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Analysis of the Consolidation Properties of Soil in the Mucherbari Regulator in Sunamganj

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Abstract
The consolidation properties of underground soil are very important parameter that is necessary for ensuring the stability of structures, designing high-rise foundations, river bank protection, dams, river erosion work, predicting settlement behavior, evaluating slope stability, etc. This research paper presents an experimental investigation and analysis of the consolidation properties of soil in the Muchibari Regulator, located in the district of Sunamgonj. The study aims to understand the consolidation behavior of the soil in this specific area, which is crucial for the design and construction of infrastructure projects. The research has involved conducting consolidation tests on soil samples collected from the site, followed by data analysis to determine the soil's consolidation parameters. The results obtained provide valuable insights into the settlement characteristics of the soil, contributing to the geotechnical understanding of the Muchibari Regulator and similar areas. It provides a framework for understanding how soils settle and deform under load over time. By understanding consolidation characteristics, engineers can make informed decisions in geotechnical engineering projects. The ASTM D2435 standard specifies the procedure for performing the consolidation test using consolidometers. Two important parameters are the coefficient of consolidation (Cv) and the coefficient of volume compressibility (mv) which are described in Karl von Terzaghi's consolidation theory. The experimental soil data from the location of Muchibari Regulator is calculated by the equation and graphically represented. For a maximum applied load of 10.112 $kgcm^{-2}$, the compression index (Cc) is 0.22045. Generally, a Cc value less than 0.1 is considered suitable for stable construction. It's important to note that this value can vary depending on the specific requirements and regulations in different regions.

Keywords: Undisturbed Soil, Consolidation Properties, Muchibari Regulator, The Coefficient Of Consolidation (C_v), Void Ratio (E), Karl Von Terzaghi Theory, Settlement.

Introduction
The quality of the soil is widespread. Different types of tasks are performed using different characteristics. Some of these features are used in geotechnical engineering to solve strategic problems. Undisturbed soil samples were collected at Muchibari in Sunamgonj district for the purpose of constructing regulators (3-vent with Boat pass). The study area provides an overview of the Muchibari Regulator project and the importance of understanding soil consolidation properties in its design and

construction. Soil consolidation is a geotechnical engineering process that refers to the gradual settlement and compaction of soil under the application of a sustained load. The consolidation process is governed by various factors, including the properties of the soil, such as its compressibility and permeability, the applied load, and the duration of loading. When a structure is built on or within the soil, the weight of the structure causes stress to be transferred to the underlying soil layers. This stress induces the consolidation process, which can continue over an extended period, ranging from weeks to years, depending on the characteristics of the soil and the magnitude of the applied load. Knowing the actual value of the coefficient of consolidation (cv) is necessary to forecast how much a structure built on a consolidated layer will settle. Time under load, load application technique, previous overburden load history, drainage conditions, and thickness of the consolidated layer are the main variables that affect the final cv value (Olek et al., 2016). It discusses the objectives of the research, which include determining the consolidation behaviour and parameters of the soil in the study area. The process of consolidation of soil refers to the process of expulsion of water from soil due to excess pore pressure, which is accompanied by a gradual reduction in soil volume and pressure transfer from water to soil particles. Karl von Terzaghi, considered by many to be the father of modern soil mechanics. He defined soil consolidation as "A process which involves a decrease in water content of saturated soil without replacement of water by air".

According to Terzaghi's consolidation theory, when a load is applied to a saturated soil layer, excess pore water pressure is generated within the soil due to the inability of water to instantaneously escape. The excess pore water pressure gradually dissipates as water slowly drains out of the soil. This process is known as consolidation. The theory assumes that the consolidation process can be described by two key parameters: the coefficient of consolidation (Cv) and the coefficient of volume compressibility (mv). Cv represents the rate at which excess pore water pressure dissipates, while mv measures the compressibility of the soil.

