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THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 6

CEX6230 - Geotechnics

FINAL EXAMINATION - 2010/2011

Time Allowed: Three (03) Hours

Date: 28-03-2011 (Monday) Time: 1400 - 1700 hrs.

Answer five (5) questions. All questions carry equal marks

Q1.

(a). Derive the following relationship between principal stresses at failure and shear strength parameters.
$\sigma_{1'} = \sigma_{3'} N_\phi + 2c' \sqrt{N_\phi}$, where, $N_\phi = (1 + \sin\phi') / (1 - \sin\phi')$ (4 marks)

(b). Proove that the total stress path for an unconsolidated undrained triaxial loading test, irrespective of the cell pressure, is 45° inclined to the positive p axis. (4 marks)

(c). Table Q1 contains data obtained from consolidated undrained triaxial tests on a saturated clay. Determine the shear strength parameters in terms of effective stress. A different specimen of the same soil is subjected to the same test at a cell pressure of 150 kN/m² and fails when the deviator stress is 75 kN/m². Calculate the pore pressure in the specimen at failure. (12 marks)

Table Q1

Cell pressure during consolidation and shear (kN/m²)	At failure	
	Deviator Stress (kN/m²)	Pore water pressure (kN/m²)
200	117	110
400	242	227
800	468	455

Q2.

(a). List two advantages and two disadvantages each of direct shear test. Give two advantages of triaxial test over direct shear test. (3 marks)

(b). A compacted sandy clay sample is subjected to a direct shear test. The sample reached its peak strength at normal stress = 40.0 kN/m² and shear stress = 23.7 kN/m². Plot the Mohr circle of stress corresponding to this failure state assuming $\phi' = 25°$. Determine the principal stresses at failure. (6 marks)

(c). List three factors affecting permeability of a soil. (3 marks)

(d). A pumping out test was carried out at a site, where 9m of relatively impermeable clay overlies a stratum of sand 1.5m thick. The sand stratum is underlain by an impermeable rock stratum. When steady state was reached the rate of flow was found to be 15 litres/second. The water levels in two observation wells located at radial distances of 6m and 15m from axis of main well were 5.0m and 4.5m below ground surface respectively. Compute the coefficient of permeability of the sand stratum. Derive any formulae used. (8 marks)

Q3.

Figure Q3 shows a flow net for flow through a homogeneous earth dam with a filter drain founded on impervious stratum.

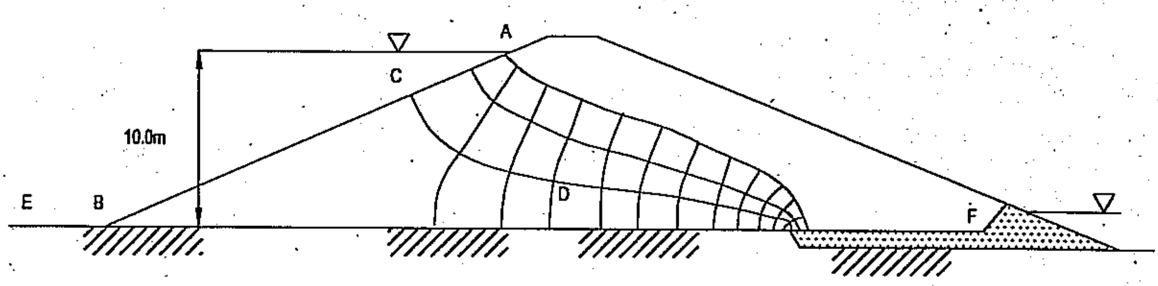

Figure Q3

(a). List the rules to be followed in drawing this flow net? (4 marks)

(b). Compute the total and pressure heads at points A, B, C and D. Take the elevations of points C and D from the datumn EF as 7.8m and 2.6m respectively. (4 marks)

(c). Indicate on a sketch the location where the hydraulic gradient will be maximum. Explain how you would calculate the value of maximum hydraulic gradient. (4 marks)

(d). Develop an expression for computing the quantity of seepage flow from a flow net in which figures are not "squares" but "rectangles" with the length along the flow line twice that along the equipotential line. (6 marks)

(e). Compute the seepage flow per meter length through the dam using the expression developed in Q3(d) for the "square" flow net in Figure Q3. Take the coefficient of permeability as 5.2×10^{-4} cm/s. (2 marks)

Q4.

(a). State two assumptions made in Terzaghi's one dimentional consolidation theory? (2 marks)

(b). Briefly explain how the parameters C_c and m_v are evaluated for an undisturbed saturated clay sample in the oedometer test. (4 marks)

(c). At a site a 12m thick layer of normally consolidated clay exists below a 5m thick layer of dense sand. A 5m high fill is constructed on this site over a very large area. The water table is at the top of the clay layer. The unit weights are: clay – 16 kN/m^3, dense sand – 20 kN/m^3 and fill – 18 kN/m^3. The void ratio-effective stress relationship for the clay is as given in Table Q4.

