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The Effect of Mineral Composition and Quantity of Fines on the Atterberg Limits and Compaction Characteristics of Soils

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Abstract

Because of the various elements that come into play in natural soil formation, the impact of varied proportions of mineral composition and fines amount on Atterberg limits and compaction characteristics of soils is not well known. Three distinct soil samples were used in this investigation. The findings indicated the effect of varied mineral composition proportions and fines amount on the liquid limit, plastic limit, and plasticity index as assessed by the Casagrande test and hand-rolling method. The fluctuation of maximum dry density and optimal moisture content with these three soils has also been studied. Furthermore, correlations were established to indicate the compaction parameters and the amount of minerals and particles in the soil. The data show that the mineral content of the soil has a direct impact on the Atterberg limits and compaction characteristics. Soils containing larger percentages of expansive minerals, such as montmorillonite, have more flexibility and volume change capability. Mineral composition influences compaction parameters such as maximum dry density, ideal water content, axial strain, and axial stress. Soils with a larger proportion of fines, such as Soil 2 and Soil 3, have stronger flexibility and lower compaction qualities, with higher ideal water content and lower maximum dry density. Soil 1 has moderate flexibility and intermediate compaction qualities due to its low fines percentage. The effect of different mineral compositions and fines on the Atterberg limits and compaction characteristics of soils can be used to predict the behavior of compacted soils encountered in engineering practices, reducing the time and effort required to assess soil suitability for engineering use.

Keywords

Atterberg Limit, Mineral Composition, Quantity of Fines, Maximum Dry Unit Weight, Optimum Water Content

1. Introduction

Field compaction is a critical process in earthwork construction where compaction effort is applied to soil particles, causing them to be compressed and brought closer together. As a result, the soil mass experiences growth in strength of shear, reduced compressibility, and decreased permeability, making it more suitable for construction purposes. The borrowed material must be compressed to form the ground embankments in engineering projects like embankments of roads, earth-fill dams, river dikes, and formations of railways. To avoid the earth-based buildings from collapsing, it is necessary to carry out site compaction management of the borrowed materials after their location has been determined [1]. The soil particles are densely packed, resulting in a decreased void ratio. This reduction in voids makes it more challenging for water or another fluid to permeate over the soil mass.

Soil's type and size of its grains are significant factors in the compaction process, as they influence the lowering of void spaces and subsequent increase in bulk density [2]. Optimum water content and maximum dry unit weight are important factors in soil compaction that are determined through laboratory testing [3]. Various factors, such as the type of soil, size of particles, specific gravity, the shape of particles, and the quantity and type of minerals in clay, greatly affect the optimal moisture content and maximum dry density of soil [4].

Soils with fine grains are mainly contained in silt, sand, and clay fractions, with clay minerals being the active components within these soils [5]. The effects of mineral composition and fines content on the Atterberg limits and compaction properties of three distinct soil samples are investigated in this study. The Casagrande test for liquid limit, hand rolling method for plastic limit, sieve analysis and hydrometer test for particle size distribution, Proctor compaction test to determine maximum water content and maximum dry density, and unconfined compressive test for strength and deformation properties were all used in the study. X-ray diffraction (XRD) examination is also used to determine the mineral composition of soils.

2. Literature Review

2.1. Soil Properties and Their Significance in Construction

Soil is an essential natural resource with diverse properties that make it a crucial element in construction projects. The behavior of soil under different loading conditions depends on its properties, including its composition, structure, and moisture content. These properties influence the stability, strength, and deformation of soil, which are critical factors in construction design, foundation engineering, and soil improvement techniques [6]. Soil properties can be broadly classified into two categories: physical and chemical. The physical properties include texture, structure, density, and moisture content, while the chemical properties include pH, nutrient content, and organic matter content. These properties affect the behavior of soil under different loading conditions, making it essential to understand their characteristics and influence on soil behavior [7]. The properties of soil can be broadly classified into two categories: physical and chemical. The physical properties include texture, structure, density, and moisture content, while the chemical properties include pH, nutrient content, and organic matter content. These properties affect the behavior of soil under different loading conditions, making it essential to understand their characteristics and influence on soil behavior [8].

In construction, soil properties have a significant function in determining the suitability of a site for a particular project. The soil's bearing capacity, shear strength, and settlement characteristics are critical factors in designing structures and foundations that have the ability to endure the various pressures and stress they will experience throughout their lifetime. The properties of soil are also essential in determining the suitability of the soil for assorted applications of engineering, such as embankments, retaining walls, and pavements. The significance of soil properties in construction is evident in the range of testing and evaluation techniques that have been developed to assess soil behavior. These techniques include experiments in the laboratory such as Atterberg Limits, Proctor Compaction test, and Triaxial Compression, as well as field experiments such as Standard Penetration, Cone Penetration, and Plate Load Test.

2.2. Soil Mineral Composition

Different types of soil minerals have different properties that can impact their behavior under load or stress. According his book [7] Kaolinite, Montmorillonite, and Illite， these clay minerals are commonly found in soil and can significantly affect its engineering properties. Quartz is a common mineral found in soil that has a high resistance to weathering and erosion. Feldspar is another common mineral found in soil that can affect its engineering properties. Calcite is a mineral found in soils that can affect its shear strength and stiffness. Iron oxide minerals, such as hematite and goethite, are commonly found in soil and can affect its color, as well as its strength and stability.

Clay soils tend to have low permeability, high plasticity, and high compressibility, which can make them challenging to work with in construction [9]. Soils with high quartz content tend to be more stable and less susceptible to settling, which can make them more suitable for construction, and high feldspar content in soil decreases strength and stability due to their susceptibility to weathering and erosion [10]. High calcite content in soil has higher strength and stiffness, which can make them more suitable for construction [11].

3. Methodology

3.1. Description of the Study Area and Preparation of Soil Sampling

This research is conducted in northern Cyprus' Haspolat districtas shown in

Figure 1. This region's unique geological and geomorphological features make it excellent for studying soil qualities and their causes. The Haspolat area lies in the Kyrenia Mountains, which run along Cyprus' northern coast and feature hills, valleys, and plateaus. Tectonic and erosional processes formed the region's limestone, dolomite, and chalk formations. The Haspolat region's unusual combination of geological, geomorphological, and climatic elements makes it excellent for researching the intricate interactions between soil attributes and their underlying determinants, revealing its soil features and behavior. Three distinct soil types were used for this investigation, as shown in Figures 2(a)-(c), and chosen from different places in the study area. These rigorous soil sample and preparation processes created a firm platform for later laboratory investigations, allowing for an accurate assessment of mineral impacts.

