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Improvement of the Engineering Properties of A-3 Soil through the Addition of Clay

Zaynab omer Alqadhqad [1 *], Shrifa Mohmed Elhamroni [2], Heba Ayad Arebi Jebali [3]
[1,2,3] Higher institute of science and technology Tripoli, Tripoli, Libya

تحسين الخواص الهندسية للتربة من الفئة أ-3 من خلال إضافة الطين

زينب عمر القضقاض [1*]، شريفة محمد الحمروني [2]، هيبة عياد عريبي الجبالي [3]
[3،2،1] المعهد العالي للعلوم والتقنية طرابلس، طرابلس، ليبيا

[*]Corresponding author: eng.civilz@yahoo.com

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Abstract:
Sandy soils are characterized by their small particle size, uniform gradation, and lack of cohesion, making them vulnerable to erosion and displacement by natural factors. In Libya, particularly in the western regions, sandy soils are widely distributed. Therefore, it is essential to investigate the properties of this soil type.
This paper presents the laboratory results of a study on the effect of adding clay (specifically Gharyan clay) to A-3 sandy soil. The clay was added at varying proportions (0%, 3%, 6%, 9%, 12%) to evaluate its impact on improving the cohesion between soil particles, thereby enhancing soil stability and strength.
The laboratory results demonstrated that the geotechnical properties of A-3 soil could be improved through the addition of clay. The compaction characteristics of the soil improved with specific clay percentages, and the dry density increased proportionally with the amount of clay added.
Furthermore, direct shear test results indicated a notable improvement in the cohesive strength of the modified soil. This improvement was primarily dependent on the type and percentage of the added clay.

Keywords: A-3 soil, clay, dry density, cohesion.

الملخص
التربة الرملية تمتاز بصغر حجم حبيباتها وانتظام تدرجها وعدم تماسكها فتكون معرضة للانجراف والتعرية بسبب العوامل الطبيعية وتشهد بلادنا ليبيا انتشارا كبيراً للتربة الرملية في معظم مناطق الجزء الغربي من ليبيا فمن الضروري البحث في خصائص هذا النوع من التربة.
وهذه الورقة تقدم النتائج المعملية للدراسة تأثير إضافة الطين (طين غريان) للتربة.
(A-3)حيث أن إضافة الطين بنسب معينة وهي (0% ، 3% ،6%،9%،12%) يعمل على تحسين خاصية التماسك بين حبيبات التربة مما يجعلها أكثر ثباتا وقدرة. ودلت النتائج المعملية على إمكانية تحسين الخواص الجيوتقنية للتربة.(A-3)
حيث وجد أن قابلية التربة (A-3) للدمك تتحسن بإضافة نسب محددة من الطين إليها وكذلك فإن الكثافة الجافة تزداد بزيادة نسبة المادة المضافة.
ودلت نتائج اختبار القص المباشر على إمكانية تحسين خاصية التماسك للتربة (C) وأن هذه الخاصية تعتمد أساساً على نوع ومقدار نسبة الطين المضافة للتربة.

الكلمات المفتاحية: التربة (A-3)، الطين، الكثافة الجافة، التماسك.

Introduction:

Sandy soil is composed of coarse, loose particles, and its engineering properties primarily depend on both bulk density and dry density [1,2]. As dry density increases, the bulk density also increases, thereby enhancing the engineering behavior of the soil. According to the AASHTO classification system, A-3 soil is poorly graded and lacks cohesion, making it weak in terms of bonding and stability.

This study aims to investigate the improvement of the engineering properties of A-3 soil by adding clay in specific proportions: 0%, 3%, 6%,9%, 12%.

Literature Review:

A limited number of studies have been conducted on the use of Hamada sand and Gharyan clay in improving soil properties, as these materials are locally available. These studies have shown that the addition of certain stabilizing agents can result in significant improvements in soil properties, such as strength, workability, and durability. Moreover, several previous investigations have been carried out to evaluate the effectiveness of these additives in stabilizing the soil.

1. Clay Addition to Sandy Soil- Influence of Clay Type and Size on Nutrient Availability in Sandy Soils Amended with Residues Differing in C/N ratio [8].
2. Addition of a Clay subsoil to a Sandy top soil alters CO2 release and the interactions in residue mixtures [9].
3. Clay Addition to Sandy Soil Reduces Nutrient Leaching – Effect of Clay Concentration and Ped Size [10].

