



Study Programme	: Bachelor of Technology Honours in Engineering : Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
<b>Course Code and Title</b>	<b>: CVX4343 Soil Mechanics</b>
Academic Year	: 2023/24
Date	: 1 <sup>st</sup> March 2025
Time	: 0930-1230hrs

**General Instructions**

1. This is a Closed Book Test.
2. Read all instructions carefully before answering the questions.
3. This question paper consists of Part A (twelve questions) and Part B (six questions) in **Eight (8)** pages.
4. Answer all questions in Part A. All questions carry equal marks. Attach this page, with your answers to Part A and Questions B1 and B3, to your answer script. You are advised to spend approximately One (1) hour on Part A (3x12 = 36 points).
5. Answer four questions in Part B. All questions carry equal marks. You are advised to spend approximately 28 minutes per question (16x4 = 64 points).

**PART A: Circle the correct response.**

- |             |           |
|-------------|-----------|
| Question 1  | a b c d e |
| Question 2  | a b c d e |
| Question 3  | a b c d e |
| Question 4  | a b c d e |
| Question 5  | a b c d e |
| Question 6  | a b c d e |
| Question 7  | a b c d e |
| Question 8  | a b c d e |
| Question 9  | a b c d e |
| Question 10 | a b c d e |
| Question 11 | a b c d e |
| Question 12 | a b c d e |