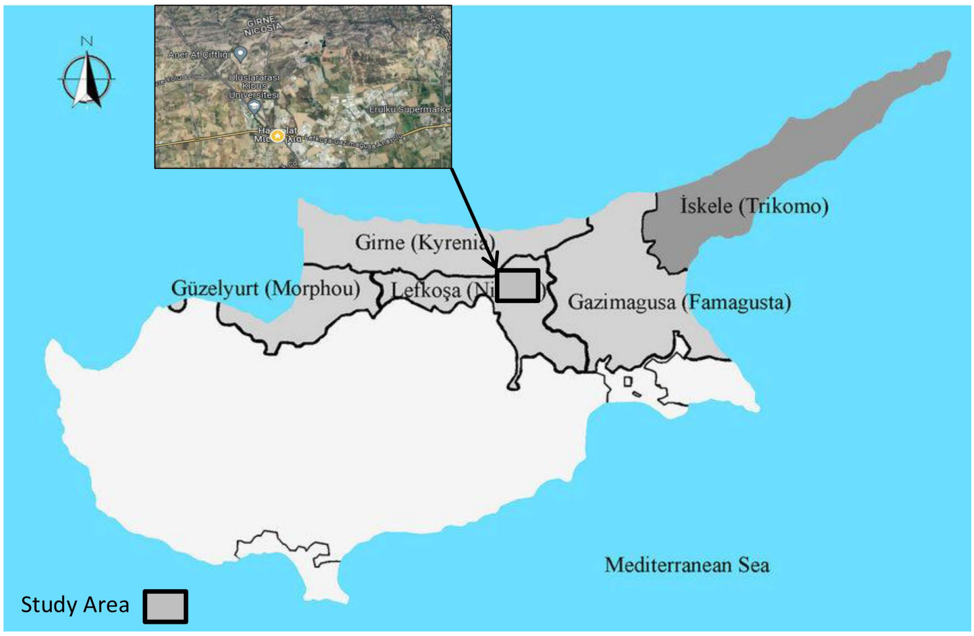
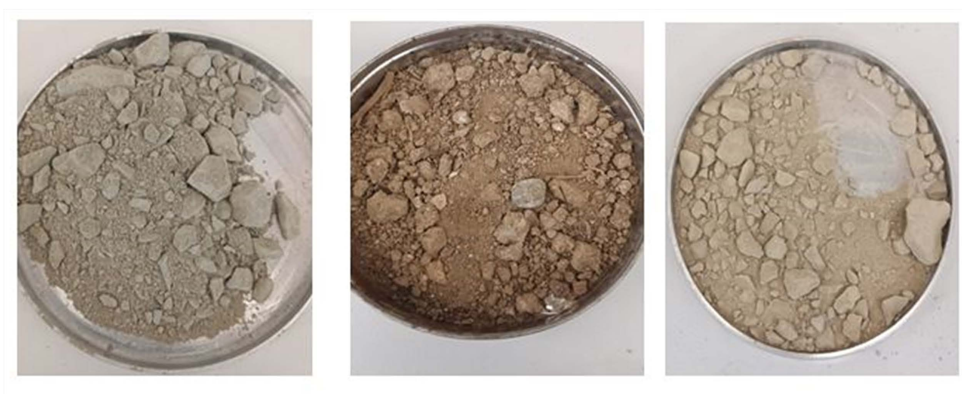


Figure 1. Location map of the study area.



(a) Soil Sample 1 (b) Soil Sample 2 (c) Soil Sample 3

Figure 2. Soil types used in the study.

3.2. Laboratory Testing Procedures

The laboratory testing protocols used in this study included a complete set of experiments to examine the Atterberg limits, particle size distribution, compaction properties, and unconfined compressive strength of the three distinct types of soil. The following techniques were used for testing:

3.2.1. Specific Gravity Determination

The specific gravity values of three soil samples, indicated as SOIL1, SOIL2, and SOIL3, were calculated. These samples comprised various mixtures of sand and clay, with percentages and specific gravity values supplied. SOIL1 had a sand content of 19.9% and a specific gravity of 2.74, while the clay component made up 80.1% and had a specific gravity of 2.65. In the instance of SOIL2, the sand fraction was 5.32%, with a specific gravity of 2.73, while the clay percentage was 94.68%, with a specific gravity of 2.46. Finally, SOIL3 included 2.518% sand and had a specific gravity of 2.7, whereas the clay fraction constituted 97.482% and had a specific gravity of 2.4. The obtained specific gravity values ranged from 2.41 to 2.67, demonstrating differences in soil density and composition across the three samples depending on sand and clay proportions as shown in **Table 1**. Because soil is found naturally as a mixture of sand and clay, I used the following calculation to calculate the specific gravity of the whole soil:

$$Total\ GS = \frac{100}{\dfrac{\%\ SAND}{GS\ OF\ SAND} + \dfrac{\%\ CLAY}{GS\ OF\ CLAY}}$$

3.2.2. Atterberg Limits Testing

Tests referred to as Atterberg limits are utilized to evaluate the plasticity and consistency properties of soils. These tests are commonly used in soil mechanics and engineering to understand the behavior of soils under different conditions. Soil has two specific moisture content points that indicate its physical properties [12]. The importance of Atterberg limits lies in their ability to provide information about the behavior of soils under different conditions [13]. For example, knowledge of the plastic and liquid limits can help predict the sensitivity of a soil to deformation and cracking due to changes in moisture content. This information is crucial in engineering and construction projects where the properties of the soil must be known to ensure the stability and safety of structures. Atterberg limits can also be used to classify soils according to their plasticity and consistency, which is useful in determining their suitability for different purposes such as foundations, embankments, and earthworks [14]. To determine the liquid limit, standard techniques such as the Casagrande method were utilized, Casagrande device has been used for it as shown in **Figure 3**. The plastic limit test was carried out in accordance with AS 1289.3.3.1as shown in **Figure 4**, as well as the plasticity index of each soil type. The water content at which the soil transitioned from a liquid to a plastic state and from a plastic to a semisolid state was determined. Because the plasticity index would be generated based on the results of this test, the soil sample (paste) used to establish the liquid limit was also utilized for the plastic limit test.

Table 1. Specific gravity for sand and clay proportions in soil.

