Alqalam Journal of Medical and Applied Sciences. 2025;8(3):1890-1896
https://doi.org/10.54361/ajmas.258388

Original article

Improvement of the Engineering Properties of A-3 Soil by the addition of plastic particles

Zaynab Alqadhqad[1], Shrifa Elhamroni[1], Abdalla Aboulkasim[2]*

[1]*Higher Institute of Science and Technology, Tripoli, Libya*
[2]*Higher Institute of Science and Technology-Souq Al-Juma, Tripoli, Libya*
Corresponding email. *Abdalla.Mohammed8521@gmail.com*

Abstract
This paper aims to investigate the use of plastic waste in sand A3. The particles of plastic materials utilized for this purpose were sourced from natural waste in the Garabulli region. Four different proportions of plastic strips (0%, 5%, 10%, and 15%) were mixed with the original dry soil. The mechanical and physical properties of the soil were then analyzed and compared before and after the addition of plastic waste. The results indicated an improvement in the soil's shear strength, along with an increase in maximum dry density and a reduction in the soil void ratio.
Keywords. Dry Density- Shear Strength- Particles of Plastic, Soil A3.

Introduction

Sandy soil is a coarse-grained, non-cohesive soil. The engineering properties of sandy soil depend on the dry density [1,2]. Due to the use of sandy soil in construction work, it is important to consider the friction resistance between the particles. Therefore, A3 soil is of lower quality because it is a fine sandy soil, poorly graded, and non-cohesive [3-7]. In this research, the possibility of improving the engineering properties of A3 soil by adding plastic particles in specific percentages of 0%,5%,10%, and 15% is studied.
The result of a few conducted studies that used plastic-based additives to stabilize the soil was a significant improvement achieved in soil strength, workability, and durability [8-11]. Therefore, it is needed to conduct extensive studies to determine the effect of this material on soil stabilization.

Materials

Soil

(Table 1) shows the physical properties of the soil used in this research.
The soil was collected from the ground surface. (Figure 2-a) and (Figure 3-a) show the grain size distribution and dry density- water content relationship, respectively.

Table 1. Physical Properties of the tested soil

Property	Maximum dry density kg/cm3	Optimum water content 0%	Liquid limit %	Plastic limit %	AASHTO specification
value	1.65	12.28	N. P	N. P	A-3
Specification	AASHTO T99-01	AASHTO T99-01	AASHTO D4318	AASHTO D4318	AASHTO D3282

Particles of plastic

Plastic is a versatile category of materials that includes a wide range of synthetic or semi-synthetic compounds. These materials consist of polymers, which are long chains of molecules, and they possess the property of plasticity, meaning they can be easily molded or shaped. Plastics are commonly used in packaging, construction, medical equipment, and electronics due to their adaptability and desirable properties such as lightweight, durability, flexibility, and low production cost. They can be derived from petrochemicals or natural substances like cellulose or starch.

Received*: 27-06-2025 -* ***Accepted****: 25-08-2025 -* ***Published****: 02-09-2025*

Figure 1. Particles of plastic

Table 2: Plastic Material Physical Properties

Plastic Type	Density (g/cm³)	Melting Point (°C)	Transparency	Flexibility	Hardness	Example Products
Polyethylene (PE)	0.91-0.96	105-135	Transparent	Flexible	Soft	Plastic bags, squeeze bottles
Polypropylene (PP)	0.89-0.91	130-171	Translucent	Flexible	Hard	Food containers, automotive parts
Polyvinyl Chloride (PVC)	1.3-1.45	100-200	Transparent	Flexible	Hard	Pipes, vinyl flooring
Polystyrene (PS)	1.04-1.06	70-115	Transparent	Rigid	Hard	Disposable cups, packaging foam
Polyethylene Terephthalate (PET)	1.38-1.40	245-265	Transparent	Rigid	Hard	Beverage bottles, polyester fibers
Acrylonitrile Butadiene Styrene (ABS)	1.03-1.06	210-240	Opaque	Rigid	Hard	LEGO bricks, computer keyboards
Polyurethane (PU)	0.95-1.25	-	Translucent	Flexible	Soft-Hard	Foam cushions, shoe soles
Polycarbonate (PC)	1.20-1.22	220-230	Transparent	Rigid	Hard	Safety goggles, CDs/DVDs

