Stabilization of Soil Using Waste Plastic Materials

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Abstract. With rapid advancement in technology globlly, the use of plastics such as polythelene bags, bottles etc. is also increasing. The disposal of thrown away wastes poses a serious challenge since most of the plastic wastes are non – biodegradable and unfit for incineration as they emit harmful gases. Soil stabilization improves the engineering properties of weak soils by controlled compaction or adding stabilizers like cement, lime, sand, fly ash and geosynthetics etc. But these additives also have become expensive in recent years. Polythene strips obtained from waste plastic containers, saline bottles, chairs, bottles, polythene bags etc., may provide an easy and economical means to improve the engineering performance of subgrade soils. This study involves the investigation of the effect of plastic saline bottle strips on expansive soils for which a series of different tests have been performed with varying percentage of plastic strips and also with different aspect ratio in terms of size. The results showed that there is significant increment in shear strength parameters and CBR value with plastic reinforcement in soil. It is observed from the study that, improvement in engineering properties of Expansive soil is achieved at 1% plastic content with strip size (20 x 4) mm.

Keywords: Expansive soil, Saline bottle, Soil stabilization.

1 Introduction

For many years, engineers have used traditional additives such as lime, cement and cement kiln dust etc. to improve the qualities of readily available local soils. The stabilization of expansive soils with cement and lime is well documented. Cement stabilization nowadays is less appreciated because of the increasing cost of cement and environmental concerns related to its production. As a consequence, the production of plastics has increased markedly over the last 60 years. Today, every vital sector of the economy has been virtually revolutionized by the application of plastic. According to recent studies, plastic can stay unchanged for as long as 4500 years on earth. To deal with the growing disposal problem of these materials is an issue that requires coordination and commitment on the part of all parties involved such as government agencies, companies, the public and professionals. In the past, numerous experimental studies have been carried out by various researchers on soil stabilization by using different materials. The use of plastic wastes as soil stabilizing material is economical. Several studies have been carried out by different researchers on soil stabilization of soil by using different materials such as Choudhary et al. (2010), Powetha et al. (2013), Chebet et al. (2014), Nagleh et al. (2014), Dhatrak et al. (2015), Fauzi et al. (2016), Kumar et al. (2018), Gangwar and Tiwari (2021). The objective of this study was to make economical and to maintain environmental balance, and avoid problems of waste plastic disposal i.e. the use of plastic waste for stabilization of soil and its possible combined utilization with various proportions to obtain maximum stability. In this study, soil stabilization has been done with the help of saline bottle as plastic material obtained from pharmaceutical waste. The improvement in the shear strength parameters has been stressed upon and comparative studies have been carried out using different methods of shear resistance measurement.

2 Materials and methods

2.1 Materials

In order to conduct this study, there are two materials such as locally available soil which was collected from Ganjam district, Odisha and plastic saline bottle strips. The strips were prepared from waste plastic saline bottles. The bottles were cleaned properly after collection. These were cut into length of 20 mm and width of 4 mm manually using scissors which is shown in Fig. 1.

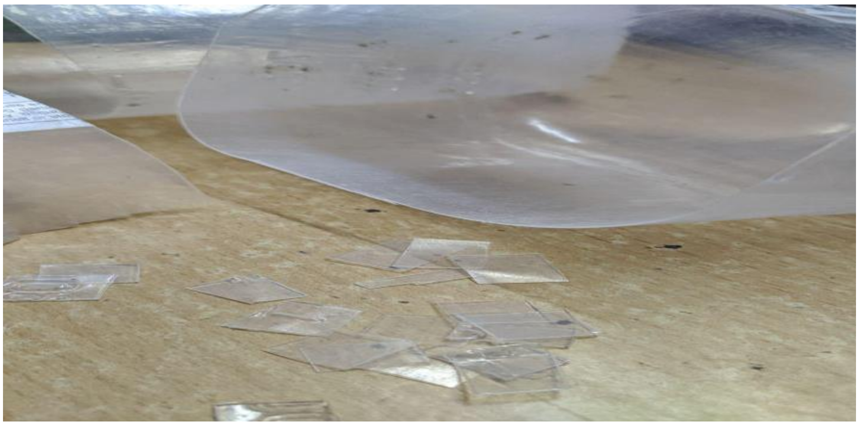

Fig. 1. Strip preparation

2.2 Material characterization

The characterization of the soil sample taken for this study included particle size distribution, Atterberg limit and specific gravity of soil tests. The sample taken was sieved in order to take out any other impurities and unnecessary particles. It was then prepared for testing according. Sieve analysis were conducted to study the particle size distribution of the soil. Plastic limit, Liquid limit and Plasticity Index of the soil were determined by performing the Atterberg Limit test. Specific gravity of the soil was determined from the specific gravity test in the geotechnical laboratory.

