UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2018

Module Number: CE6305 **Module Name: Geotechnical Engineering**

[Three Hours]

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

Q1. As a part of Southern Expressway Extension Project, it is proposed to widen the A24 Matara-Akuressa road close to Godagama interchange. Based on the borehole investigations, subsurface soil profile at the widening section can be idealized as shown inFigure Q1.1. It can be seen that subsurface consists of 8.0 m thick very soft peaty clay layerfollowed by 4.0 m thick dense sand layer. Completely weathered rock is 12.0 m below the existing ground surface. Water table was found to be at the existing ground level.

According to the plan and profile of the proposed A24 road, subgrade level is 2.0 m above the exiting ground level. A drainage layer of 1.0 m thick together with geotextiles will be placed on the existing ground to provide doubly drain condition. In order to compensate the pavement and traffic load (25.0 kN/m^2)of the road and accelerate the consolidation,4.5 m height compacted soil fill will be placed on the drainage layer as shown in Figure Q1.1. The bulk unit weights of the very soft peaty clay, drainage layerand compacted fill can be taken as 14.0kN/m^3, 18.0 kN/m^3 and 20.0 kN/m^3, respectively. The unit weight of water can be taken as 9.81kN/m^3.

The compressibility characteristics of the very soft peaty clay were determined by conducting a series of laboratory oedometer tests. Coefficient of consolidation (C_v), compression index (C_c) and void ratio (e_0)werefound as5.0 m^2/year,1.18 and 2.75, respectively.

You may refer TableQ1.1 for necessary calculations.

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

[2.0 Marks]

b) What are the purposes of placing geotextiles above and below the drainage layer?

[1.0 Marks]

c) What would be the expected primary consolidation settlement of the very soft peaty clay layer due to construction of the embankment assuming that peaty clay is normally consolidated?

[2.0 Marks]

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

[1.5 Marks]

e) If modified secondary compression index is 0.01, what would be the expected secondary consolidation settlement 3 year after the end of primary consolidation?

[2.5 Marks]

f) If excess soil is removed upto the subgrade level after 95% of the primary consolidation, what would be the expected removable soil fill height?

[1.5 Marks]

g) If 300 mm further consolidation settlement is allowed during the service, what would be the earliest time that surfacing could begin without considering the secondary consolidation settlement. Assume that surfacing will not apply any additional stress on the very soft peaty clay layer.

[1.5 Marks]

Q2. A commercial building is to be constructed facing Galle-Wackwella main road. The building is to be done on a square raft foundation of 15 m x 15 m dimensions placed at a depth of 3.0m from the ground surface. The subsurface soil profile consists of 8.0 m thick soft clay followed by a dense sand layer. The cross section of the subsurface soil profile together with foundation arrangement is presented in Figure Q2.1. Water table was found to be at the existing ground level. The average contact pressure of the building at the foundation level is estimated to be 150 kN/m². The unit weight of the saturated clay was found to be 16.0 kN/m³.
In order to determine compressibility characteristics of soft clay, a consolidation test was conducted on an undisturbed soil sample obtained from the clay layer and results are presented in Figure Q2.2. Coefficient of consolidation of the clay was found to be 2.0 m²/year. The unit weight of water can be taken as 9.81kN/m³.
You may refer Table Q1.1, Table Q2.1and Figure Q2.3 for necessary calculations.

a) Determine whether clay soil is normally consolidated or over consolidated before placing the foundation.

[1.5 Marks]

b) Calculate the coefficient of volume compressibility (m_v) of clay for the stress range of 100-200 kN/m².

[2.0 Marks]

c) What would be the stress released due to 3.0 m excavation to place foundation?

[0.5 Marks]

d) Calculate the stress increment due to building load at 2.5m below the foundation level of the clay layer at the following locations;
   i) Center of the building
   ii) Corner of the building

[3.0 Marks]

e) What would be the expected primary consolidation settlement at the middle of the building?

[2.0 Marks]

f) What would be the expected pore water pressure at 2.5 m below the foundation level, 1 year after the construction of the building? Assume that water is drained only from bottom of the clay layer (singly drained condition).

