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THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2017/2018
CVX4530, CEX4230 – SOIL MECHANICS AND INTRODUCTION TO ROCK MECHANICS

Time allowed: Three Hours. Index No. ________

Date: Monday, 11th February 2019 Time: 0930-1230

**PART A:**

Answer all questions. All questions carry equal marks. Attach Part A of this paper to your answer script. You are advised to spend approximately One (1) hour for Part A. Circle the correct response.
(3x12 = 36 points)

Questions 1 – 2

A soil has a bulk density of 1.75 g/cm$^3$ and a water content of 10.5%. The density of solids is assumed to be 2.68 g/cm$^3$.

1. The porosity of soil is equal to:

   a. 0.30 b. 0.41 c. 0.49 d. 0.55 e. 0.63 — a b c d e

2. The degree of saturation (%) is equal to:

   a. 30 b. 41 c. 49 d. 55 e. 63 — a b c d e

3. The following two equations are used when computing the variation of percent passing versus particle size, during a hydrometer test: $D = 0.00531\{[\eta H_R]/[(\rho_s - 1)t]\}^{1/2}$; $K = \{100\rho_s/m(\rho_s - 1)\} R_d$. Which of the following statements are true?

   A. The dispersing agent does not influence the particle size.
   B. The percent passing is computed relative to the soil mass passing 0.063mm sieve.
   C. The amount of soil in suspension at a given time, reflects the percent passing the relevant sieve size.
   D. Viscosity $\eta$ depends on the quantity of solids in suspension at a given time.

   a A and B only b. B and C only c. C and D only d. A and D only e. A and C only

   a b c d e

4. The increase in vertical effective stress due to lowering of ground water table from 3m to 5m elevation (refer Figure A4) is:

   a 19.6 kPa b. 23.5 kPa c. 33.5 kPa d. 41.3 kPa e. 49.0 kPa

   a b c d e

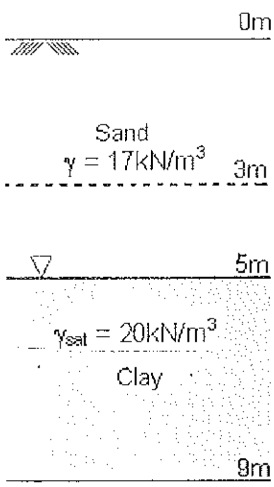

Figure A4

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5. For the state of plane stress shown in Figure A5, the major principal stress is:

   a 88.3 kPa b. 92.5 kPa c. 102.7 kPa d. 111.4 kPa e. 123.8 kPa

   a b c d e

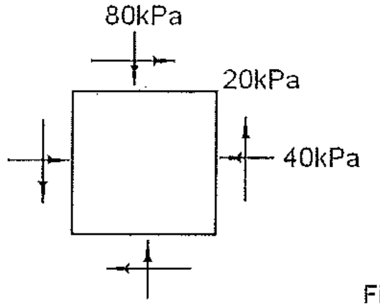


Figure A5

6. For the state of plane stress described in Figure A5, the angle between the horizontal plane and the plane of major principal stress is:

   a. $22.5^0$ b. $45^0$ c. $67.5^0$ d. $90^0$ e. $112.5^0$

   a b c d e

7. The Coefficient of Permeability, k of a sandy soil measured at $28^0$c is 0.02 $cm.s^{-1}$. What would be the value of k expressed at the standard temperature considered? Table below gives the variation of viscosity with temperature.

| Temperature ($^0$c) | Viscosity ($m^2/s \times 10^{-6}$) |
|---|---|
| 10 | 1.307 |
| 20 | 1.004 |
| 30 | 0.801 |

   a. 0.011 $cm.s^{-1}$ b. 0.013 $cm.s^{-1}$ c. 0.015 $cm.s^{-1}$ d. 0.017 $cm.s^{-1}$ e. 0.019 $cm.s^{-1}$

   a b c d e

8. Which of the following statements are true, regarding the two soils described in Table A8?

   A. Soil A is a well graded coarse to medium-coarse sandy-gravel
   B. Soil B is a fine-grained soil.
   C. Soil A may be identified as a GS-GW soil.
   D. The fines in Soil B have more silty than clayey.

