# EXPERIMENTAL STUDIES ON THE RATE OF REGAINING OF THE CEMENTITIOUS PROPERTIES OF DISTURBED LATERITIC SOILS CASE OF DILLA TOWN

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**Abstract**

The prevalence of lateritic soils in Ethiopia and various global regions, particularly in tropical climates, has sparked interest in utilizing these soils as construction materials. Early pioneers in soil mechanics and geotechnical engineering recognized the unique nature of lateritic soils, distinct from the materials they were accustomed to working with. A distinguishing feature of these soils is the presence of aluminum and iron sesquioxides, leading to a cementation effect that significantly impacts their engineering properties. Construction activities can disrupt this bond, causing a substantial loss of strength during remolding. However, these soils exhibit a reversible strength gain over time as physical bonds are gradually restored. Despite this, monitoring the long-term changes in these materials post-construction is not commonly practiced, making it challenging to predict their behavior. Therefore, it is crucial to investigate alterations in the engineering properties of lateritic soils over time. Four samples were collected from different locations in Dilla town, and laboratory tests were conducted to assess the impact of disturbance and the rate of cementation over time. Unconfined compression strength tests were performed at intervals of 0, 7, 15, 20, 30, and 55 days, while consolidation tests were conducted at 0, 7, 15, 30, and 55 days after remolding, followed by a specified resting period. The study results indicate that disturbed samples exhibited an increase in remolded strength by approximately 8.67-13.0% after a resting period of 55 days. Additionally, the compression index after remolding showed a decrease of about 4.9-6.8% after 55 days of resting. In both cases, the findings suggest a low degree of laterization in the lateritic soil of Dilla town. Notably, significant changes occurred within 30 days after remolding, with natural moisture content and density values of undisturbed samples playing a crucial role.

**Keywords:** Lateritic Soils, Unconfined Compression Strength, Compression Index, Sesquioxides

## 1 Introduction

Dilla town, serving as the administrative Centre of the Gedeo zone in the South Nation Nationality and Peoples (SNNPR), is positioned 360 km from Addis Ababa along the main road to Nairobi. The prevalent reddish-brown soil in the region, influenced by climate, drainage, topography, and parent rocks, may exhibit characteristics of lateritic soils. The distinctive red color is primarily attributed to the presence of iron oxide minerals. According to Addisu (2015), geochemical and index test results indicate that Dilla town's soil is lateritic, with high concentrations of iron oxide and aluminum oxide.

Lateritic soils, shaped by extensive weathering and alteration under tropical conditions, are rich in sesquioxides ($Fe_2O_3$ or $Al_2O_3$) and low in base and primary silicates. The unique properties of lateritic soils, found in tropical and subtropical regions, result from a hot, humid climate with no distinct winter, widespread moisture, and high annual rainfall (Huat et al, 2013).

The economic impact of lateritic soils on tropical and subtropical regions is substantial due to their extensive coverage. Widely employed in construction projects, lateritic soils serve various purposes, such as embankment dams, landfill foundations, and sub-base materials in road construction. Notably, the sesquioxides of iron and aluminum in lateritic soils play a crucial role in cementation, influencing their engineering properties (Wesley, 2010).

The primary objective of this study was to investigate changes in engineering characteristics, specifically unconfined compression strength and consolidation tests, over time following disturbance, considering the regaining of cementation in lateritic soils. Understanding the presence of sesquioxides in iron and aluminum is crucial for addressing geotechnical issues, given the impact on properties like shear strength and consolidation during construction activities. The degree of cementation in these soils varies, and its disruption can occur due to different construction activities, affecting shear strength and deformation behavior (Wesley, 2010). Shear strength and consolidation, vital engineering properties, are profoundly affected by the existence of bonds between particles and the disturbance of sesquioxides. The investigation focuses on the influence of sesquioxides after disturbance and the time rate of cementation on the engineering properties of lateritic soils in Dilla town.

The main objective is to investigate the time rate of regaining of cementation properties of disturbed lateritic soil in Dilla town on shear strength and consolidation properties. Specific objectives include categorizing the soil in Dilla town based on index properties,

indirectly assessing the effect of drying procedures on these properties, conducting field density tests on lateritic soils to determine the bulk density, and observing the impact of the time rate of regaining of cementation property on remolded samples and its effect on unconfined compression strength and consolidation characteristics of undisturbed lateritic soil samples in Dilla town.

Understanding the factors affecting the engineering behavior of lateritic soils is essential for their specific applications in road construction, landfill foundations, embankments, dams, etc. The research contributes valuable information on the effects of disturbance and the time rate of regaining of cementation properties on the shear strength and consolidation characteristics of these soils.