	Sand		Clay		Total specific gravity
	% of sand	specific gravity	% of clay	specific gravity	
Soil 1	19.9	2.74	80.1	2.65	**2.67**
Soil 2	5.32	2.73	94.68	2.46	**2.47**
Soil 3	2.518	2.7	97.482	2.4	**2.41**

Figure 3. Casagrande device.

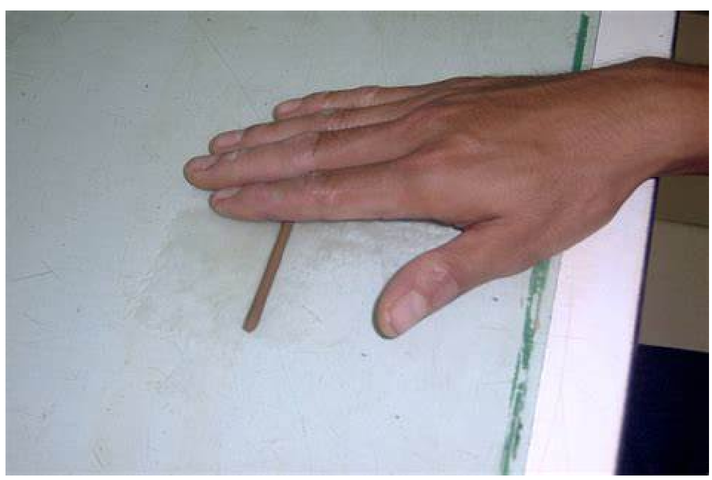


Figure 4. Plastic limit test.

3.2.3. Particle Size Distribution

Because coarse and fine grains are widely present in soil, sieve and hydrometer studies are required to identify the whole particle size distribution. The preferred method is to do sieve analysis first, followed by a hydrometer test on the particles that pass the 75 µm sieve. The particle size distribution is then determined cumulatively based on the proportion of particles that pass through each sieve.

Sieve Analysis: The particle size distribution of coarse-grained soil was determined using sieve analysis. A prepared dry soil sample was thoroughly agitated before being put through a stack of sieves with varying openings as shown in **Figure 5**. As a proportion of the total dry sample mass, the percentage of soil particles that went through different diameters of sieves was computed. Furthermore, as applied to this study, wet analysis was used as shown in **Figure 6**, which is a key laboratory process used to investigate the influence of mineral composition and fine amount on the Atterberg limits and compaction properties of soils. The wet analysis is dissolving the soil sample in water to break down cohesive clumps and separate tiny particles. The dispersed sample is next submitted to hydrometer analysis, which involves allowing the soil suspension to settle and measuring the sedimentation process with a hydrometer.

Hydrometer Analysis: The particle size distribution was determined using hydrometer analysis after soils were mixed with distilled water to produce a 1000 cc solution. The hydrometer was then used to measure the density of the solution at various periods. The time-density data was used to compute the percentage of particle sizes during the requisite 48-hour period when observations were required for each kind of soil.

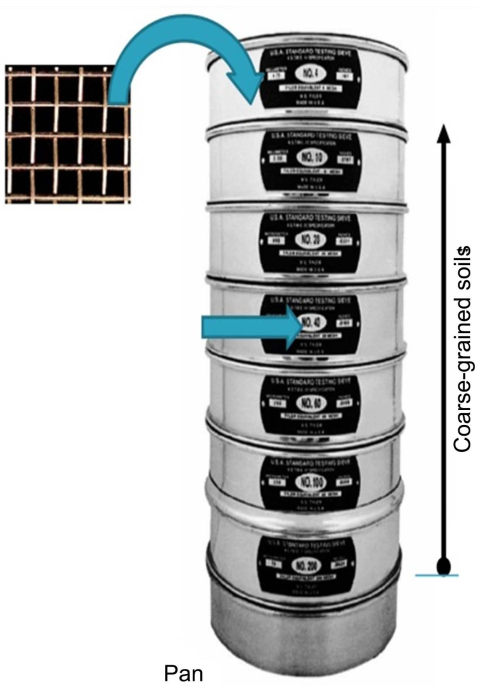


Figure 5. Dry sieve analysis.

Figure 6. Wet sieve analysis.

3.2.4. Soil Compaction Test

Compaction properties of soils refer to their behavior when subjected to mechanical energy, this leads up to a decrease in volume and a rise in density. The process of compaction is important in the engineering of structures such as roads, foundations, and embankments, as it affects the soil's ability to support loads and resist deformation [15]. The soil density and its water content are two critical factors that influence its compaction characteristics. The moisture content of soil increases, its density decreases, which can result in a loss of strength and stability [16]. However, if the soil is too dry, it may not compact efficiently, leading to voids that can compromise its load-bearing capacity [17]. The compaction test was carried out in accordance with the ASTM D698 standard in order to analyze the compaction properties of each kind of soil. Representative soil samples of various kinds were rigorously processed according to ASTM criteria, ensuring they are air-dried and free of any extraneous contaminants or big particles. For each soil type, cylindrical compaction molds with the specified size were carefully selected as shown in **Figure 7**. The initial moisture content of each soil sample was evaluated separately in accordance with ASTM D2216. Compaction techniques for each soil sample included compacting the soil in layers within the moulds with a mechanical compactor as shown in **Figure 7** and administering a consistent amount of blows. The compressed specimens were carefully taken from the moulds after completion, and their weights and measurements were painstakingly documented. To determine the dry density and water content properties of the compacted soil, bulk density, and moisture content calculations were performed for each soil type. The acquired data aid in the development of unique compaction curves by revealing the peak dry density and related optimum water content for each soil type. These factors are critical in understanding the compaction behavior of different soils and in making educated decisions about building procedures and design issues particular to each soil type.