   a A and B only b. B and C only c. C and D only d. A and D only e. A and C only

   a b c d e

Table A8

| Particle size | Percentage smaller | |
|---|---|---|
| | Soil A | Soil B |
| 63 mm | 100 | 100 |
| 20 mm | 64 | 76 |
| 6.3 mm | 39 | 65 |
| 2 mm | 24 | 59 |
| 600 μm | 12 | 54 |
| 212 μm | 5 | 47 |
| 63 μm | 0 | 34 |
| 20 μm | | 23 |
| 6 μm | | 14 |
| 2 μm | | 7 |
| Liquid Limit | | 26 |
| Plasticity Index | | 9 |

9. Which of the following statements are true?

   A. Toughness of the soil thread near Plastic Limit is a measure of the soil's ability to re-roll several times.
   B. Dilatancy reaction is high in silty soil.
   C. High plasticity soils show a high dry strength.
   D. High dry strength indicates the presence of adsorbed water.

   a. A, B and C only   b. B, C and D only.   c. A, B and D only.   d. A, C and D only.
   e. A, B, C and D.   a b c d e

10. Identify the correct relationship for the following lateral pressure coefficients:

   a. $K_0 < K_{water} < K_p$
   b. $K_{water} < K_0 < K_p$
   c. $K_p < K_0 < K_a$
   d. $K_0 < K_p < K_a$
   e. $K_a < K_p < K_0$   a b c d e

11. Which of the following statements are true?

   A. SPT-N is the number of blows counted during a penetration of 150mm
   B. SPT sampler yields disturbed soil specimens.
   C. Medium dense sands yield a SPT of 10 to 30.
   D. The recorded SPT value at significantly greater depths is greater than its actual value.

   a. A, B and C only   b. B, C and D only.   c. A, B and D only.   d. A, C and D only.
   e. A, B, C and D.   a b c d e

12. Which of the following statements are true?

   A. Smooth-wheeled rollers are used to compact crushed rock and coarse-grained soils.
   B. Static sheepsfoot rollers are used to compact fine-grained soils.
   C. Vibrating plate tampers are used when compacting small areas of coarse-grained soils.
   D. Rubber tired rollers are used when compacting asphalt.

   a. A, B and C only   b. B, C and D only.   c. A, B and D only.   d. A, C and D only.
   e. A, B, C and D.   a b c d e

**PART B:**

Answer four questions. All questions carry equal marks. You are advised to spend approximately 28 minutes per question. (16x4 = 64 points)

1. Shear Strength of soils is expressed in terms of Mohr-Coulomb failure criterion.
   - A. State the equation that expresses Mohr-Coulomb failure criterion; define its terms. (3 marks)
   - B. Field and laboratory strength tests are used to determine shear strength parameters. These parameters are used to establish Mohr-Coulomb failure criterion for a given soil, subject to given test conditions. Express the Mohr-Coulomb failure criterion as interpreted by the:
     - a. Unconfined Compression Test. (2 marks)
     - b. Consolidated Drained Triaxial Loading Test. (2 marks)
   - C. A Consolidated-Undrained triaxial loading test was performed on an undisturbed, loose to medium-dense sand. The following values were observed.

     Cell Pressure = 250kPa

     Principal stress difference at failure = 600kPa

     Excess Pore Water Pressure at failure = 50kPa.