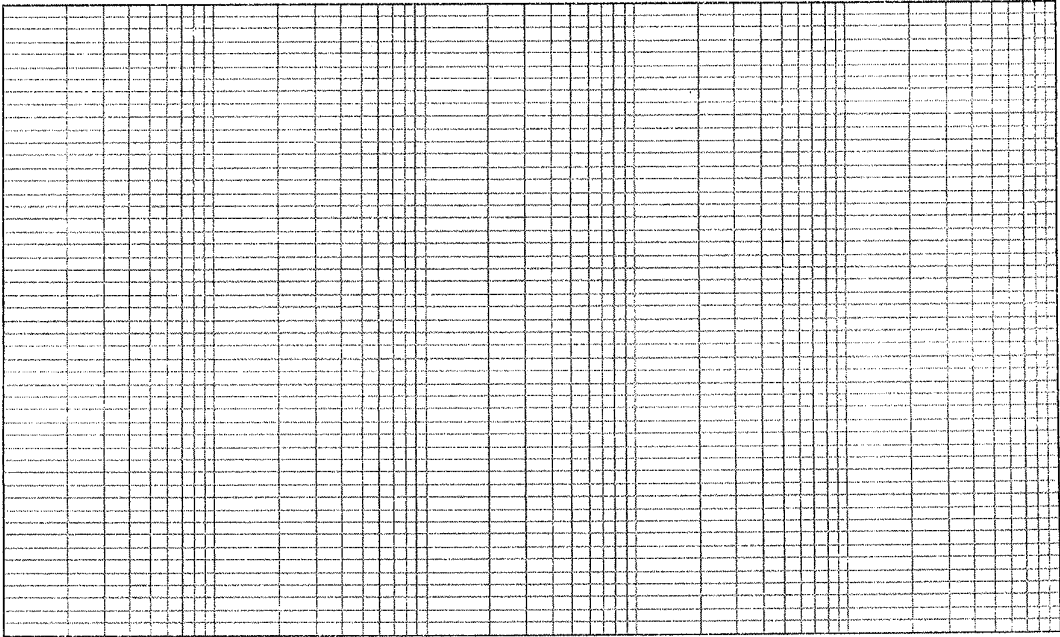


Figure B1

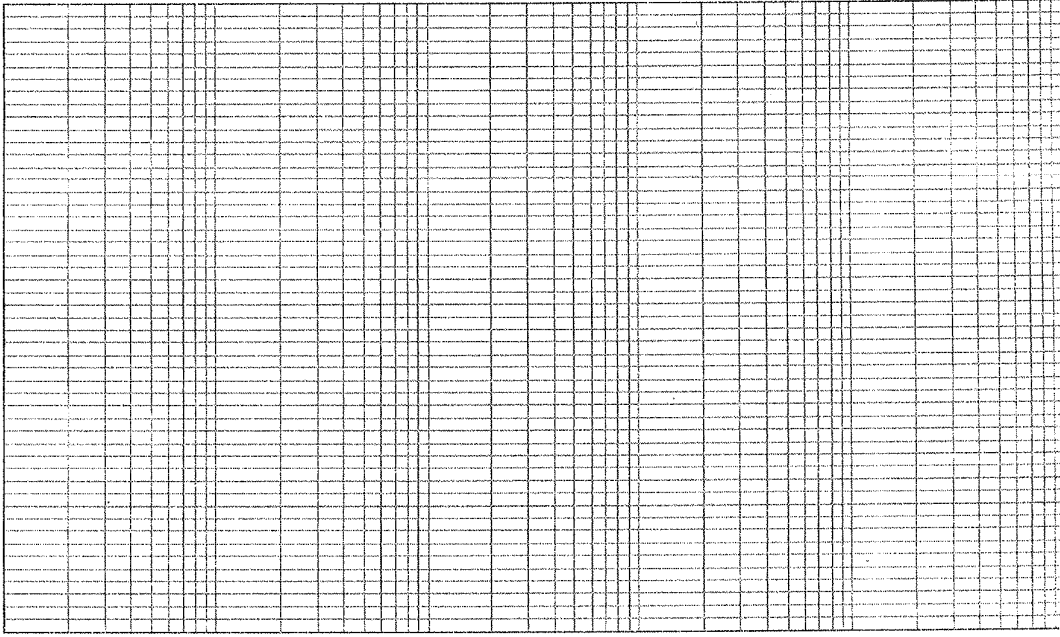


Figure B3

**PART A:**

Answer all questions. All questions carry equal marks.

1. The equation  $\rho_{bulk} = \left[ \frac{G_s + Se}{1+e} \right] \rho_w$  represents a phase relationship of an in-situ engineering soil specimen. Which of the following statements are true?
- A. During saturation parameter  $e$  remains unchanged.
  - B. Parameter  $S$  takes values 0, 1, and any other in-between value.
  - C. Parameter  $e$  should take values 0 and 1, or any other in-between value.
  - D. The Dry Density can be computed using the given parameters.
- a. A, B, and C only    b. B, C, and D only    c. A, C, and D only    d. A, B, and D only  
b. A, B, C and D
2. For the state of plane stress shown in Fig. A2, the magnitude of the normal stress acting along the stress direction that makes an angle of  $+45^\circ$  from the  $x$  – direction is:
- a. 20 kPa    b. 45 kPa    c. 54 kPa    d. 61 kPa    e. 73 kPa

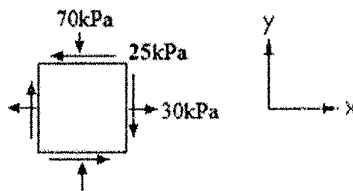
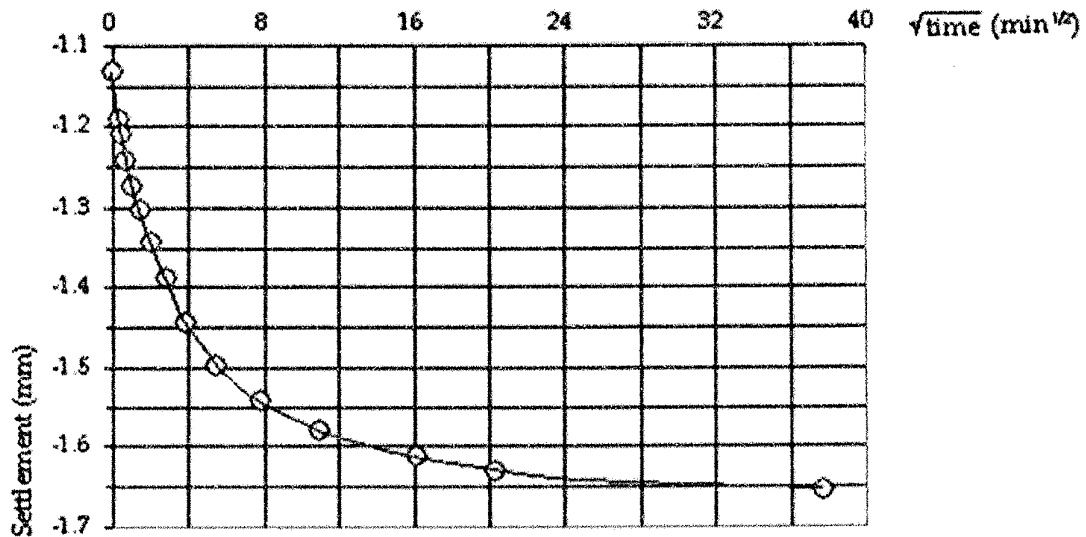


