Study And Analysis of Soil Stabilization Using Waste Plastic Material

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Abstract- Infrastructure is a key sector that drives the overall development of the Indian economy. The foundation is very important for any structure and it must be strong enough to support that entire structure. For the foundation to be strong, the soil surrounding it plays a very important role. Expansive soils such as soil always cause foundation problems. The problems are swelling shrinkage and uneven settlement. Plastic waste has become one of the major problems in the world. The use of plastic bags, bottles and other plastic products is increasing significantly year by year. Because of this we face various environmental problems. The research work is presented here focusing on soil stabilization using plastic waste products. Tests such as liquid limit, California Bearing Ratio (CBR) test and Unconfined Compressive Strength (UCS) were conducted to check the improvement in the properties of soil.

Keywords - Soil stabilization; Plastic waste; California bearing ratio; Compaction; UCS.

1. INTRODUCTION

Soil stabilization can be defined as changing or maintaining one or more soil properties to improve the engineering properties and performance of the soil. Stabilization, in a broad sense, includes the various methods used to modify soil properties to improve its engineering performance. Soil stabilization refers to the procedure in which special soil, cementitious material or other chemicals are added to natural soil to improve one or more of its properties. Stabilization can be achieved by mixing natural soil and stabilizing materials together mechanically to achieve a homogeneous mixture or by adding stabilizing materials to undisturbed soil deposits and obtaining the reaction by allowing them to permeate through soil voids. Soil stabilizing additives are used to improve the properties of less desirable moist soils. When used, these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and act as cementing and waterproofing agents.

A difficult problem exists in civil engineering works when the subgrade is clay soil. Soils with a high clay content tend to swell when their moisture content is allowed to increase. Recently, soil stabilization using polymers or waste materials such as polythene bags and plastic waste bottles is being explored by many researchers. A recent study evaluates the ability of cement kiln dust and plastic strips to enhance the properties of clay soil. Inclusion of CKD increases the maximum dry density (MDD) of dune sand.

An increase of 34% was achieved by mixing CKD. An evaluation of marble dust waste was carried out and it was reported that it resulted in significant improvement in the physical properties of soil. The plastic strips were of different lengths (1 cm, 2 cm, and 3 cm) and in different proportions of 0.2%, 0.5%, and 0.8%; Optimal improvement in soil dry weight was achieved using 2 cm plastic strips at 0.8% of soil dry weight. Fibre-reinforced soil improved soil strength and engineering properties; The best ratio achieved by plastic fibers was 0-5%, and there was an increase in CBR value, and a decrease in dimensional settlement, which indicates a higher aspect ratio for better results. The plastic strips were cut into different sizes ranging from 12 mm to 21 mm in length and 3 mm to 6 mm in width. Different concentrations of PET content were combined (0%, 0.4%, 0.6%, 0.8%, and 1% by weight of soil). The highest unconfined compressive strength (UCS) was that of 0.8% PET strips with a width of 3 mm and a length of 18 mm; They achieved an optimal UCS time of 2.17 compared to raw soil. The liquefaction susceptibility of PET fiber reinforced fine sand was demonstrated on the basis of results obtained through a series of cyclic triaxial tests. The number of cycles was four to achieve liquefaction compared to unreinforced sand with a composition of 0.6% PET plastic fibers.

Clay and silt are very common soil types found all over the world, and it is very common for soil structures such as slopes and highway embankments to be built from this soil type. For subgrades, building on natural, weak fine-grained soil can cause serious damage, risk uncontrolled erosion, and reduce the service life of the substructure. It is known that the engineering properties of soil can be improved using the soil stabilization process. The practice of mixing cement with soil is one of the most common methods of soil remediation. Cement stabilization has proven effective in enhancing the geotechnical properties of soil. However, the cement production process is harmful to the environment due to the use of large amounts of energy and natural resources, as well as the release of huge amounts of carbon dioxide (CO2).