[2.0 Marks]

g) In order to improve the bearing capacity of the formation layer, contractor has proposed to excavate upto 5.0 m and place 2.0 m thick ABC material. The foundation is proposed to place on the compacted ABC layer. As a junior engineer in this project, do you agree with this proposal? Justify your answer with the aid of e versus $log\ \sigma$ curve.

[1.0 Marks]

Q3. There is a proposal to extend the sewer network in east of Colombo. It is necessary to maintain a mild slope in sewer pipes upto the pumping station as sewer will flow to pumping station under gravity. Main sewer pipes are installed using the micro tunneling technique to minimize the ground disturbance. As such, it is very important to conduct comprehensive site investigation before start the construction.

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

[2.0 Marks]

b) Briefly describe the wash boring technique to identify subsurface soil profile.

[2.0 Marks]

c) What are the advantages and disadvantages of Cone Penetration Test (CPT) over Standard Penetration Test (SPT)?List two factorsfor each.

[2.0 Marks]

d) To determine the drained shear strength parameters of sand, undisturbed soil sample was collected and laboratory Consolidated Drained (CD) triaxial test was conducted. The data gathered from the CD test is depicted in Table Q3.1.

i) Draw a Mohr circle and determine the shear strength parameters.

[2.5 Marks]

ii) Draw the failure plane and determine the angle that the failure plane makes with the major principal plane.

[0.5 Marks]

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

[1.0 Marks]

iv) Determine the effective normal stress on the plane of maximum shear stress.

[0.5 Marks]

v) What would be the shear strength of sand when the effective normal stress is 250 kN/m^2.

[0.5 Marks]

vi) If a soil sample is subjected to an effective normal stress σ' of 150 kN/m^2 together with shear stress τ of 20 kN/m^2, determine whether the soil sample is stable or not? Justify your answer.

[1.0 Marks]

Q4. A commercial building is to be constructed with two basements for parking. The sub surface consists of silty sand up to the bed rock level and it was decided to install sheet piles up to a depth of 11.2 m as a shoring system to support the excavation for the basements.Saturated unit weight of the silty sand is 18.0 kN/m^3. Water level inside the excavation is reduced to the bottom level by continuous pumping. Outside the excavation, the water table remained at the original ground level. The flow net drawn for the above case is presented in Figure Q4.1. The coefficient of permeability of silty sand can as taken as 2.5 x 10^{-5} m/s. The unit weight of water can be taken as 9.81kN/m^3.

a) Determine the quantity of seepage under the sheet piles.

[2.0 Marks]

b) Determine the pore water pressures at points 4 and 11.

[3.0 Marks]

c) If porosity of the silty sand is 0.2, estimate the seepage velocity at the shaded element A.

[2.0 Marks]

d) What would be the maximum exit gradient?

[1.0 Marks]

e) Calculate the factor of safety against piping.

[1.0 Marks]

f) What would be the effective stress at point B?

[2.0 Marks]

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

[1.0 Marks]

Q5. A slope is supported by a 3.0 m height retaining wall as shown in Figure Q5.1. The obligatory surcharge on the retained side is 20 kN/m^2. Soil on the retained side consists of sandy soil with friction angle of 30°and saturated unit weight of 20 kN/m^3. The water table is at the existing ground surface. The unit weight of water can be taken as 9.81 kN/m^3.

To design this retaining wall, it is necessary to estimate the lateral force exerted from the retained side. In order dissipate pore water pressure behind the retaining wall, it was decided provide weep holes at regular intervals as shown in Figure Q5.1

a) Why is it important to provide rubble packing together with a geotextile behind the retaining wall?

[1.0 Marks]

b) Briefly explain a method to estimate pore water force on the trial failure surface with suitable sketches.