Since the Terzaghi consolidation theory was the first logical, quantitative method for addressing settlement issues, its debut in 1923 is considered the beginning of contemporary soil mechanics. The end of primary (EOP) settlement δ_p and the coefficient of consolidation c_v must be identified in order to apply the Terzaghi theory to settlement analysis in practice. Numerous techniques were created to estimate c_v and δ_p for the Terzaghi theory's use in settlement analysis (Al-zoubi, 2008). Terzaghi's theory introduces the concept of the consolidation settlement, which is the vertical deformation experienced by the soil due to the applied load. The settlement occurs as the excess pore water pressure dissipates and the soil particles rearrange themselves to accommodate the load. The consolidation theory is based on the assumption that the soil is fully saturated, homogeneous, and behaves as a linear elastic, isotropic, and homogeneous material. While these assumptions may be not true for all soil conditions, Terzaghi's consolidation theory remains an important opportunity for estimating settlement and understanding the time-dependent behavior of saturated soils in many geotechnical engineering applications.

The geographical location of Muchibari Regulator is at Jamalgonj Upazilla in the district of Sunamgonj. The Undisturbed soil samples were collected by BWDB, Sunamgonj O&M Division-1, Sunamgonj. The soil samples were tested in Soil Mechanics and Ground water Division's Laboratory in River Research Institute, Faridpur.

Methodology

The ASTM D2435 standard specifies the procedure for performing the consolidation test using consolidometers. Here's a general overview of the steps involved: The first step is to collect the soil specimen from the sample tube and eject the sample into a consolidation metal ring. The ring should be clean and dried, and its weight, inner diameter, and height should be measured using a electric balance and calipers, respectively. Then the soil sample is entered into the metal ring. Using hands, and it is taken out with the soil specimen. The soil specimen should project about 10 mm on either side of the metal ring. Now trim the excess soil content on the top and bottom of the rings using a spatula or fine metal wires. This excess soil can be used to measure the water content of the soil sample. Make sure that the ring does not contain any soil on its outer part, and weigh the metal ring with a soil specimen. Take two porous stones and saturate them by boiling them (15 minutes) or by submerging them (4 to 8 hours) in distilled water. Assemble the consolidometer. Place the parts of the consolidometer from bottom to top in the order beginning with bottom porous stone, filter paper, specimen ring, filter paper, and top porous stone. Place the loading pad on the top porous stone and lock the consolidometer using the metal screws provided. Mount the whole assembly on the loading frame and center it such that the load applied is axial. Arrange the dial gauge in such a way that it should allow sufficient space for the swelling of the soil specimen. A water reservoir is connected to the mounted assembly to saturate the soil. The water level in the water reservoir should be at the same level as the soil specimen. Now apply an initial load to the assembly. The magnitude of this load should be chosen by trial, so that there is no swelling. It should be not less than 50 gcm^{-2} for ordinary soils and 25 gcm^{-2} for very soft soils. The load should be allowed to stand until there is no change in dial gauge readings for two consecutive hours, or for a maximum of 24 hours.

The first load increment of 0.316 $kN^{1}cm^{-2}$ is applied, and the stop watch immediately notes down the readings of the dial gauge at various time intervals. In general, readings are taken at 6, 15, 30 seconds, then at 1, 2, 4, 8, 16, and 30 minutes, and at 1, 2, 4, 8, and 24 hours, respectively. In general, primary consolidation of soil (90% of consolidation) is reached within 24 hours. Hence, readings are noted for up to 24 hours. Next, apply the second load increment of 0.632 $kN^{1}cm^{-2}$ and repeat the same procedure as in 14th step. Similarly, apply the load increments of 1.264, 2.528, 5.056, and 10.112 $kN^{1}cm^{-2}$, repeat the same procedure, and note down the readings. When the value of the last load increment is noted, reduce the load to ¼ of the last load value and leave it for 24 hours. At this point, note down the dial gauge reading. Reduce the load again and again, and repeat the procedure until the load is 0.316 $kNcm^{-2}$. At every point, note down the final gauge readings. Now remove the assembly from the loading frame and dismantle it. Take out the specimen ring and wipe out the excess water. Weigh the specimen ring and note it down. Finally, put the specimen in the oven and determine the dry weight of the specimen. (Fundamentals of Soil Mechanics, Oxford University Press,2012)

Results and Discussion

Calculation for data analysis

Height of Solids, $H_s = W_s \div (G_s \times \gamma_w \times A)$ Eq.(1)

Height Voids, $H_v = H - H_s$ Eq.(2)

Void ratio, $e = H_v \div H_s$ Eq.(3)

Dial gauge reading Vs. logarithmic of time to determine the coefficient of consolidation (C_v).$C_v = 0.197 \times (d^2 \div t_{50})$ Eq.(4)

Dial gauge reading Vs. square root of time to determine the coefficient of consolidation(C_v),$C_v = 0.848 \times (d^2 \div t_{90})$ Eq.(5)

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The coefficient of consolidation can be determined by various methods. The results derived from various methods are different from each other (Sridharan and Prakash, 1998).