## 2 Literature Review

Residual soils, unlike conventional soils formed through additional processes post-weathering, are directly shaped by the physical and chemical weathering of parent material. They differ from sedimentary soils, which undergo erosion and transportation processes after weathering. Laterite, a term denoting red residual soils present in tropical and sub-tropical regions, was first identified by Buchanan in India in 1870. The geographical distribution of lateritic soils is widespread, primarily found between the Tropics of Cancer and Capricorn. However, favorable conditions for their formation have existed in various regions globally throughout geological history (Huat et al, 2013).

Lateritic soils are associated with tropical and subtropical environments, influenced by factors like climate, vegetation, parent material, drainage, and topography. Group C residual soils, with a focus on Dilla town, are strongly influenced by special clay minerals, particularly Halloysite and allophane. The influence of sesquioxides, acting as a cementing agent, plays a significant role in forming lateritic soils. The silica/sesquioxide ratio is used as an indicator of the degree of laterization, distinguishing true laterites, lateritic soils, and non-lateritic tropically weathered soils (Wesley, 2010).

Geochemical tests, as conducted by Addisu (2015), on soil samples from Dilla town, revealed the composition of major oxides, emphasizing hydroxides and oxides of aluminum, iron, and silicon. The ratio of silica/sesquioxides, denoted as R2O3, helps evaluate the degree of laterization. The sesquioxides of iron and aluminum play a crucial role by coating clay components, bonding them into coarser particles, and affecting the soil's shear strength. Amare's (2008) research on the compressibility properties of lateritic soil in Assossa highlights the decrease in permeability and increase in unconfined compressive strength due to regaining the soil's cementation nature over time.

Terzaghi et al (1996) emphasize the significance of practical experience in geotechnical engineering, considering

index properties as the foundation for minimizing errors in soil mechanics. Blight (2012) distinguishes tropical soils from sedimentary soils, noting their susceptibility to property changes through exposure to air and drying. Atterberg limits serve as valuable indicators for evaluating and characterizing residual soils. The position of soils on the plastic chart helps assess their engineering properties, with soils under the A-line exhibiting good properties. The effect of pre-test drying, duration, and method of mixing is crucial in determining Atterberg limits, with over-manipulation potentially leading to misleading results (Wesley, 2010).

The effect of pre-test drying on Atterberg limits, discussed by Addiszemen et al (2015), revealed that air-dried samples exhibit higher liquid limits and plasticity indices than oven-dried samples. Duration and method of mixing also influence Atterberg limits, with longer mixing times resulting in higher values due to excessive manipulation. Water content determination involves examining the loss of water when soil is dried to a steady mass. Specific gravity (Gs) is crucial for calculating volumetric parameters, with residual soils potentially exhibiting lower specific gravity due to the presence of iron sesquioxide or porous aggregation of particles (Blight, 2012).

Addiszemen et al (2015) noted that the insitu specific gravity of laterite soils in Ethiopia ranges from 2.69 to 3.02, with coarse-grained soils exhibiting higher values. The literature on lateritic soils has predominantly focused on index properties, and few studies have explored their engineering properties in connection with sesquioxide cementation. This research aims to fill this gap by investigating the engineering properties of lateritic soil in Dilla town, contributing to the existing literature for future studies.

## 3 Materials and Methods

The study area, located in Dilla, Southern Nation Nationalities and Peoples Region (SNNPR), is characterized by coordinates of 6º24’38” N latitude and 38º18’37” E longitude, with an elevation of 1570m above sea level. Dilla, part of Wenago Woreda and enclosed by Dilla Zuria Woreda, experiences a bimodal rainfall pattern with an average annual temperature of 20.6 ◦C and an annual rainfall ranging from 1062.10mm to 1669.70mm. The geological formation includes trachyte flows, minor basalts, tuffs, and ignimbrites, forming diverse layers covered by alluvial soil (The World Bank, 2010).

Materials and methods involve various field and laboratory techniques. Field tests utilize a core-cutter apparatus for undisturbed and disturbed samples. In contrast, laboratory tests include specific gravity, Atterberg’s limit, moisture content, unconfined compressive strength (UCS) test, and one-dimensional consolidation test. Pycnometer, Casagrande apparatus, unconfined compression test equipment,

and an odometer are among the laboratory equipment employed. The core-cutter apparatus, consisting of a mild steel cutting ring and a dolly, is used for undisturbed samples by ramming it into the soil with a jack. Laboratory tests, such as Atterberg's limit, involve sample preparation, where samples passing a 425$\mu$m sieve are kept wet for 24 hours before testing. Both oven-drying and air-drying mechanisms are employed to observe the temperature's effect on Atterberg limits. Moisture content determination is based on ASTM D2216-98 standard, considering water loss during soil drying at 105-110°C. Specific gravity (Gs) is determined as the ratio of soil solids' weight to the weight of water of equal volume.

