UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

Module Number: CE6304 **Module Name: Geotechnical Engineering**

[Three Hours]

[Answer **all questions**, each question carries twelve marks]

Q1. There is a proposal to construct a five storied building at a site. The building is to be constructed on a rectangular raft foundation of 10 m x 10 m dimensions placed at a depth of 2.0 m from the ground surface. Subsurface soil profile consists of 4.0 m thick soft clay layer sandwiched between two sand layers. Water table is 0.5 m below the ground surface. A cross section of the subsurface soil profile and the foundation arrangement is presented in Figure Q1.1. The average contact pressure of the building at the foundation level is estimated to be 150 kN/m^2. Unit weights of dry sand, saturated sand and clay are 18.5 kN/m^3, 20.0 kN/m^3 and 16.0 kN/m^3 respectively.

In order to determine compressibility characteristics of clay, a consolidation test was conducted on an undisturbed soil sample obtained from the clay layer and results are presented in Table Q1.1. The unit weight of water can be taken as 9.81 kN/m^3.

You may refer Table Q1.2 for necessary calculations.

a) List four factors that affect the rate of consolidation.

[2.0 Marks]

b) What would be the preconsolidation pressure at middle of the clay layer? Hence, justify that clay is over consolidated.

[2.5 Marks]

c) What would be the net stress increment at the foundation level due to proposed development by considering the stress release due to excavation.

[1.0 Marks]

d) What would be the expected primary consolidation settlement of the clay layer due to proposed development?

[2.5 Marks]

e) What would be the time required for 95% of the primary consolidation to be occurred?

[1.0 Marks]

f) What would be the expected secondary consolidation settlement 3 year after the end of primary consolidation?

[3.0 Marks]

Q2. There is a proposal to develop 25 acres of "Muthurajawela" marshy land for a "Waste to Energy" project. However, in order to initiate the project, it is necessary to get the approval from Sri Lanka Land Reclamation and Development Corporation (SLRDC) and Central Environmental Authority CEA). As a part of the process, a site investigation is planned to take place.

a) As you are a junior engineer in the project, what are the four types of informat... expected from this site investigation?

[2.0 Marks]

b) List 4 types of sources to gather information?

[2.0 Marks]

c) In order to find the coefficient of permeability of the silty sand which is used as drainage layer during ground improvement, the site engineer has arranged an experimental setup as shown in Figure Q2.1. Flow rate was found to be 6.6 cm^3/s at the steady state condition. Cross sectional area of the soil sample is 10 cm^2. Porosity of the material is found to be 0.3. The unit weight of water can be taken as 9.81 kN/m^3.

i) Assuming that there is no any head loss from X to B and Y to C, determine the coefficient of permeability of the silty sand.

[4.0 Marks]

ii) Determine the actual velocity of the flow through the soil.

[1.5 Marks]

iii) Sketch the variation of pore water pressure along the setup from A to D

[2.5 Marks]

Q3. There is a proposal to construct a 5 storied building at a site. In order to find the sub surface soil profile, borehole investigation was conducted prior to the construction. The sub surface consists of 4.0 m thick medium dense sand layer followed by medium stiff clay layer as shown in Figure Q3.1. Completely weathered rock is encountered 8.0 m below the ground surface. Water table is encountered at a depth of 2.5 m from the ground surface. Dry unit weight and specific gravity of medium dense sand are 17.0 kN/m^3 and 2.7 respectively. Saturated unit weight of medium stiff clay is 16.0 kN/m^3. The unit weight of water can be taken as 9.81 kN/m^3.

a) To determine the shear strength parameters of medium dense sand, a direct shear was conducted and results are summarized in Table Q3.1.

i) Determine the shear strength parameters of sand.

[1.5 Marks]

ii) Determine the magnitude of principal stresses in the zone of failure.

[2.0 Marks]

iii) Draw the phase diagrams for dry and saturated zones of medium dense sand layer and derive following equations with usual notations.

- $\gamma_d = \frac{G_s \gamma_w}{1+e}$
- $\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e}$

[1.5 Marks]

iv) Determine the void ratio and saturated unit weight of medium dense sand.

[1.0 Marks]

v) What is the shear strength of medium dense sand along a horizontal plane at a depth of 4.0 m from the ground surface? When the water table rise up to the ground surface, what would be the change in shear strength?