2. Materials Used in the Study:

2.1 A-3 Soil:

This type of soil is abundantly found in the Al-Hamada region of the Western Mountain in Libya. It is collected from the surface and is commonly used in major construction projects and roads in the region.

The soil used in this study is fine, uniformly graded sand classified as A-3 soil according to the **AASHTO** (American Association of State Highway and Transportation Officials) classification system. It is also classified as **SP (Poorly Graded Sand)** according to the **Unified Soil Classification System (USCS)**.

Table 1 presents the geotechnical properties of the tested soil.

Property	Value
Percentage passing No. 200 sieve (0.075 mm)	10%
Fine sand percentage	90%
AASHTO Classification	A-3
USCS Classification	SP
Gradation Description	Poorly graded
Maximum Dry Density	1.7 g/cm
Optimum Moisture Content	9%
Internal Friction Angle (Ø)	34.99^0
Cohesion (C)	-10

2.2 Clay Soil (Added Material):

The clay used in this study was obtained from the surface layer of the Qawasim area in Gharyan. The plasticity characteristics of this clay were determined, and the results showed an average **liquid limit (LL)** of 56%, and an average **plastic limit (PL)** of 29%, resulting in a **plasticity index (PI)** of 27%.

Based on these results, the clay is classified as **CH (Clay of High Plasticity)** according to the USCS system and as **A-7-6** according to the AASHTO classification system. The clay was added to the A-3 soil in the following weight percentages: 0%, 3%, 6%,9%, 12%.

3. Laboratory Experiments and Equipment Used:

A series of laboratory tests were conducted to investigate the potential enhancement of the engineering properties of A-3 soil through the addition of clay at various percentages (0%, 3%, 6%, 9%, 12%). These tests were performed in the Soil Mechanics Laboratory at the University of Tripoli. The tests carried out on the samples included Sieve analysis, Compaction test, and Direct Shear test.

1.3 Sieve Analysis Test:

The purpose of this test is to determine the particle size distribution characteristics of the soil before and after the addition of various percentages of clay. These characteristics include particle size, gradation, and the percentage of fine materials in each mixture. A set of standard sieves was used in this test, arranged in descending order of opening size, from the largest to the smallest was used for the analysis.

Table 2 Presents the Sieve Numbers and Their Corresponding Opening Diameters used in the Sieve Analysis Test.

Sieve Number	10	20	40	60	100	200
Sieve Opening (mm)	2.00	0.85	0.425	0.25	0.15	0.075

2.3 Standard Proctor Compaction Test

This test is conducted to determine the fundamental compaction characteristics of the soil, specifically the **optimum moisture content** and the **maximum dry density**. These parameters are obtained from the compaction curve, which represents the relationship between moisture content and dry density for each soil sample. The test was performed in accordance with the American Standard ASTM D698-00 [4].

3.3 Direct Shear Test

In this test, the shear angle was measured for all samples, both with and without clay addition. The procedure followed the guidelines specified in the American Standard ASTM D3080-01 [6].
The samples were tested after being compacted to their maximum dry density using the Standard Proctor method.
This test was used to determine the engineering properties of the soil, namely **the internal friction angle (Ø) and the cohesion (C).**

4. Presentation and Discussion of Laboratory Test Results

4.1 Particle Size Distribution (Grain Size Gradation) of Soil Particles

The description and classification of any type of soil fundamentally depend on its particle size distribution, which significantly influences the engineering properties of the soil.
Figure (1) illustrates the grain size distribution curves for A-3 soil mixed with varying percentages of clay. From these curves, it can be observed that the overall shape of the curves is similar and closely aligned, indicating that the addition of clay had no significant effect on the grain size distribution of the mixtures.
Therefore, all the curves can be described as representing **well-graded soils**.

