UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2024/25

GEOTECHNICAL ENGINEERING

MODULE NO: CIE6020

Date: Friday 10th January 2025 **Time: 10:00am – 1:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions.

Answer ALL FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

The examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

Supplementary Geotechnical Information is provided on page 12-14.

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Question 1

a) Produce a sketch to illustrate the relationship between the three different types of lateral earth pressure and the wall movement. With reference to your sketch, explain what happens when there is no movement of the wall, movement of the wall towards the soil and movement of the wall away from soil. In relation to strain, also explain when the minimum P_a and maximum P_p are achieved.

(5 marks)

b) A concrete cantilever wall with a sand backfill retains a layered geological sequence **(Q1 - Figure 1)** on page 3. With depth the sequence includes: 1.0m of sandy topsoil, 2.0m of dense sand and 3.0m of clay. The properties of the materials are summarised in the table **(Q1 – Table 1)** below:

Material	Unit weight (kN/m^3)	Angle of friction (°)	Cohesion (kN/m^2)
Sandy topsoil	20	24	0
Dense sand	21.1	30	0
Clay	21	12	21

Q1 – Table 1

i) Calculate and draw the distribution of the active pressure applied to the wall and backfill **(Q1 - Figure 1)** on page 3.

(10 marks)

ii) Calculate the magnitudes and line of action of the thrusts produced by active pressures above the base of the wall.

(10 marks)

Total 25 marks

Q1 - Figure 1 is shown over the page….

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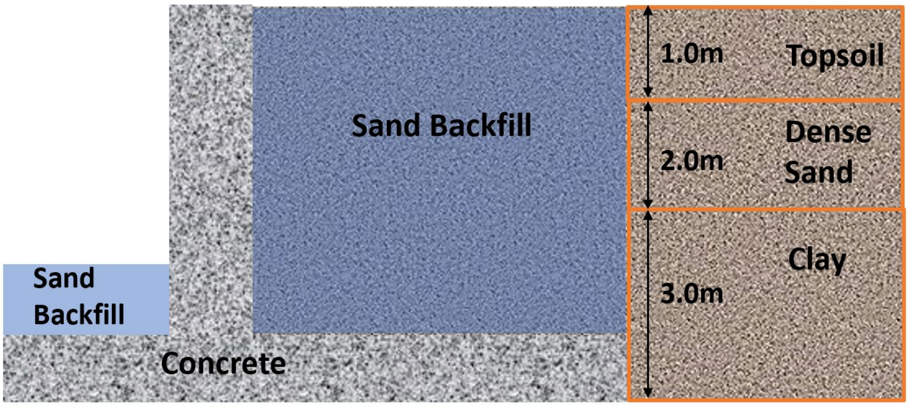
Question 1 continued….



Q1 - Figure 1

Question 2

a) For slope stability of an embankment, what are the main factors that influence slope stability? And what makes a slope globally stable? Explain your answer. **(4 marks)**

b) In **Q2 – Figure 2** (page 4), determine if the slope is stable or unstable. L_{AB} = 8.64 m, R = 5.50 m. **(7 marks)**

c) An embankment made from clay is to be constructed upon the ground surface (See **Q2 - Figure 3** page 4). The completed embankment can be assumed to be homogenous and thus will possess constant density and constant shear strength throughout its mass. Determine the factor of safety in the short term (undrained state). Area and angle of base for each slice is calculated in **Q2 - Table 2** (page 5).

(7 marks)

d) A 7m excavation is required in a mudrock where a hard limestone is known to be 8.4m below ground level. The mudrock has a cohesion of 9kN/m^2 and a unit weight of 19kN/m^3. Using Taylor's curves in **Q2 – Figure 4** (page 5), what is the angle of the critical slope. **(7 marks)**

Total 25 marks

(Q2 – Figure 2) & (Q2 – Figure 3) over the page….