[2.5 Marks]

b) To determine the shear strength parameters of medium stiff clay, Consolidated Undrained (CU) triaxial test was conducted using an undisturbed sample collected from the medium stiff clay layer. Based on the data gathered from the CU tests, effective shear strength parameters of medium stiff clay were found as

$= 16\ kN/m^2$ and $\varphi' = 29°$. Cell pressure, deviator stress and shear stress at failure of a sample are shown in Table Q3.2.

i) Draw a Mohr circle *(not to scale)* and show the failure plane, and determine the angle that the failure plane makes with the major principal plane.

[1.0 Marks]

ii) Determine the effective normal stress σ' and shear stress τ_f on the failure plane.

[1.5 Marks]

iii) If a soil sample is subjected to an effective normal stress σ' of 150 kN/m^2 together with shear stress τ of 70 kN/m^2, determine whether the soil sample is stable or not? Justify your answer.

[1.0 Marks]

Q4. A cross section of a concrete dam is shown in Figure Q4.1. The up stream water level is 5.0 m above the existing ground level where as down stream water level is 1.0 m above the existing ground level. There is a cutoff wall at the up stream of the reservoir. The flow net has been drawn by trial and error manual sketching and presented in Figure Q4.1. The coefficient of permeability of foundation soil is 2.5×10^{-5} m/s. The saturated unit weight of the soil is 16.0 kN/m^3. The unit weight of water can be taken as 9.81 kN/m^3.

a) What is the advantage of providing a cutoff wall under the concrete dam?

[0.5 Marks]

b) If length of the concrete dam is 100 m, what would be the rate of seepage under the concrete dam?

[2.5 Marks]

c) Determine the pore water pressures at points **1** and **7**.

[3.5 Marks]

d) If porosity of the soil is 0.3, estimate the seepage velocity at the shaded element **X**.

[2.0 Marks]

e) What would be the maximum exit gradient?

[0.5 Marks]

f) Calculate the factor of safety against piping.

[2.0 Marks]

g) What would be the maximum seepage force per unit volume?

[1.0 Marks]

Q5. Figure Q5.1 shows a concrete retaining wall with a sloping back retained sand with an irregular ground surface. The soil sits on impervious bedrock and submerged to a height of 3.0 m. The Coulomb's trial wedge approach is used to determine the active force on the retaining wall. A trial failure surface used for the analysis is shown in Figure Q5.1. The total weigh of the potential failure wedge is 434 kN. The unit weight of the sand above and below the water table are 15 kN/m^3 and 18 kN/m^3 respectively. Friction angle of the sand on the retained side is $\varphi' = 36°$. The interface friction angle between retained soil and concrete retaining wall is = 24° .

a) Draw ABD trial wedge and mark all the forces acting on the trial wedge.

[3.5 Marks]

b) Calculate all forces required in the analysis.

[2.0 Marks]

c) Using a scale of 10 mm = 20 kN/m, draw a vector polygon and hence determ... the Active force for this wall.

[5.0 Marks]

d) If water table is well below the ground surface, what would be the Active force on the retaining wall?

[1.5 Marks]

