Analyzing the Behavior of Soil Reinforced with Polyethylene Terephthalate (PET) Wastes

M Meenakshi[1], Mohini MB[2]

[1]*Student, Department of Civil Engineering, Marian Engineering College, Kerala, India*
[2]*Assistant Professor, Department of Civil Engineering, Marian Engineering College, Kerala, India*

---***---

Abstract - *Currently there is a boom in the plastic industry as most of the sectors like agriculture, automotive, education, government, health, marketing and advertising, transportation, to mention but a few use plastic products. Due to the wear and tear of the plastic products there is a challenge in handling the non-biodegradable plastic waste by the solid waste management field. This research aims to mitigate the challenges faced by the civil engineering field and the solid waste management field by analyzing sand-PET (Polyethylene Terephthalate) plastic waste composite. Waste plastic shreds are added in varying percentages of 0.4, 0.8, 1.2, 1.6, and 2% to the soil samples as a reinforcement material. From compaction test, maximum dry density (MDD) and optimum moisture content (OMC) and bearing capacity of soil from CBR tests were determined for both sand samples. Strength parameters for sandy soil are obtained from direct shear test. Studies indicate that the stabilized soil could be utilized for roadways, parking areas, site development projects, airports, and many other situations where subsoil is not suitable for construction.*

Key Words: **Stabilization, Polyethylene Terephthalate (PET) wastes, Compaction, CBR, Direct shear**

1. INTRODUCTION

In general, the quantity of plastics of all types consumed annually all over the world has been growing in a phenomenal way. The manufacturing processes, service industries and municipal solid wastes (MSW) generate numerous waste plastic materials. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of the generated wastes. It is believed that the management of solid waste is one of the major environmental concerns in the world.

Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. Stabilization of soil is done in various way such that mechanical stabilization, chemical stabilization and by using other improvement techniques. Some new techniques used for stabilization of soil by using steel and other admixtures will be costlier and hence for both economical and pollution reduction of plastic waste the best way is that use such wastes is for improving engineering properties.

Therefore, in present study stabilization of soil is reviewed by using locally available plastic waste products of plastic bottles are used in stabilization of soil in the form of strips of suitable dimensions. The objective of this study is to improve the properties of soil in an economical way and reducing environmental pollution, and minimize the problems of plastic waste disposal.

2. LITERATURE REVIEW

Gray & Ohashi (1983), researched about mechanics of fibre reinforcement in sand, where direct shear tests were performed on dry sand reinforced with natural fibres, synthetic fibres and metal wires. The reinforcements included common basket reeds, PVC plastics, Palmyra (a tough fibre obtained from the African Palmyra palm), and copper wire.

Yetimoglu & Salbas (2003), conducted a study on shear strength of sand reinforced with randomly distributed discrete fibres. Sand and polypropylene fibres of diameter 0.05mm and length of 20mm were used in the proportion of 0.10%, 0.25%, 0.50% and 1.00% by weight of sand.

Acharyya et al. (2013), investigated the improvement of undrained shear strength of clayey soil with PET bottle strips. Tests carried to achieve the properties of PET plastic strips included width, thickness, tensile, and density. Unconfined compressive strength of soil-fibre composite increased as percentage of PET inclusion increased up to 1% (Acharyya et al. 2013) as the results revealed.

Rajkumar Nagle et al in 2014 performed CBR studies for improving engineering performance of sub grade soil. They mixed Polyethylene materials as reinforcement with black cotton soil, yellow soil and sandy soil. Their study showed that MDD and CBR value increases with increase in plastic waste. Load bearing capacity and settlement characteristics of selected soil material are also improved.

3. MATERIALS

3.1 Sea Sand

The soil used in this study is collected locally from Kazhakkuttom, Thiruvananthapuram district. The properties of the soil are studied using standard procedures and the results are tabulated in table. From the test results, the soil can be classified as Poorly Graded Sand according to Indian Standard Classification system.