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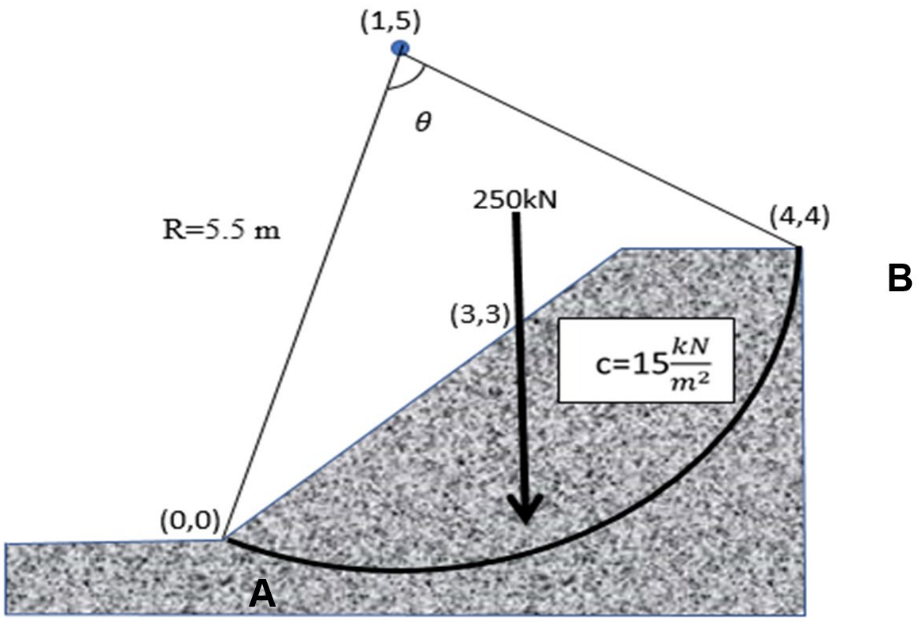
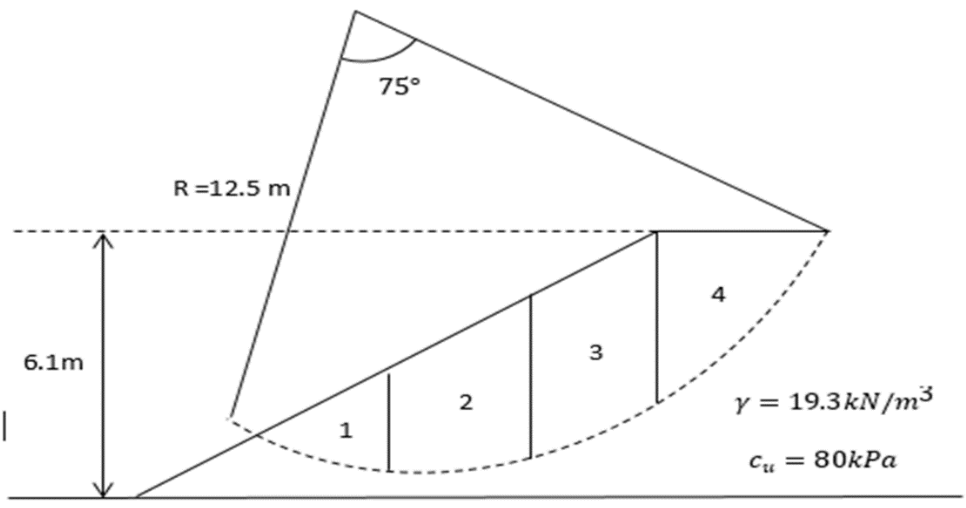
Question 2 continued….



Q2 – Figure 2



Q2 – Figure 3

(Q2 - Table 2) & (Q2 – Figure 4) over the page….

