Geotechnical Engineering Applications of Waste Plastic Bottle

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Abstract - *Soil stabilization is the technique by which the physical properties of the soil are changed. Stabilizing a problematic soil increases the shear strength of the soil; it increases the bearing capacity of the soil by chemical admixtures, mechanical and dewatering depending on the soil characteristics. Waste plastic has been effectively used to reduce the challenges of the societies. Waste plastic products are the most dangerous materials which bring a significant problem on the environment and human health. Since it is a non-biodegradable material, it can stay in the soil for a long period of time and it gets contact with the underground water and which is difficult to treat. Recycling these waste plastic products meets many advantages. These materials can be used as a soil stabilizer or as a reinforcement by infilling the stone aggregates or fly ashes. Cutting these plastics into small strips and mixing with the soil with different percentages, the properties of the problematic soil can be improved.*

Key Words*: California Bearing Ratio, Non-biodegradable, plastic, expansive soil, soil stabilization*

1. INTRODUCTION

The population of the world is increasing at a high rate from time to time and this condition enforces the people to expand the infrastructures like roads, railways, embankments, foundations, canals, electric powers and the like. Therefore, the people face big challenges to expand the cities and to construct infrastructures due to the problematic soils which cannot withstand the applied load. The researchers have been searching for the solution of this problematic soils, how to change it to a useful ground which withstands any superstructures by strengthening the internal particles of the soil.

By its nature the behavior of expansive soil changes depending upon seasonal variation. It is known by its swelling and shrinking characteristics during a rainy season and a dry season respectively.

The swelling and shrinking characteristics of this soil have a great problem on road pavements, structures, foundations, and embankments which threatens the stability of structures.

There are various methods used to improve the geotechnical properties of expansive soils. The problematic soil is removed and replaced by a good quality material or treated using mechanical and/or chemical stabilization.

According to William Powrie (1997) nowadays, there are different methods which are used to improve the geotechnical properties of the soil; Compaction, dewatering which includes electro-osmosis, chemical stabilizers, grouting, reinforcement, and geotextiles are some stabilizing methods used to treat a problematic soil at in-situ [11]. According to the idea of Powrie, problematic soils can be treated by any means depending upon the type of the grain size, type of the problem, improvement techniques, and the material used.

1.1 Expansive soil Stabilization

A) Mechanical Stabilization

Hanifi Canakci et al, (2016), Mechanical stabilization is the common methods of soil treating techniques and it is the cheapest and simplest one; the density of a problematic soil increase by applying effort to the soil, due to this the moisture content of the soil is reduced; as a result, the shear strength of a soil increases [5]. By this method, the soil is stabilized mechanically by applying forces to the soil particles. The dry density and the shear strength of the soil increases, and the moisture content available in it will be reduced.

This type of stabilization is applicable for coarse-grained soils which have low tendency to carry water inside its particles.

B) Chemical Stabilization

D. P. Purushothama, 2016, under chemical stabilization, the soil particles make a strong bond with a cementing agent which the chemical is the primary additive and creates a chemical reaction with the soil [3]. As the concept of this author, we understand that mixing the chemical materials with a problematic soil bonds the soil particles by creating intermolecular attraction between each particle.

Hanifi Canakci et al, (2016), Chemical stabilization is the process of injecting the soil with chemicals like Portland cement, lime, fly-ash, coconut shell powder, calcium chloride and any other binding agents [5].

According to this idea, the physical properties of a problematic soil can be improved by chemical means. Mixing it with a soil at different percentage the optimum content of the chemicals can be determined in laboratory experiments.

The shear strength of the soil will be increased when the additional material is added to the soil; hence the moisture content of the soil will be reduced.

Plastic waste products are the main problem in second and third world countries. It is a non-biodegradable material

which brings environmental pollution and puts human health at risk. These waste disposable plastics can be recycled and used as soil stabilizers by cutting it into different small strips and mixing it with a soil at a different percentage. Infilling materials like stone aggregates and fly ash by wrapping from inside with jute fibre can be used as reinforcement. Perforating the plastics with a hot needle material with small diameter makes the plastics to have a friction with the wrapped jute fiber. The jute material is a natural material which can be produced from different plants like inset, coconut, or any other fiber plants. Applying the unconfined compression test on the plastic bottles which are infilled with stone aggregates or fly ashes which are wrapped with jute fibers can determine the strength of the plastics. This is for the application of waste plastic materials as reinforcement. Plastic waste products are cost-effective, reduce environmental pollution, and reduce the health risk of the society.

