UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

Module Number: CE6321 **Module Name: Geotechnical Engineering (O/C)**

[Three Hours]

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

Q1. The proposed Matara-Kataragama highway is to be constructed over a low lying area overlained by 6.0 m thick peat layer near Beliatta. A dense sand layer is found to be under the soft peat layer. The sub surface soil profile is shown in Figure Q1.1.

As this area is in the flood plain and frequently subject to flooding, it was decided to raise the finished road level by 3.0 m from the existing ground level. The dead and live load of the highway is found to be 25 kN/m². In order to compensate the dead and live load of the highway, a soil fill of thickness 1.25 m will be placed over the embankment. Further, consultant engineer has advised to place a gravel mat with a geotextile over the existing ground surface before placing the fill material.

To evaluate compressibility characteristics of the soft peaty soil, laboratory oedometer test was conducted on an undisturbed soil sample obtained from a depth of 3.0 m from the ground surface and the results are presented in Figure Q1.2. The coefficient of consolidation (C_v) is found to be 2.0 m²/year. The bulk unit weights of fill material and soft peaty soil are found to be 20.0 kN/m³ and 15.0 kN/m³, respectively. The ground water table is found to be at the existing ground level. The unit weight of water can be taken as 9.81 kN/m³.

You may refer Table Q1.1 and Figure Q1.3 for necessary T_v values.

a) Why is it important to place a gravel mat with a geotextiles before starting the filling for the embankment?

[1.0 Marks]

b) Determine whether the peaty soil is normally consolidated or over consolidated?

[1.5 Marks]

c) What would be the expected primary consolidation settlement of the peaty soil due to construction of the embankment?

[3.0 Marks]

d) What is the time period required for 90% primary consolidation to be occurred?

[2.0 Marks]

e) If modified secondary compression index (C'_α) is 0.02, estimate the secondary consolidation settlement 3 years after the end of primary consolidation.

[3.5 Marks]

f) If excess soil is removed up to the finished road level after 90% of the primary consolidation, what would be the expected removable soil fill height? Justify your answer with a suitable sketch.

[1.0 Marks]

Q2. There is a proposal to construct a five storied building at a site. The building to be done on a rectangular raft foundation of 32 m x 16 m dimensions placed at a depth of 3.0m from the ground surface. Subsurface soil profile consists of a 8.0 m thick clay layer sandwitched between two sand layers. Water table is 3.0 m below the ground

surface. A cross section of the subsurface soil profile and the foundation arrangement is presented in Figure Q2.1. The average contact pressure of the building at the foundation level is estimated to be 100 kN/m^2. Unit weights of dry sand, saturated sand and clay are 18.0 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 Figure Q2.2. The unit weight of water can be taken as 9.81 kN/m^3.

You may refer Table Q1.1 and Figure Q1.3 for necessary T_v values.

a) List four factors affecting the rate of consolidation.

[1.0 Marks]

b) If thickness of the oedometer sample is 20 mm and drained at both ends, estimate the coefficient of consolidation (C_v) of clay in terms of m^2/year for the stress range of 50-100 kN/m^2.
(Note: The Figure Q2.2 should be attached to the answer book)

[2.5 Marks]

c) Calculate the coefficient of volume compressibility (m_v) of clay in terms of m^2/kN for the stress range of 50-100 kN/m^2.

[1.5 Marks]

d) Calculate the stress increment due to building load at middle of the clay layer at following locations;
   i) Center of the building
   ii) Corner of the building

   You may refer Table Q2.1 for necessary m and n values.

[2.5 Marks]

e) What would be the expected total differential settlement of the building?

[2.0 Marks]

f) What would be the expected pore water pressure at point **A**, 5 years after the construction of the building? Point **A** is located at center of the building.

[2.5 Marks]

Q3. A slope is supported by a 3.0 m height retaining wall as shown in Figure Q3.1. The unexpected load on the retained side can be simplified as a uniformly distributed load of intensity 20 kN/m^2. Soil on the retained side consists of sandy soil with the friction angle of 30°and the saturated unit weight of 20 kN/m^3. The water table is at the 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 to dissipate pore water pressure behind the retaining wall, it is decided provide weep holes at regular intervals as shown in Figure Q3.1. The Coulomb's trial wedge approach is used to estimate the lateral force.

a) Briefly explain why Rankine active pressure equation can not apply for this situation?