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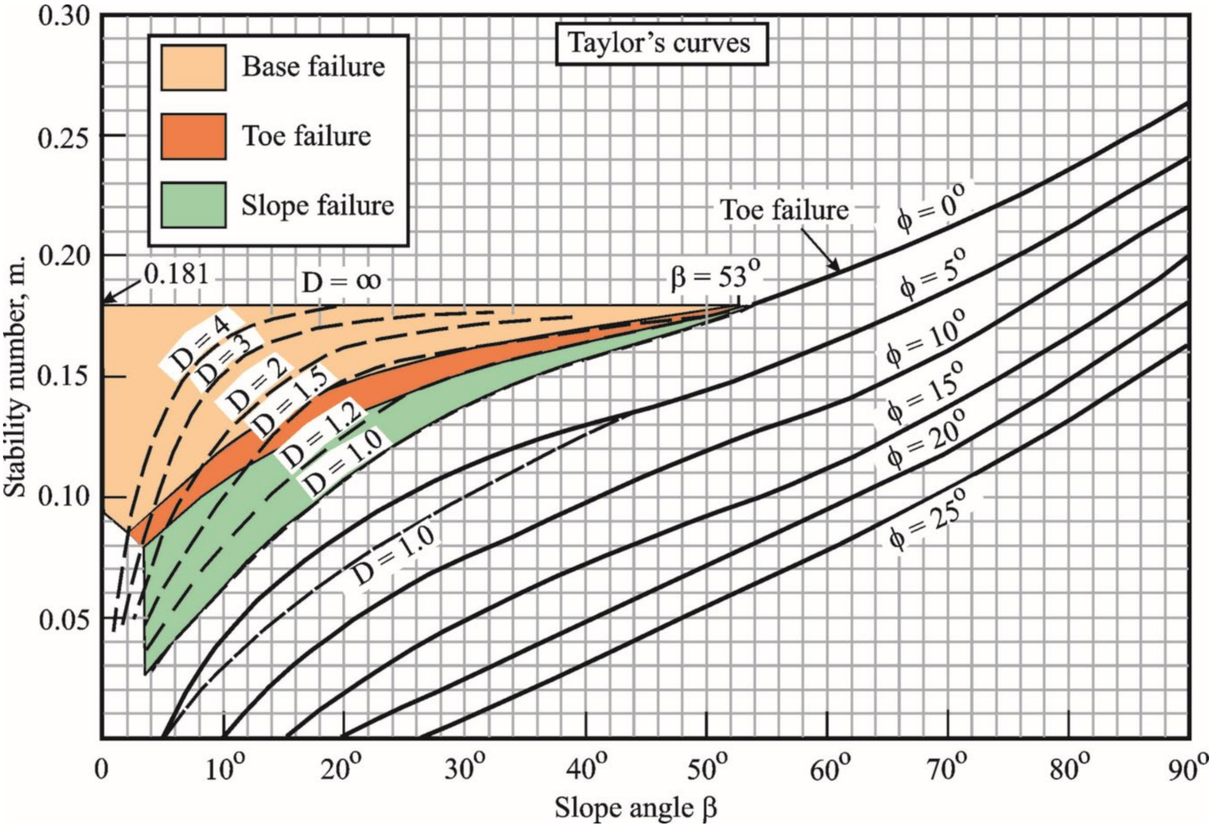
Question 2 continued….

Slice	Area (m^2)	Angle of base (˚)
1	4.6	-6.6
2	9.8	15.6
3	12.7	32.2
4	8.7	47.5

Q2 – Table 2



Q2 - Figure 4

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Question 3

a) A wide embankment, 6m high, is to be constructed over a 10m thick layer of very soft to soft clay (m_v = 0.5m^2/MN, c_v = 6m^2/yr). This clay overlies a relatively impermeable layer of mudstone. The embankment is to be formed by compacting granular material to a bulk unit weight of 21kN/m^3.

i) Calculate the total consolidation settlement within the clay layer.

(5 marks)

ii) If "finishing works" can be commenced on top of the embankment as soon as less than 30mm of consolidation settlement of the clay layer remains to be achieved, then calculate the earliest time that "finishing works" can be commenced.

(4 marks)

b) If 250mm diameter vertical sand drains are available then determine the square grid spacing of such drains that would be required to achieve the same settlement restrictions as required in Q3 a) ii) within 3-months – ie. only 30mm of consolidation settlement remaining. NOTE: c_h = 12m^2/yr and **Q3 – Figure 5** and **Q3 – Table 3** are provided (pages 7 and 8) for the solution of this question.

(12 marks)

c) Where 6m deep loose granular deposits occur along a section of proposed new high speed rail track, discuss **FOUR** ground improvement options that may be considered to ensure a stable platform is achieved. In geotechnical terms evaluate the advantages and limitations of each option you consider.

(4 marks)

Total 25 marks

Q3 – Figure 5 over the page….