Carbon dioxide (CO2) emissions from the cement industry from 1928 to 2018 amounted to approximately 38.3 Gb globally, according to Andrew. As such, many researchers have examined alternative, more sustainable materials and methods to reduce overall emissions across the construction sector. A particular challenge with the cement soil stabilization method is the durability of the treated soil against degradation. Durability can be defined as the ability of a material to withstand weather conditions, wetting, drying, freezing and thawing cycles, while maintaining its integrity and stability over a long period of time. The diminishing benefits of cement stabilization after cycles of weather exposure provide additional support for exploring alternative stabilization materials as alternatives to cement. Moreover, the growing concern about solid waste generation necessitates effective management strategies to address this environmental issue. Polyethylene terephthalate (PET) is one of the most widely used materials to manufacture products such as beverage bottles and other containers. After single use, PET bottles are disposed of and become PET waste [29, 30]. Many researchers have investigated the use of PET bottles as construction materials, revealing a wide range of advantages in soil improvement applications.

These benefits have been observed in both cohesive fine-grained soils and incohesive coarse-grained soil. Ferreira et al. It was found that in the case of sandy soil, the introduction of PET fibers contributes to increasing soil strength, reducing deformation in the vertical and lateral directions, and improving stiffness. Incorporating waste plastic bottles, particularly PET, with cement offers a potential way to dispose of waste while reducing cement requirements for soil stabilization, resulting in lower carbon dioxide emissions associated with cement manufacturing. Hence, several studies have investigated the engineering properties of stabilized cement soils reinforced with PET pieces.

2. LITERATURE REVIEW

Singh K, Mittal A (2019) Research on power of cementitious PET strips stabilized by reinforced clay, and it was reported that the addition of PET strips improves the unconfined compressive strength of clay samples. Many previous studies have investigated the reinforcement of fine-grained soils through the incorporation of cement, slag, lime and gypsum. Investigations have yielded results indicating that cement addition leads to brittle behavior in stabilized soils, with limited or negligible plastic deformation. In addition, there have been pilot experiments involving fiber-reinforced cement soil. In fact, one of the major challenges encountered in PET fiber/cement soil stabilization is the dependence of the final mixture performance on factors such as consistency of preparation and mixing procedures, soil type, compaction energy, and shape and dimensions of the added fibers.

Khattak and Al-Rasheed (2015) considered that the durability of PET fibers was enhanced by fine-grained soils and found that PET fibers improved the durability of mixtures. Zhang, et al. conducted a study on the durability of cementitious silty clay soils, and the study revealed that mass loss decreases with increasing cement content. Furthermore, Consoli, et al. (2016), established an effective approach for soils treated with stabilized cement based on the porosity/cement (binder) ratio as a strength parameter. Subhash, K.T.L. (2016) conducted an experimental study on soil stabilization using glass and plastic granules mixed in varying proportions. Modified Proctor tests were performed to study OMC and CBR. They found a decrease in MDD when glass and plastic were added in varying proportions. An MDD of 1.53 g/cc was obtained with 6% glass and plastic. The maximum OMC of 22.6% was obtained when mixing the additive at 6%. Moreover, an increase in OMC was observed, and the maximum OMC value of 22.6% was obtained when 6% glass and plastic were added to the soil. Increase in UCS from 0.609 kg/cm2 to 3.023 kg/cm2 which is equivalent to about 5 times that of virgin soil. The maximum CBR value was 7.14%, which is twice the CBR of virgin soil. Harish and Ashwini, J.M. (2016) studied the effect of plastic bottle strips as stabilizer for two soil samples, red soil and soil. Red soil consists of 4% gravel, 88% sand, 8% silt and clay, and the soil contains 2.6% gravel, 15.1% sand, 82.3% silt and 0.18% clay. They used plastic strips in the manufacture of paving, and it was found that there was an increase in the strength of the soil. The authors performed the CBR ratio test for MDD and OMC. They noticed an increase in the strength and bearing of the soil. Swollen clay soils are types of soil that show a significant change in volume.

Bozyigit I, Bulbul F, Alp C, Altun S (2021) It expands when exposed to excess water and contracts in hot weather conditions where the amount of water is scarce. They can be easily recognized in the field in dry seasons because they display deep cracks in polygonal patterns. This behavior of swelling and contraction of expanded clay soil in turn affects the stability of structures built on top of this soil causing serious danger. It greatly affects the bearing capacity and strength of foundations through heaving, as they swell and may cause from cracks to differential movements to structural failure.