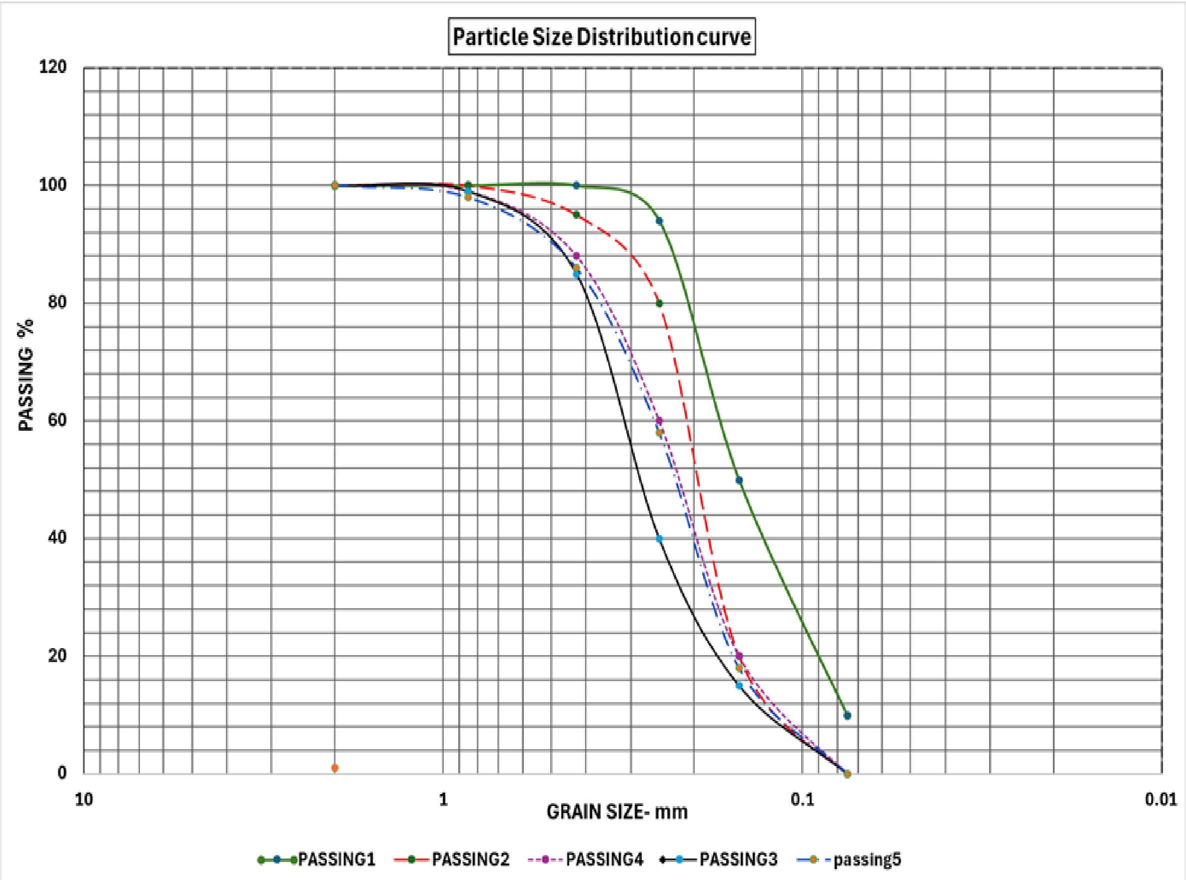

Figure (1) illustrates the grain size distribution curves of the A-3 soil mixed with varying percentages of clay.

2.4 Compaction Characteristics

Soil compaction increases the density of the soil and reduces the air voids between particles, thereby improving its load-bearing capacity and enhancing stability.

Table 3 illustrates the relationship between moisture content and dry density at varying percentages of clay.

Clay Content (%)							
	0%	Moisture Content (W%)	15%	12%	9%	6%	3%
		Dry Density (ρd) (g/cm³)	1.62	1.64	1.7	1.65	1.63
	3%	Moisture Content (W%)	15%	12%	9%	6%	3%
		Dry Density (ρd) (g/cm³)	1.63	1.73	1.8	1.76	1.73
	6%	Moisture Content (W%)	15%	12%	9%	6%	3%
		Dry Density (ρd) (g/cm³)	1.73	1.78	1.85	1.82	1.78
	9%	Moisture Content (W%)	15%	12%	9%	6%	3%
		Dry Density (ρd) (g/cm³)	1.74	1.83	1.95	1.89	1.84
	12%	Moisture Content (W%)	15%	12%	9%	6%	3%
		Dry Density (ρd) (g/cm³)	1.83	1.92	2	1.95	1.83