Table 1. Void ratio calculation for different pressure intensities and graphs plotting:

Applied Pressure ($Kgcm^{-2}$)	Scale load (Kg or ~~lb~~)	Final Dial Chang (~~cm~~ or inch)	2H-From Dial Change (~~cm~~ or inch)	Void HT. $2H-2H_0$ (~~cm~~ or inch)	Void Ratio. $(2H-2H_0)/H_0$	Fitting time in (Sec) t_{50} or ~~t_{90}~~	Coefficient of Cons $C_v(cm^2s^{-1})$ $0.197H^2/t_{50}$ or $0848H^2/$~~t_{90}~~
0.000	0	0	1	0.51602	1.06619		
0.316	1	0.0705	0.9295	0.44552	0.92052	300	0.98×10^{-3}
0.632	2	0.0915	0.9085	0.42452	0.87713	180	1.49×10^{-3}
1.264	4	0.1173	0.8827	0.39872	0.82383	81	3.14×10^{-3}
2.528	8	0.1475	0.8525	0.36852	0.76143	84	2.84×10^{-3}
5.056	16	0.181	0.819	0.33502	0.69221	39	5.69×10^{-3}
10.112	32	0.2188	0.7812	0.29722	0.61411	36	5.65×10^{-3}
2.528	8	0.212	0.788	0.30402	0.62816		
0.316	1	0.1943	0.8057	0.32172	0.66473		

