The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

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Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX7241 Geotechnical Engineering Design**
Academic Year	: 2021/2022
Date	: 03.03.2023
Time	: **0930 to 1230 hours**
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of Seven (7) questions in Seven (8) pages including the design tables.
3. Answer any **Five (5)** questions only. All questions carry equal marks. If you have answered more than five questions (either partly or in full), cross out the answers. Otherwise only the first five appearing in the answer book will be evaluated.
4. Answer for each question should commence on a new page.
5. This is a Closed Book Test (CBT).
6. Relevant tables / codes are provided in the last page of the exam paper.
7. Answers should be in clear handwriting.
8. Do not use Red colour pens.

(01)

(a) Explain the difference between Point bearing piles (End bearing piles) and Friction piles. (03 marks)

(b) Static load tests of seven trial continuous flight auger (CFA) piles are conducted and the results are shown in Table Q1. Determine the characteristic resistance of the ground from these pile tests in accordance with Eurocode 7, Design Approach 1, following the UK National Annex. Assume explicit SLS verification has **not** taken place. (07 marks)

Table Q1	
Pile number	**$R_{c;m}$ (kN)**
1	1880
2	1912
3	1600
4	1842
5	2010

(c) The ground conditions at a site of a new building have been investigated and reported as follows:

0.0 m to 4.0 m: hard clay γ_{sat}=19 kN/m^3, C_u= 200kN/m^2

4.0 m to 9.0 m: very stiff clay γ_{sat}=17 kN/m^3, C_u= 140 kN/m^2
Ground water table is located at 2.0 m depth from the ground surface.

A pile foundation consists of concrete bored piles of 0.6m diameter and 8m length have been proposed for a building. Analysis of the super structure shows that a single pile is to carry characteristic permanent and variable actions of 400 kN and 350 kN respectively, both acting vertically downwards. Determine whether the proposed pile dimensions comply with the requirements of Eurocode 7 design approach 1 with regard to the geotechnical capacity. Use 'α' method in estimating the shaft resistance. (10 marks)

(02)

(a) Terzaghi's equation for gross ultimate bearing resistance for a square footing is $q_{ult} = c'N_cF_cF_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \frac{1}{2}\gamma BN_rF_{\gamma s}F_{\gamma d}F_{\gamma i}$. Explain the significance of each of the three terms in the equation. (05 marks)

(b) A spread column footing is to be designed. Consider a square pad footing of dimensions B=1.2m. The depth of footing is 0.6 m. The footing is required to carry the following actions, both of which are applied vertically to the centre of the foundation. An imposed permanent action including self-weight of footing V_{GK}=408 kN and imposed variable action V_{QK}= 300 kN. Both the footing base and ground are horizontal. The footing is founded on a dry soil having a characteristic angle of shearing resistance ϕ_k= 32° , effective cohesion C'_k=25 kN/m^2, and the unit weight of soil is γ_k= 18 kN/m^3. Determine whether the proposed dimensions comply with the requirements of Eurocode 7 design approach 1 (combination 1) with regard to the geotechnical capacity. (15 marks)

(03)

(a) State the primary objectives of site investigation as per the Eurocode 7 (EN 1997 2:2007) (04 marks)

(b) Briefly describe the principal phases of a soil exploration programme for an area of land that is to be used for high rise building construction. (04 marks)

(c) Briefly explain a suitable sampling method to extract samples in weak soils such as soft clays. (04 marks)

(d) The lengths of intact pieces of a rock core recovered during a drilling operation are as follows: 125.8, 50.2, 150.0, 100.0, 75.3, 150.4 , 125.9, 75.0, 50.1, 175.8 mm. Length of core run is 1500 mm. Determine the core recovery and Rock Quality Designation. (04 marks)

(e) Compare the area ratios and comment on the degree of disturbance of a Split spoon sampler (outer diameter = 50.8 mm and internal diameter = 34.9 mm) and Shelby Tube sampler with 76.2 mm outer diameter with a wall thickness of 1.55 mm.