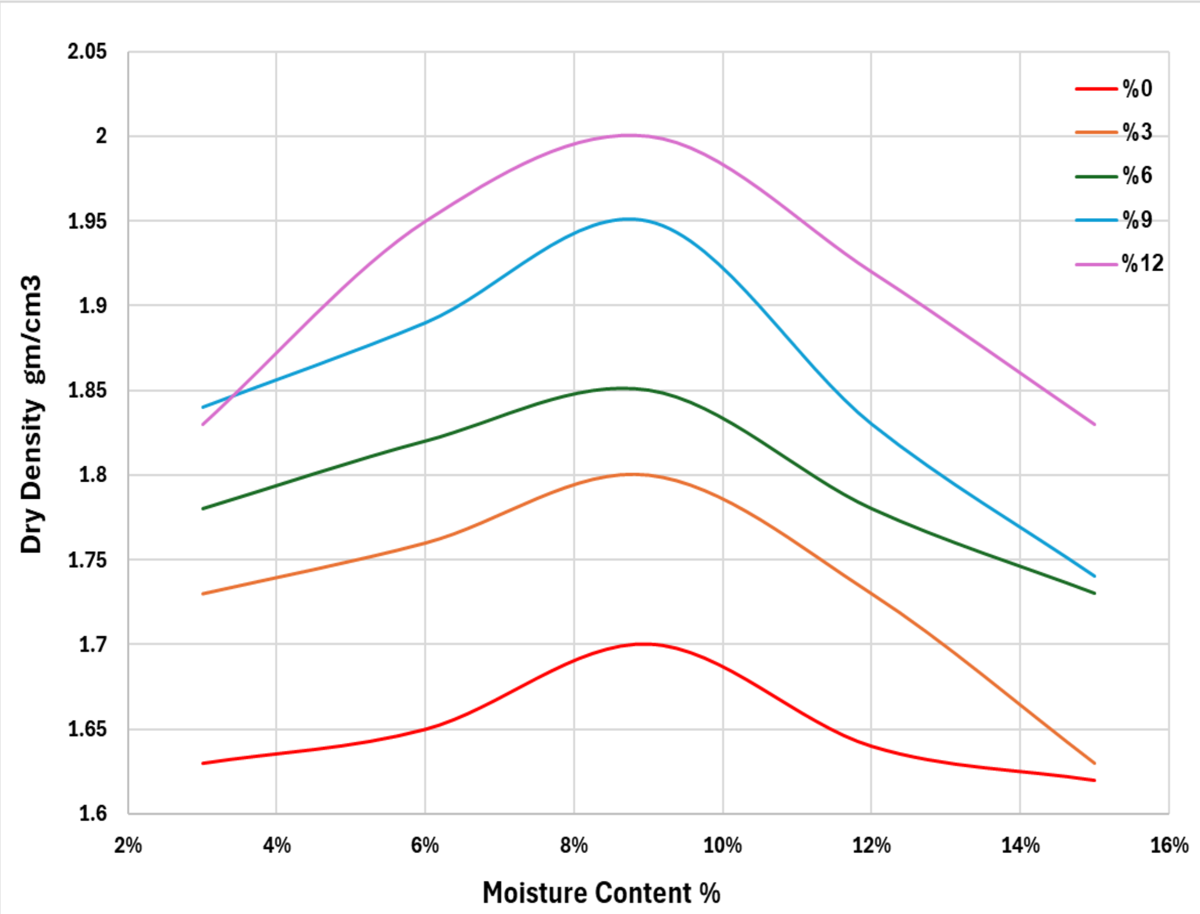

Figure (2) illustrates the compaction curves of the A-3 soil mixture with varying percentages of added clay.

As shown in Figure (3), there is no significant effect on the optimum moisture content with the addition of clay to the (A-3) soil, likely due to the relatively low percentage of the added material.