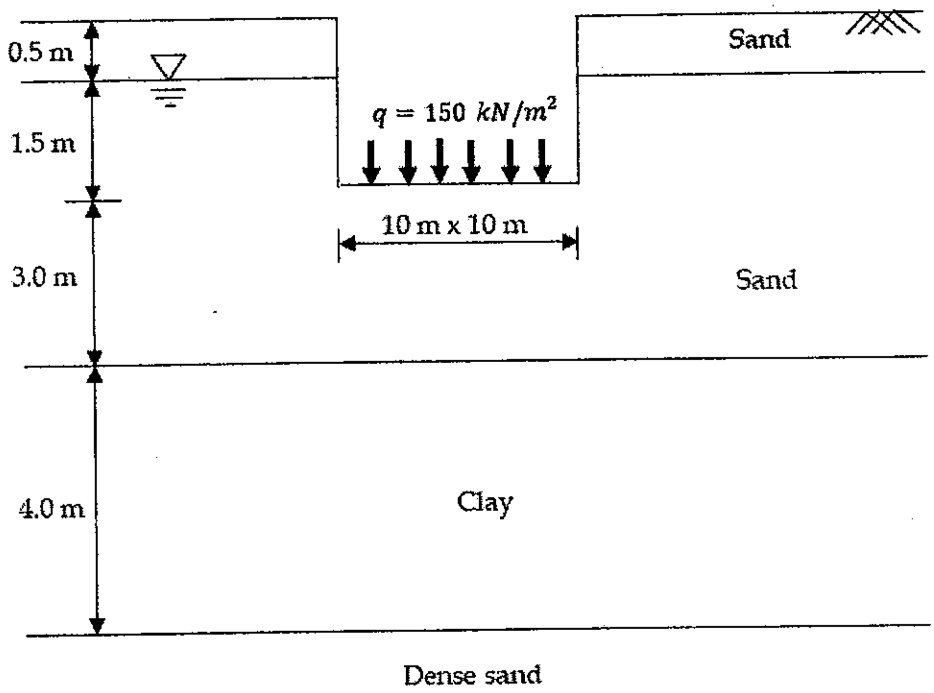

Figure Q1.1 – Subsurface soil profile and foundation arrangement

Table Q1.1 – Properties of soft clay

Saturated unit weight γ_{sat}	16.0 kN/m³
Coefficient of consolidation C_v	2.0 m²/year
Compression index C_c	0.8
Recompression index C_r	0.05
Initial void ratio e_0	0.585
Over Consolidation Ratio (OCR)	1.3
Modified secondary compression index C'_α	0.01

Table Q1.2 Variation of T_v with U

U (%)	T_v	U (%)	T_v
0	0	51	0.204
1	0.00008	52	0.212
2	0.0003	53	0.221
3	0.00071	54	0.230
4	0.00126	55	0.239
5	0.00196	56	0.248
6	0.00283	57	0.257
7	0.00385	58	0.267
8	0.00502	59	0.276
9	0.00636	60	0.286
10	0.00785	61	0.297
11	0.0095	62	0.307
12	0.0113	63	0.318
13	0.0133	64	0.329
14	0.0154	65	0.304
15	0.0177	66	0.352
16	0.0201	67	0.364
17	0.0227	68	0.377
18	0.0254	69	0.390
19	0.0283	70	0.403
20	0.0314	71	0.417
21	0.0346	72	0.431
22	0.0380	73	0.446
23	0.0415	74	0.461
24	0.0452	75	0.477
25	0.0491	76	0.493
26	0.0531	77	0.511
27	0.0572	78	0.529
28	0.0615	79	0.547
29	0.0660	80	0.567
30	0.0707	81	0.588
31	0.0754	82	0.610
32	0.0803	83	0.633
33	0.0855	84	0.658
34	0.0907	85	0.684
35	0.0962	86	0.712
36	0.102	87	0.742
37	0.107	88	0.774
38	0.113	89	0.809
39	0.119	90	0.848
40	0.126	91	0.891
41	0.132	92	0.938
42	0.138	93	0.993
43	0.145	94	1.055
44	0.152	95	1.129
45	0.159	96	1.219
46	0.166	97	1.336
47	0.173	98	1.500
48	0.181	99	1.781
49	0.188	100	∞
50	0.197		