Table 1 Properties of Sea sand

Properties	Result
D_{10} (mm)	0.300
D_{60} (mm)	0.460
D_{30} (mm)	0.370
Uniformity Coefficient, C_U	1.533
Coefficient of Curvature, C_C	0.992
Specific Gravity	2.64
Optimum Moisture Content	8%
Maximum Dry Density (g/cc)	1.68
Angle of Shearing Resistance	39^o
Cohesion (kg/cm^2)	0.2
Classification of soil	SP

3.2 River Sand

The soil used in this study is collected locally from Neyyar river banks, Thiruvananthapuram district. The properties of the soil are studied using standard procedures and the results are tabulated in table 2. From the test results, the soil can be classified as Poorly Graded Sand according to Indian Standard Classification system.

Table 2 Properties of River sand

Properties	Result
D_{10} (mm)	0.175
D_{60} (mm)	0.390
D_{30} (mm)	0.252
Uniformity Coefficient, C_U	2.228
Coefficient of Curvature, C_C	0.930
Specific Gravity	2.54
Optimum Moisture Content	10.26%
Maximum Dry Density (g/cc)	2.11
Angle of Shearing Resistance	40^o
Cohesion (kg/cm^2)	0.09
Classification of Soil	SP

3.3 Polyethylene Terephthalate (PET)

Polyethylene Terephthalate (PET or PETE), is a strong, stiff synthetic fibre and resin. PET is a member of the polyester family of polymers. PET is produced by the polymerization of ethylene glycol and terephthalic acid. Plastic waste flakes of the type of Polyethylene Terephthalate (PET) were used as reinforcing material in the present study. These were obtained from Family Plastics factory located in Kulathoor, Trivandrum, a factory that uses recycled PET plastic bottle flakes to manufacture plastic products. The PET plastic waste flakes were of assorted colours and their sizes ranged between less than 10mm to greater than 1.18mm.

4. METHODOLOGY

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 30mm x 30mm and are randomly mixed with soil in varying percentage (0.4%, 0.8%, 1.2%, 1.6% & 2.0%) by dry wet of soil.

Oven dried soil after passing through 4.75 mm sieve was taken and water added for clayey soil and mixed uniformly. For a particular percentage of fibre content, the 1/3 rd of total amount of plastic strips were distributed evenly and mixed thoroughly with wet soil. After mixing the 1/3rd amount, another 1/3rd amount was mixed in the same way. Lastly the rest 1/3rd amount was mixed with the wet soil. The wet plastic-mixed soils were then used for proctor tests and CBR test.

For determining the shear parameters of the soil oven dried soil was mixed with the required amount of PET flakes and were mixed by hand and then filled onto the shear box for direct shear test.

The study focuses on studying the effect of aspect ratio of PET flakes on the soil strength improvement and further applications of PET flakes reinforced sand.

4. RESULTS AND DISCUSSIONS

4.1 Compaction

The strength of weak soils can be altered by the addition of PET waste in varying percentages. In the present investigation a series of compaction tests were carried out by varying PET waste. The effect of PET waste on OMC and MDD are shown in Fig.1 and 2.

The data from the test indicates that the optimum moisture content of stabilized sediments is less than that of raw sediments. The maximum dry density was noted to decrease slightly with increase in addition of PET waste as the addition of PET waste to soil makes the soil-PET mixture lighter due to lower density of PET flakes. Hence, PET plastic waste which can't be recycled is withdrawn from the environment and utilized to civil engineering structures where lighter structures are needed.