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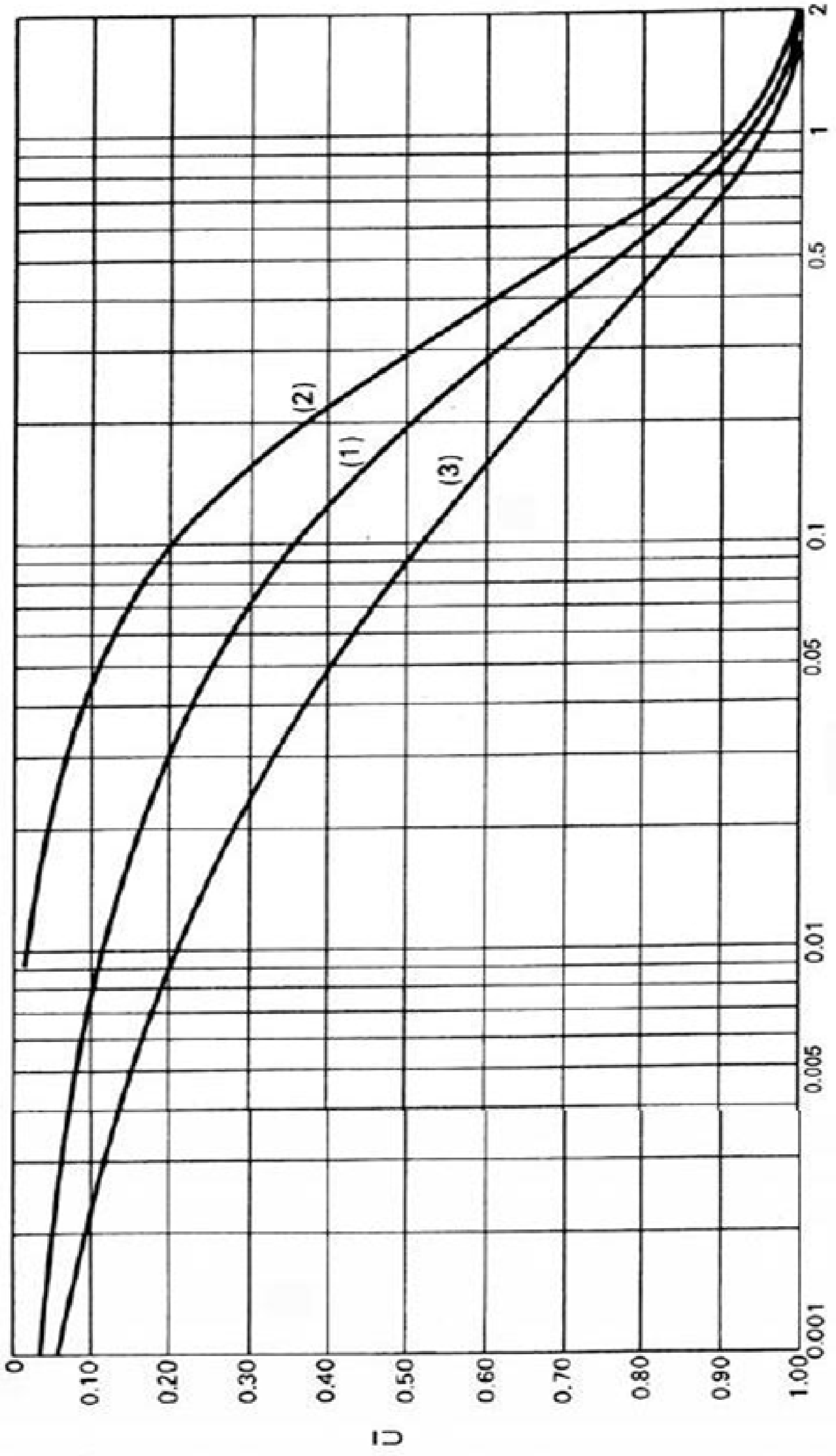
Question 3 continued….

Q3 - Figure 5



Q3 – Table 3 over the page….

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Question 3 continued….