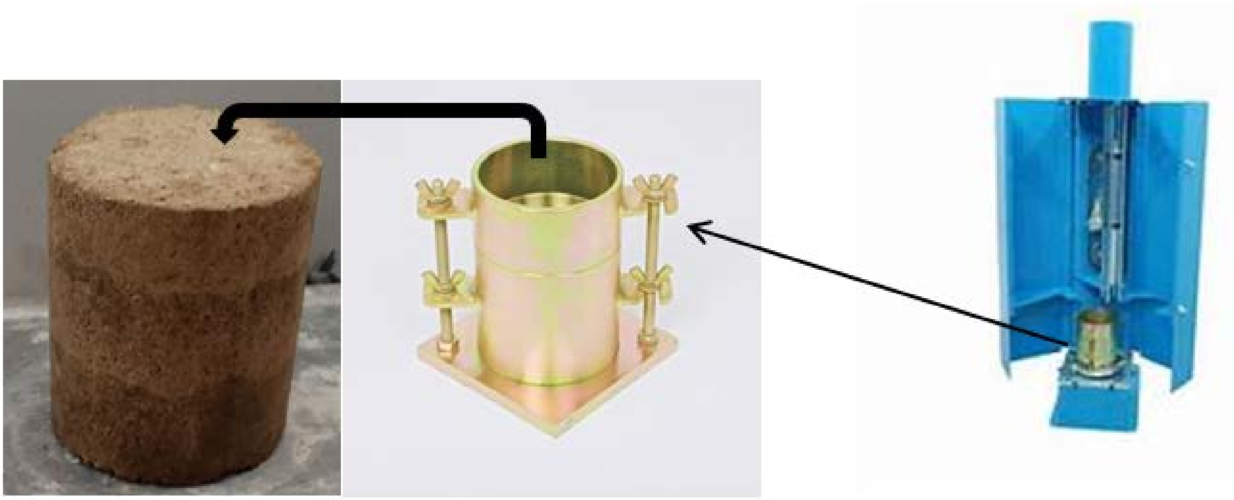


Figure 7. Compaction test mould and automatic soil compactor.

3.2.5. Unconfined Compressive Test

The unconfined compressive test, a commonly used laboratory approach in geotechnical engineering, was used to evaluate the strength and deformation properties of each kind of soil sample in the absence of any lateral confinement. This test offers useful information regarding the shear strength, compressive strength, and stress-strain behavior of the soil. To begin the unconfined compressive test, a cylindrical soil specimen with a predetermined height-to-diameter ratio is prepared. The specimen is placed carefully in a testing instrument, usually a compression machine as shown in Figure 8(a). The specimen was gradually subjected to axial stress until collapse occurred as shown in Figure 8(b). Axial stress and strain were continually monitored during the test to develop a stress-strain curve. The maximal unconfined compressive strength of the soil is represented by the peak stress at failure. The unconfined compressive test aids in understanding the shear strength qualities of the soil, revealing information about its stability, slope stability, and load-bearing capability. Furthermore, the unconfined compressive test findings may be used to determine the settlement and deformation behavior of the soil under varied loading situations, assisting in the design and study of geotechnical constructions.

3.2.6. X-Ray Diffraction (XRD) Test

The method of X-ray diffraction (XRD) was used to identify the mineral composition of each type of soil as shown in Figure 9. XRD analysis involves exposing a finely powdered sample to X-rays, which interact with the crystal lattices of the minerals contained in the sample. The X-rays are diffracted at different angles, resulting in a diffraction pattern that is particular to the mineral phases in the sample. The mineral phases are identified and measured by measuring the angles and intensities of the diffracted X-rays. XRD analysis offers useful information regarding the sample's mineralogical composition, crystalline structure, and degree of crystallinity.

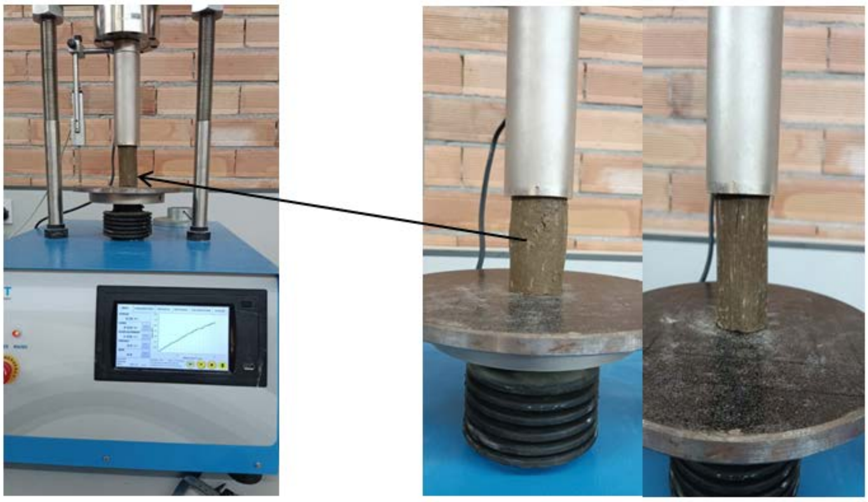


Figure 8. (a) Soil sample being tested using an unconfined compressive strength testing machine; (b) Unconfined compression test of soil sample under pressure.

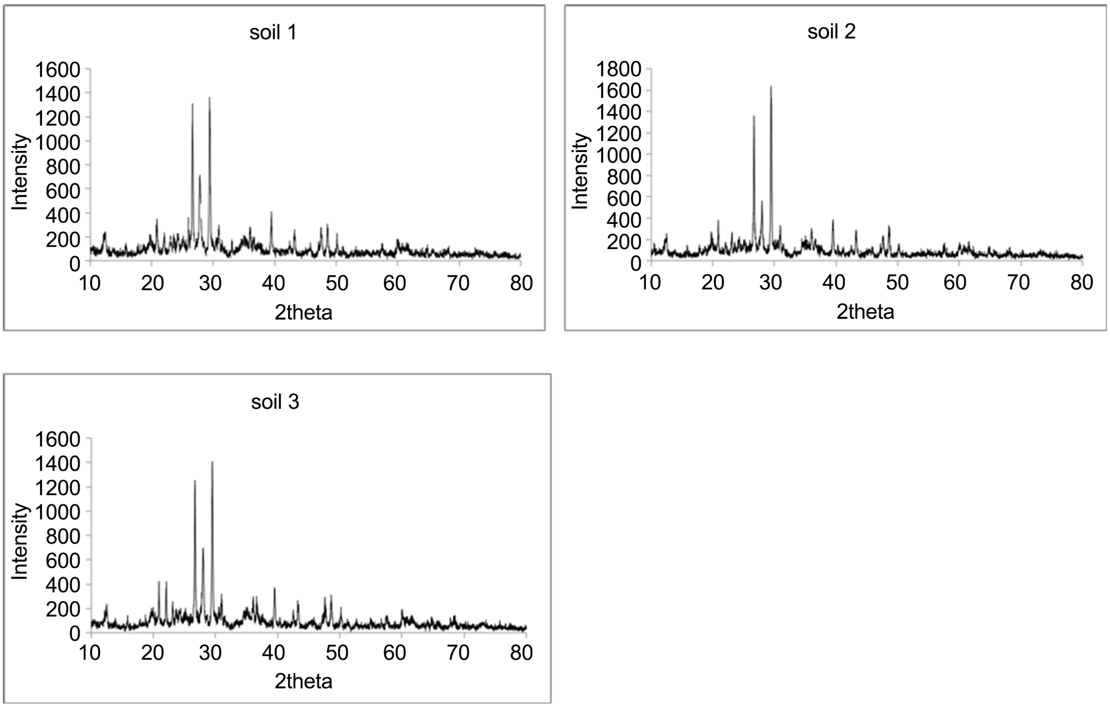


Figure 9. XRD pattern of different soil samples.