Botero E, Ossa A, Sherwell G, Ovando-Shelley E (2015), In order to build on extensive soils, they need stabilization to reduce swelling and improve their mechanical capabilities. Soil stabilization is the process by which the engineering properties of soil are improved and made more stable. It is used to reduce unqualified soil properties such as permeability, compaction potential and increase shear capacity.

Peddaiah S, Burman A, Sreedeep S (2018), this method is mainly adopted in highway and airport construction projects. In general, activities such as compaction and pre-consolidation are used to improve soils that are already in good condition. But soil stabilization encourages the use of weak soil and reduces the uneconomic process of replacing weak soil. Other than working on the interaction between the soil mass, the chemical change of the soil materials themselves is also the focus of this process. Sometimes, soil stabilization is used for urban and suburban streets to make them more noise absorbent.

Perera S, Arulrajah A, Wong Y, Maghool F, Horpibulsuk S (2020), Various methods have been previously developed for stabilizing weak and unsuitable soils. Some of these methods include mechanical (granular) stabilization, cementitious stabilization, lime stabilization, bituminous stabilization, chemical stabilization, thermal stabilization, electrical stabilization, as well as grout stabilization by geotextiles and fabrics. Recently, researchers presented another method for soil stabilization using waste materials. Plastics are one of the leading waste materials found to be suitable for this purpose. They reduce the stabilization cost at a significant rate.

Rahman MM, Siddique A, Uddin MK (2010), The use of plastic for this purpose simultaneously solves the challenges of improper recycling of plastic waste which is currently an emerging problem in most developing countries. Improper disposal of plastic waste has become a pressing environmental problem in most African countries.

Senez PC, Casagrande MDT (2021) They are currently covering landfills and water bodies, clogging sewage systems, disrupting the ecological cycle and creating an aesthetically unpleasant environment. This, in turn, causes serious damage to animal, plant and human life. Polyethylene terephthalate (PET) bottles are traditional plastic bottles that are currently in great use. They are used to package water, soft drinks, liquid foods and various other beverages. As demand for it increased, disposal became difficult. It takes a very long time to decompose waste PET bottles in nature (more than a hundred years).

Saikia N, de Brito J (2014), Recycling these plastic bottles and using them to stabilize expanded clay soil are steps in the right direction making the construction industry a suitable candidate with its high consumption capacity. This will be a decent alternative to clean and protect the environment from plastic bottle waste.

3. METHODOLOGY

A series of laboratory model tests were conducted in this experimental program. The main objective of this study is to investigate the use of plastic material by mixing it with low-resistance soil, stabilized by plastic material to improve resistance in foundations.

3.1 Soil

The soil used in this study was collected from a site in Baghraji, Kundam Tehsil, Jabalpur, Madhya Pradesh, India, at a depth of 2 m from ground level. In accordance with the IS classification system, disturbed soil samples collected from the above site were air-dried and thoroughly pulverized prior to laboratory testing. An initial screening is carried out and the soil is free of grass and weeds. Therefore, the prepared soils are bagged and used in the laboratory to determine properties.

3.2 Physical Properties of soil

Table 1. Physical Properties of soil

Sl.NO	PROPERTY	VALUE
1	Grain Size Distribution	
	Sand (%)	8
	Slit (%)	15
	Clay (%)	77
	Gravel (%)	0
2	Atterberg Limits	
	Liquid Limit (%)	60.75
	Plastic Limit (%)	21.42
	Plasticity Index (%)	39.51
3	Compaction Properties	
	Optimum Moisture Content,O.M.C. (%)	16
	Maximum Dry Density, M.D.D. (g/cc)	1.754
4	Shear Strength Parameters	
	Cohesion (kN/m2)	1.5
	Angle of internal friction (°)	10°
5	Specific gravity (G)	2.52
6	IS Classification	CH
7	C.B.R. (%)	29.94
8	Free Swell (%)	36