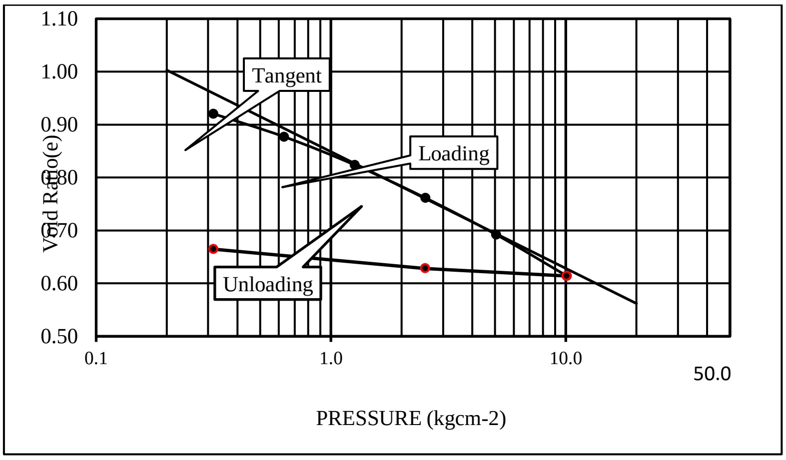

Fig. 1. Void Ratio-Log Pressure Curve

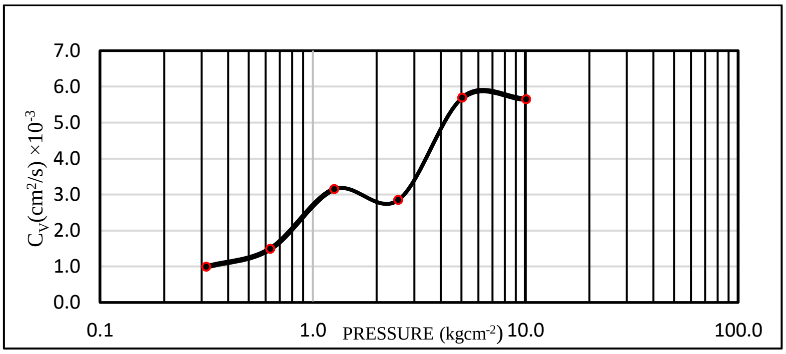

Fig. 2. C_V-Log Pressure Curve

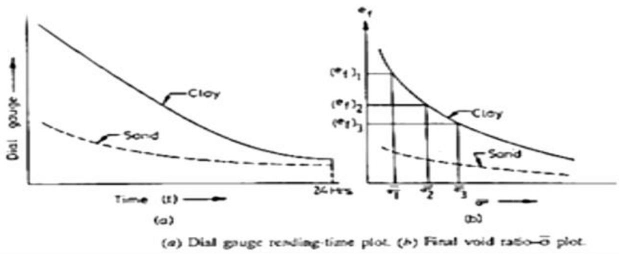

Fig. 3. Dial gauge Vs Time and Void Ratio Vs Effective Stress Graphs

Final void ratio Vs. Effective stress to determine the coefficient of compressibility (a_v) and coefficient of volume change (m_v).

$a_v = -(\Delta e/\Delta\sigma)$ $\quad$ $m_v = -\Delta e/(1+e) \times (1/\Delta\sigma)$

Final void ration Vs. logarithmic of effective stress to determine the compression index (C_c). $C_c = -\frac{\Delta e}{\log(1+\Delta\sigma/\sigma_0)}$

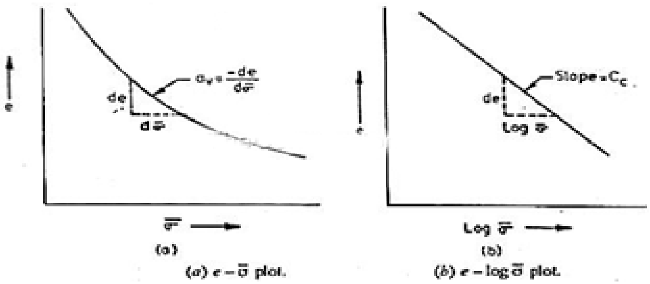

Fig. 4. Void Ratio Vs. logarithmic Effective Stress Graphs.

The tested soil samples were collected from the Muchibari Regulator site. The settlement-time data is graphically represented to illustrate the consolidation behavior of the soil. The data analysis section explains the application of Terzaghi's one-dimensional consolidation theory and other relevant models to determine the consolidation parameters, such as the compressive index (C_c) the coefficient of consolidation(C_v) and the coefficient of volume change (m_v). A lower compression index (Cc) indicates that the soil compresses less and has a smaller settlement under applied loads. It suggests that the soil is less compressible and more resistant to deformation. A lower value of m_v is considered better because it signifies that the soil has less volume change with variations in moisture content. Soils with low m_v values are typically more stable and less prone to settlement or swelling issues. Clayey soils, for example, tend to exhibit higher consolidation rates compared to sandy or gravelly soils due to their smaller particle sizes and higher water retention capabilities. Muchibari Regulator, a district of Sunamgonj located in northeastern Bangladesh, is known for its diverse soil types. The region mainly consists of alluvial soils, which are deposited by rivers and are typically composed of silt, clay, sand, and organic materials. The consolidation properties of soil are important in geotechnical engineering and construction projects, as they determine the settlement behavior of the soil under load. In-situ tests, such as the Standard Penetration Test (SPT) or Cone Penetration Test (CPT), provide data on the relative density and strength of the soil. These tests, combined with laboratory test results, help engineers assess the consolidation properties and design appropriate foundations for structures. This research explains and discusses the findings of the research in relation to the objectives and existing literature. Compares the consolidation parameters obtained in this study with published values for similar soil types. It discusses any discrepancies or deviations observed and their potential causes. This research addresses the limitations of the study and provides recommendations for future research or improvements to the experimental methodology.

Conclusion

The key is to summarize the important findings of this research and their applications for the design and construction of infrastructure projects in the Muchibari Regulator, located in the district of Sunamgonj and similar areas. It has emphasized the importance of understanding the consolidation properties of soil in ensuring the stability and durability of structures built on Such similar soil. This research is very importance for the design engineers to predict settlement, understand soil compressibility, assess consolidation rates, and make informed decisions regarding foundation design and construction techniques. Incorporating this knowledge into the design process helps ensure the stability, safety, and long-term performance of structures.

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