[2.0 Marks]

c) If pore water force on the trial failure surface is 40 kN, determine the lateral force on the retaining wall by using Coulomb's trial wedge approach for the trial wedge shown in Figure Q5.1.
(*Note: You may plot to a scale of 1 mm = 1 kN*)

[4.0 Marks]

d) In order to provide a nice appearance, there is a request to plaster surface of the retaining wall without providing weep holes. Do you agree with this decision? Justify your answer using a force polygon. Do not need to do any calculations.

[2.0 Marks]

e) If the wall surface is smooth and there is no any weep holes in the retaining wall, determine the active force on the retaining wall using Rankine earth pressure equation. Assume that there is no any seepage behind the retaining wall.

[3.0 Marks]

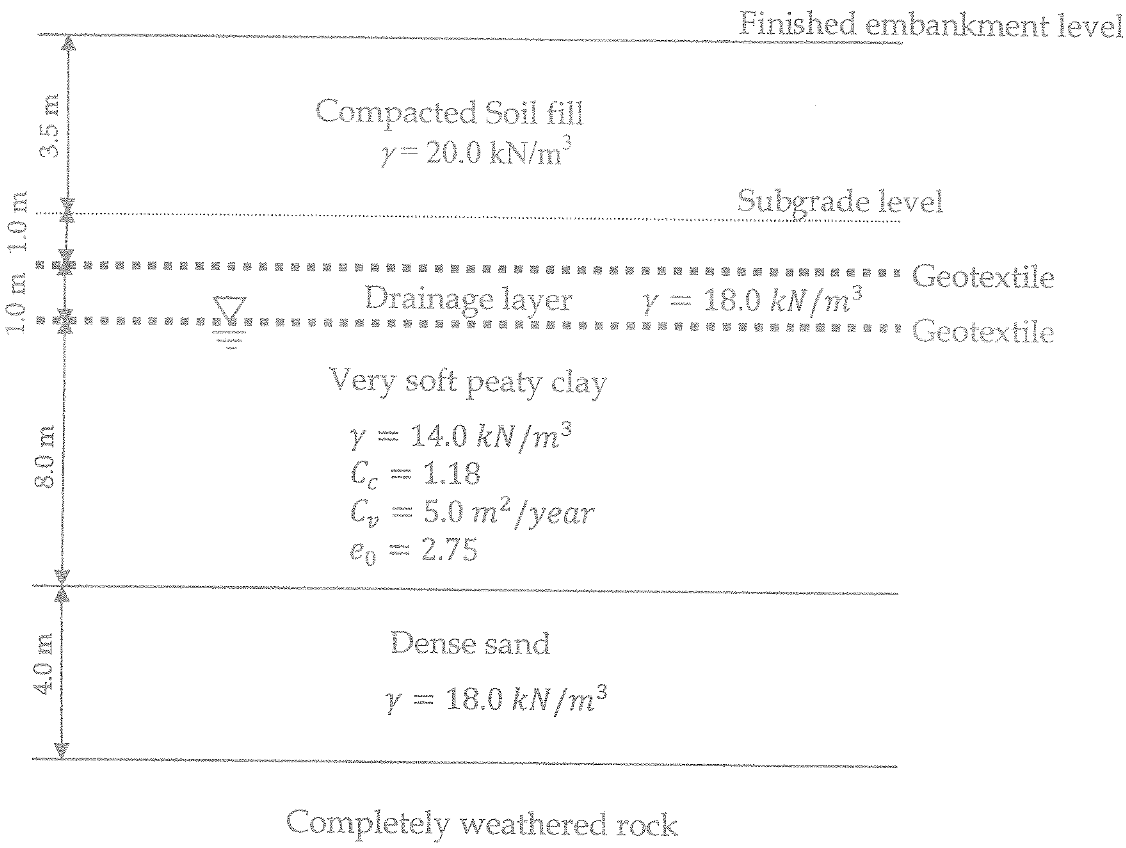

Figure Q1.1 Cross section of ground profile

Table Q1.1 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		

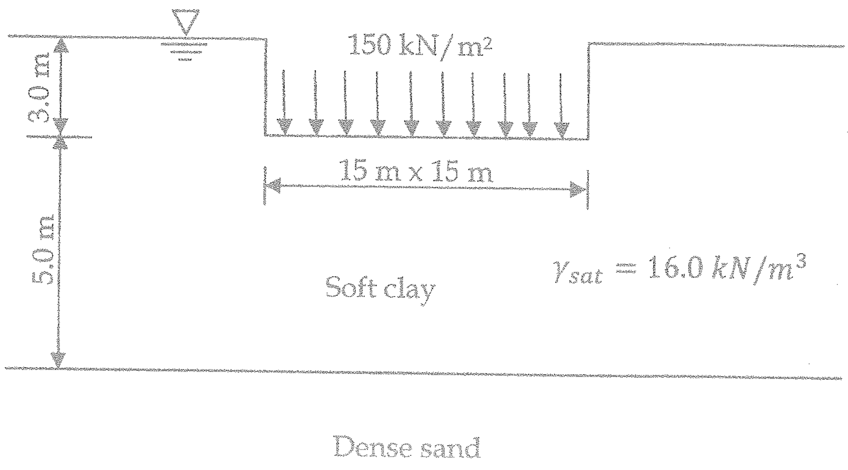

Figure Q2.1 – Subsurface soil profile and foundation arrangement

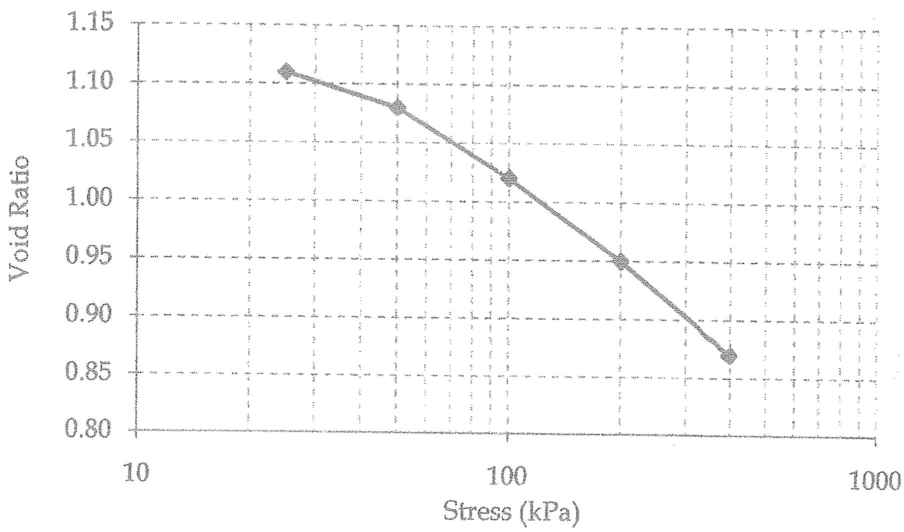

Figure Q2.2 – Consolidation test results

Table O2.1 - Variation of I_3 with m and n (corner of a rectangular loaded area)