Fig. A2

3. Which of the following statements are true regarding a fine-grained soil?
- A. Fine-grained soils shall have less than 50% passing the 0.063mm sieve.
  - B. Toughness is determined based on the pressure applied to roll a 3mm soil thread.
  - C. Soils that show a high Dilatancy reaction also show a high Dry Strength.
  - D. Dry Strength is due to the presence of bound water in the soil matrix.
- a. A and B only    b. B and C only    c. B and D only    d. A and C only  
e. A and D only
4. Which of the following statements are true regarding the Hydrometer Test?
- A. The hydrometer readings recorded during the test reflect the mass of solids in suspension.
  - B. With time, the buoyancy force acting on the Hydrometer increases.
  - C. Change in temperature during the test is corrected when computing per cent passing.
  - D. The meniscus correction is addressed when computing per cent passing.
- a. A, B, and C only    b. B, C, and D only    c. A, C, and D only    d. A, B, and D only  
e. A, B, C and D
5. Which of the following statements are true regarding the Unconsolidated Undrained (UU) Triaxial Compression Test performed on a saturated clayey soil?
- A. This test also gives the parameter  $\phi$ , with respect to total stress.
  - B. The test determines the variation of excess pore water pressure with vertical strain.
  - C. The response of the soil specimen is similar to a similar specimen in a UC test.
  - D. The original volume of the specimen remains unchanged during the test.
- a. A, B, and C only    b. B, C, and D only    c. A, C, and D only    d. A, B, and D only  
e. A, B, C and D
6. A soil has 8% of soil fraction passing 0.063mm sieve size. The soil type could be:
- a. SW    b. GW-SM    c. SM    d. SW-GM    e. SW-SM

7. The Standard Proctor Compaction Test specimen has a total volume of  $986 \text{ cm}^3$ . The Specific Gravity  $G_s$  is estimated at 2.65. The water content is 18% at full saturation. The Dry Density in  $\text{kN/m}^3$  at full saturation is:
- a. 16.1   b. 16.8   c. 17.2   d. 17.6   e. 18.4
8. Which of the following statements are true regarding 1-dimensional Consolidation theory?
- A. Dissipation of excess pore water pressure occurs in the vertical and radial directions.  
 B. Volume change due to external loads occurs only in the vertical direction.  
 C. The Coefficient of Consolidation for a particular load increment depends on the Coefficient of Compressibility and the Coefficient of Permeability  
 D. Water is considered to be a compressible fluid.
- a. A and B only   b. B and C only   c. B and D only   d. A and C only  
 e. A and D only

Questions 9 – 10: Figure below shows a plot obtained during a One-dimensional Consolidation Test.



9. The settlement in mm corresponding to the beginning of primary consolidation is:
- a. 1.101   b. 1.133   c. 1.185   d. 1.217   e. 1.254
10. The settlement in mm corresponding to the end of primary consolidation is:
- a. 1.287   b. 1.323   c. 1.412   d. 1.425   e. 1.633
11. Which of the following statements are true regarding the Constant Head Permeability Test?
- A. Increasing the total head difference between the inlet and outlet points of the soil specimen increases its  $k_{20}$ .  
 B. Increasing the total head difference between the inlet and outlet points of the soil specimen increases discharge through the soil.  
 C. Increasing the total head difference between the inlet and outlet points of the soil specimen increases the loss of total head.  
 D. An increase in the Dry Density of the soil specimen increases the Critical Hydraulic Gradient.
- a. A, B, and C only   b. B, C, and D only   c. A, C, and D only   d. A, B, and D only  
 e. A, B, C and D
12. A constant head permeability test was carried out on a cylindrical sample of sand of 72mm diameter and 170mm high.  $185 \text{ cm}^3$  of water was collected in 2.5 minutes under a total head difference of 15cm. The hydraulic conductivity in cm/s is:
- a. 0.0202   b. 0.0253   c. 0.0285   d. 0.0334   e. 0.0589

