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Study and Analysis of Soil Stabilization with Polyethylene Waste Materials

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ABSTRACT-

The problems are increasing shrinkage and uneven settlement. Plastic waste has become one of the biggest problems in the world. The use of plastic bags, bottles and other plastic products increases exponentially year after year. The stabilization of a fine-grained soil using plastic waste is experimentally investigated in this study. Samples are prepared by mixing with four different levels of plastic waste (0, 0.5, 1, 1.5 and 2% of dry soil weight). Variations in compaction characteristics and unconfined compressive strength are investigated according to standard Indian experimental procedures. The percentage of decrease/increase in the indicated parameters is calculated in relation to their untreated value. The study shows that the compressive strength is not confined to a certain extent. The plastic waste is cut into strips of size 5.5 mm × 3.5 mm.

KEYWORDS - Soil stabilization; Plastic waste; PET; Compaction; UCS.

1. INTRODUCTION

Soil stabilization refers to the procedure in which a special soil, cementing material, or other chemical materials are added to a natural soil to improve one or more of its properties. Stabilization can be achieved by mechanically mixing natural soil and stabilizing material to obtain a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and achieving interaction by letting it permeate through soil voids. Soil stabilizing additives are used to improve the properties of less desirable soils. When used, these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion, and serve as cementing and waterproofing agents.

A difficult problem in civil engineering works exists when the subgrade is clayey soil. Soils with a high clay content have a tendency to swell when their moisture content increases. One strategy to improve the qualities of poor soils is soil stabilization. Mechanical resistance, permeability, compressibility, durability and plasticity are just some of these characteristics. The polymers interact with clay particles in the soil, increasing the soil's resistance. Many of the polymers currently in use have the ability to improve the water retention and shear strength of soil. Construction on expansive soils requires stabilization to prevent swelling and increase mechanical capacity. Soil stabilization is the process of improving the engineering qualities of soil and making it more stable. It is used to reduce unqualified soil properties such as permeability and consolidation potential while increasing shear capacity. The approach is most commonly used in highway and airport construction projects. Compaction and pre-consolidation are commonly employed to improve soil types that are already in good condition. Soil stabilization goes a long way toward encouraging the use of weak soils and reducing the cost of renewing weak soils. PET bottles are common plastic bottles. Waste, soft drinks, liquid snacks and a variety of other drinks are packaged in them. Its disposal is becoming more challenging as demand for it increases. In nature, PET bottle waste takes a long time to degrade (more than a hundred years). Recycling and using these plastic bottles to stabilize expansive clay soils are positive developments, and the construction industry is an ideal choice due to their enormous consumption capacity. This will be a good way to clean and preserve the environment from discarded plastic bottles. Adding plastic strips to the floor as a stabilizer increased California's shear strength, tensile strength, and rolling rate.

Plastic bottles made from Polyethylene Terephthalate (PET) are indecomposable and destructible. If they are melted, they release a compound gas that is very harmful to health and the environment. The increased use of plastic bottles in everyday consumer use has resulted in bottled water being the fastest growing beverage industry in the world. From consumer market research firm Euromonitor, The Guardian reported that 20,000 plastic bottles are brought in every second around the world. Around 480 billion bottles were purchased globally in 2016, but less than half were recycled. Arpitha et al. (2017) studied the effects of plastic waste on soil in relation to California variations

Bearing Ratio Test (CBR). The results showed that soil CBR values increase with increasing plastic waste content up to a certain percentage of plastic waste. In this study, fine-grained soil samples are tested with different plastic waste contents and variations in the unconfined compressive strength and compaction characteristics of the sample are investigated. The percentage increase in these parameters with different plastic waste contents is calculated in relation to the untreated values. Comparison of plastic waste mixture with some common additives like RHA, lime, cement, lime fly ash, plastic imploring, etc., can be carried out as a future scope of this study. The effect of varying the curing period (1, 3, 7, 14, 28 days) can also be investigated from a lateral point of view.

2. LITERATURE REVIEW

Anjaneyappa et.al (2015) studies the action of stabilization character of polymers. Pavement construction is becoming more expensive due to the sky-high cost of quality construction materials and the cost of transportation over long distances. The conclusion of this article was that reductions of approximately 41 to 47% in radial strains beneath bituminous layers and 38 to 47% in vertical compressive strains in the subgrade were observed for polymer-stabilized soils. The use of polymer to stabilize pavement layers can be considered for low volume roads.

Athulya p.v.et.al. (2015) investigates soil stabilization in subgrades using additives as a case study. The aim of this study is to conduct an experimental study and analyze the strength properties of flat soil, terrazzo soil and cement kiln dust soil separately using consistency limit tests, CBR tests, triaxial tests and permeability tests. Increasing doses were found to lower consistency limits. As a result, it is evident that the chemical hardens the soil.