2.3 Material mixing method and proportions

The plastic strips, which are expected to act as soil reinforcements, were added to the soil in four different percentages (0.25%, 0.5%, 1%, 1.5%). Table 1 shows the treatment levels used for plastic strip while carrying out this study.

Table 1. Treatment levels

Strip size (mm)	Treatment level (%)
20 x 4	0.25
	0.5
	1
	1.5

2.4 Method of testing soil properties

Once the characterization of both the materials was complete, the plastic bottle strips were added to the soil sample described above. Standard proctor compaction test, Direct shear test, and California bearing ratio (CBR) test were carried out in order to study the effects of the addition of the plastic bottle strips on well graded sand.

3. Results and Discussion

3.1. characterization of soil

The characterization of the soil sample was done according to particle size distribution, Atterberg limit tests and specific gravity of soil test.
The results showed that the soil was a well graded sand with a specific gravity of 2.34 as well as a liquid limit of 32.08%, plastic limit of 30.25% and a plasticity index, which is the difference between the liquid and plastic limit of 1.83%.

3.2. Testing reinforced soil properties

3.2.1. Standard proctor compaction test results

Tests were conducted in two ways firstly soil sample without plastic fibers and secondly soil samples with 0.25%, 0.5%, 1%, 1.5% replacement of soil with plastic fibers. The tests were conducted as per the procedure specified in IS 2720 PART VII-1980. One of the ways the effect of adding plastic into the soil was checked in terms of improvement of strength and stiffness of soil. This improvement was expressed in the change in maximum dry density (MDD) and optimum moisture content (OMC).
From the experiments, It is observed that reduction in optimum moisture content as the percentage of plastic increased. For untreated soil sample maximum dry density observed 1.98 gm/cm^3. The soil sample with 0.25%, 0.5%, 1% and 1.5% of plastic shows Maximum dry density (MDD) values gradually increase and optimum moisture content (OMC) value decrease as the percentage of plastic increased. The reason for

the decrement of the OMC and increase of MDD is due to the decrease in the number of voids due to addition of plastic. This will enhance compaction which in turns reduce the OMC and increase the MDD. Table 2 shows MDD and OMC value of soil without plastic strips and with plastic strips. It shows variation of maximum dry density with % of plastic replacement. It can be seen that the maximum dry density increased from 1.98 for untreated soil sample to 2.13 for soil sample with 1% plastic replacement. But thereafter the value decreases. Also from table 2 shows variation of optimum moisture content with % of plastic replacement. It can be seen that the optimum moisture content decreased gradually with increase in percentage of plastic replacement.

Table 2. MDD and OMC of soil with different treatment levels of plastic

Strip size (mm)	Plastic strip (%)	MDD (gm/cm^3)	OMC (%)
20 X 4	0	1.98	16.7
	0.25	2.03	15.8
	0.5	2.05	15.2
	1	2.13	15
	1.5	2.07	14.6

3.2.2 Direct shear test results

It was possible to conclude from the test results that the arrangement of the plastic strips in the soil affects the shear capacity of the reinforced soil. If the surface of the strip is parallel to the shear plane, the shearing will be enhanced and the capacity will fail. But any other arrangement will improve the shear capacity of the soil.
The shear capacity from the tests is presented in terms of the shear strength parameters, cohesion (*C*), and an angle of internal friction (ϕ). Both increase and decrease of shear capacity were recorded for *C* and ϕ. The cohesion and angle of internal friction of the unreinforced soil was found to be 0.6 and 41 respectively. The small value of the cohesion is attributed to the cohesionless of the soil. The largest value of C and ϕ for the reinforced soil was obtained as 0.9 and 46.7 which was a 50% and 13.9% improvement respectively. Table 3 shows the *C* and ϕ results obtained for each % of plastic strips. Increasing the % of plastic content has increased both the angle of internal friction and cohesion.