(04 marks)

(04)

(a) State the three (03) conditions under which the stability of an upstream slope of a dam should be assessed. (03 marks)

(b) Discuss the difference between 'short term' and 'long term' stability of earth structures and the usage of appropriate shear strength parameters when assessing long - term and short-term stability. (04 marks)

(c) For the upstream slope of an earth dam given in Figure Q4, find the factor of safety against the trial slip surface AC. Use the Fellenius (Swedish/ Ordinary) method of slices. Effective weight of each slice and the arc lengths of each slice are given in Table Q4. (10 marks)

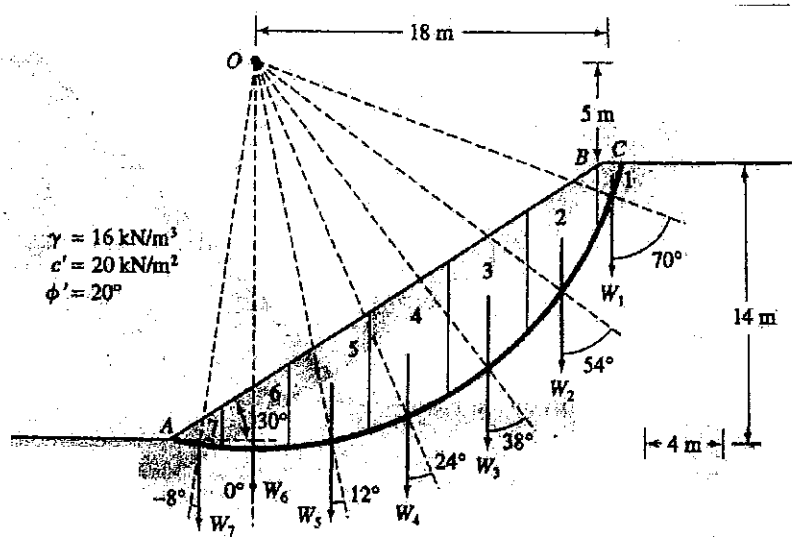

Figure Q4

Table Q4		
Slice No.	**W (kN/m)**	**ΔL (m)**
1	22.4	2.924
2	294.4	6.803
3	435.2	5.076
4	435.2	4.376
5	390.4	4.090
6	268.8	4.000
7	66.58	3.232

The equation of Fellenius method:

$$FS = \frac{\sum[c'l_i + (W_i cos\alpha_i - U_{wi})tan\phi']}{\sum W_i sin\alpha_i}$$

(d) Propose measures to improve the stability of the slope. (03 marks)

(05)

A weir, shown in Figure Q5, retains 3.7 m height of water. A sheet pile wall (cutoff curtain) on the upstream side, which is used to reduce seepage under the weir, penetrates into the thick silty sand stratum which overlies an impermeable rock. The average hydraulic conductivity of the thick silty sand stratum is 4.0×10^{-4} cm/s. Unit weight of water γ_w is 9.81 kN/m^3.