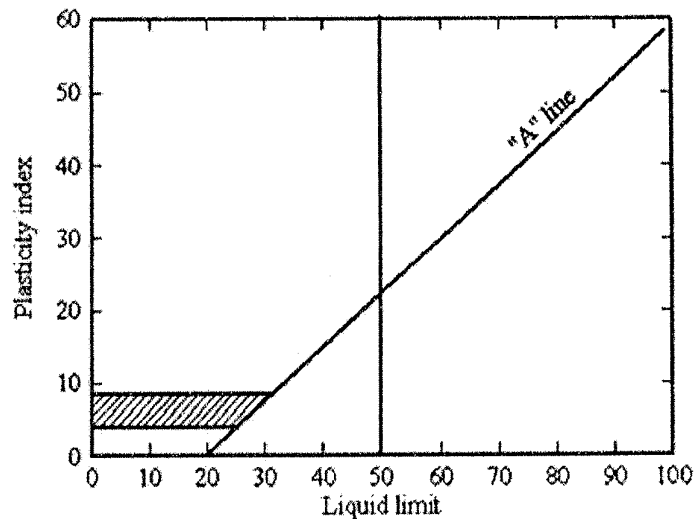
**PART B**

Answer four questions. All questions carry equal marks.

1. A combined sieve-hydrometer test performed on a soil sample is as follows:

Table B1

Size (mm)	Per cent finer by weight
2	100
0.6	90
0.212	70
0.063	45
0.035	33
0.02	25
0.01	18
0.008	17
LL	30
PL	22



- A. Determine the group symbol based on Unified Soil Classification System. Candidates may use Figure B1 provided on Page 2 of this question paper. (6 points)
  - B. State its Soil Description, considering the different soil groups and amounts present in the test specimen. (3 points)
  - C. If you are to classify this soil specimen visually, state the tests you would perform. (4 points)
  - D. If you are to determine the toughness and plasticity of the 3mm soil thread of this specimen, visually, as per the standard procedure, state your conclusions. (3 points)
- 2.
- A. Using mass and volume parameters defining the three-phase soil model derive an algebraic expression for dry density,  $\rho_d$  in terms of degree of saturation,  $S$ , specific gravity,  $G_s$ , water content,  $w$  and the density of water,  $\rho_w$ . (4 points)
  - B. Sketch the variation of dry density versus water content, as described in question 2A above, for any selected degree of saturation; name the axes. (2 points)
  - C. Explain why high plasticity clay soils have a low dry density in comparison to a well-graded sand. (3 points)
  - D. Explain why a well-graded sand has a low optimum moisture content in comparison to a uniformly graded sand. (3 points)
  - E. Figure B4 shows the variation of Dry Density with depth when a 240cm lift height was compacted using a 5670kg roller operating at 27.5Hz (after D'Appolonia, et al., 1969).
    - i. Define Relative Compaction; explain how you would determine parameter for an in-situ compacted specimen. (3 points)
    - ii. If specifications expect you to maintain a Relative compaction of 80%, compute the expected "as-compacted" lift height for 15 roller passes. (1 point)

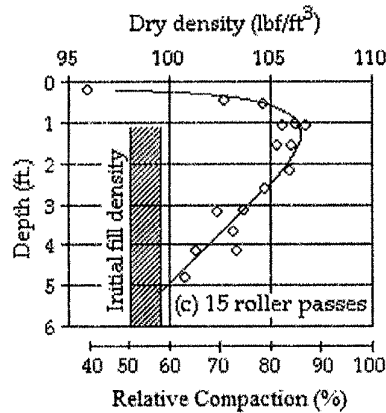


Figure B2

3. Table 3a gives Settlement vs. Time readings for 1kg load, observed during the 1-D Consolidation Test. Table 3b gives the variation of two model parameters described in Terzaghi's One-Dimensional Consolidation Theory.

