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Reinforcement of Soil Using Recycled Polyethylene Terephthalate (PET) Bottle Strips

Rashik Karmacharya [a], Indra Prasad Acharya [b]

[a, b] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
Corresponding Email: [a] rashikkarmacharya@gmail.com, [b] indrapd@ioe.edu.np

Abstract
As good soil becomes scarcer and their location becomes even more difficult and costlier, the need to improve its quality using innovative new technique is becoming ever more important. This research involves a study on the possible use of waste plastic bottles as soil reinforcement elements. A series of tri-axial test were carried out on three different samples of soil prepared from typical soil used for routine construction in and around Kathmandu valley. The analysis was carried out by varying the percentage of plastic used varying from 0.5% to 1.5% by weight of dry soil. The results indicate 25% to 125% increase in shear strength of soil for an addition of 0.5% to 1.5% of plastic strips by weight of soil under laboratory conditions. The primary objective of this research is to find out an effective utilization of waste plastic bottles in the geotechnical engineering application, simultaneously addressing some aspects of solids waste management without adversely affecting the nature.

Keywords
Soil reinforcement – Soil improvement – PET reinforcement – Fiber reinforcement – Shear strength

1. Introduction

Soils are strong in compression but weak in tension. This weak property of soil can be improved by introducing reinforcing elements in the direction of tensile stress. Reinforcement material generally consists of galvanized or stainless steel strips, bars, grids or fabrics of specified material, or wood, polymer and plastic etc. The reinforcement is placed or layered at specific direction and position, more or less the same way as steel in concrete. The end product is called reinforced soil, and effectively used for retaining structures, embankments, footings and sub-grade etc.

Soil reinforcement is the process of improving the physical properties of soil, such as shear strength, angle of internal friction & bearing capacity of the soil, in order to enhance its load carrying capacity. The two most common techniques of reinforcing a soil are:

1. Mixing of soil amendments such as lime, cement and fly-ash into weak clayey soil and re-compacting to improve its bearing capacity. (often done under the road base in highway construction)
2. Installing composite webbing layers such as geo-grid, geo-textile or geo-cell in alternating layers with compacted soil to produce a stronger sloped soil structure (often done on steep roadway embankments to improve its strength and stability)

Soil reinforcement using plastics are among the latest technique in which plastics of desired type and quantity are added in the soil, mixed and laid. Thus the method of preparation is similar to conventional stabilization techniques. Randomly Distributed PET Stabilization is different from the other reinforcing methods in its orientation. In reinforced earth, the reinforcement is in the form of sheets etc. is laid horizontally at specific intervals, where as in Randomly Distributed PET Stabilization, PET strips are mixed randomly in soil thus making a homogeneous mass and maintain the isotropy in strength. PET reinforced soil can be used effectively in embankment, sub-grade, sub-base and other such cases.

Experimental work done by various investigators such as Anas et al. [1], Benson and Khire [2], Raghu, Mukherjee and Chakrabarti [3], Choudhary and Jha

[4][5], Thakare and Sonule [6] has established beyond doubt that addition of plastics in soil improves the overall engineering performance of soil. Among the notable properties that improve are shear strength, ductility, toughness, isotropy in strength, CBR values etc. with reduction of compressibility characteristics.

2. Objective and Scope of Study

This research considers a laboratory analysis of the engineering behavior of soil reinforced with PET plastic waste. The main objective of this research is to find out the effective utilization of waste plastic bottles in the geotechnical engineering application, simultaneously addressing some aspects of recycling of plastic waste bottle without adversely affecting the nature. The introduction of plastic bottles as soil reinforcing techniques will enable engineer's to effectively use unsuitable in-situ soils as reliable construction material in a wide range of civil engineering applications. The results indicate that the plastic waste mixed soils have higher strength than plain soil. This project also meets the challenges of the society to reduce the quantities of plastic waste, producing useful material from non-useful waste materials that lead to the foundation of sustainable society.

3. Materials and Methods

The soil used in this study is a typical sandy soil used for routine construction in and around Kathmandu valley. Three different types of soil designated as soil B, Soil C and Soil D collected from three different parts of Kathmandu Valley Kusunti, Tundikhel and Balaju respectively were tested in the study.