     Determine parameters $\phi'$ and $\phi$. (6 marks)
   - D. Explain how you would check the safety of a two-dimensional stress element against possible shear failure. (3 marks)

2. Figure B2 shows the sub-surface profile of a construction site.
   - A. State the principle of effective stress; explain or define the terms that you have used. (3 marks)
   - B. Sketch the variation of total vertical stress versus depth. Indicate principal values at points A, B, C and D. (3 marks)
   - C. Sketch the variation of pore water pressure versus depth. Indicate principal values at points A, B, C and D. (2 marks)
   - D. Sketch the variation of effective vertical stress versus depth. Indicate principal values at points A, B, C and D. (2 marks)
   - E. Compute vertical stresses $\sigma_v$, $\sigma'_v$ and horizontal stresses $\sigma_h$, $\sigma'_h$ acting on a soil element located at Point E. You may assume that the `at-rest' state prevails in the soil element. (3 marks)
   - F. Sketch the Mohr's circles of stress with respect to total stress and effective stress representing soil element E. State the principal values. (3 marks)

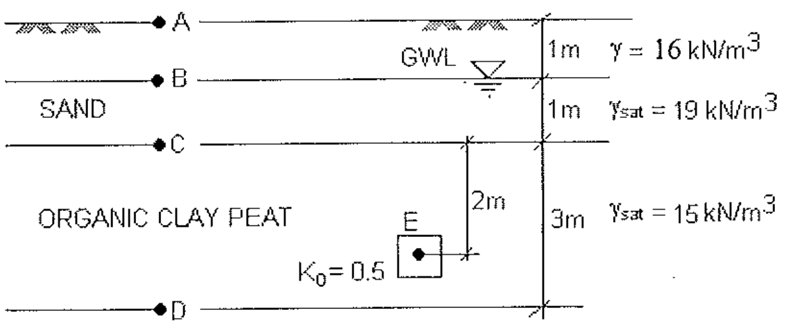


Figure B2

3. Figure B3 compares the state of compaction achieved with depth, during a trial compaction of a soil subjected to 2, 5, 15 and 45 roller passes. Optimum Moisture Content ranges between 12 – 15%
   - A. Explain how the Relative Density (i.e. the x – ordinate) was computed. (4 marks)
   - B. Explain how the y – coordinate was obtained. (4 marks)

The project consultants have recommended that a relative density of 80% be maintained, for a particular compacted highway embankment fill of 2.5m height