4. RESULT AND DISCUSSION

4.1 Specific Gravity Test Result for Untreated Soil

Table 2. Specific Gravity of Soil

Sl.No	Observations and Calculations	Sample	Sample	Sample
		1	2	3
1	Mass of empty pycnometer (M_1) gms	528	530	530
2	Mass of pycnometer and dry soil(M_2) gms	718	719	720
3	Mass of pycnometer, soil and water(M_3) gms	1588	1546	1562
4	Mass of pycnometer filled with water(M_4) gms	1487	1485	1436

Calculations

Mass of the empty pycnometer (M_1) =528 gms

Mass of the pycnometer and dry soil (M_2) =718 gms

Massof the pycnometer, soil and water (M_3) =1546 gms

Mass of the pycnometer filled with water only (M_4) =1436gms

$$G_S = \frac{\text{Mass of soil}}{\text{Mass of water displaced by soil}}$$

$$= \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

Results: The specific gravity of the soil is = 2.38

4.2 Liquid limit for untreated soil sample

Table 3. Liquid Limit for Soil Sample

Sl.No	Observations and calculations	1	2	3
1	No of blows	53	49	38

2	Mass of empty can (M1)(gms)	22	22	22
3	Mass of can + wet soil (M2)(gms)	36	40	46
4	Mass of can+ dry soil(M3)(gms)	32	34	38
5	Mass of water (M2-M3)	6	8	8
6	Mass of dry soil (M3-M4)(gms)	10	12	17
7	Water content %	56	64.25	62

Result=Average Water content= (56+64.25+62)/3 =60.75%

4.3 Plastic Limit of Soil Sample

Table 4. Plastic Limit

S.No	Observation and calculations	sample
1.	Mass of empty can, M1(gm)	22
2.	Mass of can +wet soil (M2) (gm)	39
3.	Mass of can + dry soil (M3) (gm)	36
4.	Mass of water (M2-M3) (gm)	3
5.	Mass of dry soil (M3-M1) (gm)	14
6.	Water content%	23.64

Result: The plastic limit of sample is 21.42 %

4.3 Plasticity Index

IP = WL – WP =60.75-21.42

IP = 39.33%

4.4. CBR Test of Soil Sample

Table 5. CBR Value of Soil Samples at 0% Plastic material

Sl. No.	Load (Kg)	Penetration (mm)
1.	100	1.21
2.	200	2.35
3.	300	4.58
4.	400	5.24
5.	500	6.54
6.	600	9.14
7.	700	10.02
8.	800	10.27
9.	900	11.25

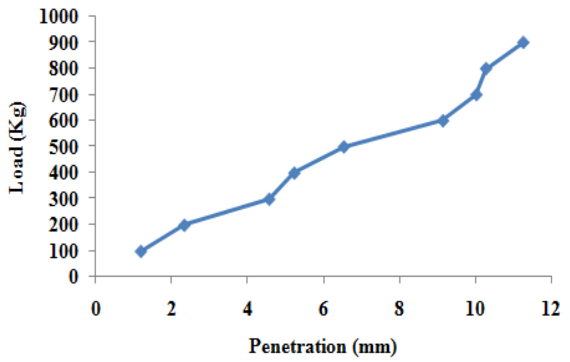

Figure 1. CBR Value of Soil Samples at 0% Plastic material

Table 6. CBR Value of Soil Samples at 2% Plastic material

Sl. No.	Load (Kg)	Penetration (mm)
1.	100	2.34
2.	200	3.51
3.	300	4.99
4.	400	6.21
5.	500	7.25
6.	600	9.57
7.	700	10.27
8.	800	11.52
9.	900	12.35
10.	1000	13.58

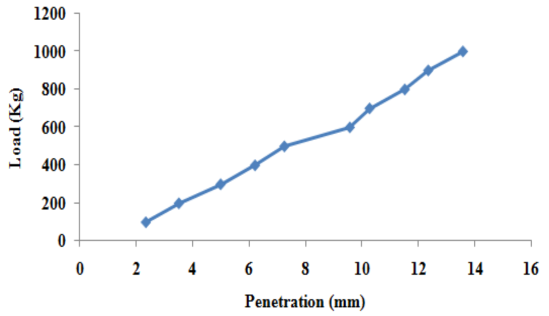

Figure 2. CBR Value of Soil Samples at 2% Plastic material

Table 7. CBR Value of Soil Samples at 4% Plastic material

Sl. No.	Load (Kg)	Penetration (mm)
1.	100	2.88
2.	200	3.97
3.	300	5.02
4.	400	6.84
5.	500	8.54
6.	600	9.88
7.	700	10.98
8.	800	11.75
9.	900	12.85
10.	1000	14.57
11.	1100	14.98