Table 3a: Observed variation of settlement with time.

Time (min.)	Settlement (mm)
0	0.160
0.1	0.178
0.25	0.182
0.5	0.189
1	0.200
2	0.219
4	0.237
8	0.252
15	0.262
30	0.269
60	0.273
120	0.275
240	0.276
480	0.277
1440	0.279

Table 3b: Variation of model parameters.

$T_v$	$U_{avg}$
0.008	0.1
0.031	0.2
0.071	0.3
0.126	0.4
0.197	0.5
0.287	0.6
0.403	0.7
0.567	0.8
0.848	0.9
1.163	0.95
$\infty$	1.0

- A. Plot Settlement vs. Time on the semi-logarithmic graph-sheet provided in Figure B3 of Page 2 of this question paper. Select an appropriate scale to extract parameters required for the sections described below. (4 points)
- B. Show on the same plot how you have obtained the settlement values corresponding to i) Initial Compression, ii) Primary Consolidation and iii) Secondary Consolidation. Compute these three settlements. (3 points)
- C. Express the process of Secondary Consolidation. State its significance. (3 points)
- D. Define the two parameters shown in Table 3b. Explain how these two parameters are computed. (3 points)
- E. The Coefficient of Consolidation is defined by the equation  $\frac{c_v t}{d^2} = T_v$  and is based on the relationship  $\frac{k}{\rho_w g} \frac{\partial^2 u}{\partial z^2} = \frac{a_v}{1+e_1} \frac{du}{dt}$ . Discuss how parameters given in the latter equation are linked to parameter  $c_v$ . (3 points)

4. Figure B4 shows an element of clay located at a depth of 6.5m from the surface.
- State the Principle of Effective Stress; define its parameters. (3 points)
  - Compute  $\sigma_{yy}$ ,  $\sigma'_{yy}$  and  $u$  at depths 0m, -1.5m, -3.5m and -6.5m (refer Figure B4). (4 points)
  - Assuming that  $\sigma'_{xx} = 0.5\sigma'_{yy}$ , compute the total horizontal stress and effective horizontal stress at depth -6.5m. (3 points)
  - For the soil element described in 2(c) above sketch the Mohr's circles of stress corresponding to total and effective stresses. State the principal values and name the two axes. You may consider that shear stress  $\tau_{xy}$  is negligible. (3 points)
  - Compute the stresses ( $\sigma'_n$ ,  $\tau$ ) acting on the same element in the direction  $\sigma$  which makes  $30^\circ$  from the horizontal plane. (3 points)

