INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500043

COURSE CONTENT

GEOTECHNICAL ENGINEERING LABORATORY								
IV Semester: CE								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
ACEC32	**Core**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		0	0	3	1.5	30	70	100
Contact Classes:	**Total Tutorials:**	**Total Practical Classes: 45**				**Total Classes: 45**		
Prerequisite: Engineering Geology Laboratory								

I. COURSE OVERVIEW:

This course will show how to conduct the various types of tests used for soil testing. Each experiment of soil testing is presented with brief introduction covering the important details of the experiment, the theory, and the purpose for which it is to be performed, followed by the detailed explanation of apparatus required, procedure and specimen calculations. These should enable students to perform the experiment and compute the results of experiments very easily.

II. COURSE OBJECTIVES:

The student will try to learn:

I. The principles and procedures for conducting soil processing and moisture content tests, specific gravity tests, and field density tests.

II. How to perform grain size analysis, determine consistency limits, and conduct laboratory compaction and permeability tests.

III. The techniques for laboratory permeability tests and gain an understanding of shear strength testing.

III. COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1 Explain the behaviour of soil with respect to water content (moisture content) for characterizing the permeability, compressibility, and shear strength of soil.

CO 2 Analyze the soils according to their grain size for determining the coefficient of uniformity and coefficient curvature to categorize the soil according to IS code.

CO 3 Choose the appropriate method to estimate the permeability of the layered soil for assessing drainage characteristics of soil, rate of consolidation, and to predict the rate of settlement of the soil bed.

CO 4 Construct the maximum dry density through compaction and consolidation to increase the bearing capacity and stiffness of in-situ soil medium.

CO 5 Explain the importance of the compressibility of the soil medium concept for taking necessary action to prevent the settlement of soil and foundation failures.

CO 6 Analyze the strength of soil sub-grades and base course materials to enable appropriate selection of suitable pavement thickness for the anticipated traffic density.

IV. COURSE CONTENT

EXCERCISES ON GEOTECHNICAL MECHANICS LABORATORY

Note: Students are encouraged to wear shoes for laboratory practice sessions.

Introduction

The Geotechnical Engineering Laboratory intends to train the students in the field of testing of soils to determine their physical, index and engineering properties. This course enables the students to perform the most important tests including soil classification, compaction, permeability, direct shear testing and cyclical triaxial testing; each experiment of soil testing is presented with brief introduction covering the important details of the experiment, the theory and the purpose for which it is to be performed, followed by the detailed explanation of apparatus required, procedure and specimen calculations.

1. Determination of water content of a given soils

1.1 Moisture content

Moisture content in soil mechanics laboratory refers to the amount of water present in a soil sample, expressed as a percentage of the soil's total weight. The testing apparatus are shown in fig. 1.

1.1. Determination of Soil Density
1.2. Determination of Aggregate Density
1.3. Determination of Bituminous Mixture Density

Fig. 1: Moisture content measuring equipment

Try: What is the overall influence of moisture content on the geotechnical properties of soils, and how can this knowledge be applied in engineering and construction practices?

1. How does the moisture content of soil affect its compaction characteristics?
2. What mechanisms explain the relationship between moisture content and shear strength in cohesive soils?
3. What factors contribute to the impact of moisture content on the shrinkage behaviour of clayey soils?

2. SPECIFIC GRAVITY

Specific gravity in soil mechanics laboratory refers to the ratio of the density of a soil sample to the density of water. The testing apparatus are shown in fig. 2.

The list of experiments:

2.1. Determination of Soil Specific Gravity
2.2. Determination of Aggregate Specific Gravity
2.3. Porosity Determination of Soil or Aggregate

Fig. 2: Specific gravity of sand equipment

Try: How can specific gravity testing techniques be applied to enhance material characterization and selection in engineering and geology?

1. How does particle size influence specific gravity in soil samples?
2. What methods are employed to determine the specific gravity of lightweight aggregate materials?
3. How can specific gravity measurements be used to assess the composition and purity of minerals?