	m																			
n	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	4.0	5.0	6.0
0.1	0.0047	0.0092	0.0132	0.0168	0.0198	0.0222	0.0242	0.0258	0.0270	0.0279	0.0293	0.0301	0.0306	0.0309	0.0311	0.0314	0.0315	0.0316	0.0316	0.0316
0.2	0.0092	0.0179	0.0259	0.0328	0.0387	0.0435	0.0474	0.0504	0.0528	0.0547	0.0573	0.0589	0.0599	0.0606	0.0610	0.0616	0.0618	0.0619	0.0620	0.0620
0.3	0.0132	0.0259	0.0374	0.0474	0.0559	0.0629	0.0686	0.0731	0.0766	0.0794	0.0832	0.0856	0.0871	0.0880	0.0887	0.0895	0.0898	0.0901	0.0901	0.0902
0.4	0.0168	0.0328	0.0474	0.0602	0.0711	0.0801	0.0873	0.0931	0.0977	0.1013	0.1063	0.1094	0.1114	0.1126	0.1134	0.1145	0.1150	0.1153	0.1154	0.1154
0.5	0.0198	0.0387	0.0559	0.0711	0.0840	0.0947	0.1034	0.1104	0.1158	0.1202	0.1263	0.1300	0.1324	0.1340	0.1350	0.1363	0.1368	0.1372	0.1374	0.1374
0.6	0.0222	0.0435	0.0629	0.0801	0.0947	0.1069	0.1168	0.1247	0.1311	0.1361	0.1431	0.1475	0.1503	0.1521	0.1533	0.1548	0.1555	0.1560	0.1561	0.1562
0.7	0.0242	0.0474	0.0686	0.0873	0.1034	0.1169	0.1277	0.1365	0.1436	0.1491	0.1570	0.1620	0.1652	0.1672	0.1686	0.1704	0.1711	0.1717	0.1719	0.1719
0.8	0.0258	0.0504	0.0731	0.0931	0.1104	0.1247	0.1365	0.1461	0.1537	0.1598	0.1684	0.1739	0.1774	0.1797	0.1812	0.1832	0.1841	0.1847	0.1649	0.1850
0.9	0.0270	0.0528	0.0766	0.0977	0.1158	0.1311	0.1436	0.1537	0.1619	0.1684	0.1777	0.1836	0.1874	0.1899	0.1915	0.1938	0.1947	0.1954	0.1956	0.1957
1.0	0.0279	0.0547	0.0794	0.1013	0.1202	0.1361	0.1491	0.1598	0.1684	0.1752	0.1851	0.1914	0.1955	0.1981	0.1999	0.2024	0.2034	0.2042	0.2044	0.2045
1.2	0.0293	0.0573	0.0832	0.1063	0.1263	0.1431	0.1570	0.1684	0.1777	0.1851	0.1958	0.2028	0.2073	0.2103	0.2124	0.2151	0.2163	0.2172	0.2175	0.2176
1.4	0.0301	0.0589	0.0856	0.1094	0.1300	0.1475	0.1620	0.1739	0.1836	0.1914	0.2028	0.2102	0.2151	0.2184	0.2206	0.2236	0.2250	0.2260	0.2263	0.2264
1.6	0.0306	0.0599	0.0871	0.1114	0.1324	0.1503	0.1652	0.1774	0.1874	0.1955	0.2073	0.2151	0.2203	0.2237	0.2261	0.2294	0.2309	0.2320	0.2323	0.2325
1.8	0.0309	0.0606	0.0880	0.1126	0.1340	0.1521	0.1672	0.1797	0.1899	0.1981	0.2103	0.2183	0.2237	0.2274	0.2299	0.2333	0.2350	0.2362	0.2366	0.2367
2.0	0.0311	0.0610	0.0887	0.1134	0.1350	0.1533	0.1686	0.1812	0.1915	0.1999	0.2124	0.2206	0.2261	0.2299	0.2325	0.2361	0.2378	0.2391	0.2395	0.2397
2.5	0.0314	0.0616	0.0895	0.1145	0.1363	0.1548	0.1704	0.1832	0.1938	0.2024	0.2151	0.2236	0.2294	0.2333	0.2361	0.2401	0.2420	0.2434	0.2439	0.2441
3.0	0.0315	0.0618	0.0898	0.1150	0.1368	0.1555	0.1711	0.1841	0.1947	0.2034	0.2163	0.2250	0.2309	0.2350	0.2378	0.2420	0.2439	0.2455	0.2461	0.2463
4.0	0.0316	0.0619	0.0901	0.1153	0.1372	0.1560	0.1717	0.1847	0.1954	0.2042	0.2172	0.2260	0.2320	0.2362	0.2391	0.2434	0.2455	0.2472	0.2479	0.2481
5.0	0.0316	0.0620	0.0901	0.1154	0.1374	0.1561	0.1719	0.1849	0.1956	0.2044	0.2175	0.2263	0.2324	0.2366	0.2395	0.2439	0.2460	0.2479	0.2486	0.2489
6.0	0.0316	0.0620	0.0902	0.1154	0.1374	0.1562	0.1719	0.1850	0.1957	0.2045	0.2176	0.2264	0.2325	0.2367	0.2397	0.2441	0.2463	0.2482	0.2489	0.2492