Bibha Mahtr et al. (2015) published a review article on the influence of RBI Grade 81 and lake ash on clay and clay soils. The objective of the study is to determine the impact of RBI Grade 81 at 1%, 2%, 3% and 4% mixed with pond ash at 3%, 6% and 9% on clay and clayey soil. The RBI 81 is successful in adjusting most soil types, according to the conclusion of this article.

Basanta Dhakal and colleagues (2016) The influence of liquid polymer on the geotechnical properties of fine-grained soils was investigated in this work. The polymer was combined in various percentages of the dry weight of both soils (2%, 3%, 4% and 5%). The results reveal that when the polymer is added to soil B samples obtained from the OMC, the UCS value increases from 12 to 14% in a confined air environment. **P.K. Kolay, et al. (2016)** investigated "the influence of liquid polymer stabilizer on the geotechnical parameters of fine-grained soils" using two types of soil for stabilization purposes: Carbondale soil and Galatia soil. The polymer was applied at 0.5%, 1%, 1.5% and 3% both in the soil and in other tests so that the results were favorable and met the conclusion of the study. With the polymer, the maximum increase in UCS value was around 23%. 2.54 shows a 200% improvement in wet CBR value compared to untreated soil. **Sameer Vyas et al. (2016)** investigated stabilization of dispersive soils by blending polymers to stabilize dispersive soils of Udaipur. The soil sample was treated with 0.5% and 1% polyvinyl alcohol and urea formaldehyde, 0.5% polyurethane and epoxy resin, and 1% styrene rubber latex. As a result of adding polymeric aggregates to the soil, the size of the soil increases, indicating that the polymer used in the study is successful in binding soil particles.

N. Shoaib et al. (2018) investigated the use of acrylic polymer in stabilizing clayey soils. The acrylic polymer was mixed with chloroform to form the acrylic paste and placed in the research soil as a stabilizer, which was mixed with the clayey soil to prepare the soil. The best percentage of acrylic solution for soil stabilization is 6% by weight. T.Raghavendra and colleagues (2018) investigate the use of terrasil and zycobond to stabilize black cotton soil. Specific gravity, liquidity limit, plastic limit, sieve analysis and hydrometer analysis were all included in the variation experiment. Terrasil and zycobond nanocompounds are applied at a constant proportion of 3% of the soil volume. When 0.6kg/m3 of terrasil and zycobond are added, the free curl index drops from 30% to 27.5%, and when 0.8kg/m3,1.0kg/m3,1.2kg/m3 are added, the free ripple index drops from 30% to 27.5%.

Subhash, K. et al. (2016) carried out an experimental study on soil stabilization using glass and plastic granules mixed in varying percentages. Modified Proctor tests were performed to study OMC and CBR. They concluded that there is a decrease in TDM with the addition of glass and plastic in varying percentages. The MDD of 1.53 g/cc was obtained with 6% glass and plastic. The maximum OMC was obtained as 22.6% with 6% additive mixture. Furthermore, an increase in OMC was observed, the maximum value of OMC was obtained as 22.6% with 6% glass and plastic additive with the soil. An increase in UCS from 0.609 Kg/cm2 to 3.023 Kg/cm2, which is about 5 times that of virgin soil. The maximum CBR value was 7.14%, which is 2 times the CBR of virgin soil.

Harish and Ashwini, H. M. (2016) studied the effect of strips of plastic bottles as stabilizer for two soil samples, red soil and black cotton soil. Red soil consists of 4% gravel, 88% sand and 8% silt and clay and black cotton soil 2.6% gravel, 15.1% sand and 82.3% silt and 0.18 % clay. They used plastic strips to create the pavement and it was found that there was an increase in soil resistance. The authors performed a CBR ratio test to discover MDD and COM. They observed an increase in soil strength and support ratio of 2.9 for red soil and 3.3 for black cotton soil by mixing 0.7% plastic strip waste into red soil and 0.5% to black cotton soil.

Jasmin Varghese Kalliyath et al. (2016) studied the effect of plastic fibers. Various tests like Standard Proctor, UCC were carried out on different silty clay samples. The authors observed that replacing 0.5% plastic fiber waste in the expansive clayey soil reduced its OMC and increased the maximum dry density, but the UCS of the soil was increased. Test results also showed that with 1% replacement, MDD and UCC were lower than 0.5% replacement, but higher than untreated soil. Further increase in plastic replacement showed a decrease in TDM and UCS. The increase in soil DDM with 1% replacement is due to the reduction in the number of voids with the addition of plastic, which leads to effective compaction and also to an increase in cohesion. Therefore, the authors concluded that the optimal percentage of plastic was 0.5% for optimal results.