4. Results and Discussion

The study paper's results and discussion part focuses on presenting and analyzing the findings from the experiments and tests that were carried out. This section would involve a comprehensive analysis of the data obtained from tests such as Atterberg limits, sieve analysis, hydrometer analysis, compaction test, and unconfined compressive test in the case of the study on the effect of mineral composition and quantity of fines on the Atterberg limits and compaction characteristics of soils.

4.1. Atterberg Limits

Based on the results, the Atterberg limits of three separate soil samples, denoted as Soil 1, Soil 2, and Soil 3, were calculated as shown in Table 2. The liquid limit was determined to be 33.49, 31.85, and 41.90 for Soil 1, Soil 2, and Soil 3, respectively. For the matching soil samples, the plastic limit, which denotes the moisture level at which the soil stops displaying plastic behavior, was determined to be 21.37, 16.96, and 23.16. The plasticity index, which quantifies the range of moisture content within which the soil stays malleable, was computed for Soil 1, Soil 2, and Soil 3 as 12.12, 14.89, and 18.74, respectively. These findings demonstrate that the soil's moisture sensitivity and propensity to undergo plastic deformation varies between samples. A higher liquid limit indicates that more moisture is required to generate plastic behavior, whereas a lower plastic limit indicates that the soil loses its plasticity at a lower moisture level. The plasticity index offers information on the general plasticity qualities of the soil, with higher values suggesting a greater range of moisture content within which the soil stays malleable. Understanding the Atterberg limits is critical for understanding the soil's engineering qualities, such as compaction behavior, shear strength, and settlement potential.

The categorization of each soil type can be established using the recommended chart for classification purposes based on the tabular data supplied above as shown in Figure 10.

Table 2. Atterberg limits and classification of soil.

	Soil 1	Soil 2	Soil 3
Liquid limit	33.49	31.85	41.90
Plastic limit	21.37	16.96	23.16
Plasticity index	**12.12**	**14.89**	**18.74**
Type of soil	**ML**	**CL**	**CL**

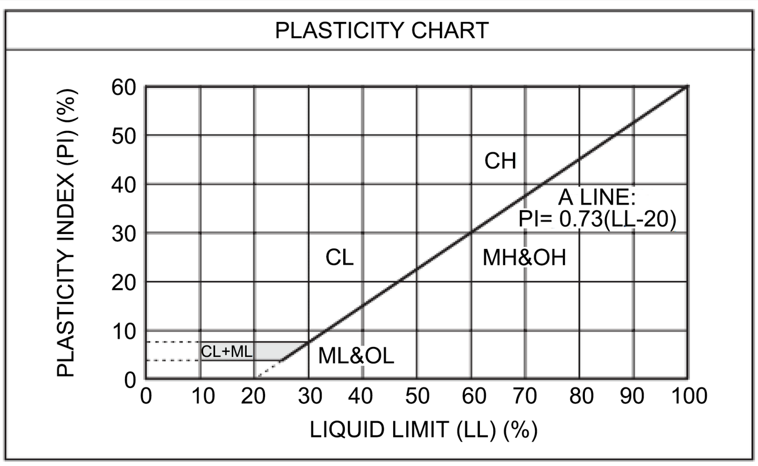


Figure 10. Soil Plasticity chart as per Unified soil classification system.

4.2. Particle Size Distribution Results

Soil 1, Soil 2, and Soil 3 sieve analysis findings show the particle size distribution and relative proportions of different particle sizes in the individual soils as shown in **Figure 11**. All three soils had a high proportion of particles pass through the bigger sieve sizes (16 mm, 8 mm, and 4.75 mm), suggesting that no gravel was present. The percentage of particles going through steadily reduced as the sieve size decreased, indicating a reduction in the fraction of smaller particles in the soils. In comparison to Soil 2 and Soil 3, Soil 1 had a larger percentage of sand particles passing through each sieve. However, Soil 1 had a much lower clay of particles passing through the smaller sieves (0.125 mm and 0.075 mm), indicating a larger amount of sand particles than the other two soils. The proportion of particles passing through the sieves in Soil 2 and Soil 3 showed comparable patterns. As the sieve diameter was reduced, the fraction of particles passed through in both soils. The greater percentages of particles passing through the smaller sieves indicate a substantially more clay percentage compared to Soil 1.

The hydrometer test results provide valuable information about the particle size distribution of Soil 1, Soil 2, and Soil 3 as shown in **Figure 12**. These findings play a crucial role in understanding the soil's behavior and the percentage of clay and silt inside as in **Table 3**. The study of Soil 1 indicates that the soil is mostly formed of silt particles, with a fraction of clay particles (0.002 mm). Clay particles (0.002 mm) account for roughly 29% of the total. Furthermore, the estimated proportion of silt is 56.53%. These findings indicate that Soil 1 has silt soil qualities, which may have ramifications for its engineering features such as compaction, permeability, and shear strength. According to the chart, soil 2 has 86.6% clay and 8.46% silt. These data suggest that the soil is mostly constituted of clay particles, with a little fraction of silt particles present. Similarly, the examination for Soil 3 shows a considerable amount of clay particles, with an estimated proportion of around 89.8%. The silt percentage is predicted to be approximately 7.70%. These data imply that Soil 3 is also characterized by clay soil qualities, which might impact its geotechnical properties.

4.3. Soil Compaction Test Results

When the data was analyzed, it was discovered that each soil sample responds differently to changes in water content. As shown in **Figure 13**, Soil 1 has a modest drop in dry unit weight when the water content rises from 15.44% to 17.25%, then rises again from 17.25% to 19.21%. Soil 2, on the other hand, shows a steady increase in dry unit weight when water content rises from 12.8% to 18.8%. As the water content increases from 17.91% to 22.02%, the dry unit weight of Soil 3 decreases.