3. ATTERBERG'S LIMITS

3.1 Index Properties of soil

Index Properties are a set of crucial tests in geotechnical engineering that determine the moisture content at which soil transitions from a solid to plastic and then to liquid state, providing essential data for soil classification and construction design.

3.1.1 Liquid limit

The "liquid limit" represents the moisture content at which a soil transitions from a plastic to a liquid state. The testing apparatus are shown in fig. 3.1.

1. Determining the liquid limit for a given sample of soils.
2. Determination of Plasticity Chart using Liquid Limit

Fig 3.1: Liquid limit apparatus

3.2 Plastic Limit

The Plastic limit is to assess its plasticity. The testing apparatus are shown in fig. 3.2.

Fig 3.2: Plastic limit apparatus

3.2.1 Determining the plasticity index limit for various soil types.

3.3 Shrinkage Limit

The shrinkage limit is the lowest moisture content at which a soil undergoes minimal volume change. The testing apparatus are shown in fig. 3.3.

Fig 3.3: Shrinkage limit apparatus

3.3.1 Determining the shrinkage limit for various soil types.

Try: What insights can the study of Atterberg's limits and their relationship to soil properties provide for geotechnical engineering and construction practices?

1. How does soil particle size distribution affect the Atterberg's limits of soils?
2. What methods are used to determine the plasticity index and shrinkage limit in diverse soil types?
3. How does varying moisture content impact the liquid and plastic limits of different soil samples?

4. Field Density-Core Cutter

A core cutter is used for extracting undisturbed soil samples from the field. Allowing to analyze the soil's properties, density, and structural characteristics for various construction and research purposes.

The testing apparatus are shown in fig. 4.1.

1. Determination of In-situ Soil Density
2. Determination of Soil Compaction Effort

Fig 4.1: Field compaction equipment

5. Field Density-Sand replacement

Sand replacement method used to determine the in-situ density and compaction of soils by replacing a known volume of soil with dry sand and measuring the volume change.

The testing apparatus are shown in fig. 5.1.

5.1. Determination of Field Density
5.2. Determination of In-situ Moisture Content

Fig 5.1: Sand replacement test equipment

Try: How can the choice between core cutter and sand replacement methods be optimized to ensure accurate and efficient field density assessment across various soil types and compaction conditions in geotechnical engineering and construction?

1. What are the key differences in field density measurements when comparing the core cutter and sand replacement methods, and how do they affect the results?
2. How does the compaction energy applied during testing impact the field density outcomes obtained from core cutter and sand replacement techniques?
3. What factors affect the accuracy and efficiency of field density assessment in different soil types, and how do core cutter and sand replacement methods compare in this regard?

6. GRAIN SIZE ANALYSIS

Grain size analysis involves determining the distribution of particle sizes within a soil sample.

The testing apparatus are shown in fig. 6.

6.1. Determination of Particle Size Distribution
6.2. Determination of Grain Size Distribution Curve
6.3. Determination of Effective Size and Uniformity Coefficient

Fig 6: Sieve setup

Try: How can the analysis of grain size distribution be applied to enhance our understanding and management of soils, sediments, and riverbeds in geotechnical and environmental engineering?

1. How do different sample preparation techniques impact the accuracy and consistency of grain size analysis results in geotechnical laboratories?
2. What variations exist in grain size distributions when comparing different soil types, and how does this knowledge inform geotechnical engineering and construction practices?
3. How does sediment transport affect the grain size distribution within riverbeds, and what implications does this have for sedimentation studies and hydraulic engineering?

7. PERMEABILITY OF SOIL

The permeability test is used to assesses the ability of soil to transmit fluids and plays a vital role in drainage, groundwater flow, and the design of civil engineering structures.

7.1 Constant Head Permeability

Constant head permeability is used to determine the hydraulic conductivity of soils by maintaining a steady flow of water through a soil sample with a fixed water level difference.

The testing apparatus are shown in fig. 7.1.

7.1. Determination of Permeability Coefficient
7.2. Determination of Hydraulic Conductivity

Fig 7.1: Constant head apparatus

7.2 Variable Head Permeability

Variable head permeability test that assesses the hydraulic conductivity of soils by measuring the flow of water through a soil sample with varying water levels.

