engineering proceedings

Proceeding Paper

Soil Improvement Using Waste Polyethylene Terephthalate (PET) †

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† Presented at the 5th Conference on Sustainability in Civil Engineering (CSCE), Online, 3 August 2023.

Abstract: This study investigates the use of waste polyethylene terephthalate (PET) bottle strips for soil stabilization in the Potohar region. Uncontrolled filling during housing societies development has led to settlement issues and structural cracking. By incorporating PET bottle strips in varying compositions, the engineering properties of the soil were improved, including increased maximum dry density, bearing capacity, and unconfined compression strength. This research paper offers an innovative technique to mitigate settlement problems and presents an eco-friendly waste management solution for sustainable development.

Keywords: bearing capacity; maximum dry density; PET bottle strips; plate load test

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Citation: Saeed, T.; Arshid, M.U. Soil Improvement Using Waste Polyethylene Terephthalate (PET). *Eng. Proc.* **2023**, *44*, 14. https://doi.org/10.3390/engproc2023044014

Academic Editors: Majid Ali, Muhammad Ashraf Javid, Shaheed Ullah and Iqbal Ahmad

Published: 28 August 2023

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1. Introduction

Recently soil stabization using polymers or waste materials such as polythene bags and waste plastic bottles are being explored by various researchers. A recent stud assesses the potential of cement kiln dust and plastic strips to enhance the properties of clayey soil. The inclusion of CKD increases the maximum dry density (MDD) of dune sand. An increase of 34% was achieved by mixing CKD [1,2]. An evaluation of waste marble dust has been carried out and reported to produce a considerable improvement in the physical properties of soil [3]. The plastic strips were of varying lengths (1 cm, 2 cm, and 3 cm) and different proportions of 0.2%, 0.5%, and 0.8%; an optimal improvement in the dry weight of soil was achieved with 2 cm plastic strips at 0.8% of the dry weight of the soil [4]. The fiber-reinforced soil improved the strength and engineering properties of the soil; the best percentage the plastic fiber achieved was 0–5%, there was an increased CBR value, and a reduction in the settlement of the dimensions, showing a higher aspect ratio to obtain better results [5]. The plastic strips were cut into different sizes, with lengths ranging from 12 mm to 21 mm and widths of 3 mm and 6 mm. Different concentration of PET content (0%, 0.4%, 0.6%, 0.8%, and 1% by soil weight) were incorporated. The highest unconfined compressive strength (UCS) was the one containing 0.8% PET strips with a width of 3 mm and a length of 18 mm; they achieved an optimum UCS 2.17 time compared to raw soil [6]. The liquefaction susceptibility of PET fiber-reinforced fine sand has been presented on the basis of results obtained through a series of cyclic triaxial tests. The number of cycles was four to reach liquefaction compared to unreinforced sand at a composition of 0.6% PET plastic fiber [7].

2. Materials and Methods Section

2.1. Sieve Analysis and Atterberg's Limit Test

The sieve analysis test was performed in accordance with ASTM D-6913. A 250 g soil sample was taken and washed through a sieve with a mesh size of 0.075 mm. After drying the sample for 24 h, the sample retained on sieve no. 200 was passed through a series of sieves in descending order, ranging from 4.75 mm to 0.075 mm. The Atterberg's limits tests were performed in accordance with ASTM D-4318. The liquid limit and plastic limit tests were performed on raw soil and composite samples with plastic strips contents of 0.4%, 0.7%, and 1.0%.

2.2. Standard Proctor and Plate Load Test

The standard proctor tests were performed following ASTM D-698. The soil sample was compacted in a 4″ diameter mold in three equal layers. Each layer was compacted by applying 25 blows with a hammer of 5.5 lb weight. The plate load tests were performed as per ASTM D-1194. A pit was excavated with dimensions of 2.50′ × 2.50′ × 2.0′ feet. The tests were performed on loosely filled soil, partially compacted soil, well-compacted pure soils, and well-compacted composite soils with plastic strips content of 0.4%, 0.7%, and 1.0%.