1.2 Materials

A) Expansive Soil

Expansive soils are distributed all over the world which is the primary cause for the damage of structures and buildings. Expansive soil is the most dangerous soil which changes its characteristics depending upon the seasonal variations. It is by the vertical movement that it brings a major problem on the stability of structures. Leema Peter et al, (2016) explains as expansive soil have no sufficient strength to withstand the applied load, in this case a pavement which is constructed on a clay soil are subjected to early degradation if not stabilized with a suitable material at a suitable standard [7]. As the concept of this author, expansive soil has no tendency to carry a load which is supposed to constructed over it; this is because the minimum internal strength between each soil particles. If any structure is constructed over such like soil, the settlement will occur immediately.

The most dangerous soil which threats the stability of structure and pavement is a clay soil (Hanifi Canakci et al, 2016) [5]. The stability of any pavement or structure is in danger if it is constructed on clay soil; because by its nature clay soil has the behavour of swelling and shrinking characteristics depending upon the seasonal variations.

B) Waste plastics

Plastics are materials which are produced from polymers. The Plastic Industry Trade Association (SPI), identifies plastic into seven (7) broad categories.

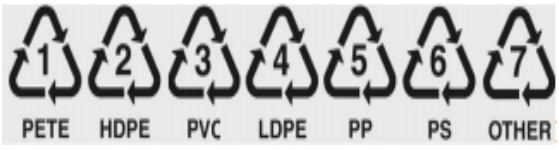

Figure-1 Plastic Identification code

Sushovan Dutta (2016) suggested that disposing of non-biodegradable plastic bottles to the environment is a major concern which each and everybody should take its part to reduce the amount of wastes released [10]. As the concept of Sushovan Dutta (2016), waste plastic bottles are the dangerous materials which affect the quality of the environment and everybody should take his part to minimize the amount to be deposited.

Hanifi Canakci et al, (2016) suggests that disposal of waste materials to the environment is a serious challenges facing a developing countries due to increase in solid wastes released from each households, commercials, industrials, and this issue should be discussed as a major concern with the community [5]. The waste plastics are a non-biodegradable and one of the major catastrophic materials which has a risk on human health, environmental pollution, and also which infertile the soil. Disposable waste plastics are produced as a container of whether liquid or solid products and it is thrown everywhere after use. Changing these waste products to a useful product is the new innovation which has been started not more than a decade. Researchers have been trying to find a solution for waste plastic products.

Arpitha G C1 (2017) suggests that addition of plastic bottle strips to a problematic soil with the optimum content increases the value of California Bearing Ratio (CBR). The value of CBR was checked for different plastic bottle strips of 0.5%, 1%, 1.5%, 2%, and 3%. From the results, the value of CBR increased at 2% of waste plastic bottle strips. But when the content of plastic bottles exceeds 2% the value of CBR starts decreasing. From the laboratory test he observed that the value for CBR increased from 29.34% to 31.67% at 2% of plastic bottles. At 2.5% of plastic bottles the value of CBR became 31.45%. This result shows that 2% of plastic bottle strips are the optimum amount of strips which should be added to the soil to stabilize the soil. The physical property of soil alone and with plastic bottles trips has been observed by this author, and it was found that the physical properties of soil improved with plastic bottle strips as the following table [2].

Table-1 Value of CBR from the result of Arpita GC (2017)

% added	CBR value
Only soil	29.34%
0.5%	30.72%
1%	31.38%
1.5%	31.89%
2%	31.67%
2.5%	31.45%

Prof. Harish C et al, (2016) performed the effects of different percentage of plastic bottle strips on CBR values of the stabilized soil. It was observed that the CBR value of black cotton with 0.5% of plastic bottle strips increased from 2.7% to 3.3% [8]. The results of CBR value at different percentage of plastic content is in the following graph.