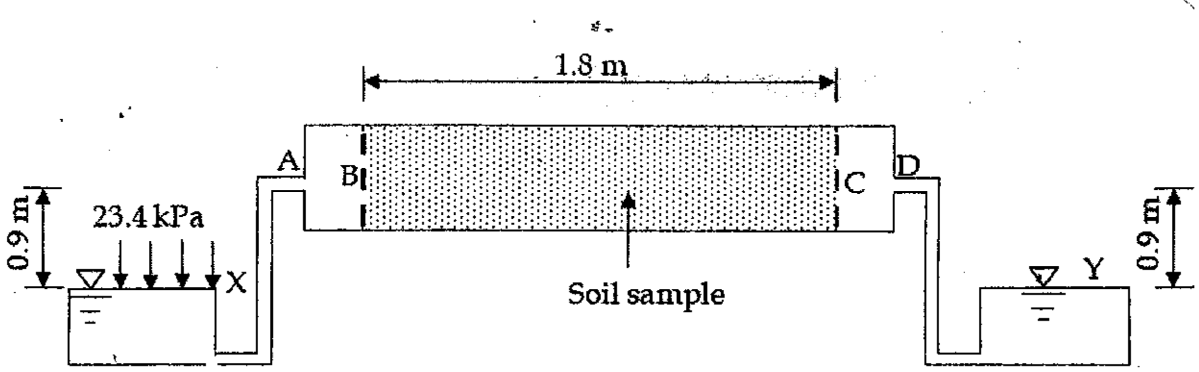

Figure Q2.1 - Experimental setup

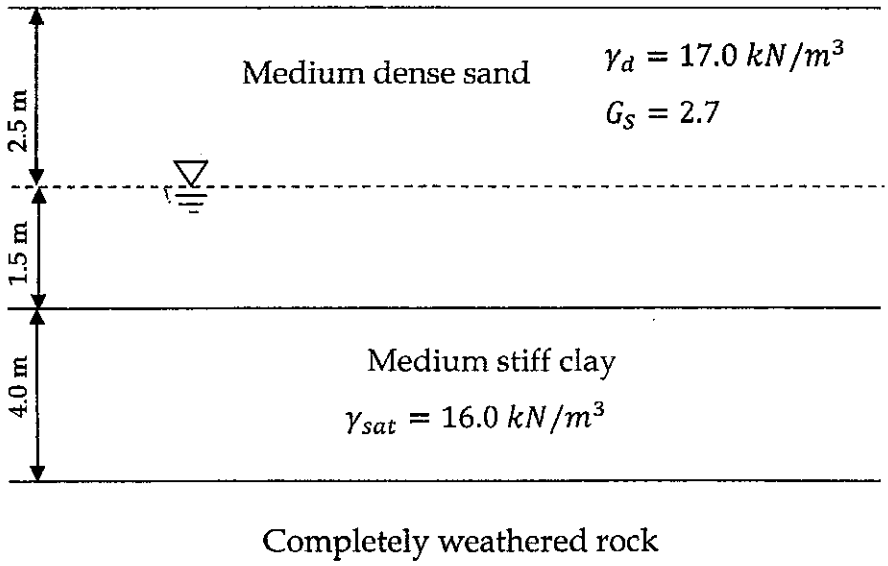

Figure Q3.1 Sub surface soil profile

Table Q3.1 Direct shear test results on medium dense sand

Normal force	= 200 N
Shear force at failure	= 140 N
Cross sectional area of sample	= 36 cm^2

Q3.2 Consolidated Undrained Triaxial test results on medium stiff clay

Cell pressure	= 150 kN/m²
Deviator stress at failure	= 192 kN/m²
Pore water pressure at failure	= 80 kN/m²