C. Determine the number of roller-passes and the compacted thickness you would recommend. (4 marks)

D. Write a method specification detailing out the procedure to carry out the said activity. (4 marks)

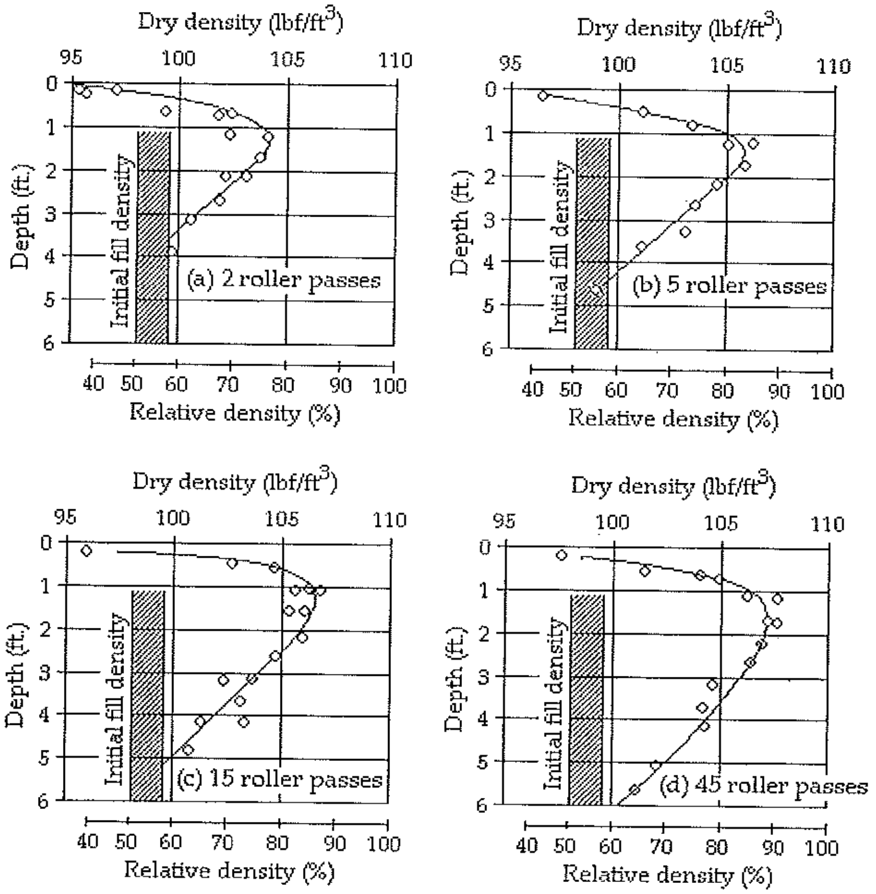


Figure B3: Density-depth relationship for a 5670kg roller operating at 27.5Hz for a 240cm lift height (after D'Appolonia, et al., 1969).

4. Figure B4 shows a free body diagram representing a submerged infinite slope in a cohesionless soil.

A. Write the equations of force equilibrium representing Figure B4 (a) (4 marks)

B. Write the equations of force equilibrium representing Figure B4 (b) (4 marks)

C. Express Mohr-Coulomb failure criterion (2 marks)

D. Express the Factor of Safety in terms of $\tau_{max}$ and $\tau$. (2 marks)

E. Hence derive and expression for the Factor of Safety (4 marks)

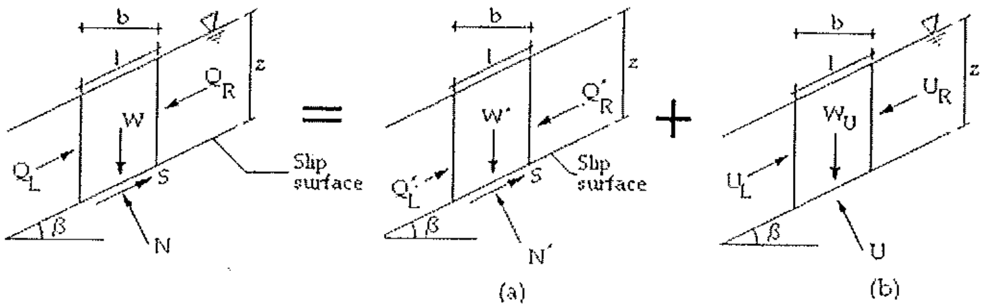


Figure B4

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5. Figure B5 shows a detailed view of a cantilever retaining wall supporting a sandy soil formation with properties $c' = 0$, $\phi' = 38°$ and $\gamma = 17.5$ kN/m³. The unit weight of concrete is 24 kN/m³. There is no influence due to the water table. The friction angle between the wall base and the soil, $\delta = 30°$.

   A. Considering that the backfill is at an active state of plastic equilibrium, compute the magnitude of the force due to earth pressure acting along the imaginary line AB, per meter length of the retaining wall. (3 marks)

   B. Compute the weight of soil and the weights of concrete elements acting on the base BC, per meter length of the retaining wall structure. (3 marks)

   C. Show on a sketch the magnitudes, directions and the lines of action of all forces acting on 1m length of the retaining wall structure, at its static equilibrium state. (2 marks)

