UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 7 Examination in Engineering: June 2014

Module Number: CE7237 **Module Name: Ground Improvement Techniques**

[Two Hours]

[Answer **all questions**, marks assigned for Q1 is 14.0 and Q2 is 6.0]

Q1. A four lane highway is to be constructed over a low lying area underlained by 5.0 m thick normally consolidated soft clay layer. A 2.0 m thick dense sand layer is sandwiched between impermeable bed rock and soft clay layer. As this area is frequently subjected to flooding, it was decided to raise the elevation of the road (sub grade level) by 4.0 m. The dead load of the pavement and live load of the highway are found to be 15 kN/m^2 and 10 kN/m^2, respectively. In order to compensate the dead and live load of the highway, a soil fill will be placed over the embankment.

The saturated unit weight of the clay is 16.0 kN/m^3. Compressibility characteristics and shear strength properties of soft clay were determined by collecting undisturbed clay samples from the site and conducting laboratory oedometer and triaxial tests. Compression index, void ratio and coefficient of consolidation of soft clay were found to be 0.8, 2.0 and 2.0 m^2/~~kN~~, respectively. The undrained shear strength of the soft clay is 12.0 kN/m^2. year

The natural water table was found to be at the ground surface. A gravel mat is used over the soft clay layer to facilitate the drainage. The bulk unit weight of fill material is 20 kN/m^3. The unit weight of water can be taken as 9.81 kN/m^3.

It is important to place fill in stages to avoid shear failure at the edges. The maximum possible height of fill to have a factor of safety of at least 1.3 on slope instability is given in Table Q1.1. The strength gained due to consolidation with usual notations can be expressed by $\Delta C_u = 0.2\Delta\sigma$.

The information provided in Table Q1.2 may be useful in the calculations.

Note:- You may consider the variation of the thickness of the clay layer in different stages. But consider the unit weight to be the same.

a) What would be the expected fill height to be placed to compensate the dead and live load of the highway?

[0.5 Marks]

b) What would be the suitable maximum fill height for the first step of filling without causing any shear failure at edges? Hence, calculate the expected primary consolidation settlement and time period to achieve 90% of the primary consolidation settlement.

[2.0 Marks]

c) If second stage of filling is started after the 90% consolidation of the stage 1 filling, what would be the stage 2 fill thickness? Hence, calculate the expected primary consolidation settlement and time period to achieve 90% of the primary consolidation settlement. Further, estimate the top elevation of the fill after the 90% primary consolidation of the stage 2 filling taking bed rock as datum.

[3.0 Marks]

d) The third stage of filling will be started after 90% consolidation of the stage 2 filling. What would be the stage 3 fill thickness? Hence, calculate the expected primary consolidation settlement and time period to achieve 80% of the primary consolidation settlement. Further, estimate the top elevation of the fill after the 80% consolidation of the stage 3 filling taking bed rock as datum.

[2.5 Marks]

e) Based on the results of above sections (a) – (d), suggest a suitable programme for preloading technique.

[0.5 Marks]

f) What would be the expected removable surcharge thickness at end consolidation in order to construct the pavement?

[0.5 Marks]

g) Suggest a suitable method to quantitatively evaluate the improvement of clay layer due to preloading.

[1.0 Marks]

h) In order to evaluate the degree of consolidation of a test embankment in the field, "Observational Procedure" was suggested by the consultant. The observed settlement after end of embankment construction is shown in Table Q1.3. Using Asaoka's graphical method, determine the degree of consolidation of the clay.

[2.0 Marks]

i) What are instruments used to monitor consolidation behaviour of soft soil in the field? Name the instruments with the monitoring parameters. Also, with the aid of a sketch arrange the monitoring instruments in a test embankment?

[2.0 Marks]

Q2. In a building development project at an abundant landfill, contractor has chosen dynamic compaction method to improve sub surface. In order to improve the sub surface of thickness 5.0 m, 20 ton tamper was fallen from a height of 15 m. The crane employed was 150 ton capacity type.

a) Check whether the given tamping weight and falling height are sufficient to improve the entire depth of the soft soil deposit. You may use the following equation with usual notations.

$$D = 0.3\sqrt{WH}$$

[0.5 Marks]

b) Assume that energy loss during tamping is 25 % and compaction energy required to improve the landfill deposit is 60 tm/m^3. Design a suitable dynamic compaction programme in order to improve the sub surface of the landfill. Specify the spacing, number of blows per phase and number of phases with a suitable sketch.

[4.0 Marks]

c) What are the expected future problems of this proposed development?

[1.0 Marks]

d) What are the limitations of utilization of dynamic compaction technique to improve loose soil deposits in urban areas?

[0.5 Marks]

Table Q1.1 – Maximum possible height of fill

Shear strength C_u (kN/m²)	12.0	15.0	21.0	25.5	30.9	35.2
Safe fill height (m)	2.5	3.2	5.0	6.3	7.0	8.6

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		

Table Q1.3 – Variation of settlement with time

Day after end of embankment construction	Settlement (m)
0	1.575
10	1.619
20	1.709
30	1.730
40	1.741
50	1.758
60	1.767
70	1.778
80	1.785
90	1.789