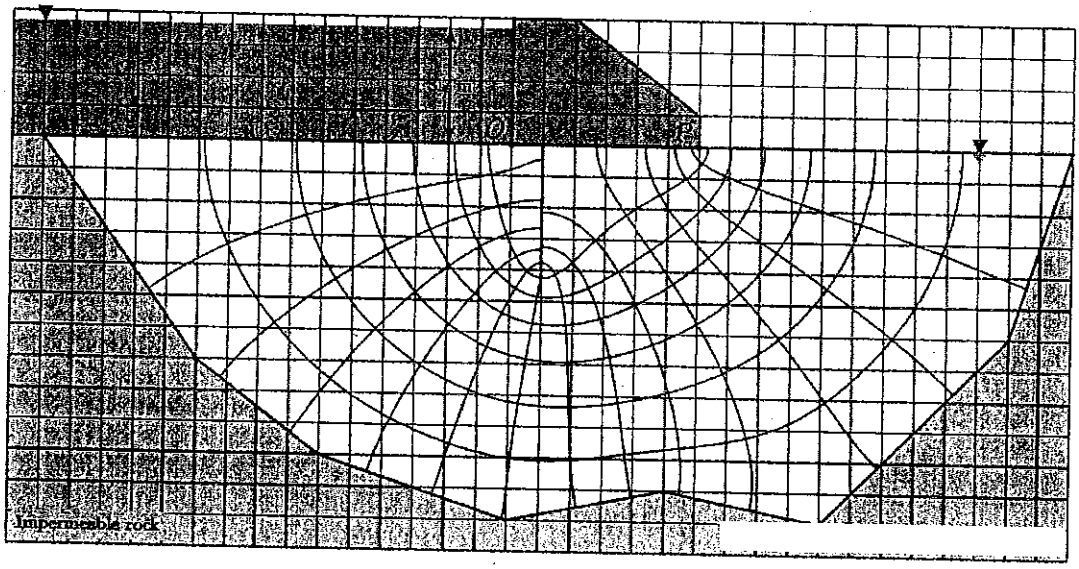

Figure Q5: Flow net under the weir

(a) Calculate the quantity of seepage underneath the weir in m^3/day along per meter length of the weir. (03 marks)

(b) Calculate the uplift pressure at distances 0, 1.5, 2, 3, 4, 5 and 6 m from point O along the bottom side of the weir and draw the uplift pressure distribution graph along the bottom side of the weir. You should calculate the pressures in kPa. (07 marks)

(c) Calculate the total uplift force due to the uplift pressure (in kN/m) and its location measured from the heel in m (point O). (07 marks)

(d) List the possible measures that could be adopted to reduce the seepage flow through the thick silty sand stratum. (03 marks)

(06)

(a) State basic requirements of a good Dam site. (05 marks)

(b) List five (05) differences between embankment dams and rigid dams. (05 marks)

(c) Indicate five (05) observations which are useful during site reconnaissance survey and their relevance for the preliminary design of an embankment dam. (05 marks)

(d) Explain the importance of assessing the nature and the position of Ground Water Table of a dam site. (05 marks)

(07)

(a) With the aid of a Mohr's circle diagram explain what is meant by active Rankine state in a C- φ soil with a horizontal ground surface. (05 marks)

(b) State five (05) limit states that should be considered when designing gravity retaining walls as per the Eurocode 7 design approach. (03 marks)

(c) The cross section of a cantilever retaining wall is shown in Figure Q7 below. Calculate factors of safety with respect to overturning and sliding based on the given information using traditional approach. You may neglect wall friction in estimating the lateral earth pressure. (12 marks)

Surcharge load (w) = $20kN/m^2$

Backfill soil; $\varphi' = 30^0$, $\gamma = 19kN/m^3$, $c'=0$

Existing soil; $\varphi' = 28^0$, $\gamma = 18kN/m^3$, $c'=0$,

Density of Concrete = $25kN/m^3$

coefficient of friction between base and soil = $\tan 28^0$

Dimensions; H1=4m, H2=0.5m, At=Ab=0.3m, B=0.5m, C=0.3m, D=2m

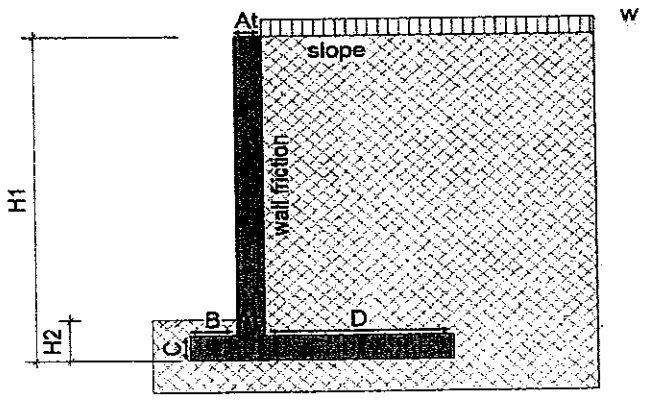

Figure Q7

Table 1 Correlation factors - static load tests results (from NA to BS EN1997-1:2004, Table A.NA.9).

	Number of piles tested				
	1	2	3	4	≥ 5
ξ_1	1.55	1.47	1.42	1.38	1.35
ξ_2	1.55	1.35	1.23	1.15	1.08

Table 2 Piles in compression: partial factor sets R1, R2, R3 and R4 (from NA to BS EN1997-1:2004,Tables A.NA.6, A.NA.7 and A.NA.8).