The UCS test, following the ASTM D2166 standard, aimed to determine the compressive strength of soils exhibiting optimal cohesion. The testing involved 4 undisturbed and 24 remold samples. Initially, the field density and natural moisture content of the soil samples were assessed in the laboratory. Subsequently, the soil samples were air-dried in the lab until a constant mass was achieved. To match the water content of undisturbed samples, water was added to the dried soil samples.

The unconfined compression test employed soil samples with a 38mm diameter and 76mm height. The sample volume and field density were determined in the laboratory. The sample mass was calculated to achieve the field density, and then the mass was equally divided and compacted layer by layer using a laboratory hammer. If any soil was lifted after compaction, adjustments were made through trial and error to ensure even distribution. Initial tests were performed on undisturbed and disturbed samples at t=0 to assess the soil sample's sensitivity and the unconfined compression strength of undisturbed samples.

Remold samples were packed and air-soaked to maintain moisture content. Unconfined compression tests were conducted at different intervals of 7, 15, 20, 30, and 55 days, based on Amare's (2008) research, which indicated that the time rate of cementation was significantly influenced within the first 30 days, remaining constant after that. The one-dimensional consolidation test aims to assess the compressibility of saturated fine-grained soils, a phenomenon known for its time-dependent nature. In this research, the testing protocol followed the ASTM D2435-96 standard. A total of 4 undisturbed and 20 remolded samples were designated for the test. Initially, laboratory tests were conducted to determine the field density and natural moisture content of the soil samples. The soil samples were then subjected to air drying until a constant mass was achieved. To match the water content of

undisturbed samples, an appropriate amount of water was added to the dried soil samples. The consolidation test employed soil samples with a diameter of 50mm and a height of 20mm, and the sample volume and field density were established in the laboratory.

The sample mass was calculated to achieve the desired field density, and the mass was evenly divided for compaction on the sample ring using a laboratory hammer in a layer-by-layer fashion. In cases where soil was left after compaction, adjustments were made through trial and error to ensure an even distribution of the soil mass on the sample ring. Experienced laboratory technicians were essential for the successful execution of this test. At t=0, tests were conducted on both undisturbed and disturbed samples to determine the compression index. Remold samples were enclosed in plastic and soaked in water to maintain moisture content, allowing them to rest for a maximum of 55 days to observe the effect of the time rate of cementation. Consolidation tests were then conducted at intervals of 0, 7, 15, 30, and 55 days, based on Amare's (2008) research, which indicated that the time rate of cementation is significantly influenced within the initial 30 days and remains constant thereafter.

## 4 Result and Discussions

In this investigation, the assessment of soil sample moisture content in the laboratory adhered to the protocols outlined by Blight (2012). The drying techniques applied included air drying at 50◦C with a maximum relative humidity (RH) of 30% and oven drying at 105◦C. The researcher systematically organized the test outcomes in Table 1 to elucidate the repercussions of moisture content determination. This detailed examination focused particularly on delineating the influence of temperature variations on the process.

**Table 1** Effect of Temperature on Moisture Content Determination

| Sample designation | Sampling depth(m) | Air dried | Oven-dried | Difference [%] |
|---|---|---|---|---|
| **TP1-1** | 3.0 | 32.45 | 33.53 | 3.2 |
| **TP2-2** | 3.0 | 29.84 | 30.06 | 0.7 |
| **TP3-3** | 3.0 | 36.46 | 37.03 | 1.5 |
| **TP4-4** | 3.0 | 33.75 | 34.45 | 2.0 |

Note: Air-dried moisture content is determined through air drying, and oven-dried moisture content is determined through oven drying.

The results in Table 1 indicate that the variation in dry conditions is less than 4%, demonstrating the insignificance of structural water. Consequently, for the remainder of the research, moisture content determination was consistently conducted through oven drying at 105◦C. Many Ethiopian laterite soils, including those examined in this research, exhibit a minimal amount of water

of hydration or structural water, making the use of conventional oven drying at 105◦C suitable for moisture content tests. Therefore, the ASTM D2216-98 standard test method for laboratory determination of moisture content is considered acceptable for determining the natural moisture content of Ethiopian laterite, as indicated by Addiszemen et al (2015). Additionally, all remolded samples in this study were adjusted to match the natural water content of the undisturbed samples, determined through the conventional oven drying method at 105◦C, as detailed in Table 1.

The Atterberg limits serve as a valuable tool for assessing and characterizing lateritic soils, providing insights into the consistency of fine-grained soils. The determination of Atterberg limit values was carried out using both air-dried and ovendried soil samples, following the procedures outlined in ASTM D4318-00. For oven sample preparation, soil samples were dried overnight at 105◦C, while air-dried samples were prepared by either placing them in an oven at 50◦C with a relative humidity of 30% for at least 5 days or by exposing the soil samples to open air in the soil laboratory for a minimum of 10 days. The soil laboratory maintained a room temperature of approximately 19.8◦C. These varied sample preparation methods were employed to assess the impact of sample preparation on lateritic soils in Dilla town. Table 2 presents the outcomes of the Atterberg limit tests conducted under different conditions of sample preparation, comparing the effects of oven-drying (OD) and air-drying (AD) on the plasticity characteristics of the investigated lateritic soil samples. The results, as illustrated in Table 2, indicate that the diverse temperature treatments exert an influence on the Atterberg limits of these specific soils.