Satyam tiwari et al. (2016) They explained “Soil Stabilization Using Waste Fiber Materials”, and investigated the use of waste fiber materials in geotechnical applications and evaluated the effects of waste polypropylene fibers on the shear strength of unsaturated soils , performing direct and unconfined shear tests. compression tests on two different soil samples. The percentages of fiber reinforcement added are 0, 0.05, 0.15 and 0.25. Based on the specific gravity of a soil - With the mixture of 0.05% fibers (PPF), the specific gravity of the soil increases by 0.3%. Soil resistance is directly proportional to specific gravity, the greater the specific gravity, the greater the soil resistance. Based on the liquidity limit of a soil without reinforcement and with reinforcement, they have a difference in liquidity limit of 18.18%.

Achmad Fauzi et al. (2016) used two soil samples R2 and R24 collected from various locations in KUANTAN. HDPE cutting waste and crushed glass waste were used as additives. The variations in additive content were 4%, 8%, 12% by total dry weight of the soil sample, respectively. They evaluated engineering properties such as sieve analysis, Atterberg limit, specific gravity, standard compaction, soggy California rolling rate, and triaxial testing of the soil sample before and after stabilization. The result showed that with the addition of HDPE and glass waste there was an increase in IP, around 10% for samples R24 and 2% for samples R2 respectively. The optimum water content value decreased and the MDD increased when the HDPE and glass waste content was increased, but there was an increase in the CBR value. The authors also observed that there was a decrease in the cohesion value and an increase in the friction angle of samples R2 and R24 with additives. **Ankit Jain, et al. (2016)** Explained the "Effect of lime on the index properties of black cotton soil". A series of laboratory tests carried out on black cotton soil mixed with different proportions of lime i.e. 0%, 2%, 4%, 6%, 8% and 10% by weight of dry soil. Based on their research, they concluded that the soil liquidity limit decreases from 67.49% to 52.01% with increasing lime content up to 8%, after which there is no significant change with increasing lime content. The soil plasticity index decreases from 37.16% to 10.43% with an increase in limestone content of up to 8%. The differential free swelling of the soil decreases from 60% to 14% with increasing limestone content. The above results show that the swelling characteristics of the soil are reduced and the ideal lime dosage is found to be 8%.

3. METHODOLOGY

3.1 Soil

Soil was collected locally from Baghraji, Kundam Tehsil, Jabalpur, Madhya Pradesh. The sample was obtained from 3 m depth below the soil surface and was tested for its geotechnical properties and strength characteristics. The various tests carried out to obtain geotechnical parameters are specific gravity test, soil sieve analysis, liquidity limit, plastic limit, Standard Proctor test, UCS test.

Table 1. Physical Properties of soil

Sl. No.	Properties of soil	Test result
1.	Specific gravity	2.751
2.	Liquid limit (%)	25.68
3.	Plastic limit (%)	17.257
4.	Plasticity index	8.423
5.	Maximum dry density (g/cm^3)	1.519
6.	Optimum moisture content (%)	12.88

3.2 PLASTIC WASTE

Table 2. Physical properties of PET

Sl. No.	Behaviour parameters	Values
1	Chemical formula	$(C_{10}H_8O_4)n$
2	Molar mass	Variable
3	Density	1.52g/cm^3
4	Melting point	>250 °C
5	Boiling point	>350 °C
6	Solubility in water	Insoluble

This study used two materials: a representative strip of a rectangular PET bottle made from clayey soil and a representative strip of a rectangular PET bottle made from virgin soil. The strips were made with the remains of plastic bottles found in the neighborhood. After collection, the bottles were properly cleaned and manually cut into three strips of different sizes.

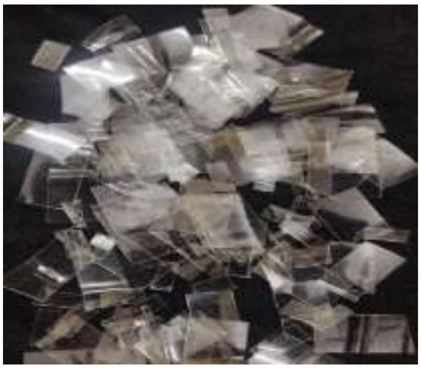

Figure 1. Image of different shapes of PET

4. UNCONFINED COMPRESSIVE STRENGTH TEST

To determine the unconfined compressive strength of fine-grained soil, the remolded compacted sample is prepared in a cylinder (40 mm diameter, 80 mm length) by adding the required water (OMC). Then wrap it tightly in a polyethylene cover and place it in a desiccator containing little water and place the desiccator in a room with constant temperature after 7 days of curing. Unconfined compressive strength test is carried out and reading was noted as per IS 2720 (part 10): 1973

It can be seen that the untreated soil has a low UCS value, whereas after the addition of plastic waste content of 0.5 to 1%, a substantial increase in the unconfined compressive strength is observed (almost 2– 15%). It should be noted that samples treated with plastic waste are cured for 7 days keeping the water content equal to the ideal water content. With the addition of plastic to the soil sample, there is an increase in soil cohesion, which leads to an increase in the unconfined compressive strength of the soil. However, a further increase in plastic content leads to a decrease in cohesion and therefore a decrease in strength. Unconfined compression test is conducted for both soils in different mix designs to find out which mix offers maximum strength.