The data must be investigated further to establish the optimal water content, which corresponds to the maximum dry unit weight. We can discover the water content value that provides the maximum dry unit weight by comparing the dry unit weights at different water content levels for each soil.

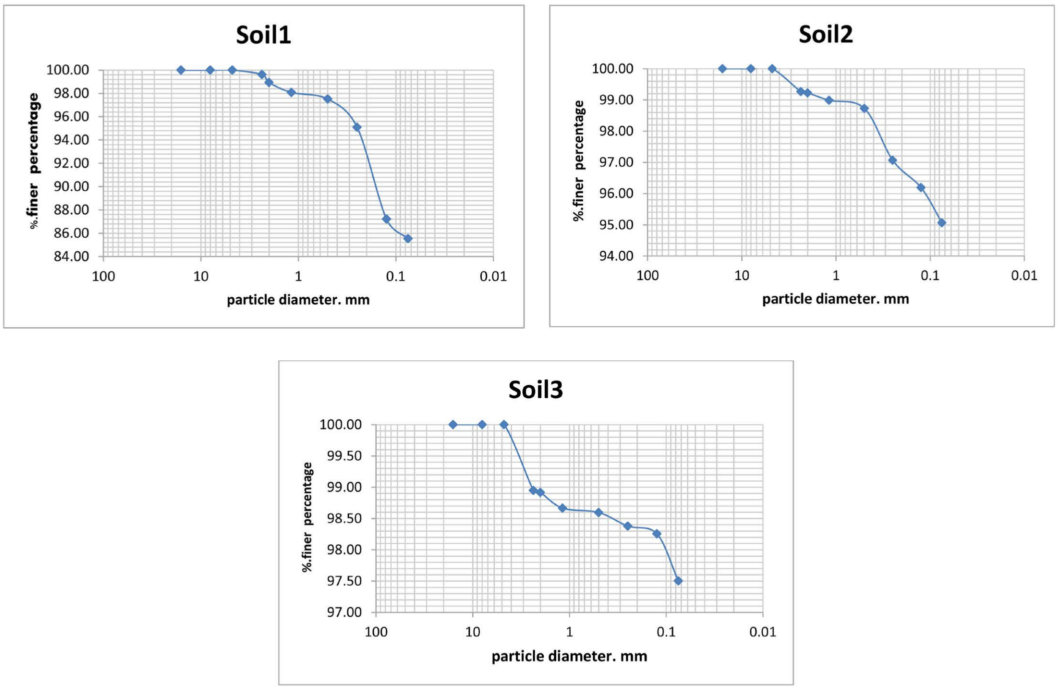


Figure 11. Particle size distributions charts of the three soils used in this study.

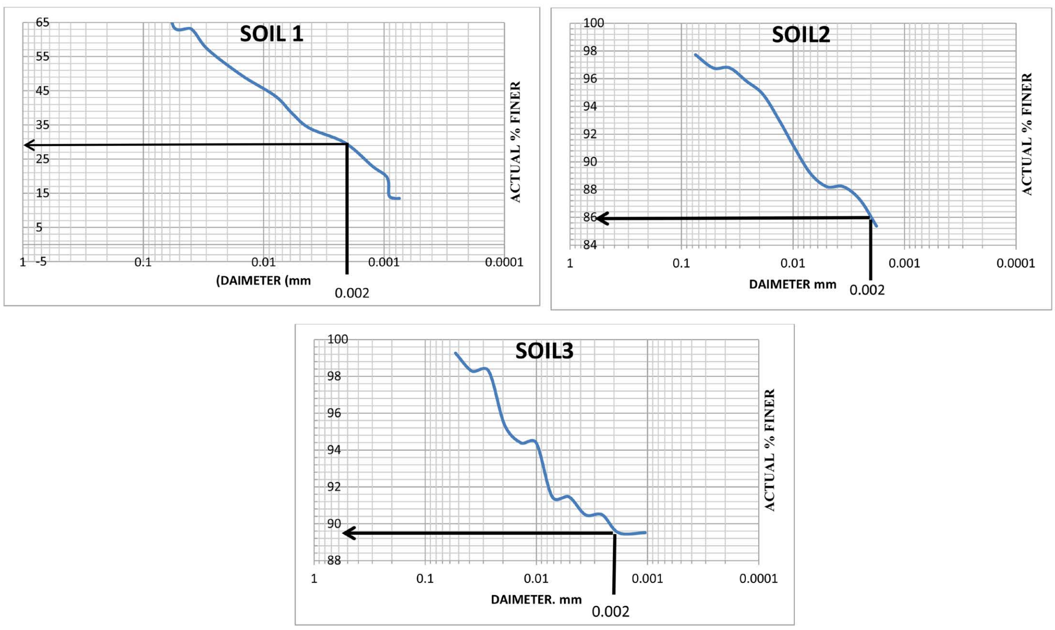


Figure 12. Sedimentation analysis charts.

Table 3. The percentage for fine, clay, and silt in types of soil.

	% Fines	% Clay	% Silt	Type of soil
Soil 1	85.53	29	56.53	Silt "ML"
Soil 2	95.06	86.6	8.46	Clay "CL"
Soil 3	97.5	89.8	7.70	Clay "CL"

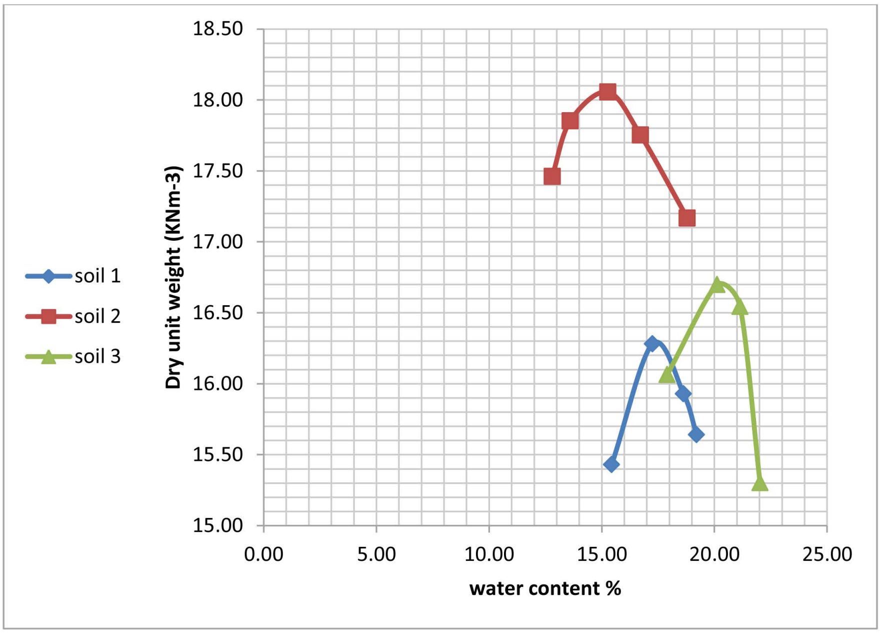


Figure 13. Compaction curves for soil samples showing the typical behaviour of an optimum moisture content (OMC) where the dry density is maximised.