Notably, the air-dried samples exhibit liquid limits somewhat higher than those of the oven-dried samples across the entire sample set. These findings align with the broader observations made by Blight (2012). These results underscore the need for careful consideration of sample preparation methods in evaluating the plasticity characteristics of lateritic soils.

**Table 2** Atterberg limit values at different testing conditions

| Sample Designation | Sample Depth | Condition | Liquid limit (%) | Plastic limit, (%) | Plasticity index (%) |
|---|---|---|---|---|---|
| TP1-1 | 3 | AD | 66 | 36 | 30 |
| | | OD | 61 | 33 | 28 |
| TP2-2 | 3 | AD | 65 | 29 | 36 |
| | | OD | 62 | 28 | 34 |
| TP3-3 | 3 | AD | 63 | 35 | 28 |
| | | OD | 62 | 34 | 27 |
| TP4-4 | 3 | AD | 65 | 36 | 29 |
| | | OD | 61 | 34 | 27 |

The specific gravity (Gs) is the ratio of the weight of soil solids to the weight of an equal volume of distilled water at the same temperature. In this study, the ASTM D854-58 standard test procedure was employed to determine the specific gravity of the examined sample. The experiment involved

conducting the test under two different dry conditions to assess the impact of pre-test drying on specific gravity values. Typically, the specific gravity of residual soil can vary, being either consistently high or low based on mineralogy (Blight, 2012).

**Table 3** Specific Gravity Comparison by Different Drying Conditions after Testing

| Sample designation | Sample Depth | Condition | |
|---|---|---|---|
| | | Oven-dried | Air dried |
| TP1-1 | 3 | 2.82 | 2.88 |
| TP2-2 | 3 | 2.91 | 3.07 |
| TP3-3 | 3 | 2.75 | 2.84 |
| TP4-4 | 3 | 2.75 | 2.83 |

Table 3 presents the specific gravity values obtained under different pre-test drying conditions. A noticeable trend is observed, with air-dried samples exhibiting higher specific gravity values. This is attributed to the loss of water or crystallization from clay minerals during oven-drying or conventional oven-drying methods, leading to a reduction in the density of the solid matter.

**Table 4** Classification According to USCS

| Sample Designation | Sample Depth | Condition | Liquid limit (%) | Plastic limit (%) | Plasticity index (%) | Classification According to USCS value |
|---|---|---|---|---|---|---|
| TP1-1 | 3 | AD | 66 | 36 | 30 | MH |
| | | OD | 61 | 33 | 28 | MH |
| TP2-2 | 3 | AD | 65 | 29 | 36 | MH |
| | | OD | 62 | 28 | 34 | MH |
| TP3-3 | 3 | AD | 63 | 35 | 28 | MH |
| | | OD | 62 | 34 | 27 | MH |
| TP4-4 | 3 | AD | 65 | 36 | 29 | MH |
| | | OD | 61 | 34 | 27 | MH |

Consequently, it is recommended to test the specific gravity of lateritic soils at their natural moisture content to prevent a decrease in measured specific gravity, as suggested by previous research (Addiszemen et al, 2015).

Wesley (2010) categorizes residual soil based on mineral composition and pedological classification factors such as climate, drainage, topography, and parent material. The classification follows the Unified Soil Classification System (USCS), as outlined in Table 4. In this classification, the majority of values fall below the A-line on the plasticity chart, indicating an MH classification. Research conducted by Addisu (2015) and Addiszemen et al. (2015) on the classification of Dilla town and Ethiopian lateritic soils, respectively, using the USCS method, revealed that a significant portion of the samples falls within the MH category.

The findings reveal that the measured sensitivities generally fall within the range of 1.49 to 2.33, categorizing them as "little sensitive" to "moderate sensitive" according to Rosenqvist (1953). Amare (2008) found in a study on the sensitivity of lateritic soils in Assossa that high sensitivity corresponds to low remold strength, as the presence of iron and aluminum sesquioxides increases sensitivity. The remolded material underwent remolding and resting, and the strength characteristics of Dilla town's lateritic soils