Table 3. Plastic Material Chemical Properties

Plastic Type	Chemical Resistance	Flammability	Thermal Stability	Electrical Insulation
Polyethylene (PE)	Good	Flammable	Limited	Excellent
Polypropylene (PP)	Excellent	Flammable	Good	Excellent
Polyvinyl Chloride (PVC)	Good	Flammable	Limited	Good
Polystyrene (PS)	Limited	Flammable	Limited	Good
Polyethylene Terephthalate (PET)	Good	Flammable	Good	Good
Acrylonitrile Butadiene Styrene (ABS)	Good	Flammable	Good	Good
Polyurethane (PU)	Good	Flammable	Good	Good
Polycarbonate (PC)	Good	Flammable	Good	Good

Methodology

The tested soil was mixed with four dosages of plastic particles i.e., (0.0,5.0,10.0, and 15) % of the weight of dry soil.

Figures 2-a,2-b,2-c,2-d shows the grain size distribution of mixed soil. Four groups of mixtures were prepared. Each group invaded, mixing the soil with some dosage of particles of plastic. That's shown in (Figures 3-a, 3-b, 3-c, 3-d) and (Figures 4-a, 4-b, 4-c, 4-d)

The particles of plastic were then added step by step and well mixed with the soil samples to ensure that the particle of plastic is well distributed over the soil sample, particularly. The Shear Box Test was carried out to evaluate the evolution in soil strength. All specimens were tested with a loading rate (mm/min) standard proctor test was carried out to determine the maximum dry density for the mixture. Comparison was made between pure and mixed soil.

Received: *27-06-2025* - ***Accepted***: *25-08-2025* - ***Published***: *02-09-2025*

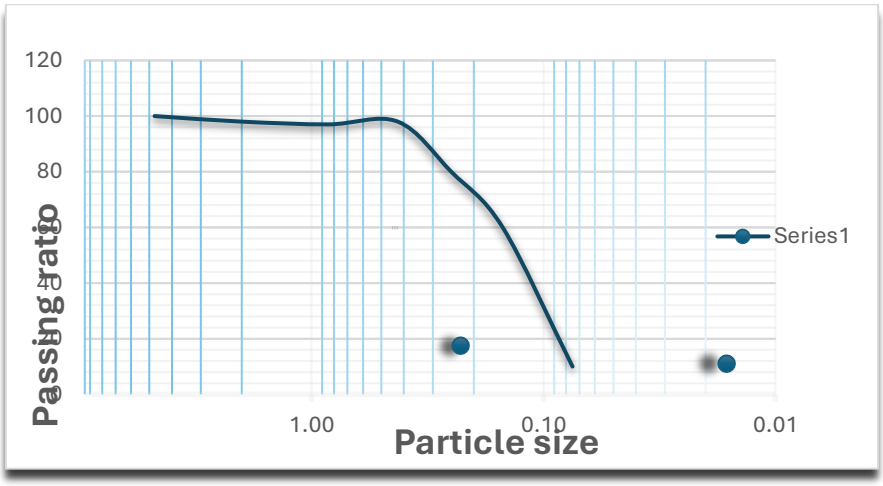

Figure 2-a. The relationship between the sieve opening and the passing rate by adding 0% particles of plastic

