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Influence of Polyethylene Terephthalate Waste on Mechanical Properties of Clayey Soil

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Abstract. This paper presents the study on the clayey soil reinforced with polyethylene terephthalate (PET) waste. Post-consumer plastic water bottle was used as a PET waste. Plastic bottles were cleaned and stripes were cut manually maintaining aspect ratio 2 & 4. The recycled PET strips were mixed in clayey soil in various combination. This combination ranges from 0 % to 1 % of the weight of soil. Especially the study was carried out on the properties of soil such as compaction characteristics and CBR value of soil. Main parameter was to investigate the optimum dosage and effective aspect ratio influencing the behavior of clayey soil. The investigation shows that there is significant improvement in the properties of soil like OMC, MDD and CBR value. This experimentation shows the potential use of waste plastic in improving the problematic or weak soil. The entire world is facing the nuisance of plastic pollution, so this may prove the effective way of recycling of waste plastic in the application of pavement.

Keywords: Clayey Soil, CBR, OMC, MDD, Polyethylene Terephthalate (PET).

1 Introduction

In the current time of sustainable development, it is a practice to use varieties of waste materials for modification of soil worldwide. In past numerous studies was carried out with waste materials such as fly ash, natural fibers of plam, reed, coir, bihul, chir, sabia, hemp, rice husk ash, lime, jute, polypropylene & nylon fibers and waste tire to investigate the properties of soils like compaction characteristics, shear parameters, unconfined compressive strength, CBR value and tensile strength [1-6]. Polypropylene and nylon were the types of waste materials used in many past studies to observe the effect of dosage, dimensions, form, etc. on different properties of soils [7-17]. Different forms of waste tires such as fibers, shredded flaks, chips were also studied to examine the mechanical properties of soils [18-20]. All such studies reported the effective modification of weak soils with waste material inclusion. On the other side very few effective studies available on the use of plastic waste for soil stabilization. The dumping of plastic products here and there become the sensitive problem due to modern life style of an individual, easy of doing any work, unawareness, etc. As per the 2019 CPCB report, every day around 26,000 tonnes of plastic waste generate and out of it around 10,400 tonnes of waste disposal are uncollected and littered in india [21].

1.1 Literature review and Scope of the Study

Plastic products categorized in to seven types i. e. PET, HDPE, PVC, LDPE, PP & others as per standards. Out of these PET, HDPE and LDPE is the types of plastic widely used in manufacturing of plastic water bottles, home cleaning products carrier, and packaging of electronics items which creating the issue post-consumer handling and gets littered. The study was carried out using HDPE strips to examine the effect of HDPE content and aspect ratio on CBR value of sandy soil which shows the effective improvement in CBR value [22]. PET water bottle chips were used along with fly ash to determine consolidation characteristics, shear parameters of soils waste mixture. Results shows decrease in compressibility with addition of plastic waste [23]. Along with PET plastic waste, lime and kaolin clay were used as an additive to investigate the point load strength index, compaction & strength parameters and deformation characteristics [24, 25]. Shake table test was carried out to observe the sand-PET mixtures behavior. Study reported that the plastic waste strips change behavior of mixture from brittle to ductile [26]. Full plastic waste bottle filled with sand was used by researches as a bed below foundation. It was observed from study that such bed performed well at a higher pressure [27]. PET waste converted in to form of geogrid, geocell and strips to examine the soil waste mixture. Study reports the significant modification in soil properties [28,29]. It is found from literature relatively less amount of work reported on soil-plastic waste mixtures and effective form of plastic waste. So looking towards such gaps the systematic experiments was carried out on soil-PET mixtures. In this connection, standard proctor test and California bearing ratio test series was performed in laboratory with different content and form. Table 1 show the different mix under consideration for the study.

2 Materials and Experiments

2.1 Materials

The soil was collected locally from the nearby region chekhla. Table 2 shows the properties of the soil. As per the IS classification the soil is classified as CI soil. For PET waste, post-consumer plastic water bottle was collected form canteen.