[1.0 Marks]

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

[2.5 Marks]

c) If pore water force on the trial failure surface is 20 kN, determine the lateral force on the retaining wall by drawing a force polygon for the trial wedge shown in Figure Q3.1.
(Note: You may plot to a scale of 1 mm = 1 kN)

[5.0 Marks]

d) The client has requested not to provide weep holes in the retaining wall for the nice appearance of the surface. As you are a junior in the project, would you agree for this request? Justify your answer with suitable calculations assuming that wall surface is smooth.

[2.5 Marks]

e) The client has an idea to construct a building in front of the retaining wall taking this retaining wall as one of the supporting wall. Therefore, it is not possible to provide weep holes in the retaining wall. Suggest a suitable method to improve the drainage behind the retaining wall.

[1.0 Marks]

Q4. To construct a basement for a multi storey building, an excavation is to be done to a depth of 4.0 m as shown in Figure Q4.1. The excavation is supported by sheet piles driven to a depth of 9.5 m from the ground surface. The bed rock is at a depth of 11.2 m and water table is at the ground surface. The soil up to the bed rock is found to be silty sand which has the saturated unit weight of 20 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 be taken as 2.5×10^{-5} m/s.

a) List three factors that must be satisfied in a flow net for it to be an acceptably accurate solution of Laplace equation.

[1.5 Marks]

b) Estimate the rate of pumping required to remain the water level just below the excavation level.

[2.5 Marks]

c) Draw pore water pressure distribution diagram in side **A** of the sheet pile, hence estimate the pore water force on side **A** of the sheet pile.

[5.0 Marks]

d) What would be the maximum exit gradient?

[1.5 Marks]

e) Will there be a danger of piping?

[1.5 Marks]

Q5. a) What are the factors affecting the coefficient of permeability?

[2.0 Marks]

b) Explain why the coefficient of permeability found in-situ is more beneficial than that of laboratory?

[2.0 Marks]

c) A pumping test was carried out to find the coefficient of permeability in the field. Soil profile in the area consists of 3.0 m thick impermeable clay layer underlained by 6.0 m thick silty sand layer. Impermeable bed rock is below the silty sand layer. Two observational bore holes (BH1 and BH2) were advanced at a distance of 15.0 m and 20.0 m away from the pumping well. The water table before commencing pumping was at 1.0 m below the ground surface. Steady state water levels in the observational bore holes were 2.5 m and 1.9 m from the ground surface in BH1 and BH2 respectively. The corresponding discharge rate of pumping well is 10.0 m^3/hr.

i) Determine the coefficient of permeability of the aquifer

[4.0 Marks]

ii) Determine the distance from the pumping well that the water would not be affected by the pumping.

[2.0 Marks]

iii) If the soil profile consists only of 9.0 m thick silty sand layer above the impermeable bed rock, determine the coefficient of permeability of the aquifer.

[2.0 Marks]