Based on the results of the analysis, Soil 1 has a maximum dry unit weight of 16.28 kN·m^{-3} at an optimum water content of 17.25%. Soil 2 has the greatest dry unit weight of 18.1 kN·m^{-3} at an optimum water content of 15.3%. However, when the water content increases, the dry unit weight of soil 3 decreases, with the greatest value of 16.7 kN·m^{-3} found at an optimum water content of 20.12%.

These results show that Soil 2 has better compaction properties than Soil 1 and Soil 3, since it reaches a greater dry unit weight at the optimal water content. Soil 1 has a lower dry unit weight, which might indicate poor compaction for the given water content range. Soil 3 has the lowest dry unit weight, indicating poor compaction under the measured conditions.

4.4. Unconfined Compressive Test Results

The presented data illustrates the results of an unconfined compressive test performed on three soil samples designated Soil 1, Soil 2, and Soil 3. The test involves submitting each soil sample to increasing amounts of axial strain and measuring the resulting axial stress. According to the charts, when the axial strain increases, so does the axial stress for all three soil samples. This relationship represents the soil's reaction to compressive loading.

In the case of soil 1, as shown in **Figure 14**, when the three samples of soil1 are examined, it is clear that sample 1/3 has higher axial stress values than sample 1/1 and sample 1/2 at identical degrees of axial strain. This implies that sample 1/3 has better compressive strength at 348 KPa and can tolerate larger loads at 13% of strain before failing. Sample 1/1 and sample 1/2, on the other hand, have lower axial stress values, suggesting lesser strength qualities than Soil 1/3.

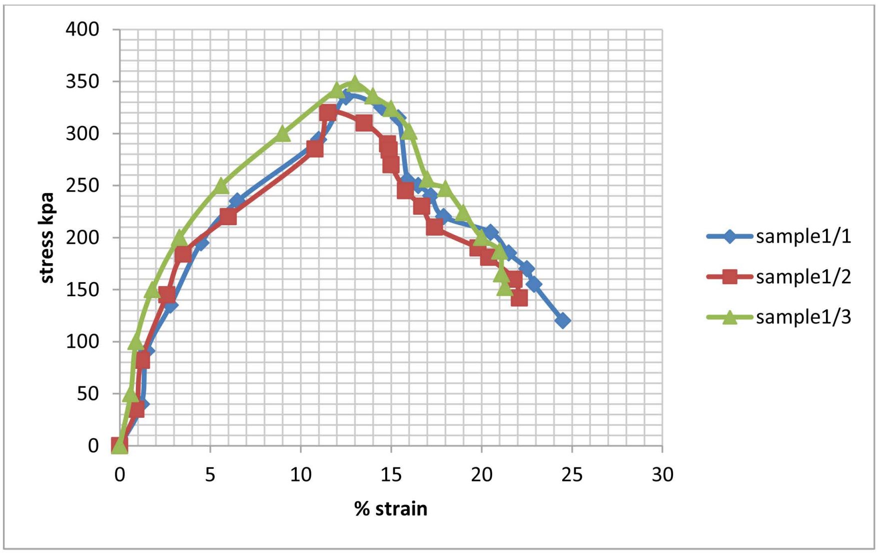


Figure 14. Stress and axial strain as measured on the three different samples of Soil 1.

For Soil 2, we see various patterns of axial stress and axial strain for each sample as shown in **Figure 15**. In Soil 2/1, the axial stress steadily increases from 0 KPa to 325 KPa as the axial strain increases from 0% to 3.4%. Soil 2/2 follows a similar pattern, with the axial stress increasing from 0 KPa to 370 KPa when the axial strain hits 3.9%. Finally, for Soil 2/3, the axial stress increases from 0 KPa to 439 KPa, equal to an axial strain of 2.45%.

To determine the sample with the highest stress and strain, we must compare the maximum axial stresses attained by each sample. Based on the statistics, we can conclude that Soil 2/3 has the highest axial stress, reaching 439 KPa. This stress level corresponds to an axial strain of 2.45%. It can be determined that among the three samples examined in the unconfined compressive test (Soil 2/1, Soil 2/2, and Soil 2/3), Soil 2/3 has the maximum axial stress of 439 KPa, with an associated axial strain of 2.45%. This suggests that, as compared to the other two samples, Soil 2/3 can sustain larger levels of applied load before failing.

In the case of soil 3 when the maximum axial stresses of each sample are compared, we can see that Soil 3/1 has the greatest axial stress of 361 KPa as shown in **Figure 16**. For this stress level, the equivalent axial strain is 12.6%. It may be determined that among the three materials examined in the unconfined compressive test (Soil 3/1, Soil 3/2, and Soil 3/3), Soil 3/1 had the maximum axial stress of 361 KPa, with an associated axial strain of 12.6%. This shows that, as compared to the other two samples, Soil 3/1 can sustain larger levels of applied load before failing.