**Table 5** Strength of Undisturbed and Remolded Samples over Time

| Sample Identification | The Unconfined Compression Strength of the Undisturbed Sample (kN/m$^2$) (Undisturbed Clay (qu)u | The Unconfined Compression Strength of Disturbed Sample (kN/m$^2$) Remolded Clay (qu)r | The Sensitivity of the Sample | The Unconfined Compression Strength of Remolded Sample with Time (kN/m$^2$) | Increase of Remolded Unconfined Compression Strength in % with time | Regain of Undisturbed Unconfined Compression Strength in % with time | The Time Rate of Regaining Cementation(days) |
|---|---|---|---|---|---|---|---|
| TP1 | 337.82 | 146.37 | 2.31 | 153.074 | 4.584 | 3.504 | 7 |
| | | | | 159.527 | 8.992 | 6.875 | 15 |
| | | | | 161.296 | 10.201 | 7.799 | 20 |
| | | | | 162.963 | 11.340 | 8.669 | 30 |
| | | | | 163.156 | 11.472 | 8.770 | 55 |
| TP2 | 390.46 | 167.89 | 2.33 | 176.184 | 4.940 | 3.726 | 7 |
| | | | | 185.063 | 10.228 | 7.715 | 15 |
| | | | | 187.456 | 11.653 | 8.791 | 20 |
| | | | | 188.912 | 12.521 | 9.445 | 30 |
| | | | | 189.757 | 13.024 | 9.824 | 55 |
| TP3 | 218.10 | 146.67 | 1.49 | 151.388 | 3.218 | 6.608 | 7 |
| | | | | 155.104 | 5.752 | 11.810 | 15 |
| | | | | 156.216 | 6.510 | 13.367 | 20 |
| | | | | 158.883 | 8.328 | 17.101 | 30 |
| | | | | 159.621 | 8.831 | 18.134 | 55 |
| TP4 | 211.99 | 122.646 | 1.73 | 126.265 | 2.951 | 4.051 | 7 |
| | | | | 129.903 | 5.917 | 8.122 | 15 |
| | | | | 130.997 | 6.809 | 9.347 | 20 |
| | | | | 132.944 | 8.397 | 11.526 | 30 |
| | | | | 133.276 | 8.667 | 11.898 | 55 |

***Notes***: indicate that the rise in remolded unconfined compression strength is determined by the ratio $\frac{qu_o - qu_r}{qu_r}$ while the recovery of undisturbed unconfined compression strength is defined by the ratio $\frac{qu_o - qu_r}{qu_u - qu_r}$Here, (qu)r, (qu)o, and (qu)u represent the unconfined compression strength at time = 0, the unconfined compression strength of remolded samples over time, and the unconfined compression strength of undisturbed samples, respectively.

were examined. The remolded samples were stored at their natural water content and field density in sealed plastic bags, mimicking undisturbed samples. Unconfined compression tests were conducted after a resting period ranging from 7 to 55 days. Results showed an increase in remolded unconfined compression strength by 8.67% to 13.0% within 55 days (Table 5). These results affirm that remolded samples exhibit enhanced unconfined compression strength due to sesquioxides recovery over time.

The study also confirms that Group C residual soil, specifically lateritic soils, classified by Wesley (2010), exhibit a strong mineralogical influence not present in sedimentary or conventional soils. This influence stems from the presence of aluminum and iron sesquioxides in the soil mass, affecting shear strength. Generally, lateritic soils in Dilla town are influenced by sesquioxides in engineering properties like unconfined compression strength after disturbance. Figure 1 illustrates the strength increase of freshly remolded material after a resting period of up to 55 days. The time-dependent cementation of iron and aluminum sesquioxides contributes to the rise in unconfined compression strength within thirty days, with a gradual increase observed over the subsequent twenty-five days post-remolding.

The variations in failure patterns between undisturbed and remolded samples are due to their inherent properties. As depicted in Figure 2, the undisturbed sample exhibits a rapid increase in shear stress, peaking at low shear strains before decreasing with further shear strain, a behavior known as strain-softening. This strain-softening is associated with the formation of shear bands, which are localized failure zones where the soil loosens and reaches the critical state of shear stress.

In contrast, remolded samples, which characterize normally consolidated or lightly overconsolidated clays, exhibit a steady rise in shear stress as shear strain increases, eventually stabilizing at a constant shear stress termed the critical state shear stress. These soils also undergo compression and densification until they reach a stable void ratio, referred to as the critical ratio. As a result, the findings highlight that the recovery process has a significant mineralogical impact on the remolded unconfined compression strength, demonstrated by a decreasing shear strain over time, as illustrated in Figure 2. The consolidation behavior of the undisturbed samples leads to higher strength and stiffness, which is evident from the unconfined compression tests conducted on the lateritic soil samples. These material characteristic differences result in distinct failure patterns in UCS test results, highlighting the impact of soil consolidation and density on their mechanical properties and failure mechanisms.