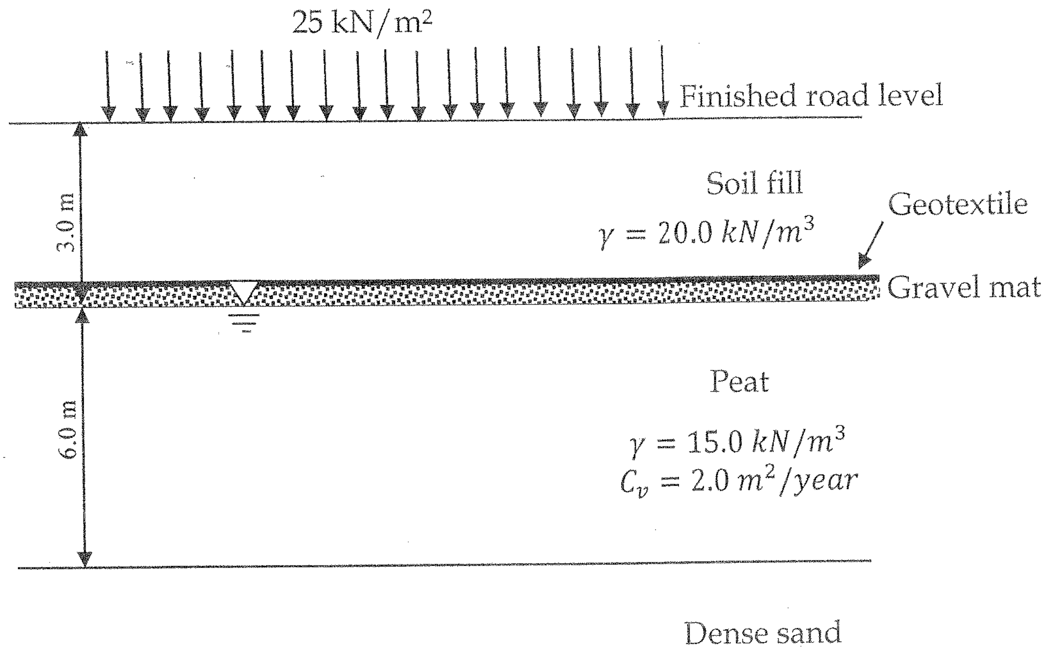

Figure Q1.1 - Sub surface soil profile

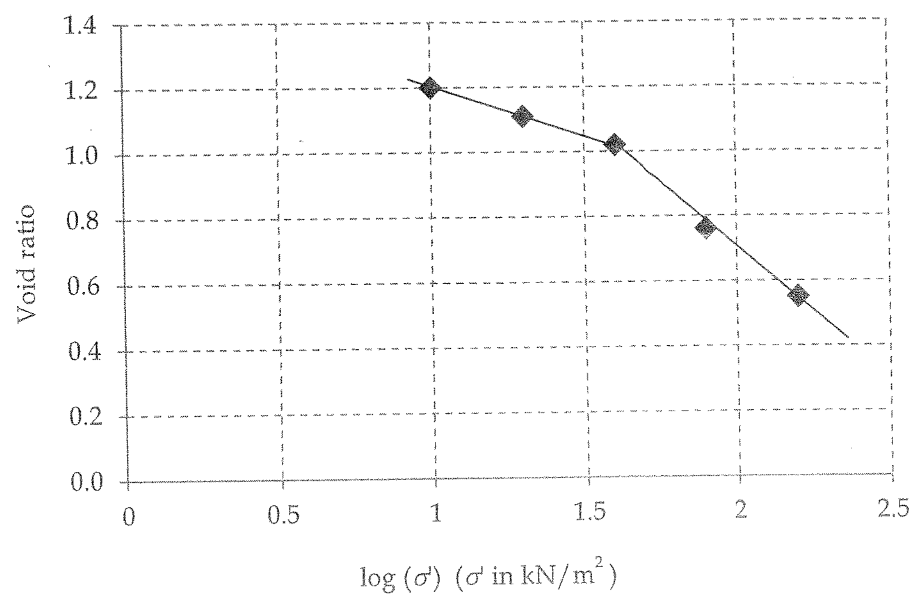

Figure Q1.2 - Oedometer test results

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		

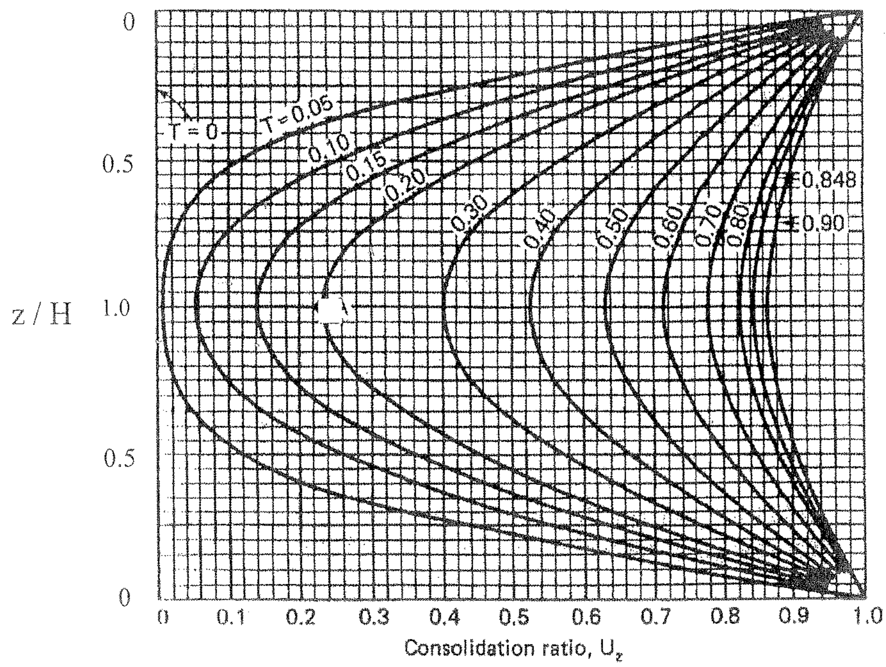