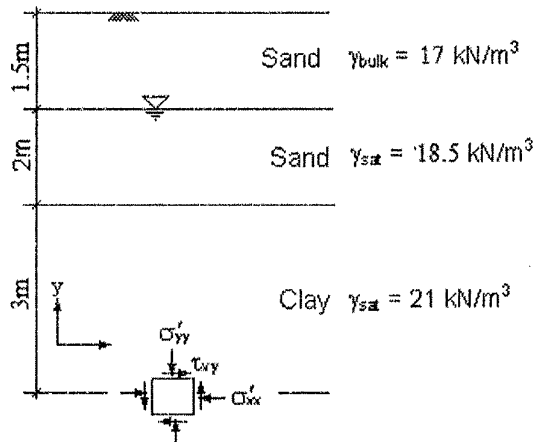


Figure B4

- A series of conventional Consolidated Undrained (CU) triaxial tests were performed on a saturated clayey soil.
  - Discuss the importance of using a saturated test specimen, over a partially saturated test specimen. Explain the significance of saturation on the outcome of test. (4 points)
  - During the consolidation stage, the specimen consolidates under the applied cell pressure. Explain how you would compute the average diameter and the height of the test specimen at the end of the consolidation stage. (4 points)
  - During the undrained testing stage, the deviatoric stress is observed for increasing vertical strain, while preventing dissipation of excess pore water pressure.
    - Discuss how the dissipation of the excess pore water pressure is prevented. (2 points)
    - Discuss how the Deviatoric Stress is computed for increasing vertical strains. (2 points)
  - Compare the outcome of the above CU Test and the Unconfined Compression Test. Hint: the candidate shall compare the types of shear strength parameters obtained in both tests, and their use. (4 points)
- Discuss the term piezometric level in relation to a confined aquifer. Explain how you would establish the piezometric head for a confined aquifer. (4 points)
  - Table B6B shows the ranges of Young's moduli and Poisson's ratios for two sand types.
    - Explain how you could obtain the Young's Modulus for a sandy soil. (2 points)
    - Define the term Poisson's ratio. (2 points)

Table B6B

Type of soil	Young's modulus, $E_s$ MN/m <sup>2</sup>	Poisson's ratio, $\mu$
Loose sand	10.35 – 24.15	0.20 – 0.40
Dense sand	34.50 – 55.20	0.30 – 0.45

- C. Figure B6C shows a Falling Head Permeability apparatus, with a specimen height of CD. The datum is considered at Point E. The measurements are made when the water level falls from Point A to Point B.

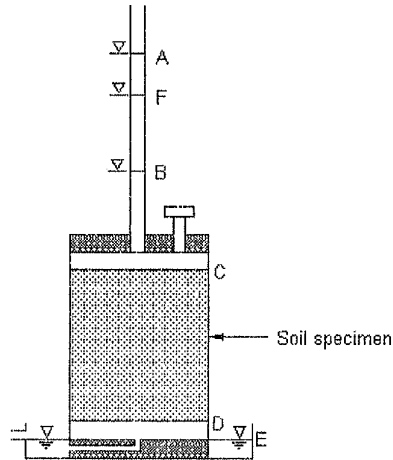


Figure B6C

- Reproduce this sketch on your answer script; show the heights corresponding to the elevation and pressure heads acting at points C and D, respectively, when the water level is at Point A. (2 points)
  - During flow through the permeameter, the hydraulic gradient across points CD remains constant. Discuss the validity of this statement. (2 points)
- D. Figure B6D shows a square footing with a structural load of 800kN. Compute the stress due to the given structural load at a Point A. (4 points)

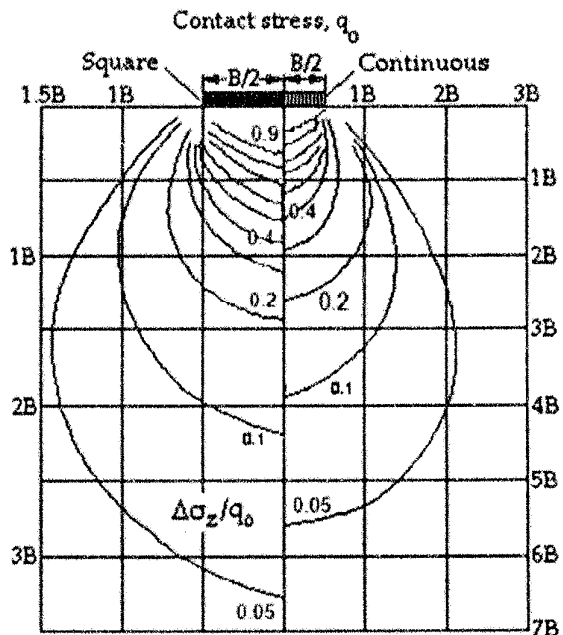
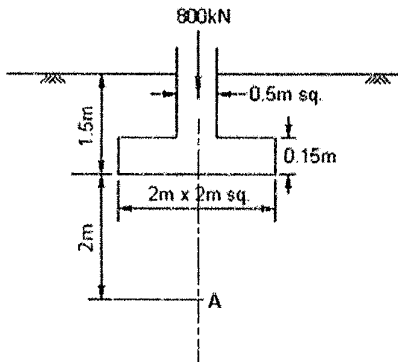


Figure B6D