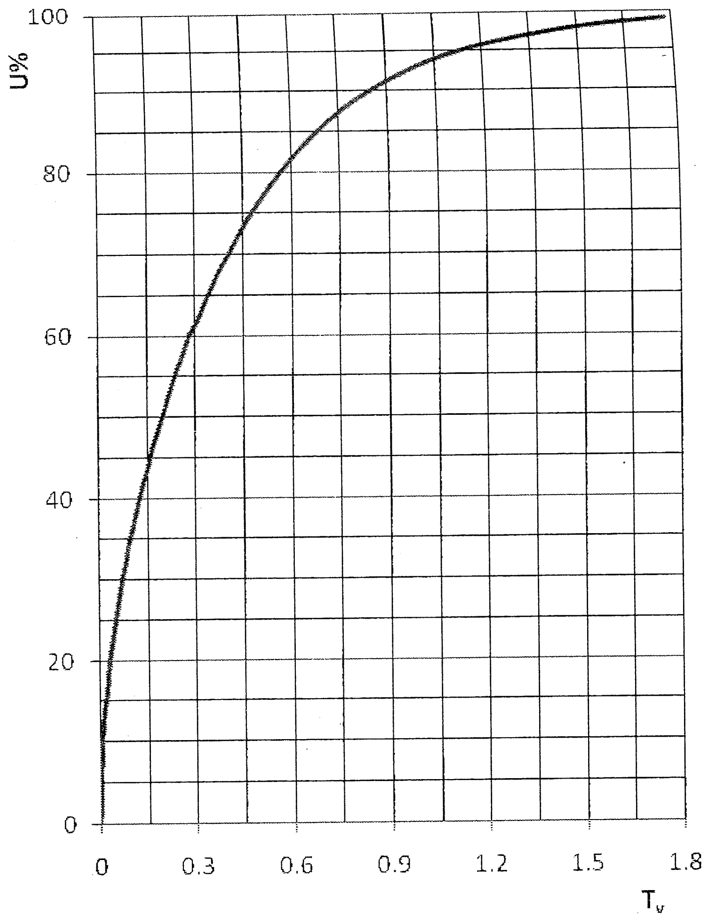


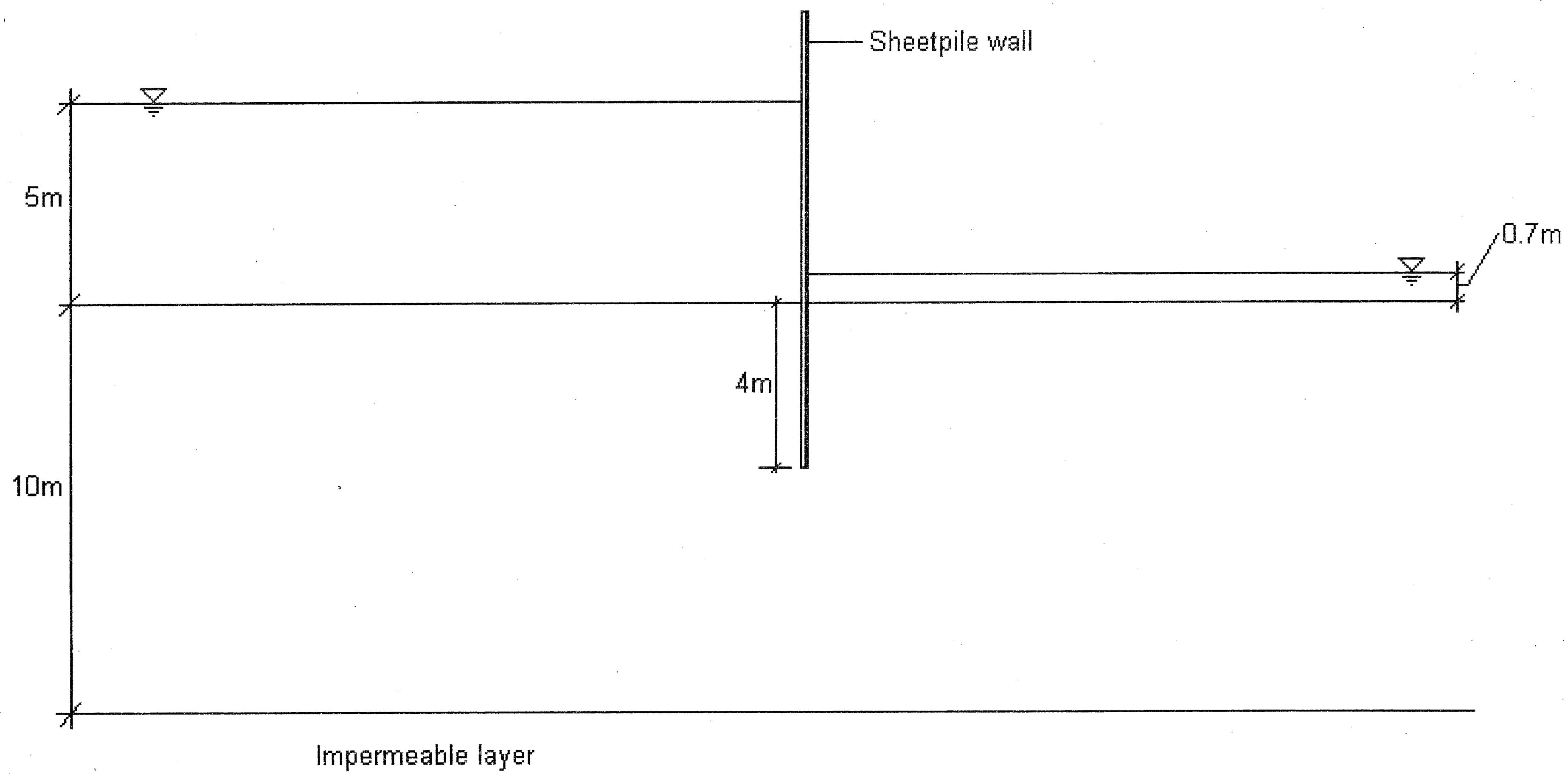
1000
100
10
1
Shallow footing
Pile tip
N'_c
N_c
N'_q
N_q
10
8
6
4
2
1
0
10
20
30
40
Bearing capacity factors, N_q, N'_q, N_c, N'_c
Angle of internal friction Φ, degrees



0.30
0.25
0.20
0.15
0.10
0.05
0
N_s
D
∞
4.0
2.0
1.5
1.2
1.0
ϕ_u
0°
5°
10°
15°
20°
25°
30°
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
β


Square
B/2
B/2
Continuous
1.5B
1B
1B
2B
3B
0.9
0.8
0.5
0.4
0.3
0.3
0.2
0.2
q/q₀ = 0.1
0.1
0.05
q/q₀ = 0.05
2B
3B
4B
5B
6B
7B


U%
100
80
60
40
20
0
0
0.3
0.6
0.9
1.2
1.5
1.8
Tv


Sheetpile wall
5m
0.7m
4m
10m
Impermeable layer