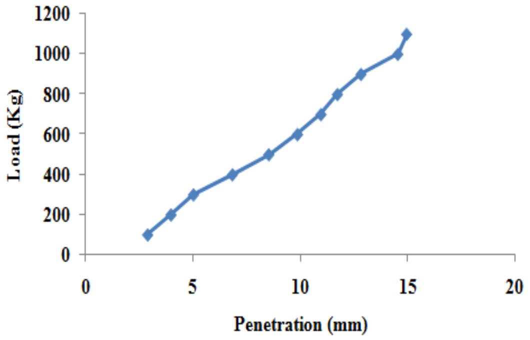

Figure 3. CBR Value of Soil Samples at 4% Plastic material

Table 8. CBR Value of Soil Samples at 6% Plastic material

Sl. No.	Load (Kg)	Penetration (mm)
1.	100	3.01
2.	200	4.02
3.	300	5.88
4.	400	7.54
5.	500	8.98
6.	600	10.52
7.	700	11.24
8.	800	12.51
9.	900	13.25
10.	1000	14.88
11.	1100	15.01
12.	1200	15.98

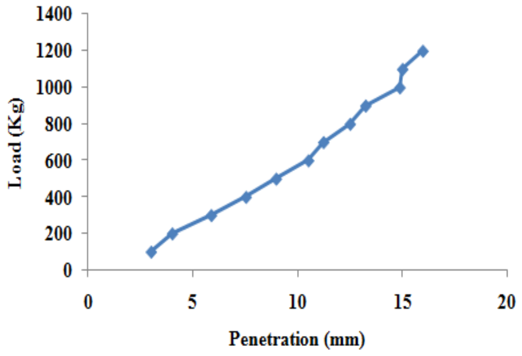

Figure 4. CBR Value of Soil Samples at 6% Plastic material

Sample 1, Plastic material 0%

The load vs. penetration for the untreated soil, it can be observed that the UN soaked CBR value is 29.94%.

Sample 2, Plastic material 2%

The load vs. penetration for untreated soil and 1% plastic material, it can be seen that the UN soaked CBR value is 32.53%.

Sample 3, Plastic material 4%

The load vs. penetration for untreated soil and 3% plastic material, it can be seen that the UN soaked CBR value is 34.56%.

Sample 4, Plastic material 6%

The load vs. penetration for untreated soil and 5% plastic material, it can be seen that the UN soaked CBR value is 35.26%.

4.5 Unconfined Compressive Strength Test

Table 9. UCS Value of Soil Sample 1

Sl. No.	Axial Stress	Axial Strain of Sample 1
1.	0.5	2.12
2.	1.0	3.03
3.	1.5	4.09
4.	2.0	5.34
5.	2.5	7.24
6.	3.0	9.67
7.	3.5	12.96
8.	3.0	15.94

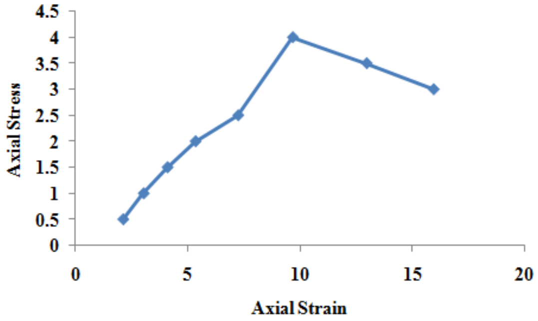

Figure 5. UCS Value of Soil Sample 1

Table 10. UCS Value of Soil Sample 2

Sl. No.	Axial Stress	Axial Strain of Sample 2
1.	0.5	2.23
2.	1.0	3.58
3.	1.5	4.24
4.	2.0	6.24
5.	2.5	8.57
6.	3.0	10.64
7.	3.5	13.67
8.	3.0	16.17