Chart Q4

σ' (kN/m²)	50	100	200	400	800
e	1.82	1.77	1.68	1.56	1.39

(i). Sub divide the clay layer into four sub layers of equal thickness and compute the effective vertical stress at the center of each sub layer before and after the construction of the fill. (7 marks)

(ii). Determine the consolidation settlement of the clay layer. (7 marks)

Q5.

(a). Terzaghi's equation for the gross ultimate bearing capacity, q_f, of a strip footing of breadth B and depth z on soil of cohesion c and unit weight γ is,

$q_f = cN_c + \gamma z N_q + 0.5\gamma B N_\gamma$

Explain the significance of each of the three terms in this equation. (3 marks)

(b). Prove that the resultant vertical load acting on a rectangular footing should lie within the middle third of the footing to ensure that the resultant contact pressure is compressive everywhere. (5 marks)

(c). A strip footing of width 2.0m is constructed 1.0m below the ground surface in a deep sand layer. Determine the maximum load the footing can carry with a factor of safety of 3.0 on gross foundation pressure if the ground water table is,

(i). at the ground surface (4 marks)
(ii). at the base of the footing (4 marks)
(iii). Very deep (4 marks)

Assume; $\gamma_{bulk} = 17.0$ kN/m^3, $\gamma_{sat} = 18.5$ kN/m^3, $\phi' = 35°$, $N_q = 41$ & $N_\gamma = 42$.

Q6.

An anchored flexible sheet pile wall with a smooth back is shown in Figure Q6. There is a uniformly distributed surcharge of 20 kN/m^2 acting on the sand behind the wall. The river water level and the ground water level are 2m above the river bed level. The cohesionless sand into which the wall is driven has a bulk unit weight of 18 kN/m^2 above the water table, a submerged unit weight of 11 kN/m^2 below the water table and an angle of shearing resistance 28 degrees.

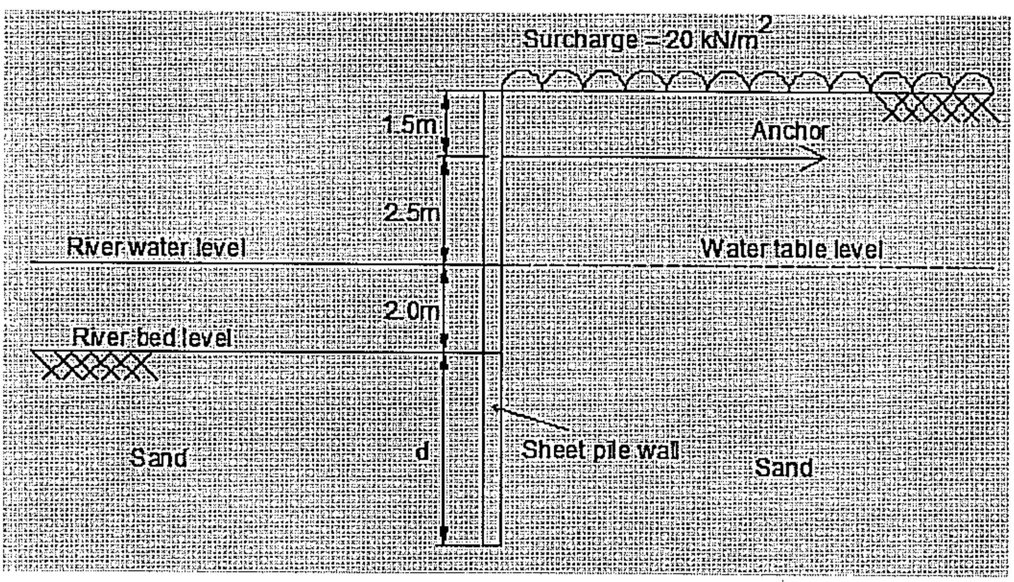

Figure Q6

(a). Evaluate the earth pressure distributions on either side of the wall. (8 marks)

(b). Determine the depth of penetration, d, required. (6 marks)

(c). Determine the pull of the anchor ties if anchors are spaced at 2m centres. (6 marks)

Use free earth support method and a factor of safety of unity for all parameters.

Q7.

(a). List four assumptions made in analyzing stability of slopes using Taylor's stability number and demonstrate how it is used in the stability analysis of slopes

(i). Under fully submerged condition and (5 marks)

(ii). after a sudden drawdown (5 marks)

by calculating the factor of safety with respect to cohesion of the 45° slope shown in Figure Q7a. Assume that friction is fully mobilized and use the Taylor's stability numbers given in Table Q7a. Assume, $\gamma_{sat} = 18.5\ kN/m^3$, $C' = 20\ kN/m^2$ and $ø' = 15°$ for soil.