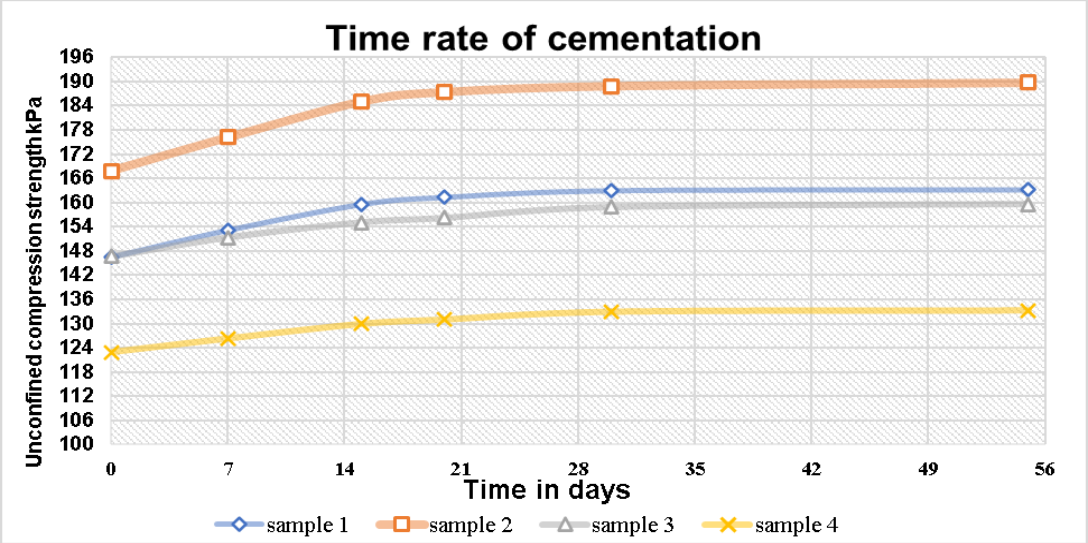



**Figure 1** The Effect of Regaining Cementation on Unconfined Compression Strength

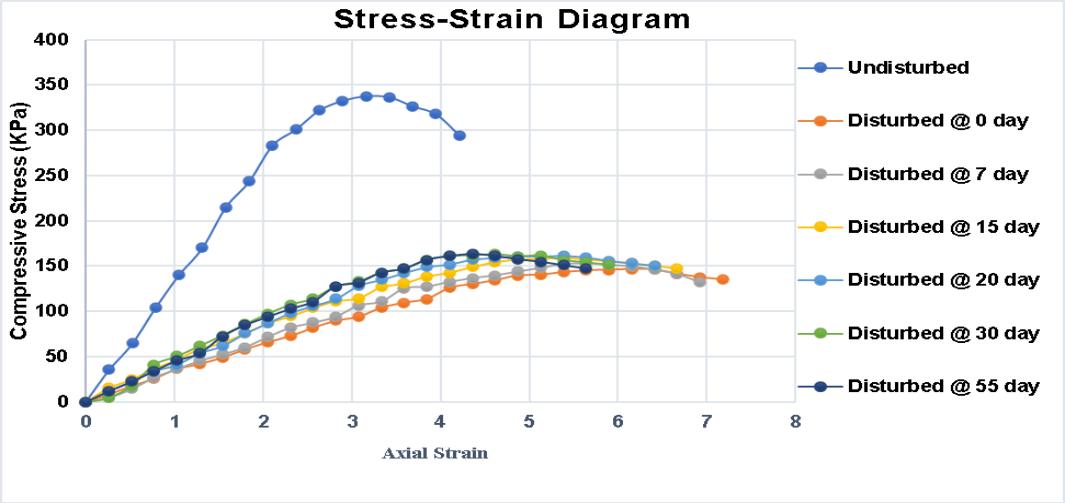



**Figure 2** Stress-Strain Diagram for Undisturbed Sample and Disturbed Sample with Time for Sample 1

Notes: The reduction in the remolded compression index is expressed as the ratio (CcoCcr)/Ccr, while the recovery of the undisturbed compression index is characterized by the ratio (Cco-Ccr)/(Ccu-Ccr), where Ccr, Cco, and Ccu represent the

compression index at time=0, the compression index of the remolded sample over time, and the compression index of the undisturbed sample, respectively.

To comprehensively investigate the sustained recovery of the compression index postdisturbance in specimens, an extensive resting period of fifty-five days was implemented. Within this duration, meticulous remolding of the specimens occurred, accompanied by a precise measurement of the compression index. These remolded samples, meticulously adjusted to align with the moisture content and bulk density of undisturbed counterparts, underwent immersion in water to maintain uniform moisture levels. Subsequently, a series of subsequent resting periods were introduced, spanning 7, 15, 30, and 55 days, strategically designed to scrutinize the evolving impact of recommendation on the compression index of the initially disturbed samples. This comprehensive investigative framework provided a nuanced understanding of the interplay between varying resting durations and the recovery dynamics of the compression index. Such in-depth analyses are crucial for discerning the intricate temporal aspects influencing soil behavior, contributing valuable insights to geotechnical studies and engineering practices.