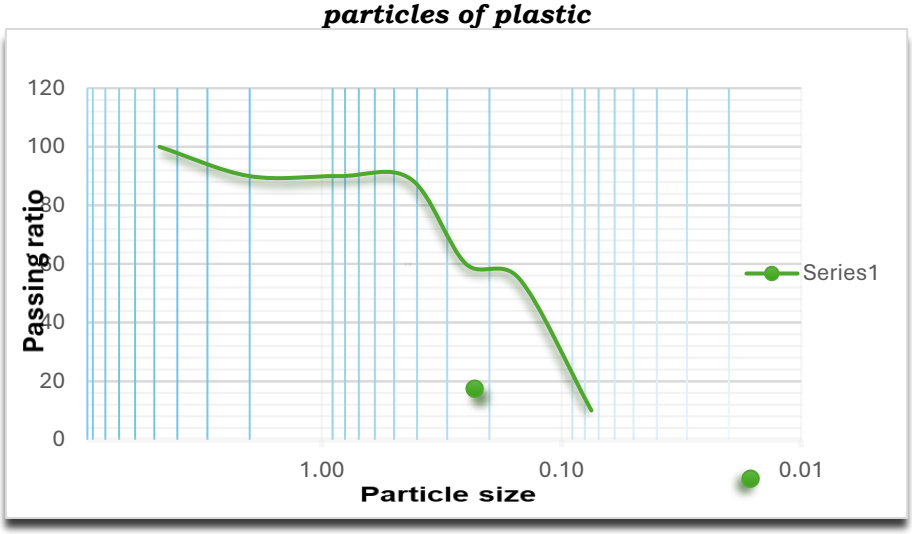

Figure 2-b. The relationship between the sieve opening and the passing rate by adding 5% particles of plastic

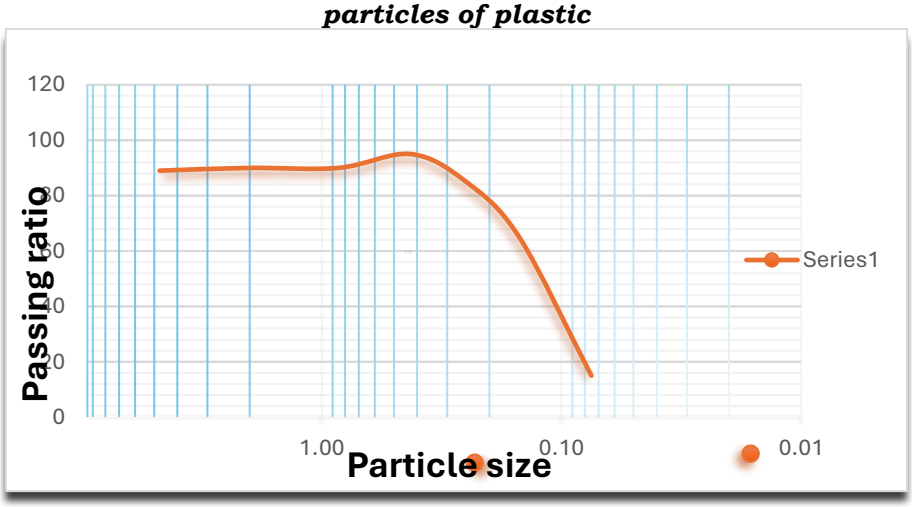

Figure 2-C. The relationship between the sieve opening and the passing rate by adding 10% particles of plastic

Received*: 27-06-2025 -* ***Accepted****: 25-08-2025 -* ***Published****: 02-09-2025*

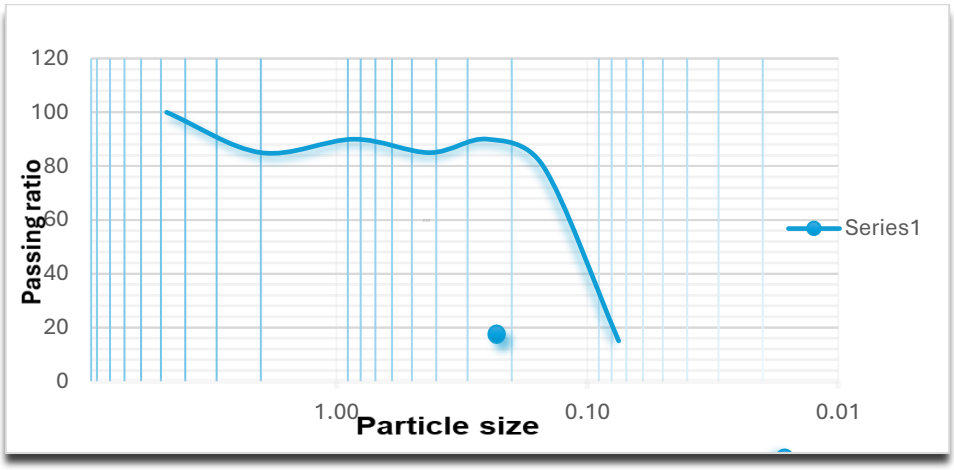

Figure 2-d. The relationship between the sieve opening and the passing rate by adding 15% particles of plastic