Table 1: Index Properties of Soil

SN	Properties	Soil B	Soil C	Soil D
1	Sp. Gravity (G_s)	2.48	2.67	2.4
2	Cohesion (c)	0.15	0.22	0.12
3	Angle of Internal Friction (ϕ)	41.42°	43.63°	38.87°
4	Average grain size (D_{50})	0.398	1.882	0.455
5	Effective grain size (D_{10})	0.11	0.466	0.076
6	Coefficient of uniformity (C_u)	5.53	5.7	9.4
7	Coefficient of curvature (C_c)	1.4	1.07	0.4
8	Liquid Limit (LL)	21	38	25.5
9	Plastic Limit (PL)	9.53	15.95	9.55
10	Plasticity Index (PI)	11.47	22.05	15.95
11	USCS Classification	SW	SP	SC

The index properties of soil were determined as per the respective IS Codes.

The reinforcement used consists of PET bottle cut in longitudinal slender strips of dimension 3mm x 30mm, derived from conventional cold drinks PET bottle of 2.2 liter capacity and are randomly mixed with soil in varying percentage (0.5%, 1.0% & 1.5%) by dry wet of soil.

Plastic reinforced soils were prepared manually by hand mixing. Oven dried soil after passing through 4.75 mm sieve was taken and added with water for clayey soil and mixed uniformly. For a particular percentage of plastic content, $1/3^{rd}$ of total amount of plastic strips were distributed evenly and mixed thoroughly with wet soil and compacted. After mixing the $1/3^{rd}$ amount, another $1/3^{rd}$ amount were mixed in the same way. Lastly the rest $1/3^{rd}$ amount was mixed with the wet soil and compacted. The wet plastic-mixed soils were then used for performing a series of Tri-axial test.

To study the reinforcing effects of randomly mixed PET bottle strips Tri-Axial Shear Test were done on each mix. The tests were done as per the prescribed IS code [7] which was done in the remolded soil. 5 kg of oven dried soil after passing through 4.75 mm I.S sieve was taken and mixed evenly. The plastics were then distributed evenly and mixed with the wet soil uniformly and thoroughly. The wet plastic-mixed soil was then compacted using light compaction in 3 equal layers by giving to each layer 25 uniformly distributed blows of standard rammer. The specimen was then tested in the loading machine.

When the test was done due consideration was taken care of and minimum fault due to instrument and environment were also taken into consideration.

4. Results and Discussion

The engineering behavior of the soil-PET composite was examined by focusing on the influence of percentage inclusion of PET to the soil. Based on the various experiments elaborated in the above sections, this section presents the test results, analysis and discussions. Tests were performed on both reinforced and unreinforced soil. The unreinforced soil served as reference to evaluate the effect of PET plastic waste on studied soil.

Table 2: Tri-Axial Compression (UU) Test Results

S.No	Soil	PET Reinforcement	q_{Ult} (KPa)	Percentage Change
1	B	0.0%	89.83	0%
		0.5%	126.01	40%
		1.0%	135.72	51%
		1.5%	149.36	66%
2	C	0.0%	149.16	0%
		0.5%	184.56	24%
		1.0%	220.85	48%
		1.5%	258.80	74%
3	D	0.0%	73.06	0%
		0.5%	123.66	69%
		1.0%	151.90	108%
		1.5%	167.12	129%

Above Table 2 shows the result of Tri-Axial Compression tests of soil at varying PET strips contents. The results clearly indicate an increase in ultimate load carrying capacity of the soil with fiber reinforcement within a range from 0.5% to 1.5% fiber content for all three types of soil under consideration.

From the obtained test results graphs are plotted as shown below. Fig.1 to Fig.3 indicates increase in shear strength while performing Tri-axial test on soil sample with 0.5% to 1.5% of PET reinforcement as compared to soil sample without addition of PET reinforcement. This increase in strength of soil is considered to be due to the increase in friction between soil and PET strips and the development of tensile stresses in the included PET strip. Although, further research is necessary to clearly understand the load transfer mechanism on the interface between PET strips and soil.