3. Research Methodology

Plastic bottles were collected from the disposal point. The head and tail of the bottles were cut, and a tool was used to convert the bottles into spirals. These spirals were then further cut into final strips of different sizes. The PET bottles were cut into strips of 3 × 6 mm, 3 × 9 mm, and 3 × 18 mm composition at 0.4%, 0.7%, and 1.0%. The stepwise procedure for cutting the waste plastic bottles into strips is presented in Figure 1.

(**a**) (**b**) (**c**)

Figure 1. Waste PET bottle strip process: (**a**) strip cutting tool; (**b**) PET spiral; (**c**) plastic strips sizes.

4. Results and Discussion

4.1. Sieve Analysis Test and Index Properties

The soil sample was collected locally followed by evaluation of the index and physical properties of the raw soil as shown in Table 1. The soil was classified according to the Unified Soil Classification System (USCS) as CL-ML, belonging to the Silty Clay group. The gradation curve of the back fill material is shown in Figure 2.

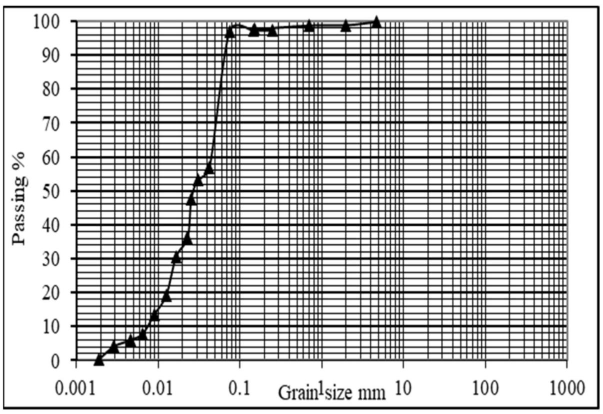

Figure 2. Gradation curve of back fill material.

Table 1. Properties of raw soil.

Test Description	Result	Test Description	Result
Specific gravity	2.76	Liquid limit	24.08%
OMC	14.50%	In situ Density	78.03 lb/ft^3
Natural moisture content	15–21%	MDD	110.48 lb/ft^2
Plastic limit	19.08%	UCS	983.1 lb/ft^2

4.2. Standard Proctor and Plate Load Test

The maximum dry density of the raw soil sample was measured as 110.48 lb/ft^3, while the optimum moisture content was found to be 15%. These values are depicted in Figure 3. The plate load test was conducted to determine the bearing capacity of the soil in different conditions: loose soil, partially compacted soil, and well-compacted soil after adding PET bottle strips at compositions of 0.4%, 0.7%, and 1.0% by weight. The stress settlement curve of loose soil is shown in Figure 4. The results showed that the bearing capacity increased with the addition of plastic strips up to a composition of 0.7%, as shown in Figure 5.

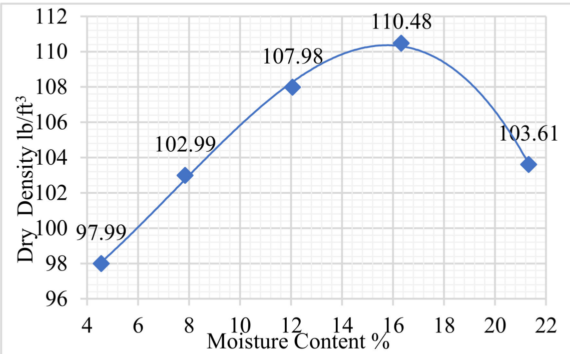

Figure 3. Moisture density curve.

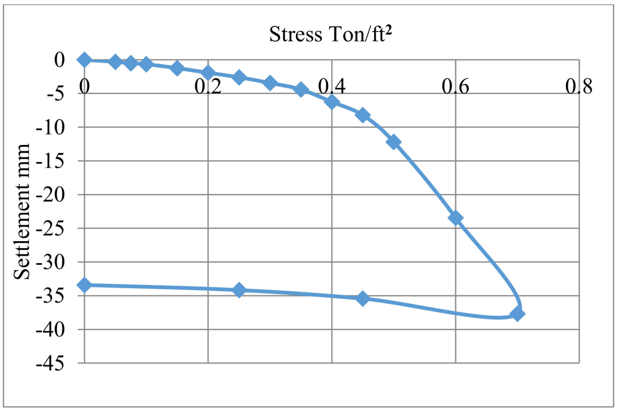

Figure 4. Stress settlement loose soil.