Soil 2 had the lowest axial strain value of 2.45% and a comparatively high axial stress value of 439 KPa among the three soils. This suggests that Soil 2 has a stronger resistance to deformation under compression than Soils 1 and 3. Based on the findings of the Unconfined Compressive Test, Soil 2 is the most favourable of the three evaluated. Its lower axial strain and higher axial stress readings

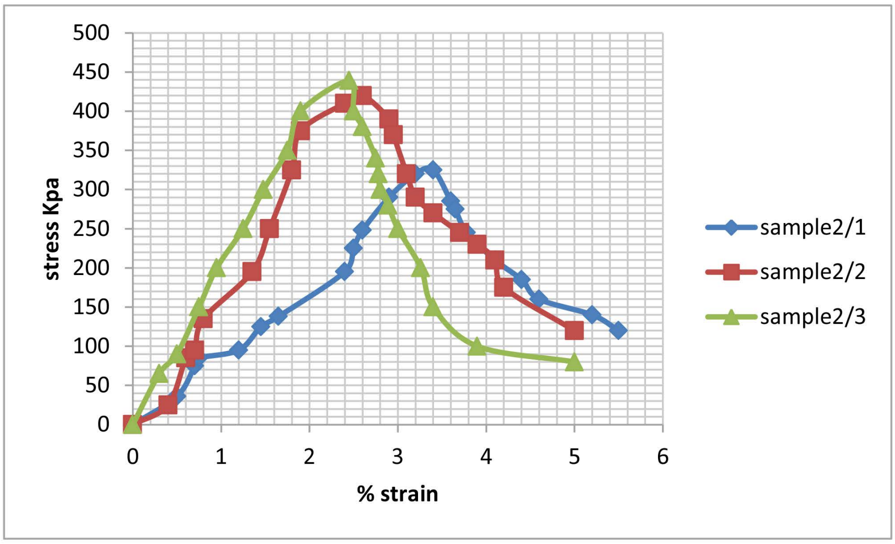


Figure 15. Stress and axial strain as measured on the three different samples of Soil 2.

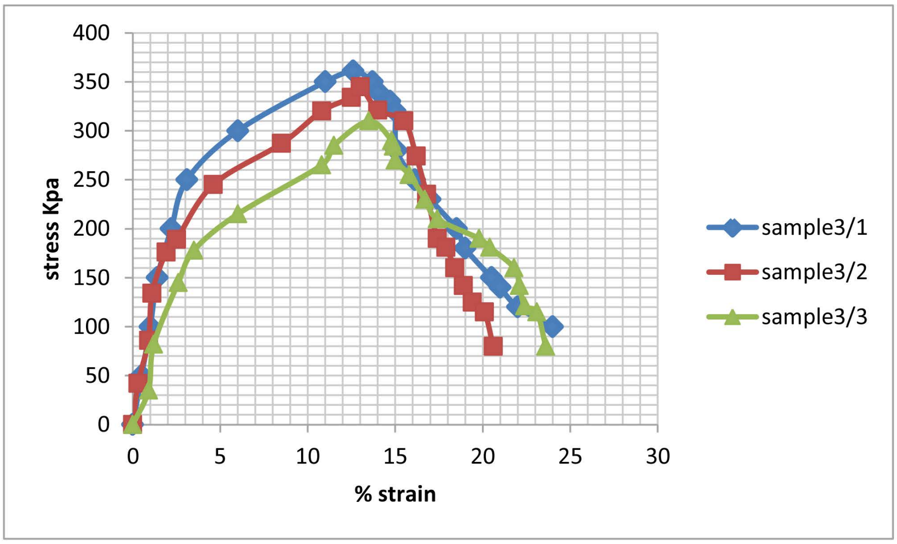


Figure 16. Stress and axial strain as measured on the three different samples of Soil 3.

suggest stronger strength and stability under compression. Soil 1 and Soil 3, on the other hand, showed more deformation and lower compression resistance, making them less appropriate for applications requiring stability and strength.

4.5. X-Ray Diffraction (XRD) Test Results

The XRD test findings give valuable information on the mineral composition of the soils, which can have a substantial influence on their characteristics and behavior. Soil 1 has been classed as silt. Here's a thorough breakdown of the composition:

Soil 1's unique mineral combination and percentages suggest a complicated soil makeup as shown in Table 4. The presence of quartz and feldspar indicates

Table 4. The percentage of mineral composition in Soil 1.

	Quartz %	Feldspar %	Calcium Carbonate %	Chlorite %	Mica %
Soil 1	30.5	26.1	28.5	9.2	5.8

Table 5. The percentage of mineral composition in Soil 2 and Soil 3.

	Illite %	Montmorillonite %	Calcium Carbonate %	Kaolinite %
Soil 2	37.7	7	33.1	22.2
Soil 3	8.9	29.1	45.7	16.3

that the soil is well-graded and stable. The presence of calcium carbonate suggests the possibility of alkaline conditions, which should be taken into account in engineering design and material selection. The presence of chlorite and mica in the soil might contribute to its flexibility and water retention capabilities, influencing its behavior under various moisture circumstances.

Based on their characters, Soils 2 and 3 were classified as clay soils. As shown in Table 5.

Soil 2 has a high amount of illite, suggesting excellent plasticity and cohesiveness. Calcium carbonate indicates alkaline conditions, while kaolinite adds to soil stability and decreased flexibility. The smaller the amount of montmorillonite, the lower the influence on the soil's swelling potential. Soil 3 contains a high concentration of calcium carbonate, suggesting alkaline conditions. Because of the high amount of montmorillonite, the soil has a high flexibility and swelling potential, making it more vulnerable to volume changes due to moisture fluctuations. The presence of kaolinite helps to stabilize the soil, however, the lower amount of illite suggests reduced flexibility and cohesive behavior when compared to Soil 2.

5. Conclusions

The study delineates the characteristics of three distinct soils. Soil 1 has a moderate level of plasticity, characterized by a plasticity index of 12.12% and a liquid limit of 33.49%. The composition of this substance includes significant quantities of quartz, feldspar, calcium carbonate, chlorite, and mica. It has a maximum dry density of 16.28 g/cm^3 and an ideal water content of 17.25%. Soil 2 exhibits reduced flexibility compared to Soil 1 because it has a greater plasticity index of 14.89% and a lower liquid limit of 16.96%. Nevertheless, it exhibits a greater maximum dry density of 18.06 g/cm^3 and a lower optimal water content of 15.27%. Soil 3 has the most plasticity among the three soils, with a plasticity index of 18.74% and a liquid limit of 41.90%. The material has a peak dry density of 16.7 grams per cubic centimeter and a moisture content of 20.1 percent.

The qualities of soil are significantly influenced by its makeup. Soils containing a greater proportion of expansive minerals, such as montmorillonite, exhibit increased flexibility and a greater propensity for changes in volume. Soils that include a larger proportion of fine particles, like Soil 2 and Soil 3, exhibit increased flexibility and reduced compaction characteristics, such as a higher ideal water content and a lower maximum dry density. Soil 1 exhibits a moderate degree of flexibility and intermediate compaction qualities as a result of its decreased fines content. Soil 3 is distinct because it demonstrated expansion rather than fracture when subjected to an unconfined compressive force. This might be attributed to several variables, such as the existence of expansive clay minerals, elevated moisture content, chemical reactions, or a substantial quantity of organic matter.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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