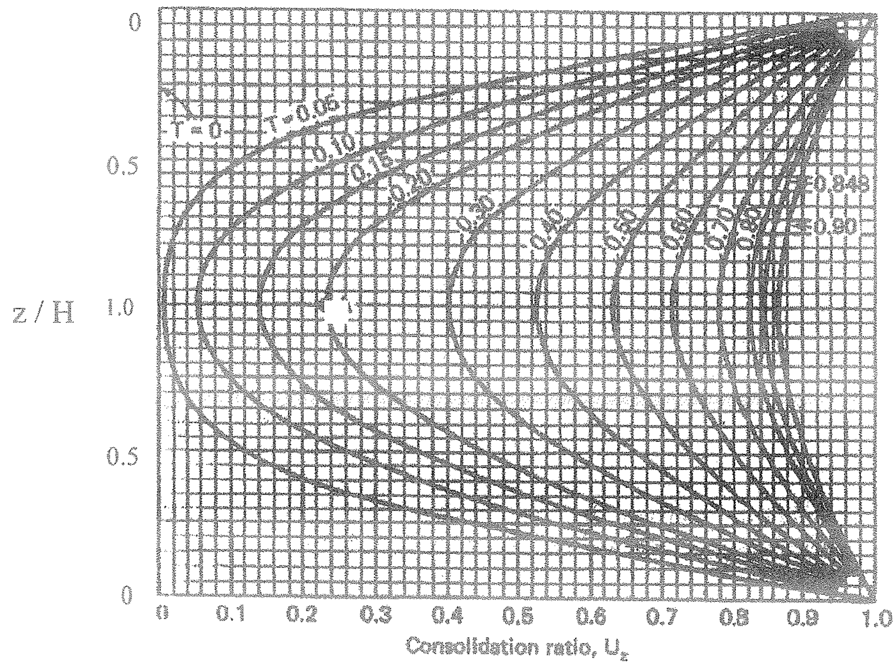

Figure Q2.3 Variation of Tv with z / H and Uz

Table Q3.1 Consolidated Drained Triaxial test results

Specimen	Cell pressure (kN/m²)	Deviator stress (kN/m²)