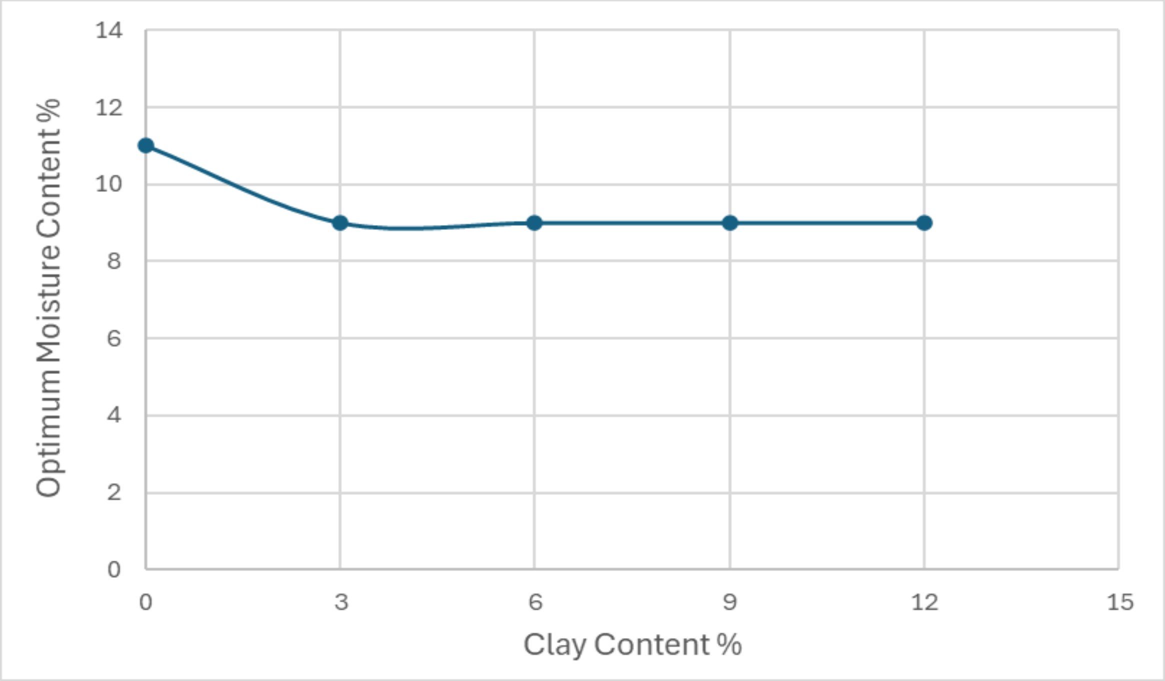

Figure 3 illustrates the relationship between the percentage of added clay and the optimum moisture content of the A-3 soil-clay mixture.

However, Figure (4) demonstrates that the maximum dry density increases with increasing clay content. It rises from approximately (1.7 g/cm³) for the first soil mixture to about (2.0 g/cm³) for the fifth soil mixture containing 12% clay.

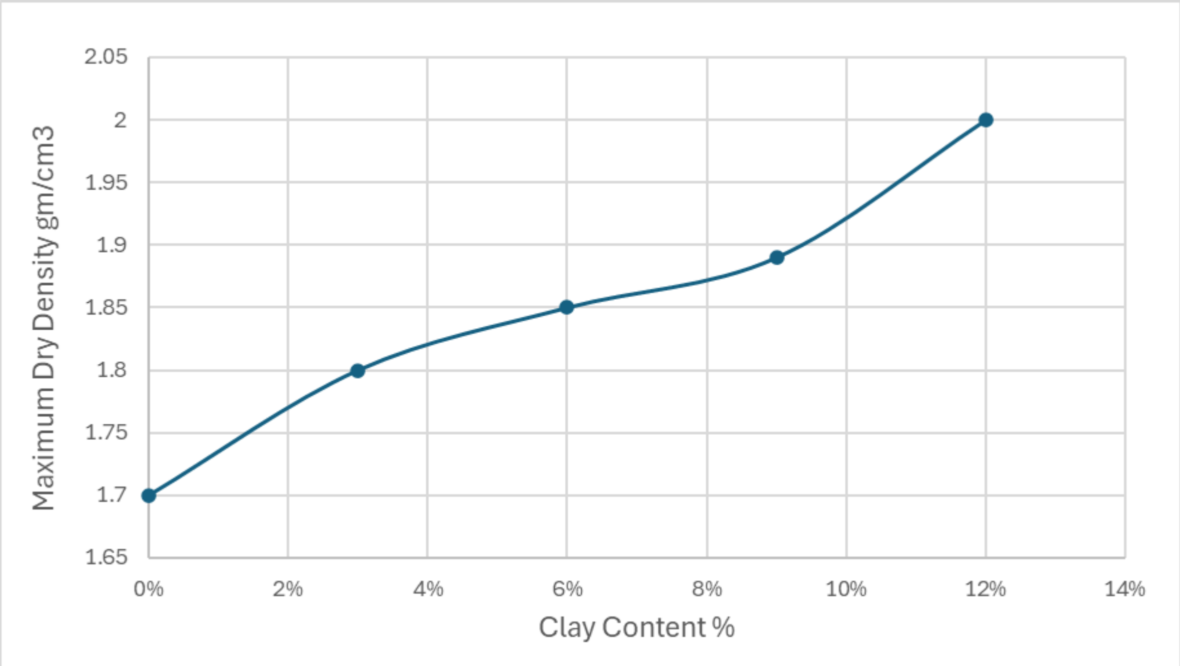

Figure (4) illustrates the relationship between the percentage of added clay and the maximum dry density of the (A-3) soil-clay mixture.