Figure Q1.3 Variation of T_v with z / H and Uz

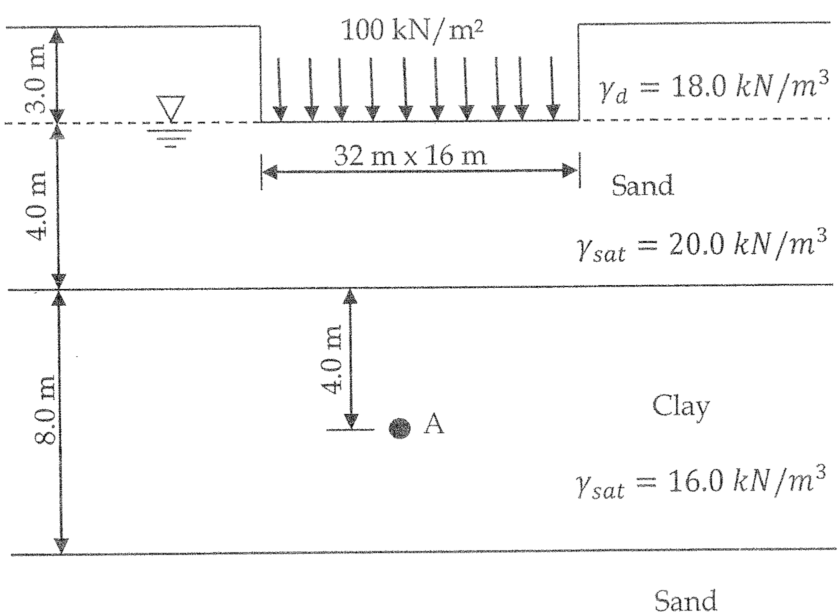

Figure Q2.1 - Subsurface soil profile and foundation arrangement

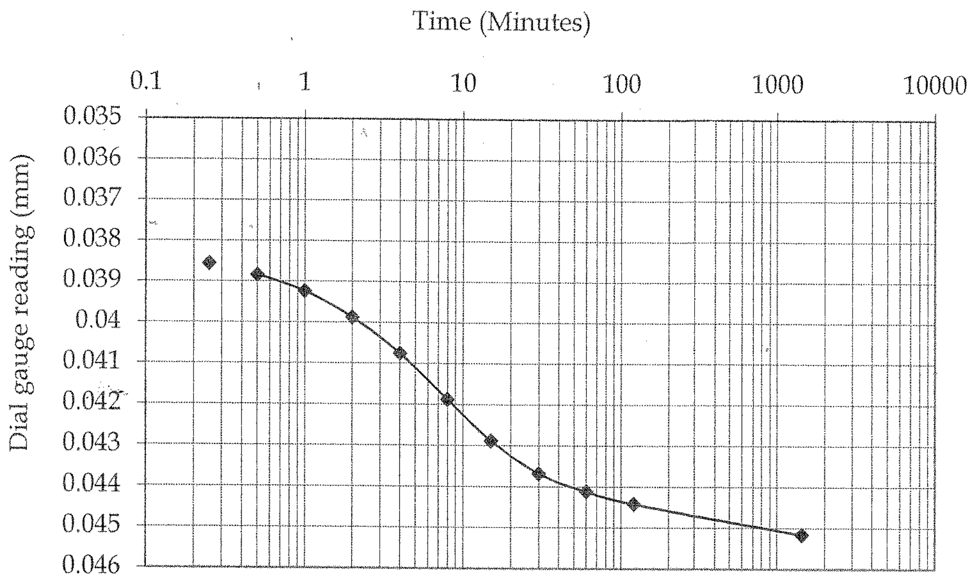

Figure Q2.2 - Variation of settlement with Log(time)