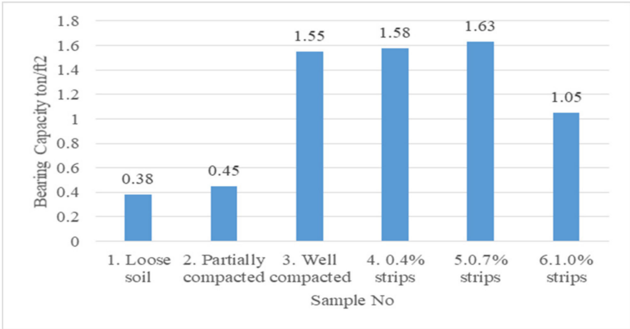

Figure 5. Effect of percentage PET bottle strips on bearing capacity.

5. Conclusions

The current study aimed to improve the bearing capacity of loosely filled fine-grained soils, hence reducing post-construction settlement. The uncontrolled filling comprised the silty clay group (CL-ML), as classified according to the Unified Soil Classification System (USCS). The following conclusions have been drawn following the laboratory and field investigation.

- The in situ density of the soil was 78.03 lb/ft^3, and the bearing capacity of the loose soil was 0.38 ton/ft^2.
- The dry density of well-compacted soil without any strips was found to be 94.88 lb/ft^3, and the corresponding bearing capacity was determined to be 1.55 ton/ft^2.
- The dry density of well-compacted soil with a 0.7% strip content was found to be 106.11 lb/ft^3, while the corresponding bearing capacity was determined to be 1.63 ton/ft^2.
- The maximum improvement in the bearing capacity of soil was observed as 328% compared to loosely filled soil in the field.

PET bottle strips are effective for soil stabilization and improving the engineering properties of soil. Utilizing PET bottle waste materials for soil stabilization is not only environmentally friendly but also economically viable.

Author Contributions: M.U.A.: Conceptualization, methodology, Supervision, writing—review and editing, administration; T.S.: Experimentation, formal analysis, investigation, writing—original draft preparation. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All the data has been incorporated in the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Hassan, S.; Sharma, N. Strength improvement of clayey soil with waste plastic strips and cement kiln dust. *Int. J. Eng. Appl. Sci. Technol.* **2019**, *4*, 123–127. [CrossRef]
2. Arshid, M.U.; Sadia, Z.; Abdul, W. Evaluation of Cement Kiln Dust (Ckd) for the Improvement of the Thal Desert Dune Sand of Pakistan. In Proceedings of the 16th International Conference on Geotechnical Engineers, Lahore, Pakistan, 7–8 December 2022; Volume 16, pp. 131–135.
3. Waheed, A.; Arshid, M.; Khalid, R.A.; Gardezi, D.S.S.S. Soil Improvement Using Waste Marble Dust for Sustainable development. *Civ. Eng. J.* **2021**, *7*, 1594–1607. [CrossRef]
4. Kumar, T.; Panda, S.; Hameed, S.; Maity, J. Behaviour of soil by mixing of plastic strips. *Int. Res. J. Eng. Technol.* **2018**, *5*, 2578–2581.
5. Iravanian, A.; Haider, A.B. Soil Stabilization Using Waste Plastic Bottles Fibers: A Review Paper. *IOP Conf. Series Earth Environ. Sci.* **2020**, *614*. [CrossRef]

6. Roustaei, M.; Tavana, J.; Bayat, M. Influence of adding waste polyethylene terephthalate plastic strips on uniaxial compressive and tensile strength of cohesive soil. *Geopersia* **2022**, *12*, 39–51.
7. Jain, A.; Mittal, S.; Shukla, S.K. Use of polyethylene terephthalate fibres for mitigating the liquefaction-induced failures. *Geotext. Geomembranes* **2023**, *51*, 245–258. [CrossRef]

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