Results and discussion

Results of dry density

Figure 3-a shown the results obtained from the standard proctor test. They show the maximum dry density 1.65g/mm2 and optimum moisture content is (12.28%), An improvement in the compaction properties of the mixed soil: the maximum dry density rises, while the optimal water content drop, the maximum dry density has increased progressively by increasing the content of the particles of plastic, and the maximum dry density, and optimum dry water content has decreased at (15% plastic), that's show in (Figure 3-b, 3-c, 3-d).

Results of shear strength

Figures 4-a,4-b,4-c,4-d shown below present the results obtained from the shear box test, showing the strength gain for various contents of the plastic particles. The results of the shear box test for the pure soil show that the shear strength was (310.25) for a normal stress is (408.75 kPa), the strength drops to (277.28) after mixing the tested soil with particles of plastic at the same normal stress. However, there is a dramatic decrease in soil strength by increasing the increase in plastic.

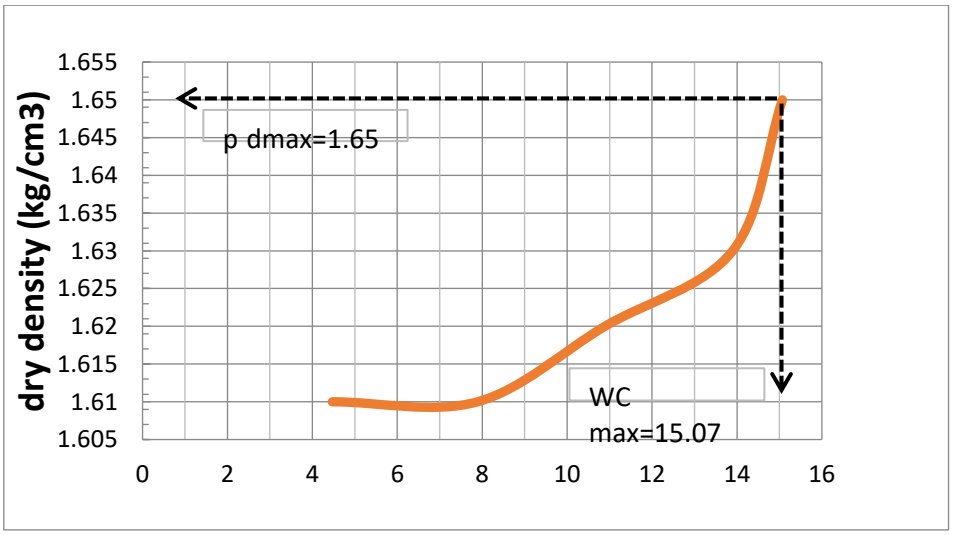

Figure 3-a. The relationship between water content and dry density by adding 0% particles of plastic

Received: *27-06-2025* - ***Accepted***: *25-08-2025* - ***Published***: *02-09-2025*