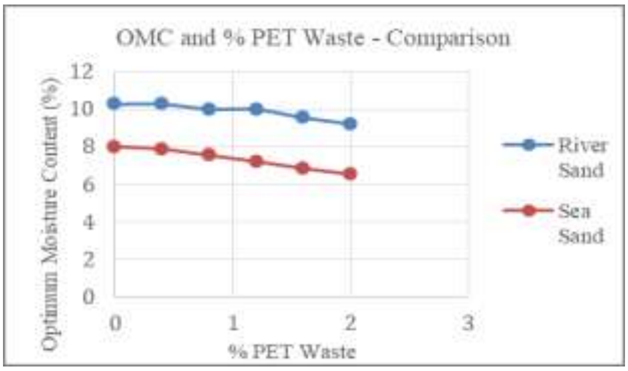

Chart -1: Variation on OMC with different percentages of PET waste

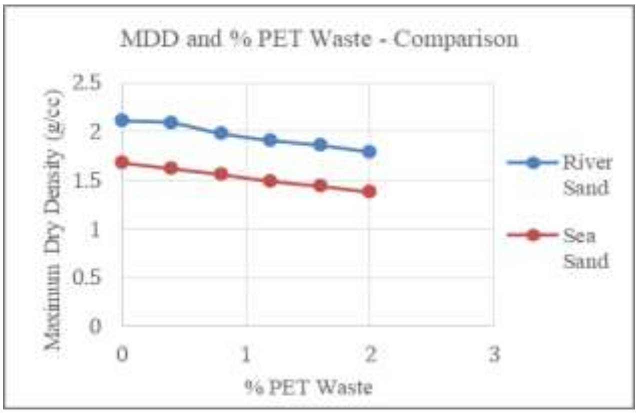

Chart -2: Variation on MDD with different percentages of PET waste

4.2 Direct Shear

The angle of shearing resistance (φ) increased exponentially with that of the addition of PET waste. Whereas, the cohesion (c) was noted to slightly decrease and then increase with further addition of PET waste. This result is consistent with results obtained by Kalumba & Chebet (2013).

The increase in angle of friction is due to increased friction between the particles. The value of cohesion decreased initially, which could be due to the hindrance caused by the PET flakes between the soil particles. After a certain percentage of PET flake addition, the cohesion value was noted to increase due more amounts of similar particles, which led to higher cohesion.

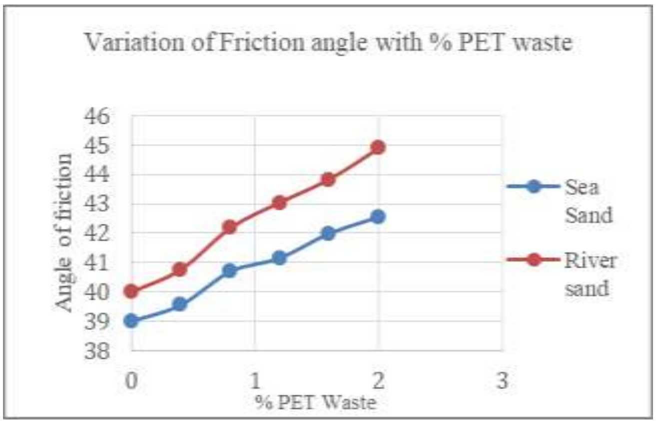

Chart -3: Variation of Friction angle with percentage PET waste for sand

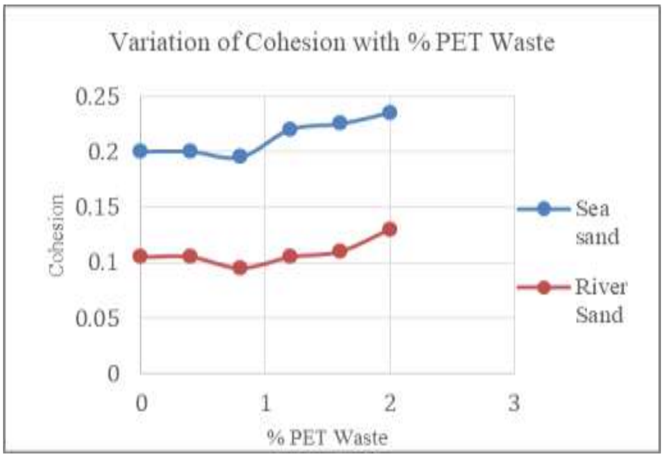

Chart -4: Variation of Cohesion with percentage PET waste for sand

4.3 California Bearing Ratio (CBR)

CBR values are used as an index of soil strength and bearing capacity in the design of base and sub-base of a pavement. It was noted that with the addition of PET waste to sand, it showed an increase in CBR strength. The increase in CBR with the increase in percentage PET waste is mostly due to the reinforcement behavior of the PET waste in sand.