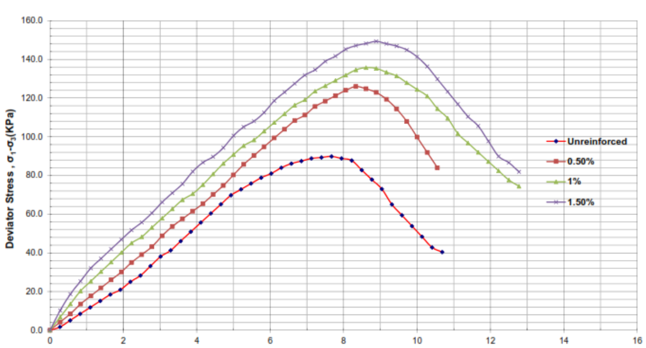

Figure 1: Stress-Strain curve of soil-B for various test set-ups

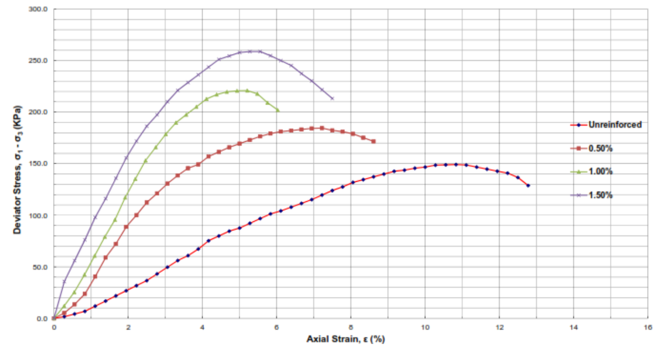

Figure 2: Stress-Strain curve of soil-C for various test set-ups

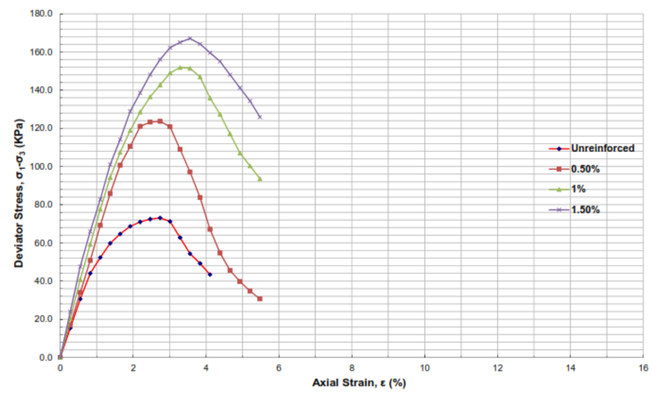

Figure 3: Stress-Strain curve of soil-D for various test set-ups

It is evident from the test results that as the percentage of reinforcement is increased, the maximum shear strength also increases up to the 1.5% of reinforcement, for the soil under consideration. Variation of shear strength with % of PET reinforcement strips have been presented in Figure 4 for all three soils sample under consideration.

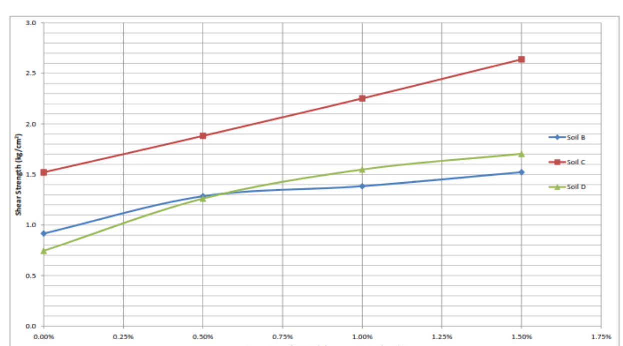

Figure 4: Variation of shear strenght with % of Reinforcement Strips

5. Conclusion

To investigate the effects of plastic waste mixed in soil, a series of Tri-axial compression (UU) tests have been performed with different percentages of plastic waste. Our experimental results clearly show that there is an appreciable improvement in the strength of soil with the inclusion of plastic strips. Ultimate load carrying capacities of a soil were significantly improved in all three types of soil tested. This increase in strength of soil is due to increase in friction between soil particles and the plastic waste and development of tensile stresses in the plastic waste. On the basis of the results and analysis presented in this paper, it can be concluded that Soil-PET mixtures improve the shear strength of the soil and consequently the bearing capacity. It has also been observed that the modulus of elasticity increases with the addition of the PET strips. However, further study is needed to optimize the size and shape of strips and to assess the durability and aging of the strip. Large scale test is also needed to determine the boundary effect influence on the test results. It may also be noted that the analysis carried out herein is only indicative of the possible improvements as the actual improvement depends on the choice of correct reinforced soil parameters and the dimensions and the concentration of the PET strips used.

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