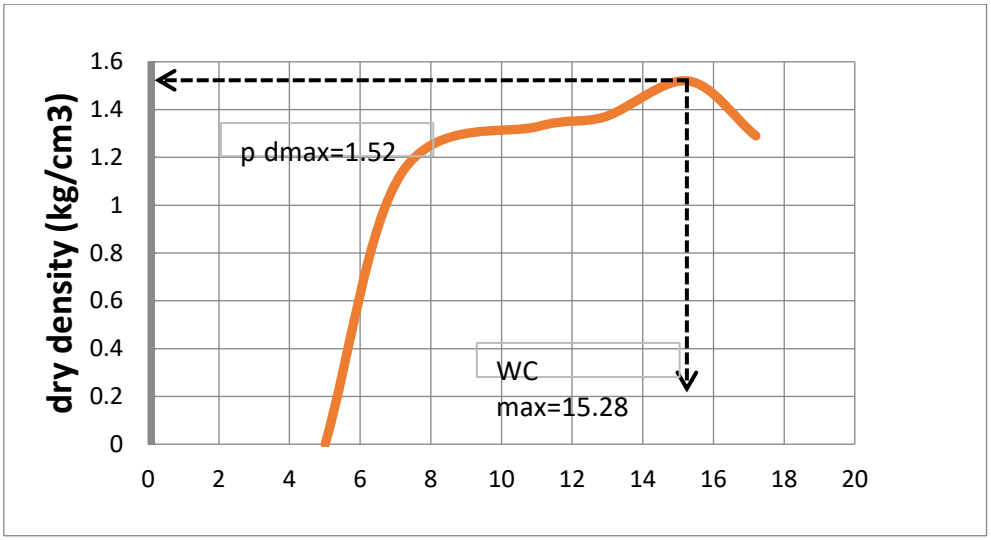

Figure 3-b. The relationship between water content and dry density by adding 5% particles of plastic

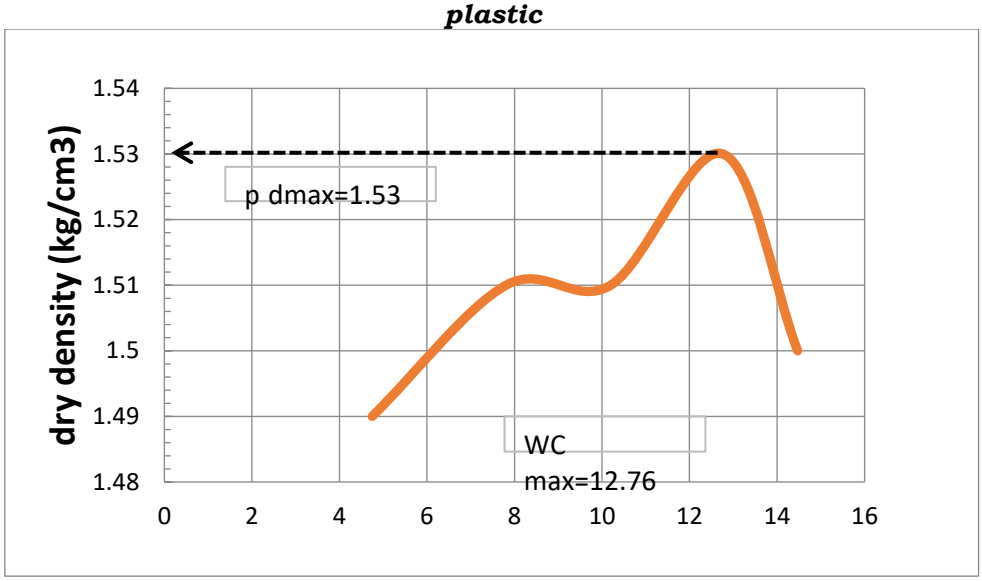

Figure 3-C. The relationship between water content and dry density by adding 10% particles of plastic

