PREFACE

The accurate determination of soil consolidation properties is essential for successful geotechnical engineering design. Although laboratory tests are commonly used, one-dimensional incremental loading (IL) consolidation tests have limitations. These tests can take up to two weeks to complete, and the data points collected are discrete, which can lead to imprecise estimation of consolidation properties. To address these limitations, constant rate strain consolidation has been developed, but this method can also be time-consuming and may not be suitable for highly compressible soils.

Fine-grained soils pose significant challenges for geotechnical engineering due to their high compressibility and low shear strength. Traditional hydraulic ground improvement methods, such as pre-loading and vacuum pressure, may not be effective for these soils and can be time-consuming. In order to establish a laboratory consolidation technique that conforms to electroosmosis standards, extensive research on soil samples is necessary. This research would enable a better understanding of the soil behavior on a smaller scale and allow for replication to field conditions, as required. The laboratory technique developed through this research would involve applying an electrical potential gradient to the soil, which results in fundamental changes in its electro-hydro-mechanical (EHM) behavior. This technique can be used to address the consolidation of problematic, soft-grained soils in geotechnical engineering.

The thesis is comprised of seven main chapters, followed by references. Chapter 1 provides an overview of the geotechnical background and the objectives of the present study. Chapter 2 presents a comprehensive review of one-dimensional consolidation concepts, including the incremental loading (IL), constant loading (CL), and constant rate-strain (CRS) techniques, and also discusses electro-osmotic consolidation for surcharge loading with and without electric gradient application. The aim of this discussion is to interpret different consolidation parameters in soft/problematic soils. Chapter 3 provides a detailed account of the materials and methodology used in the study. The chapter discusses the use of two different types of oedometers, namely a conventional oedometer with a height of 2 cm and a diameter of 6 cm and a modified oedometer with a height of 4 cm and a diameter of 10 cm. Two different loading assemblies were used with the oedometers, one providing constant stress and the other controlling the strain rate. The chapter also outlines the experimental procedures that were employed for performing one-dimensional mechanical consolidation techniques, including incremental loading with conventional and modified oedometer (IL-C and IL-M), constant loading with modified oedometer (CL-M), and an indigenously developed constant rate-strain with modified oedometer (CRS) techniques. The experiments were conducted in accordance with the American Society for Testing and Materials (ASTM) codes ASTM D2435-11 and ASTM D4186-12.

However, for the electrokinetic coupled constant loading (EKCL) and electrokinetic coupled constant rate strain (EKCRS) consolidation tests, no standard codes were available to guide the experimental procedures. The tests involved the application of electric gradients of 2, 4, and 6V which were used to facilitate the consolidation process. Special considerations had to be made for these tests, such as the need for continuous real-time data monitoring with a data acquisition system (DAQ) and the availability of suitable sensors for measuring multiple parameters such as deformation, current and voltage with time.

In Chapter 4, a detailed description of the design, drawing, and fabrication of both mechanical (CL, IL and CRS) and coupled electrokinetic consolidation (EKCL and EKCRS) indigenously developed assemblies is presented. The chapter proposes the necessary specifications for the consolidation cell design and testing procedures related to the proposed continuous controlled rate of strain coupled with voltage gradient for expediting the consolidation process. However, commercially available conventional consolidation cells that meet these specifications are often costly, which poses a limitation for teaching and research laboratories in accessing them. In addition, the parameters such as deformation, void ratio, pore pressure, pore pressure ratio, voltage, current, pH, moisture content, and energy consumption are compared, analyzed, and further validated also as per the study performed.

In Chapter 5 of the thesis presents the results of applying one-dimensional mechanical consolidation techniques to four different geomaterials, including Mumbai Marine soil (MS), Black cotton soil (BCS), Red mud (RM), and Varanasi local soil. The study employed conventional and modified oedometers with different loading assemblies that allowed for constant stress and controlled strain rate application. The obtained consolidation parameters were then compared and validated with the modified oedometer CRS consolidation. Although the test duration for the proposed CRS technique for marine soil and black cotton soil was slightly longer when compared to red mud, and Varanasi local soil, which were tested at their corresponding strain rates. Still, it was found to be faster and more accurate in completing the consolidation process than the conventional incremental loading technique. The results from the prediction formulae were found to be consistent with all test results, indicating their reliability.

Chapter 6 of the thesis presents a comparison of the mechanical and coupled electrokinetic consolidation techniques applied to Mumbai Marine soil and Black cotton soil using a modified oedometer. The study was conducted in two phases: (i) IL-M, CL-M, and EKCL (coupled with 2,4 and 6V) consolidation and (ii) CRS and EKCRS (coupled with 2,4 and 6V) consolidation. The EK consolidation techniques (EKCL and EKCRS) were found to be more rapid than conventional methods due to faster dissipation of pore water pressure and increased electro-osmotic flow velocity. The maximum settlement was observed for the 1V/cm gradient, resulting in early dissipation of pore water through the sample, which was confirmed by moisture content measurements. The current variation with time for constant voltage gradient application showed a decrease in current attributed to increased soil resistance and reduced electrical conductivity. Consolidation parameters were analyzed and discussed in detail. Further, scanning electron microscopy (SEM) and X-ray Diffraction (XRD) studies were carried out to study surface morphology, crystallographic structure phase composition of the material to compare the experimental results obtained.

Lastly, Chapter 7 provides a brief summary of the thesis and draws major conclusions from the research. Additionally, potential areas for future research on this topic was suggested.