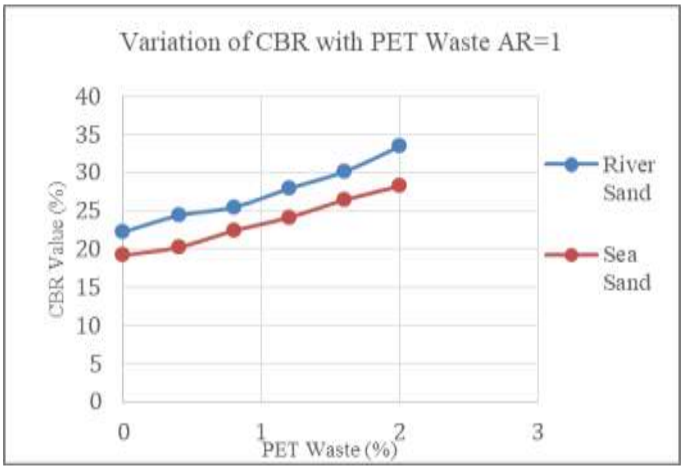

Chart -5: Variation of CBR with percentage PET waste for sand.

5. CONCLUSIONS

From the test results it was noted that:

- Addition of PET flakes to sand leads to a decrease in both the optimum moisture content and maximum dry density. The above trend was observed for both river sand and sea sand.
- The reason for the decrease in the maximum dry density is due to the fact that sand particles are denser than PET plastic waste. As more PET plastic waste is added in the sand-PET plastic waste composite, the composite becomes lighter and such composite can be used in projects that require lower MDD.
- The result from the direct shear test indicated that the angle of friction increased with the addition of PET waste and that cohesion varied PET flake addition.
- The increase in angle of friction is due to increased friction between the particles.
- The value of cohesion decreased initially, which could be due to the hindrance caused by the PET flakes between the soil particles. After a certain percentage of PET flake addition, the cohesion value was noted to increase due more amounts of similar particles, which led to higher cohesion.
- The increase in CBR with the increase in percentage PET waste is mostly due to the reinforcement behaviour of the PET waste in sand.

REFERENCES

[1] Barnes., D. K. A., Galgani, F., Thompson R. C., Barlaz, M. (2009). "Accumulation and fragmentation of plastic debris in global environments". Phil. Trans. R. Soc. B (364) 1985–1998.

[2] Botero, E., Ossa, A., Sherwell, G., Ovando-Shelley, E. (2015) "Stress–strain behavior of a silty soil reinforced with polyethylene terephthalate (PET)." Geotextiles and Geomembranes., 43 (4), 363-369.

[3] Ingles, O. G., Metcalf, J. B. (1972). Soil Stabilization Principles and Practice, Butterworths, Sydney.

[4] Kalumba, D., Petersen, M.A. (2010). "Using shredded plastic shopping bags in soil improvement for civil engineering projects", Proceedings of 20th Waste Conference, Gauteng, South Africa.

[5] KankanaMajhi.,ChampaKhatun.,ArunabhaMaiti. (2017). "Soil Stabilization using Plastic Strips of Varied Sizes by enhancing the Bearing Capacity." International Journal of Scientific & Engineering Research., 8(3), 74-79

[6] Pereira de Oliveira., L. A., Castro-Gomes J. P. (2011). "Physical and mechanical behaviour of recycled PET fibre reinforced mortar." Construct. Build. Mater., 25 (4), 1712-1717.

[7] Shwetha Prasanna.(2019). "Utilization of Waste Plastic Shreds for Stabilization of Soil." Geotechnics for Transportation Infrastructure., 46(4), 619-628.