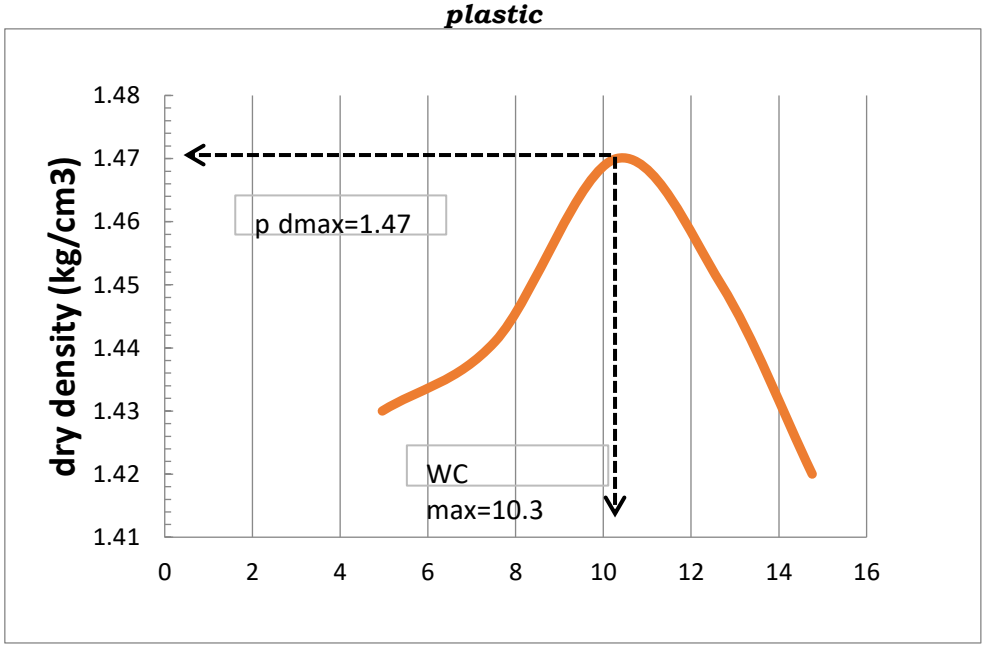

Figure 3-d. The relationship between water content and dry density by adding 15% of plastic particles.

Received*: 27-06-2025 -* ***Accepted****: 25-08-2025 -* ***Published****: 02-09-2025*

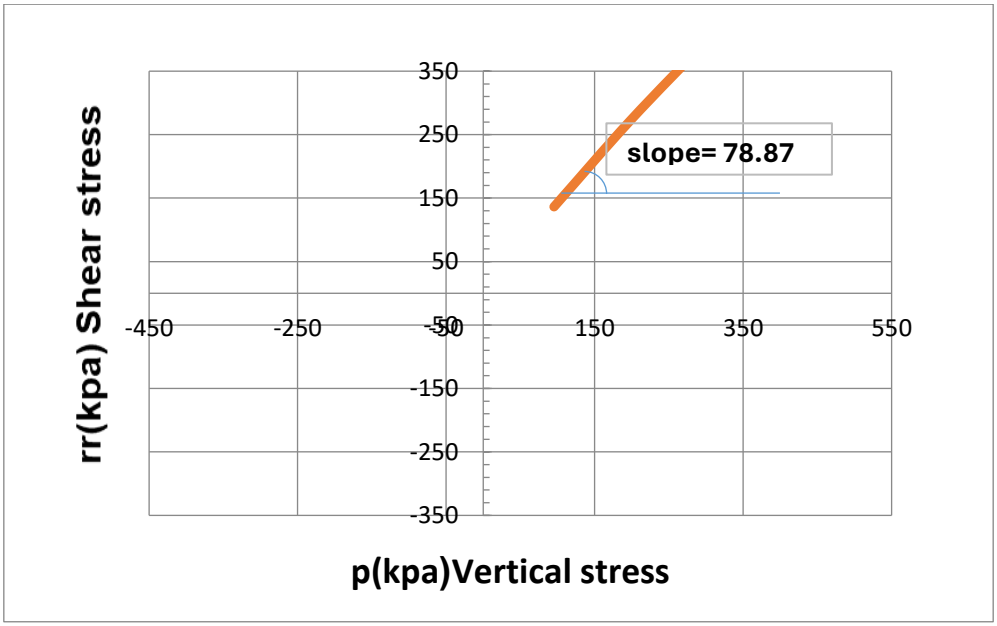

Figure 4-a. The relationship between shear stress and column stress by adding 0% plastic particles.