From Figure (2), the trend of increasing dry density from left to right is evident until the maximum dry density is reached, followed by a decrease in dry density beyond that point.

4.3 Shear Strength Characteristics of the Soil

The internal friction angle reflects the soil's resistance to sliding under applied loads and depends on particle nature and interlocking patterns. For sandy soil without any additives, the internal friction angle was found to be 34°, which is relatively high due to the non-cohesive nature of sand particles.

When 3% clay was added, a slight increase in the internal friction angle (34.99°) was observed. This can be explained by the fact that a small amount of clay fills the voids between sand grains but does not form a continuous matrix sufficient to prevent direct frictional contact between the sand particles.

It was found that the addition of clay to A-3 soil had significantly small effect the internal friction angle. However, a notable improvement in cohesion was observed, as the cohesion value for the A-3 soil mixed with 12% clay increased to (180), compared to zero cohesion for untreated A-3 soil.

Table 3 This table presents the measured values of internal friction angle (φ) and cohesion (c) for A-3 soil mixed with varying percentages of clay.

Clay Content (%)	Internal Friction Angle (φ) [degrees]	Cohesion (c) [kPa]
0	34.99	-10
3	34.99	30
6	45	50
9	51.34	73.3
12	56.31	180

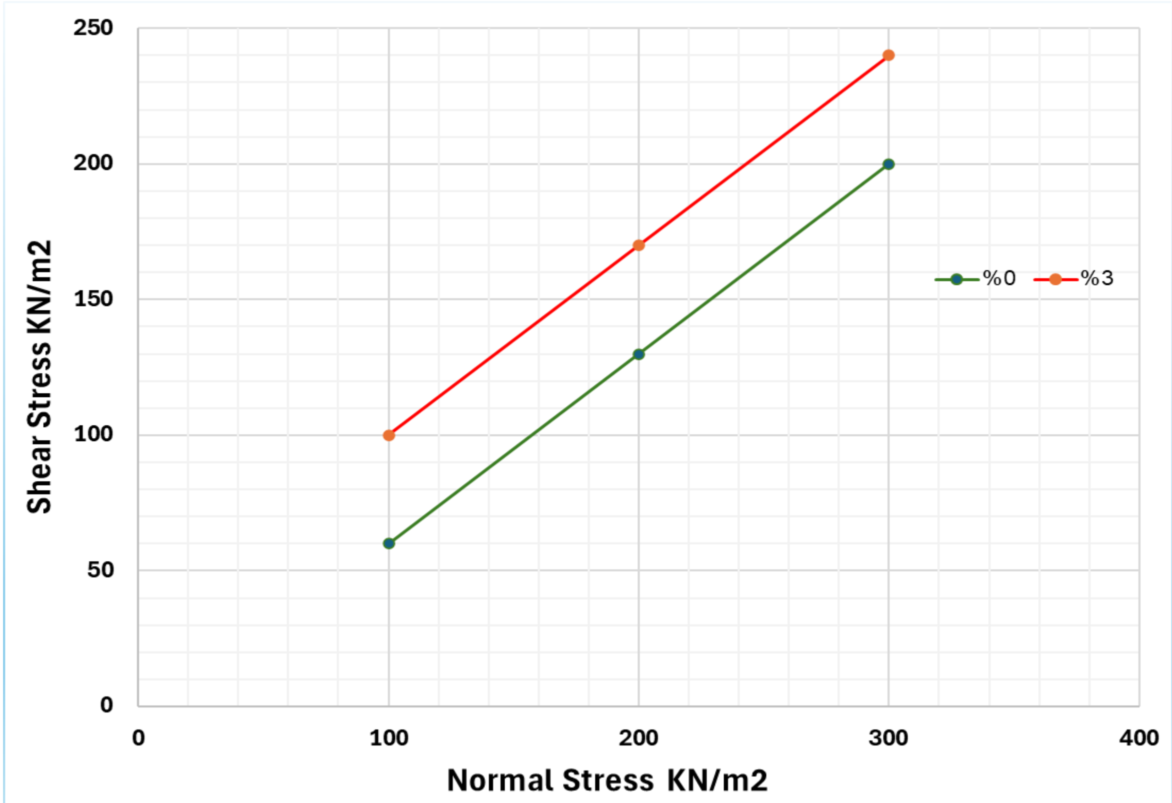