Table 1 Details of Soil – PET Combination

SN	Aspect Ratio	Mixture Combination	Mixture designation
1	-	Soil + 0 % PET	O1
2	AS = 2 W = 5 MM L =10 MM	Soil + 0.2 % PET	M1
3		Soil + 0.4 % PET	M2
4		Soil + 0.8 % PET	M3
5		Soil + 1 % PET	M4
6	AS = 4 W = 5 MM L =20 MM	Soil + 0.2 % PET	N1
7		Soil + 0.4 % PET	N2
8		Soil + 0.8 % PET	N3
9		Soil + 1 % PET	N4

Plastic water bottle with a symbol of PET was only collected. These bottles were cleaned and cut in to two different sizes of strips manually. The width of the strips was 5 mm and length were 10 and 20 mm thus the aspect ratio of pet strips was 2 and 4. The aspect ratio is defined as the ratio of length to width of strips. The PET stripes was shown in figure 1 and Table 2 shows the properties of PET plastic.

2.2 Experiments

Basic laboratory test was carried out to classify the soil. Two test series of experiments were conducted in the laboratory respectively for determination of compaction parameters and CBR value of clayey soil with 0, 0.2, 0.4, 0.8 and 1% PET content. Both test series were conducted as per the IS standard.

Table 2 Properties of Soil and PET Plastic Waste

SN	Properties	Value	Properties	Value
Properties of Soil			Properties of PET Waste	
1	Specific Gravity	2.66	Type of Plastic	PET
2	Liquid Limit	41%	Tensile Strength MPa	80-100
3	Plastic Limit	14%	Strip Length mm	100
4	Shrinkage Limit	8%	Strip Width mm	5
5	Plasticity Index	27	Strip Thickness mm	0.13
6	Soil Classification	CI	Colour	White

3 Results and Discussion

Firstly, the compaction parameters were obtained by performing the standard proctor test with clay and PET strips mixture. Figure 2 shows the clay PET mixture. Compaction test series was performed on the all the mix specified in table number 1 for determination of optimum moisture content and maximum dry density. Based on the OMC and MDD of all the mixes, CBR test series was conducted to find the CBR value of all mixes.

Fig. 1. Clay – PET stripes Mixture

Fig. 2. PET Strips

3.1 Effect of PET Strips on Compaction Parameters

Results of standard compaction test for all the mixes is shown in figure 3 and 4. From the compaction curves it is evident that with increase in PET strips content there is decrease in value of compaction characteristics. The continuous decrease is due to density of PET material compared to soil material. Moreover, such behavior is also due to water absorption characteristics of clay and PET waste mixture. The capacity of virgin clayey soil for absorbing the water is more and with addition of PET waste it will restrict the same. Figure 5 and 6 representing the comparison of OMC and MMD for the mixture of aspect ratio 2 and 4. The maximum decrease in OMC is for the content of 0.4 % in both the cases of aspect ratio. In case of aspect ratio 2 this decrease is around 3% and in case of aspect ratio 4 this value is 14%, which indicating the good compaction characteristics. The optimum maximum dry density is also achieved at 0.4% but there in not much difference in the value. As the optimum density for the mix M2 is 1.65 gm/cm^3 while this value for the N2 is 1.67 gm/cm^3.