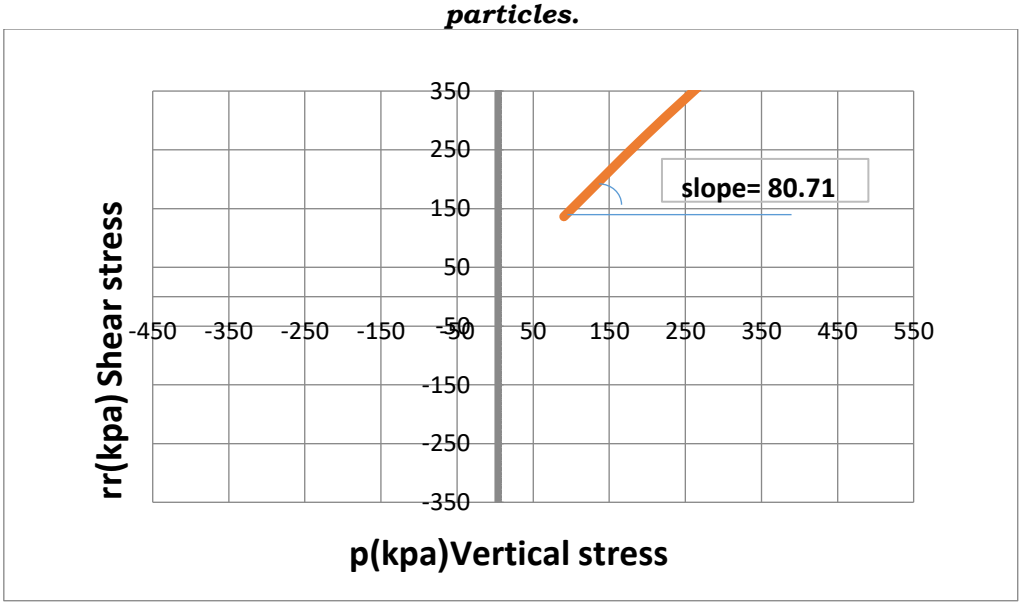

Figure 4-b. The relationship between shear stress and column stress by adding 5% plastic particles.

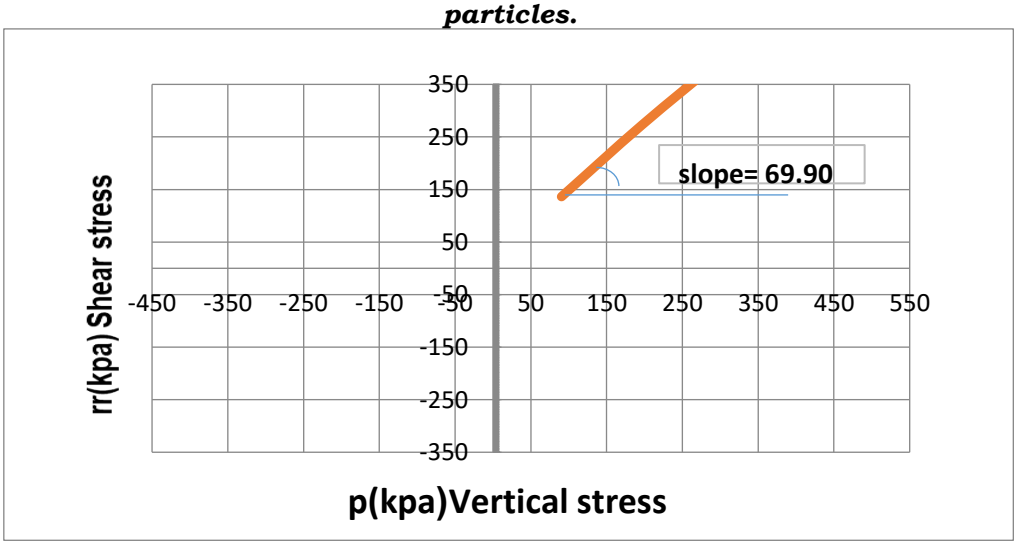

Figure 4-C. The relationship between shear stress and column stress by adding 10% plastic particles.

Received*: 27-06-2025 -* ***Accepted****: 25-08-2025 -* ***Published****: 02-09-2025*