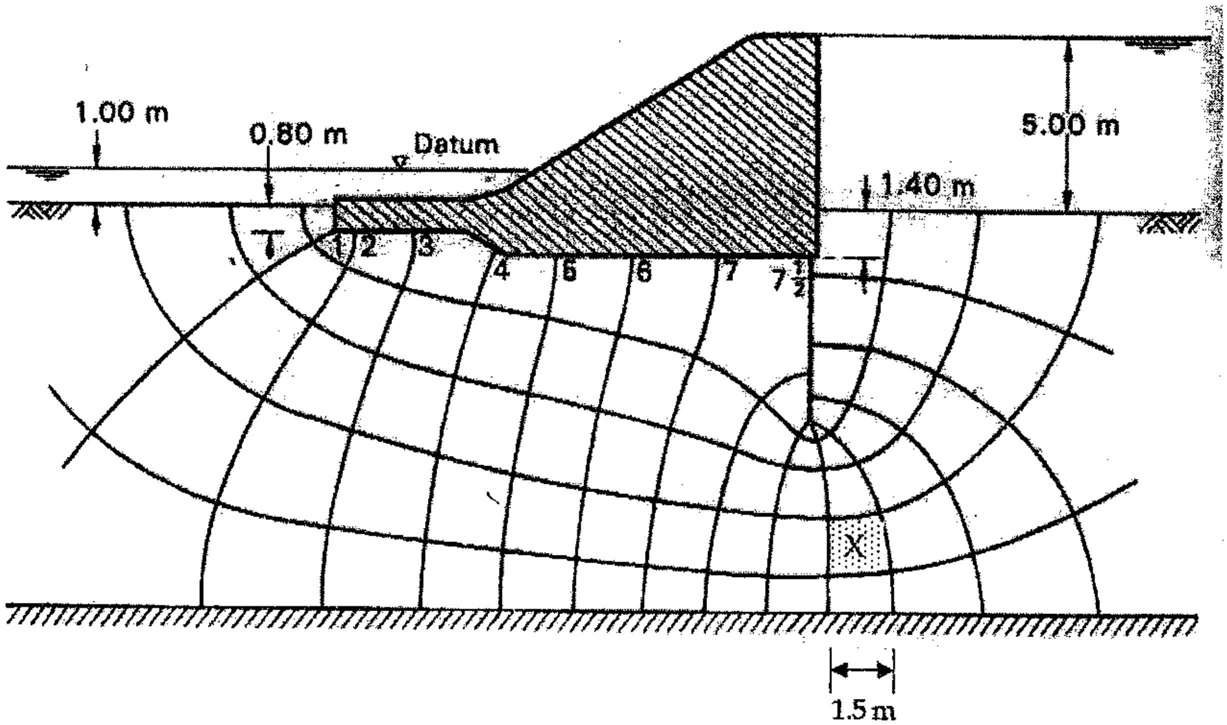

Figure Q4.1 - Flow below the concrete dam

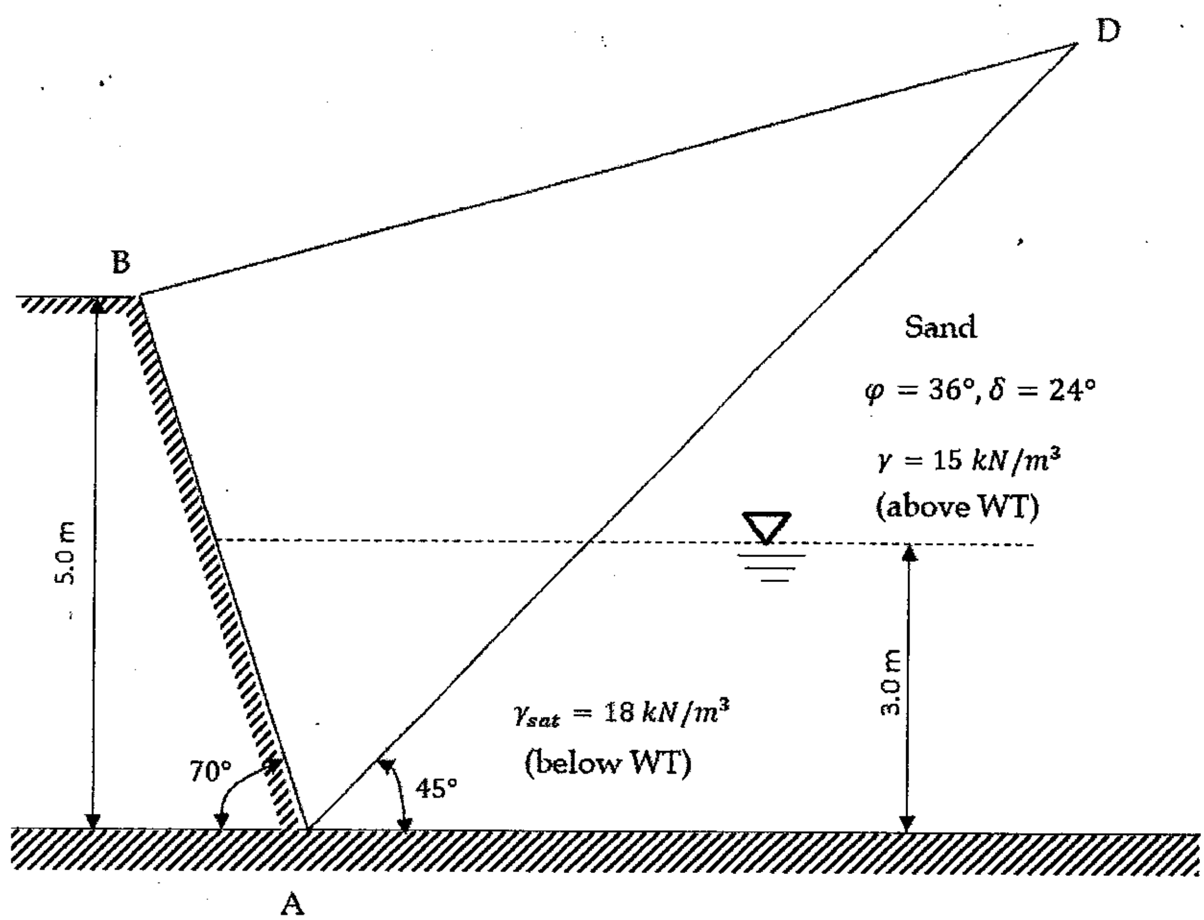

Figure Q5.1 Trial wedge