Degree of consolidation U_r (%)	Dimensionless Time Factor, T_r										
	n=5	10	15	20	25	30	40	50	60	80	100
10	0.012	0.021	0.026	0.030	0.032	0.035	0.039	0.042	0.044	0.048	0.051
20	0.026	0.044	0.055	0.063	0.069	0.074	0.082	0.088	0.092	0.101	0.107
30	0.042	0.070	0.088	0.101	0.110	0.118	0.131	0.141	0.149	0.162	0.172
40	0.060	0.101	0.125	0.144	0.158	0.170	0.188	0.202	0.214	0.232	0.246
50	0.081	0.137	0.170	0.195	0.214	0.230	0.255	0.274	0.290	0.315	0.334
55	0.094	0.157	0.197	0.225	0.247	0.265	0.294	0.316	0.334	0.363	0.385
60	0.107	0.180	0.226	0.258	0.283	0.304	0.337	0.362	0.383	0.416	0.441
65	0.123	0.207	0.259	0.296	0.325	0.348	0.386	0.415	0.439	0.477	0.506
70	0.137	0.231	0.289	0.330	0.362	0.389	0.431	0.463	0.490	0.532	0.564
75	0.162	0.273	0.342	0.391	0.429	0.460	0.510	0.548	0.579	0.629	0.668
80	0.188	0.317	0.397	0.453	0.498	0.534	0.592	0.636	0.673	0.730	0.775
85	0.222	0.373	0.467	0.534	0.587	0.629	0.697	0.750	0.793	0.861	0.914
90	0.270	0.455	0.567	0.649	0.712	0.764	0.847	0.911	0.963	1.046	1.110
95	0.351	0.590	0.738	0.844	0.926	0.994	1.102	1.185	1.253	1.360	1.444
99	0.539	0.907	1.135	1.298	1.423	1.528	1.693	1.821	1.925	2.091	2.219

Q3 – Table 3

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Question 4

a) A pad foundation, 3.0 x 2.0m is to be located at a depth of 2.0m in a uniform bearing stratum of firm clay. The clay soil properties are;

Bulk unit weight	γ = 20.0 kN/m^3
Depth of Foundation	z = 2.0 m
With respect to Total Stresses	c = 40.0 kN/m^2
	Φ = 30^0

Determine the allowable bearing capacity (q_{all}), the net allowable bearing capacity ($q_{(net)all}$), the allowable load (Q_{all}), and the net allowable load ($Q_{(net)all}$) that the foundation can support (in kN). **Use the suitable formulae provided on page 13, 14 and also Q4 - Figure 6 on page 10 and/or Q4 - Table 4 in page 11 (if appropriate).**
Use Factor of Safety 2.5.

(12 marks)

b) A bored pile (15m long and 600mm diameter) is to be installed into the following soil profile;

Depth m	Description	Unit Weight kN/m^3	c_u kN/m^2	Adhesion Factor α
0 – 4	Soft CLAY	21.0	30.0	0.52
4 – 8	Firm to stiff CLAY	22.0	75.0	0.48
8 - 30	Stiff to very stiff CLAY	22.5	180.0	0.42

Determine the ultimate capacity and the safe load carrying capacity of the pile (in kN). N_c = 9.0

(13 marks)

Total 25 marks

Q4 – Figure 6 over the page….