Partial factor set	R1			R2	R3	R4*		
	Driven	Bored	CFA	All	All	Driven	Bored	CFA
Base, γ_b	1.0	1.0	1.0	1.1	1.0	1.7/1.5	2.0/1.7	2.0/1.7
Shaft, γ_s	1.0	1.0	1.0	1.1	1.0	1.5/1.3	1.6/1.4	1.6/1.4
Total, γ_t	1.0	1.0	1.0	1.1	1.0	1.7/1.5	2.0/1.7	2.0/1.7

Table 3 Partial factor sets for EQU, GEO and STR limit states.

Parameter		Symbol	GEO/STR - Partial factor sets							
			EQU	A1	A2	M1	M2	R1	R2	R3
Permanent action (G)	Unfavourable	$\gamma_{G;dst}/\gamma_{G;unfav}$	1.1	1.35	1.0					
	Favourable	$\gamma_{G;stb}/\gamma_{G;fav}$	0.9	1.0	1.0					
Variable action (Q)	Unfavourable	γ_Q	1.5	1.5	1.3					
	Favourable	–	–	–	–					
Accidental action (A)	Unfavourable	γ_A	1.0	1.0	1.0					
	Favourable	–	–	–	–					
Coefficient of shearing resistance ($\tan\phi'$)		$\gamma_{\phi'}$	1.25			1.0	1.25			
Effective cohesion (c')		$\gamma_{c'}$	1.25			1.0	1.25			
Undrained shear strength (c_u)		γ_{cu}	1.4			1.0	1.4			
Unconfined compressive strength (q_u)		γ_{qu}	1.4			1.0	1.4			
Weight density (γ)		γ_γ	1.0			1.0	1.0			
Bearing resistance (R_v)		γ_{Rv}						1.0	1.4	1.0
Sliding resistance (R_h)		γ_{Rh}						1.0	1.1	1.0
Earth resistance (R_e)		γ_{Re}						1.0	1.4	1.0

Table 4 Bearing Capacity Factors for general failure mode

ϕ' (deg)	N_c	N_q	N_γ	ϕ' (deg)	N_c	N_q	N_γ
0	5.14	1.00	0.00	26	22.25	11.85	12.54
1	5.38	1.09	0.07	27	23.94	13.20	14.47
2	5.63	1.20	0.15	28	25.80	14.72	16.72
3	5.90	1.31	0.24	29	27.86	16.44	19.34
4	6.19	1.43	0.34	30	30.14	18.40	22.40
5	6.49	1.57	0.45	31	32.67	20.63	25.99
6	6.81	1.72	0.57	32	35.49	23.18	30.22
7	7.16	1.88	0.71	33	38.64	26.09	35.19
8	7.53	2.06	0.86	34	42.16	29.44	41.06
9	7.92	2.25	1.03	35	46.12	33.30	48.03
10	8.35	2.47	1.22	36	50.59	37.75	56.31
11	8.80	2.71	1.44	37	55.63	42.92	66.19
12	9.28	2.97	1.69	38	61.35	48.93	78.03
13	9.81	3.26	1.97	39	67.87	55.96	92.25
14	10.37	3.59	2.29	40	75.31	64.20	109.41
15	10.98	3.94	2.65	41	83.86	73.90	130.22
16	11.63	4.34	3.06	42	93.71	85.38	155.55
17	12.34	4.77	3.53	43	105.11	99.02	186.54
18	13.10	5.26	4.07	44	118.37	115.31	224.64
19	13.93	5.80	4.68	45	133.88	134.88	271.76
20	14.83	6.40	5.39	46	152.10	158.51	330.35
21	15.82	7.07	6.20	47	173.64	187.21	403.67
22	16.88	7.82	7.13	48	199.26	222.31	496.01
23	18.05	8.66	8.20	49	229.93	265.51	613.16
24	19.32	9.60	9.44	50	266.89	319.07	762.89
25	20.72	10.66	10.88				