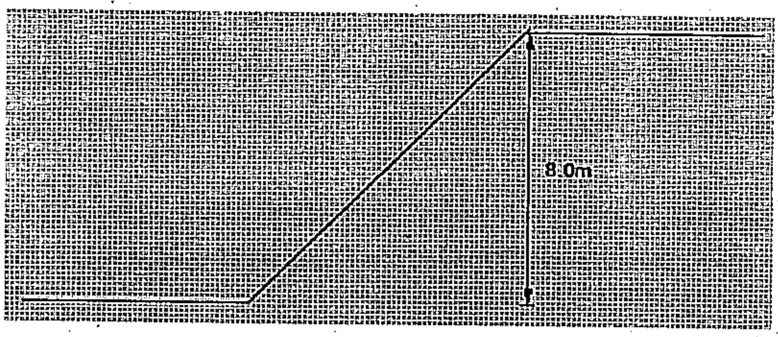

Figure Q7a

Table Q7a

$\phi°$	5	10	15	20
$C_d/\gamma H$	0.136	0.108	0.083	0.062

(b). Figure Q7b shows a slope with an assumed circular failure surface. The soil mass is divided into 8 slices for the purpose of slope stability analysis. It is recommended that you use Swedish Method of Slices to determine the Factor of Safety against slope failure. The data given in the Table Q7b can be used for your calculations. Assume, $C' = 10\ kN/m^2$ and $ø' = 29°$ for soil and the water table is below the failure surface.

$$FOS = \sum \{C.\Delta s + W \cos\alpha \tan ø\} / \sum W \sin\alpha$$

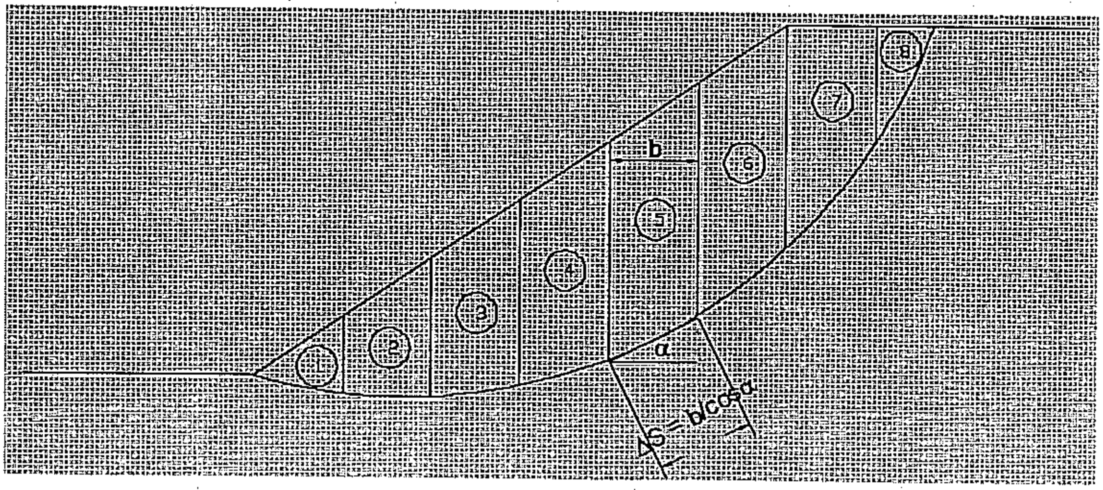

Figure Q7

Table Q7b

Slice No	α (degrees)	Width - b (m)	Weight - W (kN)
1	-11	1.5	20.6
2	-2	1.5	55.4
3	8	1.5	83.0
4	17	1.5	102.9
5	27	1.5	118.0
6	37	1.5	117.4
7	50	1.5	92.2
8	63	1.0	21.8

(i). Determine the forces causing sliding at the base of each slice (some of the forces may have a negative value but show them with their signs). Tabulate these forces. (4 marks)

(ii). Determine the forces resisting sliding. Tabulate these forces. (4 marks)

(iii). Determine the factor of safety against sliding. (2 marks)

Q8.

(a). State three instances where pile foundations become necessary. (3 marks)

(b). State three different criteria used to classify piles. (3 marks)

(c). Ultimate load capacity of a single pile installed in cohesive soil can be expressed as,
$P_u = 9C_u.A_b + \sum \alpha\, C_u.A_s,$
Identify each term in the equation. (2 marks)

(d). Determine the allowable capacity of a single pile, 1.20m in diameter, 30m in length, installed in a thick deposit of clay with an undrained shear strength increasing linearly with depth from 35 kN/m² at ground level and at 5 kN/m² per meter depth. Use a factor of safety of 2.5 on both skin friction and end bearing and take $\alpha = 0.6$.

A group of these piles, 20 x 20 in number is arranged in a square grid with piles at 3.6m center to center distance in both directions. Considering both individual and block shear failure of pile group, determine the carrying capacity of the group. Neglect the difference in weight of soil and concrete and use same factor of safety against block failure. Take the efficiency of the pile group as 0.70. (12 marks)