Figure 2. Sample of Unconfined Compressive Strength Test

Figure 3. Sample preparations of Unconfined Compressive Strength Test

Figure 4. Compressive Strength Test

5. RESULT AND DISCUSSION

Table 1. Unconfined Compression Strength Test

SL. No.	Strain (%)	Unconfined Compressive Strength (kg/cm^2) at 0.0% PW	Unconfined Compressive Strength (kg/cm^2) at 0.5% PW
1.	1	2.51	3.42
2.	2	3.17	4.57
3.	3	5.72	6.89
4.	4	6.44	8.24
5.	5	9.21	10.41
6.	6	12.17	14.18
7.	7	11.03	11.17
8.	8	8.02	9.02

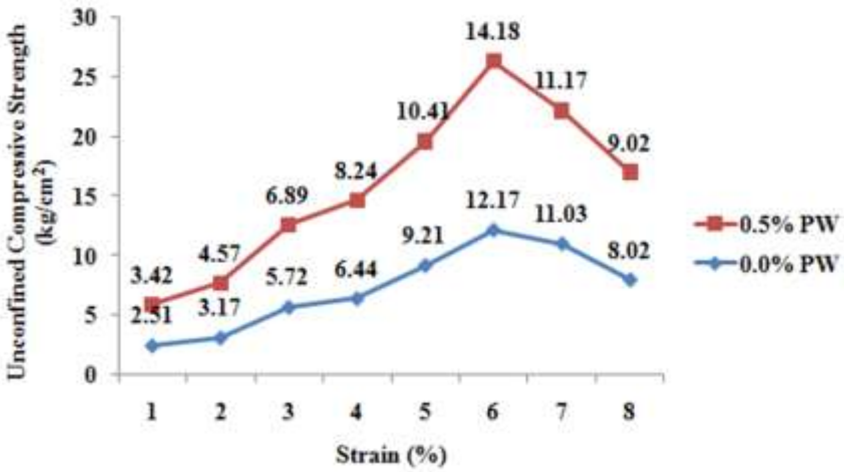

Figure 5. Unconfined Compression Strength Test

Table 4. Optimum proportion of strips

SL. No.	Plastic Waste (%)	Unconfined Compressive Strength (kg/cm^2)
1.	0.0	11.08
2.	0.5	13.12
3.	1.0	15.17
4.	1.5	9.24
5.	2.0	7.02

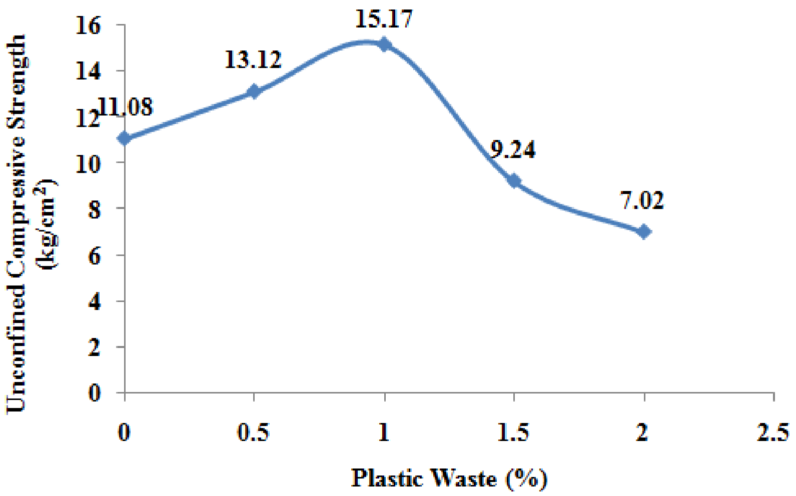

Figure 6. Graph for optimum proportion of strips (strength vs. plastic waste)

6. CONCLUSIONS

Infrastructure is an important sector that drives the overall development of the Indian economy. The foundation is very important for any structure and it has to be strong enough to support the entire structure. For the foundation to be strong, the soil around it plays a very important role. Soil stabilization can be defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. Stabilization, in a broad sense, incorporates the various methods employed to modify the properties of a soil to improve its engineering performance. This study is focused on reviewing the performance of plastic waste as a soil stabilizing material. The study suggests the following conclusions. Study reveals that the parameter that drastically improves with the addition of plastic waste is the Unconfined Compressive Strength (UCS) of the soil. Adding 0.5–1% plastic waste increases UCS. The addition of plastic waste content (0.5–1.5%) has increased.

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