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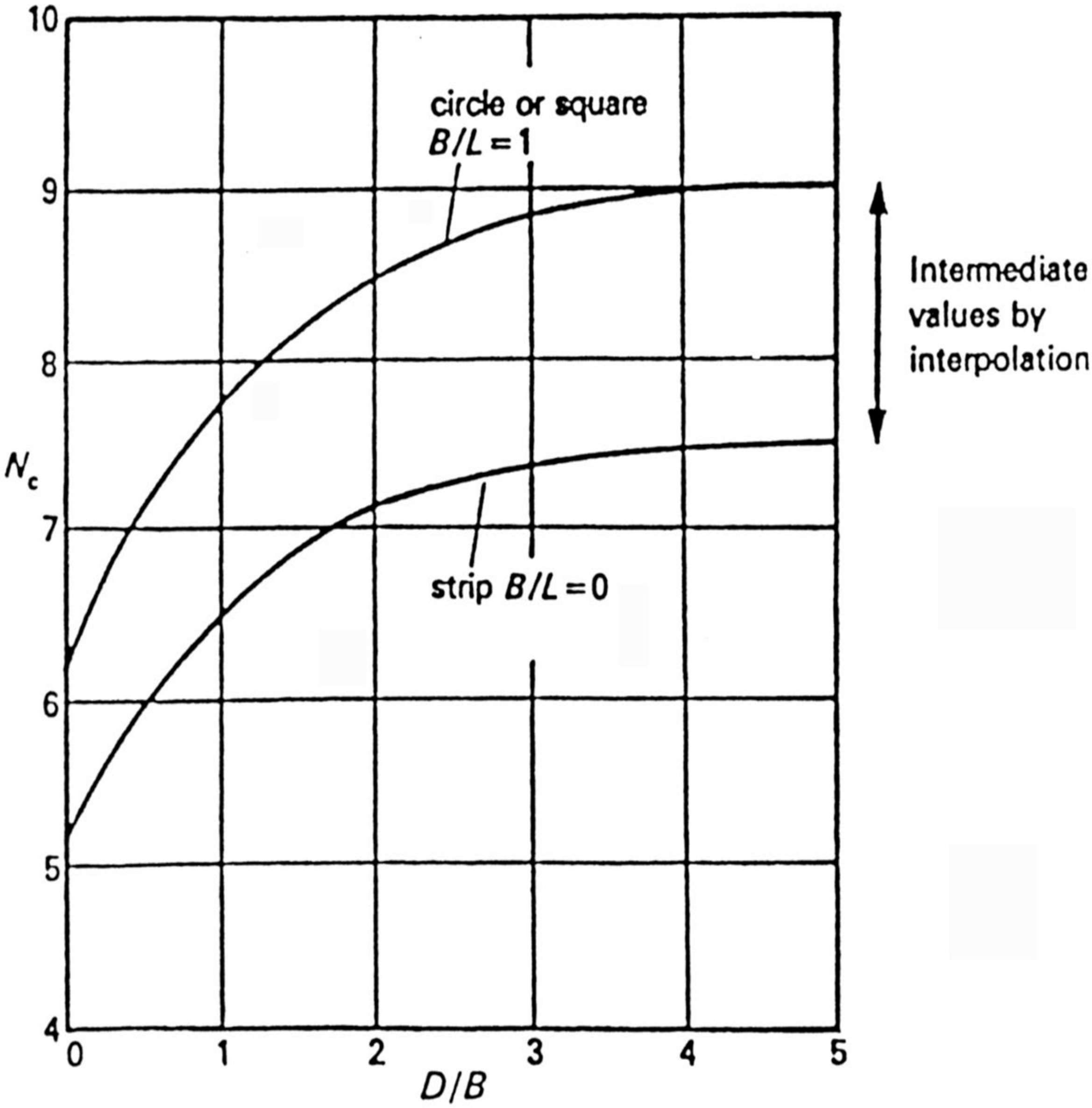
Question 4 continued….



Q4 – Figure 6

Q4 – Table 4 over the page….

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Question 4 continued….

ϕ	N_c	N_q	N_γ
0	5.14	1.0	0
1	5.4	1.1	0
2	5.6	1.2	0
3	5.9	1.3	0
4	6.2	1.4	0
5	6.5	1.6	0.1
6	6.8	1.7	0.1
7	7.2	1.9	0.2
8	7.5	2.1	0.2
9	7.9	2.3	0.3
10	8.4	2.5	0.4
11	8.8	2.7	0.5
12	9.3	3.0	0.6
13	9.8	3.3	0.8
14	10.4	3.6	1.0
15	11.0	3.9	1.2
16	11.6	4.3	1.4
17	12.3	4.8	1.7
18	13.1	5.3	2.1
19	13.9	5.8	2.5
20	14.8	6.4	3.0
21	15.8	7.1	3.5
22	16.9	7.8	4.1
23	18.1	8.7	4.9
24	19.3	9.6	5.7
25	20.7	10.7	6.8
26	22.3	11.9	7.9
27	23.9	13.2	9.3
28	25.8	14.7	10.9
29	27.9	16.4	12.8
30	30.1	18.4	15.1
31	32.7	20.6	17.7
32	35.5	23.2	20.8
33	38.6	26.1	24.4
34	42.2	29.4	28.8
35	46.1	33.3	33.9
36	50.6	37.8	40.0
37	55.6	42.9	47.4
38	61.4	48.9	56.2
39	67.9	56.0	66.8
40	75.3	64.2	79.5

Q4 – Table 4

END OF QUESTIONS

Please turn the page for Supplementary Geotechnical Information….
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Supplementary Geotechnical Information