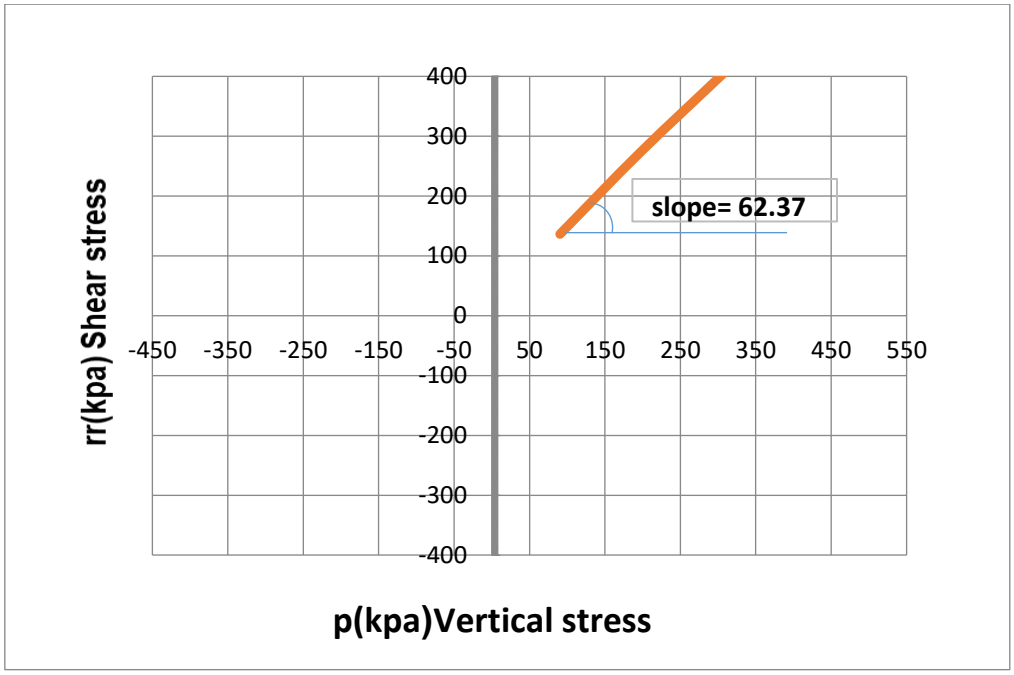

Figure 4-d. The relationship between shear stress and column stress by adding 15% plastic particles.

Conclusion

The results indicate the potential for improving the properties of sandy soil by adding plastic.

The maximum dry density increased significantly with the addition of the particles of plastic to the sandy soil, with an observed increase. However, the optimum moisture content was not significantly affected by the addition of plastic particles.

The cohesion of sandy soil increases with the addition of the particles of plastic, as the particles of plastic increases, a noticeable improvement in cohesion is observed . In contrast, the internal friction angle shows only a slight increase.

It is recommended to continue further research using different types of plastic particles and varying the proportion (both higher and lower) to better understand their influence on soil improvement.

References

1. Hogentogler CA. Essentials of soil compaction. Proc Highway Res Board. 1936;16:209-216.
2. Das B. Advanced Soil Mechanics. 3rd ed. Taylor & Francis; 2008.
3. ASTM. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³)). ASTM International; ASTM D698-91; 1999.
4. Liu X, Lu Z, Zhu Y, Lei Q. Estimation of shear strength of sand–clay mixtures. Geotech Geol Eng. Published online. doi:10.1007/s10706-022-02252-0.
5. Kim DH, Nam BH, Youn H. Effect of clay content on the shear strength of clay-sand mixture. J Mater Civ Eng. Published online. doi:10.1061/(ASCE)MT.1943-5533.0000966.
6. Bagheri M, Matziaris V. The combined effect of clay fraction and moisture on soil behavior. In: Proc 3rd International Conference on New Developments in Soil Mechanics and Geotechnical Engineering. Near East University; 2012:608-615.
7. Seed HB, Woodward RJ. Compaction characteristics of clay–sand mixtures. Proc Highway Res Board. 1961;40:146-168.
8. Yin K, Fauchille AL, Di Filippo E, Kotronis P, Sciarra G. A Review of Sand Clay Mixture and Soil–Structure Interface Direct Shear Test. Geotechnics. 2021;1(2):260-306. doi:10.3390/geotechnics1020014.
9. Tahir S, Marschner P. 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. J Soil Sci Plant Nutr. 2016;16(4):864-875. doi:10.4067/S0718-95162016005000061.
10. Shi A, Marschner P. Addition of a clay subsoil to a sandy topsoil alters CO_2 release and the interactions in residue mixtures. Sci Total Environ. 2013;465:248-254. doi:10.1016/j.scitotenv.2013.02.017.
11. Tahir S, Marschner P. Clay addition to sandy soil reduces nutrient leaching—Effect of clay concentration and ped size. Commun Soil Sci Plant Anal. 2017;48(14):1813-1821. doi:10.1080/00103624.2017.1395454.

Received*: 27-06-2025 -* ***Accepted****: 25-08-2025 -* ***Published****: 02-09-2025*