The findings from consolidation tests indicate that a resting period of fifty-five days is necessary for the compression index to stabilize. Notably, the regaining of sesquioxide (cementation effect) appears to exhibit a significant impact within the initial 30 days. According to James and Soga (2010), the destruction of undisturbed soil characteristics during the remolding process can be reversible or irreversible, with cementation identified as a major factor influencing remold characteristics.

Table 6 reveals a reduction in there mold compression index (Cc) of lateritic soil from Dilla town by approximately 4.9% to 6.8% after a resting period of 55 days. This decrease suggests that the alteration in the remold compression index post-disturbance of undisturbed samples is influenced not solely by the disturbance of iron and aluminum sesquioxides in lateritic soils but also by various factors outlined by James and Soga (2010). Consequently, the results indicate that the recovery process exerts a robust mineralogical influence on the remold compression index of specimens. The distracting properties of lateritic soils seem to reflect the mineralogical composition of aluminum and iron sesquioxides, impacted during the gradual regaining of mineralogical bonding over time.

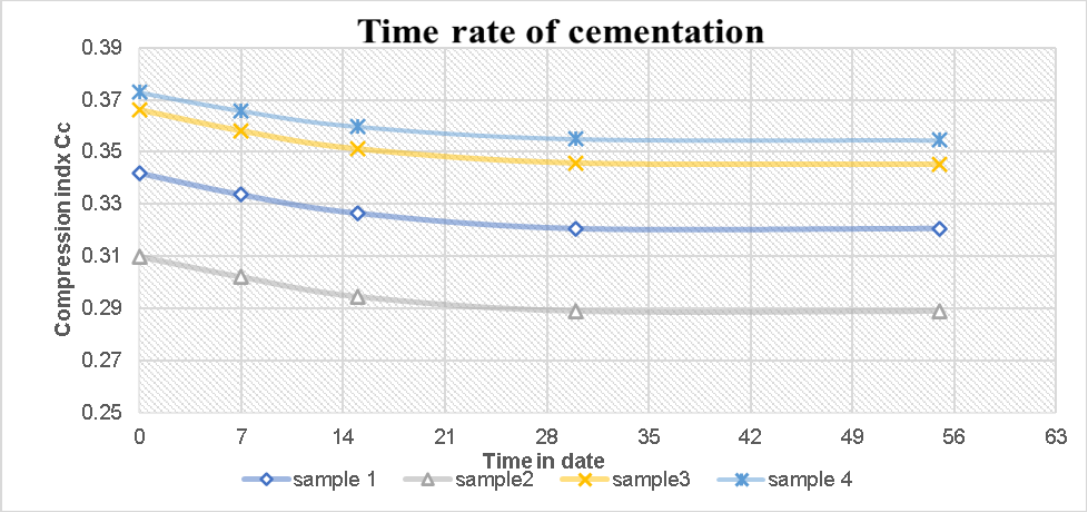



**Figure 3** The effect of Regaining Cementation on the Compression Index

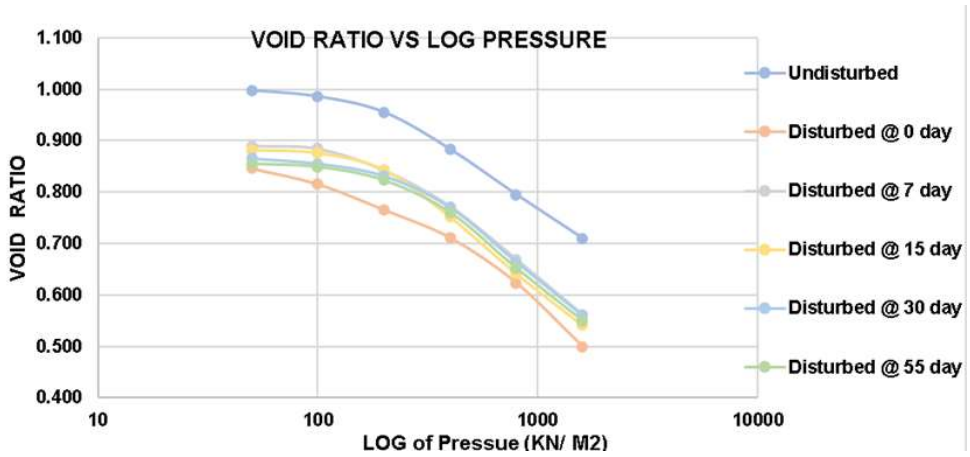



**Figure 4** e-log P Graph for Undisturbed Sample and Disturbed Sample with Time for Sample 3

The reduction in the compression index is linked to the heightened cementation attributes exhibited by iron and aluminum sesquioxides, which act as potent binding agents. This observation underscores a prolonged phenomenon where, as the remolded sample is kept over an extended period, the binding effectiveness of these cementing agents intensifies. Consequently, this gradual enhancement in binding efficacy progressively hinders the permeation of water through the soil, reflecting a dynamic and prolonged impact on the soil's structural behavior.