   D. Compute the factor of safety against over-turning. (3 marks)

   E. Compute the factor of safety against sliding. (2 marks)

   F. Compute the stress distribution beneath the footing base BC; show its principal values. (3 marks)

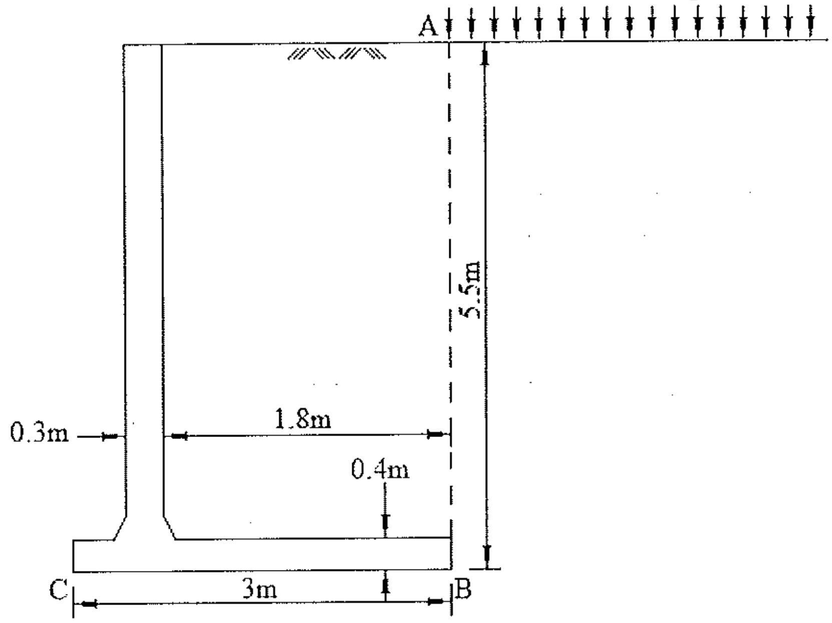


Figure B5

6.

   A. The water movement through a rock fracture (refer Figure B6A) is expressed as $k = \frac{\gamma_w}{6\mu}\left[\frac{d^3}{s}\right]$.

   Name the independent variables. Discuss how these variables are related to k. (4 marks)

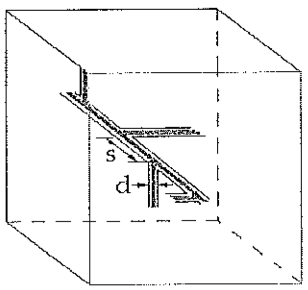


Figure B6A

B. Figure B6B shows the idealized in-situ compression curve generated from the laboratory compression curve constructed during the 1-dimensional consolidation test. Explain how you would obtain the x and y coordinates of points A, B and C. (4 marks)

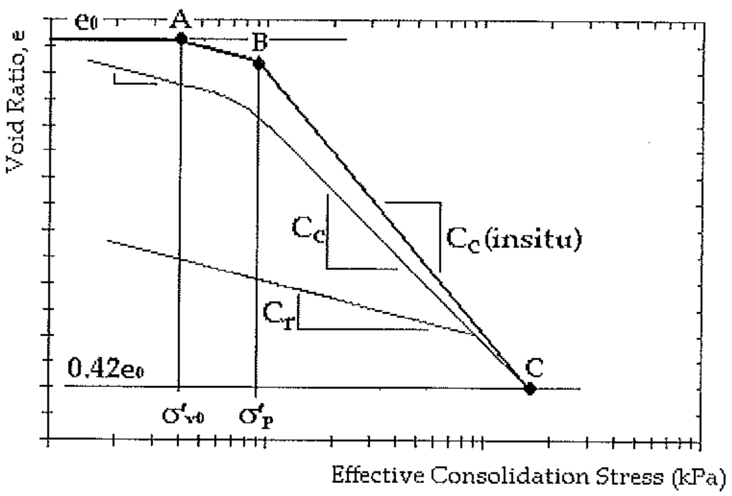


Figure B6B

C. Discuss how you would use the tip resistance obtained during a Cone Penetration Test, to compute the angle of internal friction $\phi'$ at a given depth. (4 marks)

D. Describe General Shear Failure, Local Shear Failure and Punching Shear Failure. Discuss the conditions under which the above three types of shear failure may occur. (4 marks)