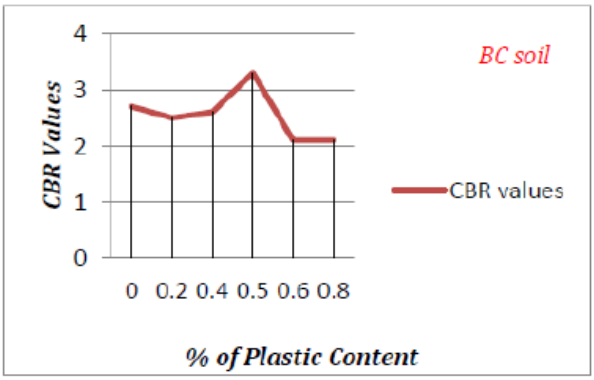

Figure-2 CBR values of black cotton soil with different % of plastics

Abhishek Patil (2016) performed the tri-axial and direct shear test on soil alone and with the addition of plastic strips. The author cut the plastic bottles in to 1cm * 1cm strips and mixed it with black cotton soil. The percentage of plastic bottles he used was 1% and he tried to put the tests of soil alone and the addition of 1% of plastic bottles for tri-axial and direct shears tests [1]. The differences are discussed below in table form.

Table-2 Stress differences with and without plastic bottles

		Without plastic		With plastic	
Sr. No	Cell Pressure	Deviator stress	Normal Stress	Deviator Stress	Normal Stress
1	1.2	0.65	1.85	1.35	2.55
2	1.6	0.93	2.53	2.74	4.34
3	1.8	1.04	2.84	2.29	4.09
4	2	1.07	3.07	2.65	4.65
5	2.2	1.10	3.30	3.10	5.30

In the same manner, direct shear test has been performed on soil sample and with plastic bottles. The following table is the result after the laboratory investigation of Abhishek Patil (2016) to find out the direct shear test.

Table-3 Shear direct test result

		Without Plastic	With Plastic
Sr. No	Normal Stress	Shear Stress kg/cm2	Shear Stress kg/cm2
1	0.2	0.32	0.39
2	0.3	0.45	0.50
3	0.7	0.62	0.74

The following figure shows the result of increment in stress and strain of soil with addition of 1% of plastic bottles as the laboratory performance of the author

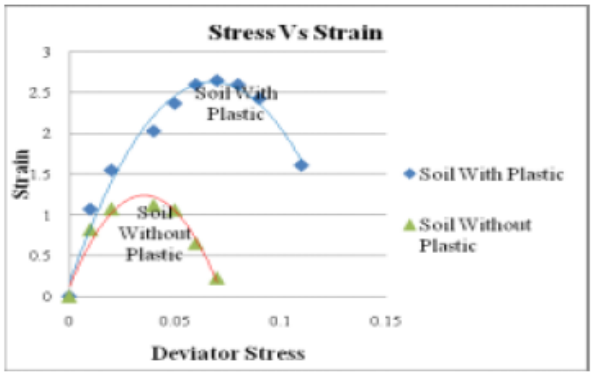

Figure-3 Deviator stresses vs. strain for tri-axial test

This author also calculated the value of cohesion (C) and angle of friction (Φ) from Mohr's circle for tri-axial and direct shear test and put as the following table.

Table-4 Comparison test of direct shear and tri-axial test with plastic and non-plastic

Test	Without Plastic	With 1% Plastic	% change
Tri-axial test	C=0.21kg/cm2	C=0.64kg/cm2	%increase=67
Direct Shear Test	C=0.19kg/cm2	C=0.67kg/cm2	%increase=24

From the direct shear and tri-axial test results it can be observed that there is an increase in cohesion value with addition of plastic to the soil which suggests that there is an improvement in load carrying capacity of soil.

Conclusion

From studies discussed above from different authors the following conclusions can be summarized.

[1]. Results of various researchers give a positive indication to the possibility of using waste plastic bottles as a reinforcement material in expansive soil.

[2]. Waste plastic bottles can be used as a soil improvement as it is locally available and cheaper alternative.

[3]. Disposal of plastic waste generated every year is a big problem, using it for soil stabilization can provide a better alternative to disposal problem.

[4]. Results show increase in cohesion of soil value with addition of plastic thus increasing the shear strength and bearing capacity of soil.

For future works can be done on to what degree different types of waste plastics like High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Polystyrenes (PS) etc. impact different soil properties in various problematic soils.

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