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ijrset@gmail.com

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A Laboratory Investigation on Increment in Shear Strength of Soil Using Plastic Waste

Rohit Kumar¹, Ajay Kumar Khokhad², Ajay Meena³, Rahul Gehlot⁴, Shweta Kanwar⁵

Assistant Professor, Department of Civil Engineering, Vivekananda Institute of Technology, Jaipur, India ¹

U.G. Student, Department of Civil Engineering, Vivekananda Institute of Technology, Jaipur, India ²⁻⁵

ABSTRACT: The main objective of this study is to investigate the use of waste fiber materials in geotechnical applications and to evaluate the effects of waste PET bottle plastic waste on shear strength of unsaturated soil by carrying out direct shear tests and on two different soil samples. The results obtained are compared for the two samples and inferences are drawn towards the usability and effectiveness of fiber reinforcement as a cost-effective approach. Soil stabilization is one of the best methods for improving physical properties like shear strength, bearing capacity etc. of the soil. For soil stabilization various admixture such as cement, lime, fly ash, gypsum etc. can be used. But these admixtures are costly so their use for soil stabilization are limited. In some research it is found that utilization of waste material like plastic, bamboo etc. are quite helpful in stabilization of soil. In present world there is scarcity of good soil which makes construction process difficult. So, to enhance the properties of soil so that it can be used for various construction there is need to add the suitable admixture in soil. These admixtures should enhance properties of soil and also be economical. In this study plastic bottles are used as an admixture. The waste plastic bottles are cut into small strips and these strips are added in the soil in different percentage of 0%, 0.25%, 0.5% and 0.75% of dry weight of soil. After finding the shear strength of different soil sample they are mixed with different percentage of plastic strips. Then the graphs and tables are plotted for the comparison of strength of different samples of soil.

KEYWORDS: Shear strength, Soil stabilization, PET bottle, Atterberg limit.

I. INTRODUCTION

For any land - based structure, the foundation is very important and has to be strong to be support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work. In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favor. In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement. Here, in this project, soil stabilization has been done with the help of randomly distributed polypropylene fibers obtained from waste materials. 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. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project.

Shear strength:

Shearing stresses are induced in a loaded soil and when these stresses reach their limiting value, deformation starts in the soil which leads to failure of the soil mass. The shear strength of a soil is its resistance to the deformation caused by the shear stresses acting on the loaded soil. The shear strength of a soil is one of the most important characteristics. There are

several experiments which are used to determine shear strength such as DST or UCS etc. The shear resistance offered is made up of three parts: The structural resistance to the soil displacement caused due to the soil particles getting interlocked, The frictional resistance at the contact point of various particles, and Cohesion or adhesion between the surface of the particles. In case of cohesion less soils, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion.

Methods for measuring shear strength:

Direct Shear Test (DST)

This is the most common test used to determine the shear strength of the soil. In this experiment the soil is put inside a shear box closed from all sides and force is applied from one side until the soil fails. The shear stress is calculated by dividing this force with the area of the soil mass. This test can be performed in three conditions- un-drained, drained and consolidated un-drained depending upon the setup of the experiment.

II. LITERATURE REVIEW

Lavanya et al. [2011] studied about utilization of copper slag in geotechnical applications. In this paper, she investigated about the Index properties, free swell index, compaction properties, CBR and UCC. She concluded that the partial replacement of copper slag from 30% to 50% with black cotton soils, considerably showed the increase in properties of the soil. She also concluded that partial replacement of copper slag with black cotton soil resulted in utilization of such soils in sub grade, sub base and embankment of roads and it was also improved the sub grade soil condition.

Otoko Rowland et al. [2011] investigated about the stabilization of Nigerian Deltaic Laterites with saw dust ash. The soil properties were identified by conducting tests of liquid limit, plastic limit, shrinkage limit, free swell index, plasticity index, MDD with OMC, UCC and CBR. He finally concluded that physical properties and engineering characteristics of Nigerian deltaic laterites were improved with addition of 4% of saw dust ash, and there was also increase in 14% of CBR values. He also concluded that there was reduction in cost of construction because of the use of solid waste.

Patel V Arpita et al. [2011] investigated about the geotechnical properties of black cotton soil which are contaminated by castor oil and stabilized by saw dust. Several Tests were conducted like specific gravity, Atterberg limits, MDD with OMC, CBR (soaked and unsoaked) and UCC. He discussed about the index and engineering properties of contaminated black cotton soil. Then he discussed, that the results were increased with 7.5% partial replacement of saw dust in contaminated black cotton soil. He finally concluded that though soils were contaminated using castor oil, its properties were improved when sawdust was added up to 10% to the soil.

Malhotra Monica et al. [2013] investigated about stabilization of expansive soils by using low-cost materials. In this paper fly-ash and lime were added as stabilizing agents with varying percentages. He had conducted various tests like liquid limit, free swell index and standard proctor test. He finally concluded that partial replacement of soil with both lime and fly-ash showed a considerable increase in properties like unequal settlement. He also concluded that shrinkage and swelling characteristics of the soil was reduced.