**Table 6** Summary of the Compression Index of Undisturbed and Remolded Samples after Testing

| Sample Identification | The Compression Index (Cc) of Undisturbed Sample | The Compression Index (Cc) of Disturbed Sample at Time=0 | The Compression Index (Cc)of Disturbed Sample in Time | The Decreased Remolded Sample in Compression Index (Cc) with Time in % | Regain of the Undisturbed Compression Index (Cc) in Time % | Time rate of Regaining Cementation in (days) |
|---|---|---|---|---|---|---|
| **TP1** | 0.243 | 0.342 | 0.3336 | 2.449 | 8.461 | 7 |
| | | | 0.3264 | 4.550 | 15.719 | 15 |
| | | | 0.3205 | 6.300 | 21.764 | 30 |
| | | | 0.3205 | 6.300 | 21.764 | 55 |
| **TP2** | 0.231 | 0.31 | 0.3021 | 2.540 | 9.967 | 7 |
| | | | 0.2946 | 4.978 | 19.534 | 15 |
| | | | 0.2890 | 6.780 | 26.605 | 30 |
| | | | 0.2889 | 6.800 | 26.684 | 55 |
| **TP3** | 0.261 | 0.366 | 0.3580 | 2.175 | 7.581 | 7 |
| | | | 0.3512 | 4.041 | 14.085 | 15 |
| | | | 0.3459 | 5.500 | 19.170 | 30 |
| | | | 0.3454 | 5.628 | 19.619 | 55 |
| **TP4** | 0.294 | 0.373 | 0.3659 | 1.898 | 8.959 | 7 |
| | | | 0.3599 | 3.524 | 16.639 | 15 |
| | | | 0.3551 | 4.800 | 22.663 | 30 |
| | | | 0.3546 | 4.923 | 23.244 | 55 |

The analysis of the test results, as portrayed in Figure 3 and Figure 4, underscores a distinct and substantial decrease in the compression index (Cc) value across all four samples within the initial 30 days post-disturbance. This decline serves as a tangible indicator of an amplified presence of the cementation agent, specifically iron and aluminum sesquioxides, during this particular timeframe. Furthermore, over the subsequent 25 days of preserving the soil samples, there is a modest decrease in the compression index, aligning harmoniously with the conclusions drawn by Amare in 2008. Amare's observations revealed a gradual and sustained rate of sesquioxide cementation during this specific duration, thus providing additional support and validation to the broader experimental dataset.

## 5 Conclusions

Based on a meticulous examination of laboratory tests conducted in Dilla town, the following conclusions have been drawn:

- Prolonged preservation of remolded soil samples is associated with a rise in the unconfined compression strength of lateritic soils in Dilla town. The duration following remolding has a substantial impact on the values of the unconfined compression strength (UCS). Remolded materials, kept at their natural water content and bulk density, exhibited a significant improvement in unconfined compression strength (8.67 to 13.0%) after a resting period of up to fifty-five days. This enhancement is ascribed to the cementation properties of sesquioxides, which serve as binding agents, fostering particle cohesion over an extended period.
- The sesquioxides of iron and aluminum assume a pivotal role in diminishing the compression index of remolded samples as time progresses. This decline takes place as the sesquioxides gradually reinstate their cementation effect during a resting period extending up to fifty-five days. The compression index of remolded lateritic soils in Dilla town manifests a reduction (4.9-6.8%) after the resting period, suggesting a constrained degree of laterization in these soils. This observation underscores the intricate and time-sensitive interplay between sesquioxide dynamics and the compression index in the lateritic soils of Dilla town.

- An exploration into the consequences of drying on the determination of moisture content in Dilla lateritic soils uncovers the absence of ”water of hydration” or ”structural water” in these soils, resulting in inconsequential and reversible changes during the drying process. The marginal variance in moisture content (below 4%) renders the drying effect inconspicuous in the lateritic soils of Dilla town. Consequently, an oven temperature of 105°C is considered appropriate for determining water content in these soils, providing valuable insights into their moisture dynamics.
- In adherence to the Unified Soil Classification System (USCS), it is noted that all soil specimens are categorized as MH (inorganic silt). This classification, situated below the A-line on the plasticity chart, corresponds to the prevailing categorization observed in the majority of examined laterite soils across Ethiopia.

- The outcomes of the specific gravity tests reveal values spanning from 2.75 to 2.81, exceeding the conventional range of 2.65 to 2.7 typically observed in temperate regions. This elevated specific gravity is ascribed to the heightened concentration of iron oxides. As evidenced in this study, lateritic soils showcase a distinctively elevated specific gravity, fluctuating between 2.6 and 3.4, indicating a noteworthy deviation from the norms encountered in temperate zones.

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