1	140.0	104.0

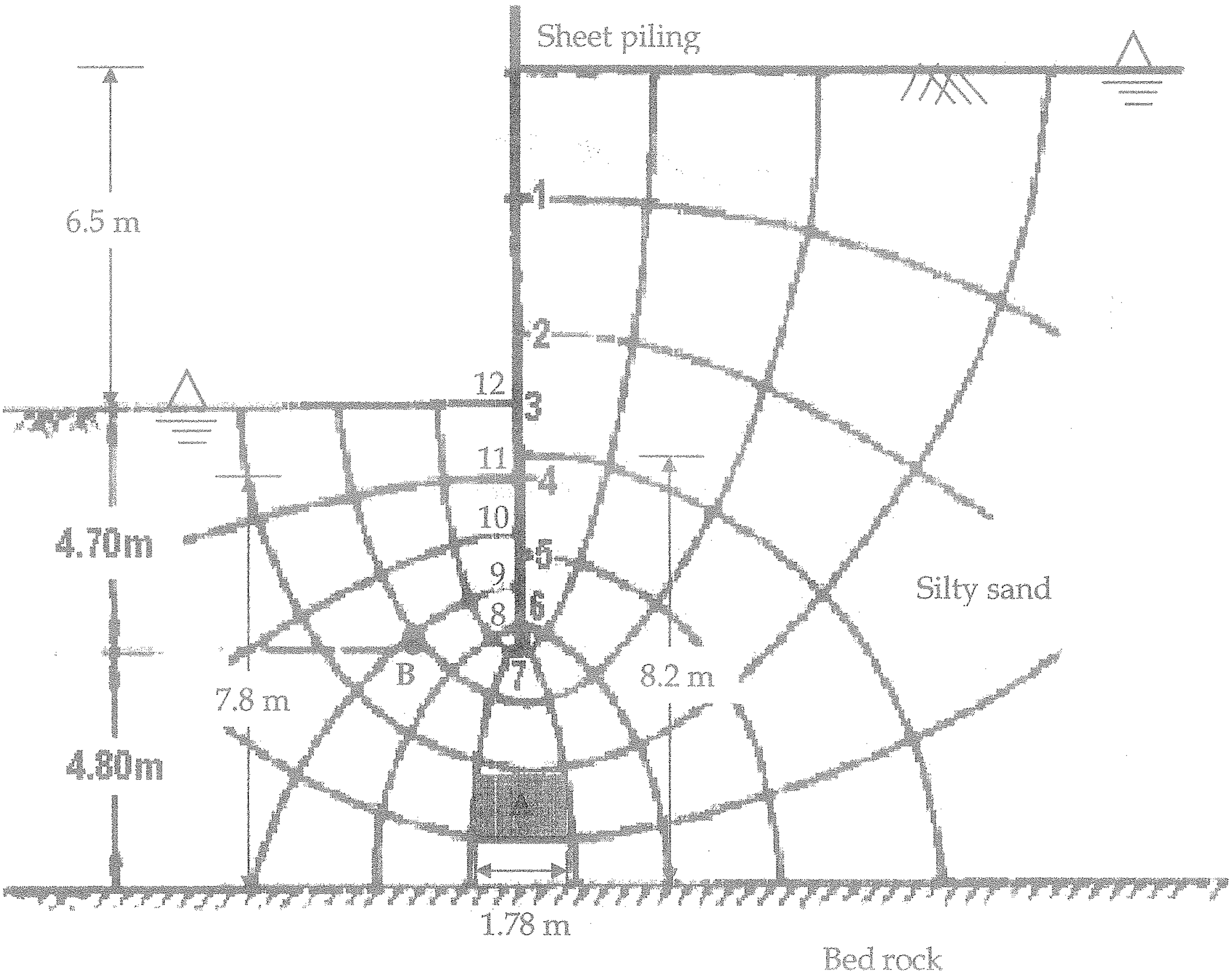

Figure Q4.1 – Flow net for the proposed excavation

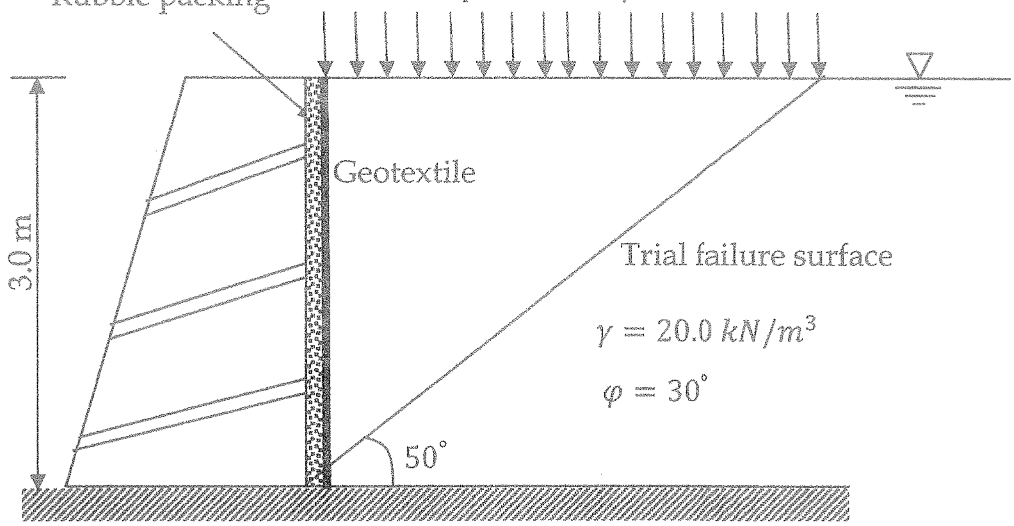

Figure Q5.1Cross section of the proposed retaining wall