The testing apparatus are shown in fig. 7.2.

7.2.1 Determination of Coefficient of Permeability
7.2.2 Determination of Seepage Velocity
7.2.3 Determination of Permeability of Compacted Soil Samples

Fig 7.2: Falling head apparatus.

Try: How can a comprehensive understanding of soil permeability, considering factors like particle size, compaction, and moisture content, be applied to improve geotechnical engineering practices and environmental management?

8. COMPACTION TEST

The compaction test is used to assess the maximum dry density and optimum moisture content of soils.

The testing apparatus are shown in fig. 8.

8.1. Determination of Maximum Dry Density and Optimum Moisture Content
8.2. Determination of Compaction Characteristics Curve
8.3. Determination of Field Compaction Control Parameters

Fig. 8: Compaction apparatus.

Try: How can a comprehensive study of compaction methods, moisture content effects, and vibratory compaction techniques enhance our understanding and application of soil compaction in geotechnical engineering and construction?

1. How does soil particle size affect permeability, and what differences arise when evaluating it with constant and variable head tests?

9. CBR TEST

The California Bearing Ratio (CBR) test used to evaluate the subgrade strength of soils for pavement design and construction.

The testing apparatus are shown in fig. 9.

9.1. Determination of CBR Value for Soil
9.2. Determination of Soaked CBR Value for Soil
9.3. Determination of CBR Value for Subgrade Soil Under Different Conditions (e.g., soaked, unsoaked, compacted at different moisture contents)

Fig. 9: CBR test apparatus

Try: How can CBR testing be effectively utilized in geotechnical engineering to improve pavement design and subgrade material assessment?

1. How does varying moisture content affect CBR values for different soil types?
2. What is the influence of compaction methods on CBR results for subgrade materials?

10. CONSOLIDATION TEST

The consolidation test used to determine the settlement characteristics of soil under a sustained load.

The testing apparatus are shown in fig. 10.

10.1. Determination of Coefficient of Consolidation
10.2. Determination of Compression Index
10.3. Determination of Settlement Characteristics

Fig.10: Consolidation test apparatus

Try: How can an understanding of consolidation characteristics and settlement be applied in geotechnical engineering to optimize construction and mitigate potential issues in various soil types?

1. How does soil type affect consolidation characteristics, including settlement and pore pressure?
2. What is the impact of preloading on consolidation settlement in various soil types?
3. What are the key differences in consolidation test procedures, and how do they affect results?

11. UNCONFINED COMPRESSION TEST

The unconfined compression test is used to measure the strength of a cohesive soil sample when it is subjected to axial compression without lateral confinement.

The testing apparatus are shown in fig. 11.

11.1. Determination of Unconfined Compressive Strength of the given sample
11.2. Determination of Stress-Strain behavior
11.3. Determination of Shear Strength Parameters
11.4. Determination of Elastic Modulus

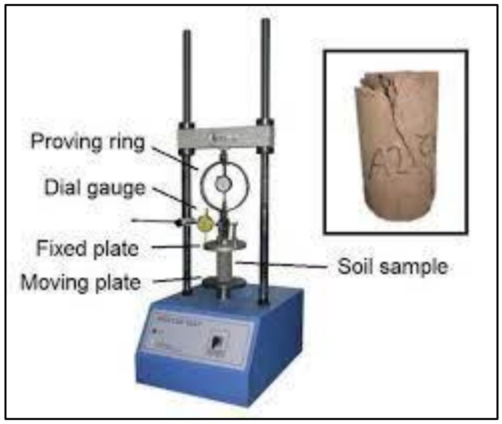

Fig. 11: Unconfined compression test apparatus

Try: How can the unconfined compression test and its various parameters be leveraged to assess and compare the mechanical properties of different soil types for geotechnical engineering applications?

1. How does the initial moisture content impact the unconfined compression strength of cohesive soils?
2. What are the differences in unconfined compression test results when applied to various soil types?
3. How does the curing time affect the unconfined compression behaviour of soil specimens?