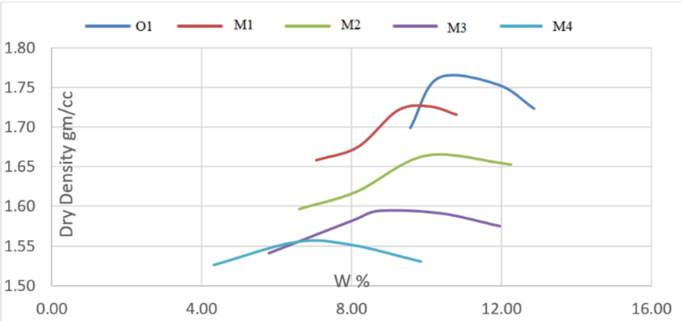

Fig. 3. Compaction Curve for the Clay PET Mixture for Aspect Ratio 2

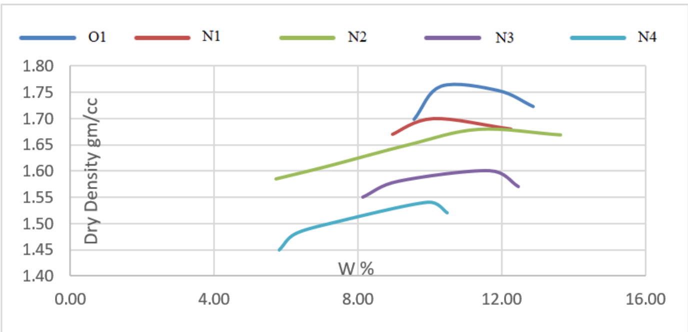

Fig. 4. Compaction Curve for the Clay PET Mixture for Aspect Ratio 4

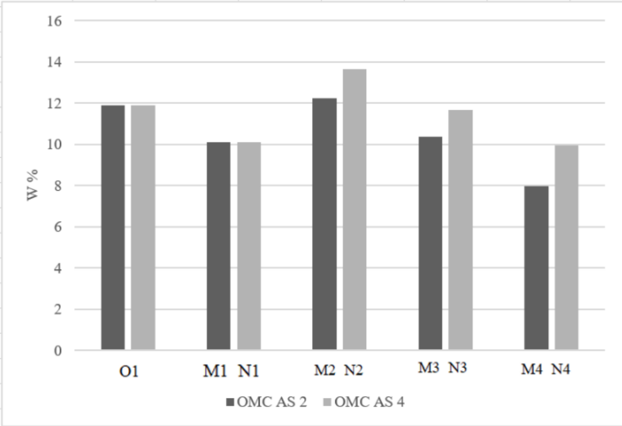

Fig. 5. Comparison of Optimum Moisture Content

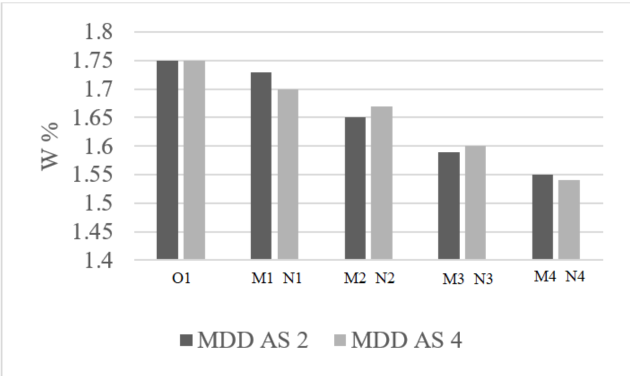

Fig. 6. Comparison of Maximum Dry Density

3.2 Effect of PET Strips on CBR value

California bearing ratio test series were carried out for all the mix. Figure 7 shows the CBR values for soil and waste PET strips mix for aspect ratio 2 and 4. From this first observation is that the CBR value having nature of increasing with addition up to 0.4 % and then decrease for other contents. CBR test shows the good result with the addition of PET strips with size 5 mm by 10 mm. For the PET strips size of 5 mm by 20 MM the CBR value is low compare the previous. This behavior is due to length of PET strip. The strip with aspect ratio 2 having length of 10 mm so it can easily distribute in the entire mix result in higher value of CBR. While the strip with aspect ratio 4 having length 20 mm which increasing PET content may cause weaker bond.

4 Conclusions

By addition of waste plastic water bottle strips there is decrease in the compaction parameters. Strips with aspect ratio 4 gives effective result for OMC and MDD with a 0.4 % optimum dosage. In case of CBR test, strips with aspect ratio 2 is increasing CBR value potentially for the same 0.4 % content. 0.4 % is the optimum dosage. Looking to the PET strips size and results of entire study it is recommend to use strips of aspect ratio 2 and with 0.4 % dosage. This systematic and detailed study tried to shows the significant reuse of post-consumer water bottle creating litter of the same for the improvement of the properties of clayey soil.

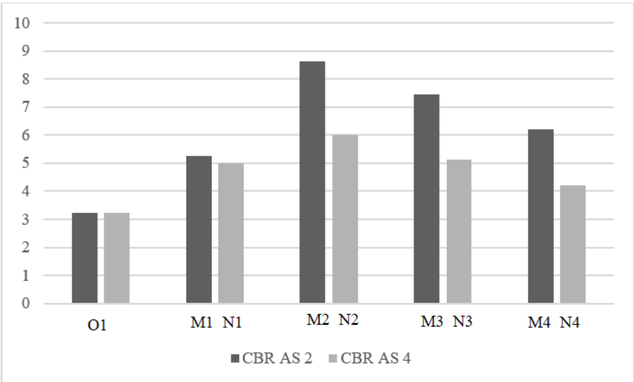

Fig. 7. Comparison of CBR Value

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