Table Q2.1 Variation of I_3 with m and n

n \ m	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

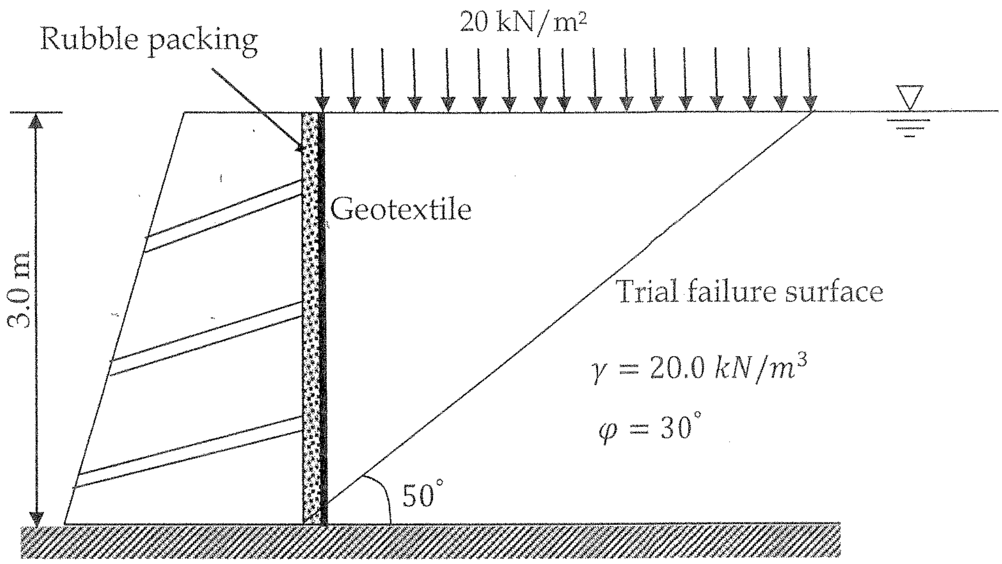

Figure Q3.1 Coulomb's trial wedge

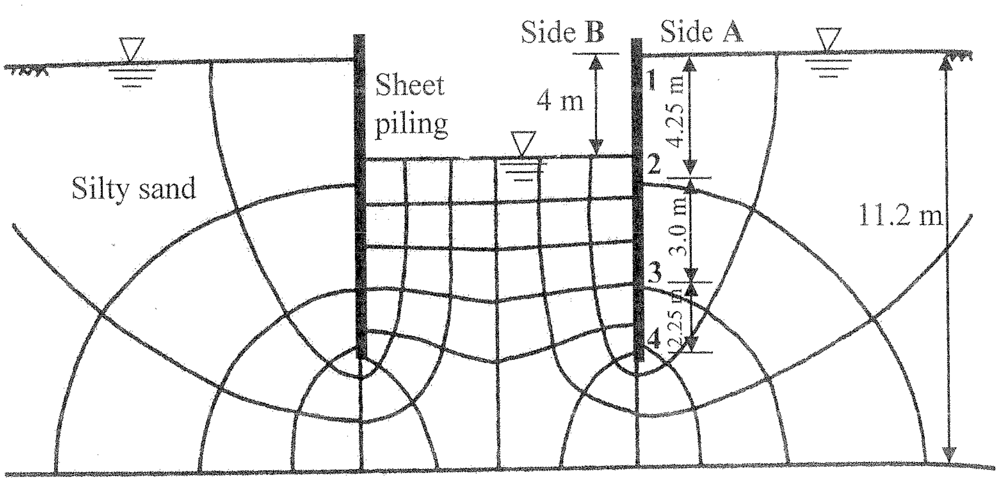

Figure Q4.1 Flow net for the sheet pile wall