Figure 5 illustrates the relationship between the normal stress and shear stress for the non-submerged soil(A-3)-clay mixture samples.

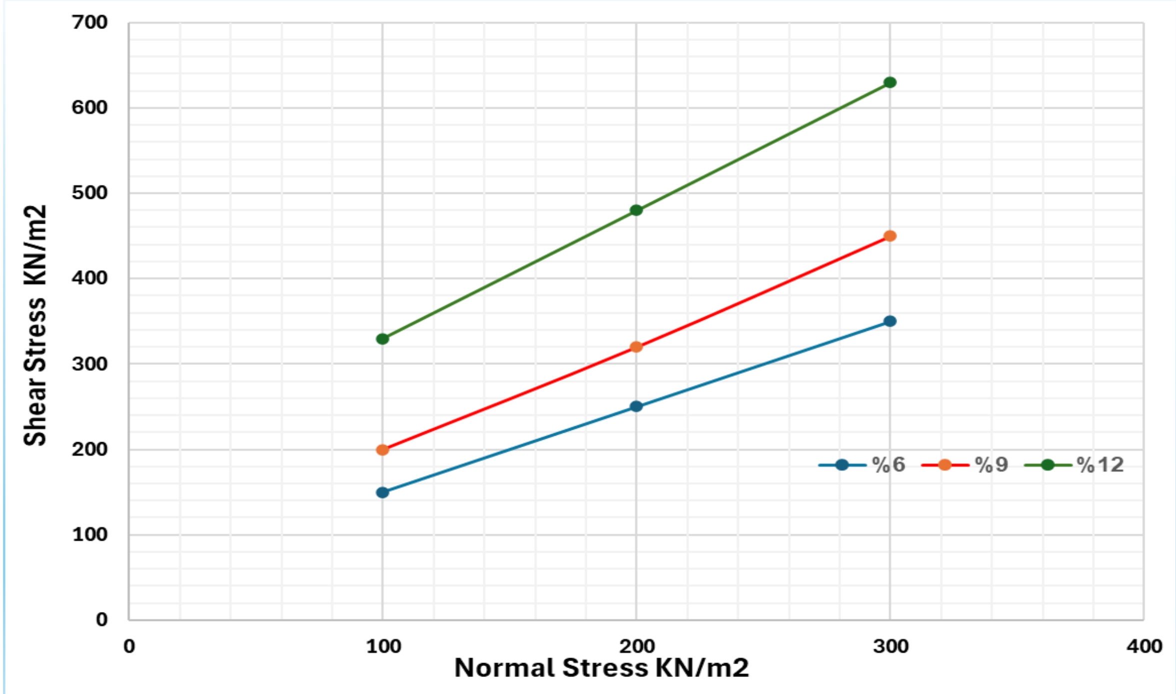

Figure 6 illustrates the relationship between normal stress and shear stress for the submerged soil(A-3)-clay mixture samples**.**

Conclusions

Based on the results of the laboratory tests, the following conclusions were drawn:

1. The engineering properties of the soil improved by adding clay to sandy soil in specific proportions.
2. The maximum dry density increased significantly with the addition of clay to the sandy soil, with an observed increase of up to 17.6%. However, the optimum moisture content was not significantly affected by the addition of clay.
3. The results indicate the potential for improving the properties of sandy soil by adding clay. One of the main drawbacks of sandy soil is its weak engineering behavior, which can be enhanced depending on the type and percentage of clay added.
4. It is recommended to continue further research using different types of clay and varying the proportions (both higher and lower) to better understand their influence on soil improvement.
5. The cohesion of sandy soil increases with the addition of clay; as the clay content increases, a noticeable improvement in cohesion is observed. In contrast, the internal friction angle shows only a slight increase, indicating that clay has a more significant impact on cohesion than on frictional resistance.

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