Table 3. Direct shear test results

Strip size (mm)	Plastic strip (%)	*C*	ϕ
20 X 4	0	0.6	41
	0.25	0.74	43.2
	0.5	0.82	45.4
	1	0.87	46.5
	1.5	0.9	46.7

3.2.1 California bearing ratio test results

The bearing capacity of the soil was measured indirectly by conducting the CBR test. The soaked CBR is tested in this study because it is only test simulate actual site condition. The soaked CBR of unreinforced soil was found to be 2.0. Increase in % of plastic strip has resulted in an increase in CBR value and then decrease. The improvement in CBR can attributed to the ability of the plastic strips in resisting swelling prior to penetration and load exerted by the plunger during penetration. Table 4 shows the CBR values.

Table 4. CBR values (%)

Strip size (mm)	Plastic strip (%)	CBR values
20 X 4	0	2.0
	0.25	2.3
	0.5	2.5
	1	2.75
	1.5	2.6

4. Conclusion

The following conclusions are drawn based on the results obtained.

The value of maximum dry density gradually increase with the increase in % of plastic. Maximum value is observed in 1% of plastic replacement after that the value decreases.

The value of optimum moisture content gradually decrease with the increase in % of plastic.

The angle of internal friction and cohesion intercept increased significantly as the reinforcement percentage increased.

Increase in % of plastic has resulted in an increase in soaked CBR value upto 1% of plastic replacement after that the value decreases.

From the above study it is observed that with the utilizing of plastic material increase the resistance to shear, maximum dry density and CBR value.

References

1. Ashraf, A., Sunil, A., Dhanya, J., Joseph, M., Varghese, M., Veena, M.: Soil Stabilisation using Raw Plastic Bottles. In:Indian Geotechnical Conference Proceedings, pp. 489-492, (2011).
2. Belay Kassa, R., Workie, T., Abdela, A., Fekade, M., Saleh, M., Dejene, Y.: Soil Stabilization using Waste Plastic Materials. Open Journal of Civil Engineering 10, 55-68 (2020).
3. Chavan, A. H., Waghre, A. M., Khainar, V. A., Zagade, S. v., Chaudhary, V. S.: Stabilization of Black Cotton Soil using Plastic Strips. Journal of Engineering Technologies and Innovative Research 6(6), 87-93, (2019)
4. Choudhary, A. K., Jha, J. N., Gill, K. S.: A Study on Behaviour of Waste Plastic Strip Reinforced Soil. Emirates Journal for Engineering Research, 15 (1), 51-57, (2010).
5. Fauzi, A., Djauhari, Z. Fauzi, U.J.: Soil Engineering Properties Improvement by Utilization of Cut Waste Plastic and Crushed Waste Glass as Additive. International Journal of Engineering and Technology, 8, 15-18, (2016).
6. Gangwar, P., Tiwari, S.: Stabilization of soil with waste plastic bottles. Environmental science, 2021.
7. Ibrahim, H. H., Mawlood, Y. I., Alshkane, Y.: Using waste glass powder for stabilizing high plasticity clay in Erbil city-Iraq. International Journal of Geotechnical Engineering, (2019).
8. Kumar, A. B. G., Vageesh H.P.: Effect of discarded plastic waste as stabilizer on engineering properties of cohesive soil. International Journal of Techno Sci Research, 4(12), 779-786. (2017).
9. Maria Ilies, N., Petru Circu, A., Csongor Nagy, A., Costel Ciubotaru, V., Kisfaludi Bak, Z.: Comparative Study on Soil Stabilization with Polyethylene Waste Materials and Binders. In: 10th International Conference Interdisciplinary in Engineering, INTER ENG-2016 on Procedia Engineering, pp. 444-451.Elsevier,(2017).
10. Singh, K., Mittal, A.: Soil Stabilisation using Plastic Waste. Recycled Waste Materials, pp.91-96. Springer, (2019).