Retaining Walls (Q1)

$$P_A = K_A(\gamma z + q\ ) - 2c\sqrt{K_A} \qquad P_P = K_P(\gamma z + q\ ) + 2c\sqrt{K_P}$$

$$K_A = \frac{1 - sin\,\phi}{1 + sin\,\phi} = tan^2\left(45 - \frac{\phi}{2}\right) \qquad K_P = \frac{1 + sin\,\phi}{1 - sin\,\phi} = tan^2\left(45 + \frac{\phi}{2}\right)$$

($\boldsymbol{P_A, P_P, K_A}$ ***and*** $\boldsymbol{K_P}$ ***are the active and passive pressures and coeffecients respectively,*** $\boldsymbol{z}$ ***is the depth,*** $\boldsymbol{\gamma}$ ***is the unit weight and*** $\boldsymbol{q}$ ***is the surcharge***)

Slope stability (Q2)

$$F = \frac{c_u R^2 \theta}{W x\ d}$$

$$F = \frac{c_u R \theta}{\sum T}$$

$$F = \frac{c_u R \theta}{\sum W\ sin\,\alpha}$$

(***R is the radius of the slip circle,*** $\boldsymbol{\theta}$ ***is the included angle,*** $\boldsymbol{\alpha}$ ***is the base angle and W is the weight of soil for each slice***)

$$m = \frac{c'}{FH\gamma}$$

(***m is the stability number, F is the factor of safety and H is the height of the slope***)

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3-d Consolidation (Q3)

$\Delta h = \Delta\delta' \, m_v H$ $\Delta\delta' = \gamma z$

$(1 - U) = (1 - U_v)(1 - U_r)$

$T_v = c_v \, t / d^2$ $T_r = c_h \, t / 4R^2$

$R = 0.564\ S$ for square grid pattern

$n = R/r_d$

Shallow and Pile Foundations (Q4)

q_{all} = allowable bearing capacity = q_u / F

$q_{net(all)}$ = net allowable bearing capacity = $(q_u - \gamma z)/F$

Circular: $q_u = 1.3\ c\ N_c + \gamma\ z\ N_q + 0.3\ \gamma\ B\ N_\gamma$

Square: $q_u = 1.3\ c\ N_c + \gamma\ z\ N_q + 0.4\ \gamma\ B\ N_\gamma$

Rectangular: $q_u = c\ N_c\ [1 + 0.3(B/L)] + \gamma\ z\ N_q + 0.5\ \gamma\ B\ N_\gamma\ [1-0.2(B/L)]$

Strip (Continuous): $q_u = c\ N_c + \gamma\ z\ N_q + 0.5\ \gamma\ B\ N_\gamma$

Where N_c ; N_q ; N_γ are bearing capacity factors.

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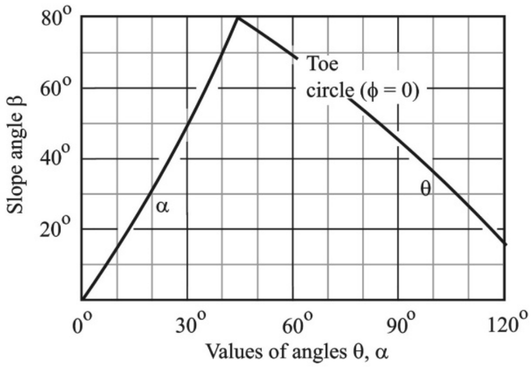
Shaft Resistance $Q_s = \alpha c_u \pi d L$

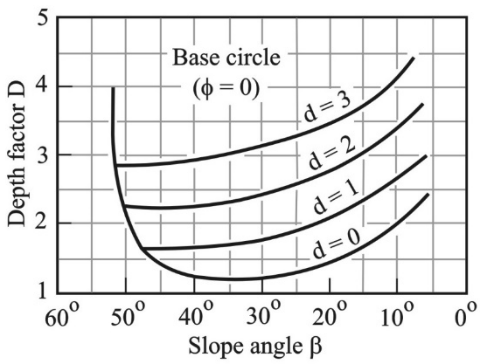
Base Resistance $Q_b = c_u N_c \pi d^2 / 4$

$Q_u = Q_b + Q_s$

$Q_{safe} = Q_b/3 + Q_s$ OR $Q_{safe} = (Q_b + Q_s) / 2.5$

Additional Data





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