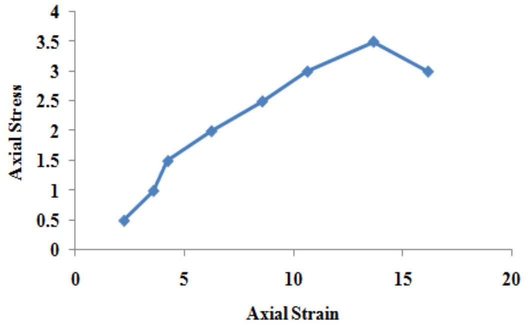

Figure 6. UCS Value of Soil Sample 2

Table 11. UCS Value of Soil Sample 3

Sl. No.	Axial Stress	Axial Strain of Sample 3
1.	0.5	3.24
2.	1.0	4.58
3.	1.5	5.67
4.	2.0	7.89
5.	2.5	9.87
6.	3.0	11.69
7.	3.5	14.87
8.	3.0	18.23

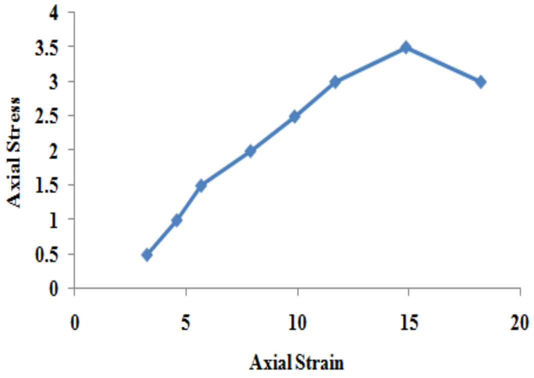

Figure 7. UCS Value of Soil Sample

Table 12. UCS Value of Soil Sample 4

Sl. No.	Axial Stress	Axial Strain of Sample 4
1.	0.5	3.24
2.	1.0	4.58
3.	1.5	5.67
4.	2.0	7.89
5.	2.5	9.87
6.	3.0	11.69
7.	4.0	14.87
8.	3.0	18.23

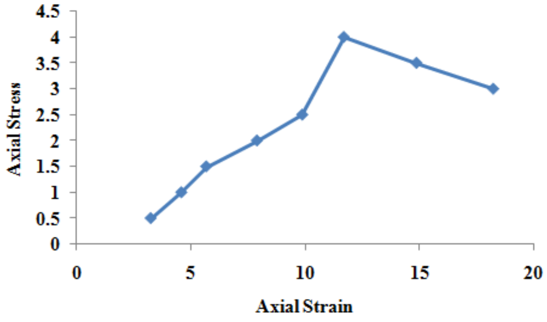

Figure 8. UCS Value of Soil Sample 4

Sample 1 Plastic material 0%

The stress vs strain for untreated expansive clay is given in Figure 5. It can be seen that the value of the unconfined compressive strength test (qu) = 2.65 kg/cm^2.

Sample 2, Plastic material 2%

The stress vs strain for untreated expansive clay and 1% plastic material is given in Figure 6. It can be seen that the unconfined compressive strength test value (qu) = 2.78 kg/cm^2.

Sample 3, Plastic material 4%

The stress vs strain for untreated expansive clay and 3% plastic material is given in Figure 7. It can be seen that the unconfined compressive strength test value (qu) = 2.88 kg/cm^2.

Sample 4, Plastic material 6%

The stress vs strain for untreated expansive clay and 5% plastic material is given in Figure 8. It can be seen that the value of the unconfined compressive strength test (qu) = 3.98 kg/cm^2.

6. CONCLUSIONS

The following conclusions are drawn based on the laboratory studies carried out in the work. When soil is treated with plastic material, there is an increase in the CBR value by up to 4%, while further increase in plastic material decreases the CBR value. Where the increase in CBR value is 2 times that of virgin soil. Simple compressive strength tests were carried out for 3 different percentages such as soil and 2% plastic material, soil and 4% plastic material and 6% plastic material. The stress-strain behavior increases from the combination of soil plus 4% plastic material.

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