12: TRIAXIAL COMPRESSION TEST

The triaxial compression test used to assess the shear strength and stress-strain behaviour of soil specimens under different confining pressures.

The testing apparatus are shown in fig. 12.

12.1. Determination of Shear Strength Parameters (Cohesion and Friction Angle)
12.2. Determination of Consolidated Undrained (CU) Shear Strength
12.3. Determination of Consolidated Drained (CD) Shear Strength


Fig 12: Triaxial test apparatus

Try: How can triaxial compression testing be employed to comprehensively understand the mechanical behaviour of different soil types under varying conditions, aiding geotechnical engineering design and analysis?

1. How does varying confining pressure affect the shear strength of clayey soil in triaxial compression?
2. What is the stress-strain behaviour and failure characteristics of granular soil at different strain rates

in triaxial compression?
3. How does pore water pressure influence the deformation and strength properties of saturated sand in triaxial compression?

13. DIRECT SHEAR TEST

The direct shear test is used to determine the shear strength properties of soil materials.

The testing apparatus are shown in fig. 13.

13.1. Determination of Shear Strength Parameters (Cohesion and Friction Angle)
13.2. Evaluation of Shear Strength under Different Normal Stresses
13.3. Study of Shear Strength Behavior with Varying Shear Rates
13.4. Investigation of Shear Strength in Saturated and Unsaturated Soils

Fig 13: Triaxial test apparatus

Try: How can direct shear testing be applied to assess and improve the understanding of the shear strength and behaviour of different soil types under various conditions in geotechnical engineering applications?

1. How does moisture content influence the shear strength of cohesionless soils in a direct shear test?
2. What is the impact of confining pressure on the shear behaviour of clayey soils in a direct shear test?
3. How do varying strain rates affect the shear strength properties of granular materials in a direct shear test?

14. VANE SHEAR TEST

The vane shear test is used to determine the shear strength of cohesive soils.

The testing apparatus are shown in fig. 14.

14.1. Determination of Undrained Shear Strength using Vane Shear Test
14.2. Measurement of Sensitivity using Vane Shear Test
14.3. Evaluation of Rate of Consolidation using Vane Shear Test
14.4. Investigation of Shear Strength Profile in Cohesive Soils using Vane Shear Test

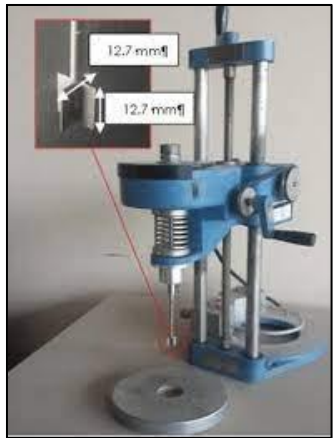

Fig 14: Vane shear test apparatus

Try: How can vane shear testing be effectively utilized to characterize and differentiate the shear strength properties of different soil types and optimize sample preparation methods in geotechnical engineering?

1. How does soil moisture content affect vane shear strength?
2. What are the differences in vane shear test results when applied to cohesive and non-cohesive soils?

V. TEXTBOOKS

1. Das, B M. “Soil Mechanics Laboratory Manual”, 2021. Engineering Press at OUP, 2001.
2. Kalinski, Michael E. “Soil Mechanics: Lab Manual”, John Wiley & Sons, 2nd Edition, 2011.
3. Ventura Tejeda, Fernando R. "Soil Mechanics Laboratory Manual." (2020).

VI. REFERENCE BOOKS:

1. Das, B M., and N Sivakugan. Fundamentals of geotechnical engineering. Cengage Learning, 2016.
2. Murthy, V. N. S. Geotechnical engineering: principles and practices of soil mechanics and foundation engineering. CRC press, 2002.

VII. WEB REFERENCE BOOKS

1. https://onlinecourses.nptel.ac.in/noc23_ce72/preview
2. https://onlinecourses.nptel.ac.in/noc22_ce60/preview

VIII. ELECTRONICS MATERIAL

1. Course Template
2. Lab Manual