Gundaliya et al. [2013] studied about the black cotton soil characteristics with partial replacement of cement waste dust and lime. He computed the behavior of those soils with various tests such as liquid limit, plastic limits and UCC. There results concluded that cement dust acted as a good stabilizing agent for Black cotton soil. He also concluded that compressive strength was improved with partial replacement of cement with soil.

III. METHODOLOGY

The experimental work consists of the following steps:

- Specific gravity of soil
- Determination of soil index properties (Atterberg Limits)
- Liquid limit by Casagrande's apparatus
- Plastic limit



- Particle size distribution by sieve analysis
- Determination of the maximum dry density (MDD) and the corresponding optimum - moisture content (OMC) of the soil by Proctor compaction test
- Preparation of reinforced soil samples.
- Determination of the shear strength by: Direct Shear Test (DST)

DIRECT SHEAR TEST

This test is used to find out the cohesion (c) and the angle of internal friction (ϕ) of the soil, these are the soil shear strength parameters. The shear strength is one of the most important soil properties and it is required whenever any structure depends on the soil shearing resistance. The test is conducted by putting the soil at OMC and MDD inside the shear box which is made up of two independent parts. A constant normal load (ζ) is applied to obtain one value of c and ϕ . Horizontal load (shearing load) is increased at a constant rate and is applied till the failure point is reached. This load when divided with the area gives the shear strength ' τ ' for that particular normal load.

The equation goes as follows:

$$\tau = c + \sigma \cdot \tan(\phi)$$

After repeating the experiment for different normal loads (ζ) we obtain a plot which is a straight line with slope equal to angle of internal friction (ϕ) and intercept equal to the cohesion (c). Direct shear test is the easiest and the quickest way to determine the shear strength parameters of a soil sample. The preparation of the sample is also very easy in this experiment.

IV. RESULTS AND DISCUSSION

Properties	Specific gravity	Liquid limit	Plastic limit	Plasticity index	Soil type
Soil sample 1	2.72	28.90	22.5	6.32	Silt
Soil sample 2	2.60	43.49	19.56	24.35	Clay

DIRECT SHEAR TEST

Soil sample 1 :-

Cohesion value increases from 0.325 kg/cm² to 0.3887 kg/cm², anet**19.6%**.

The increment graph shows a gradual decline in slopes.

The angle of internal friction increases from 47.72 to 48.483 degrees, anet**1.59%**.

The increment in shear strength of soil due to reinforcement is **marginal**.

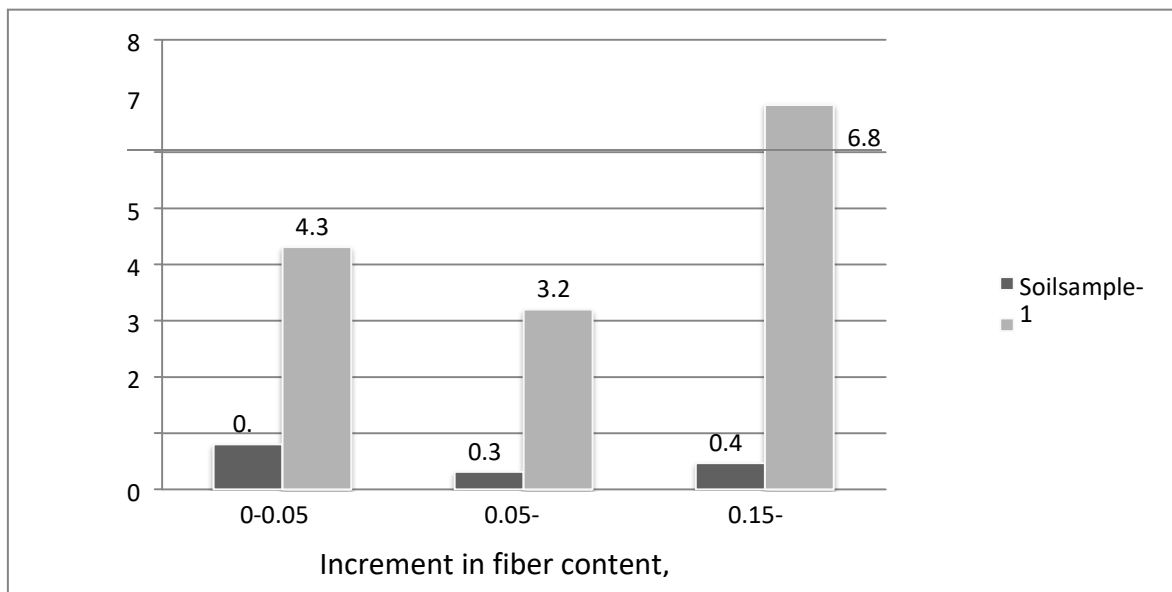
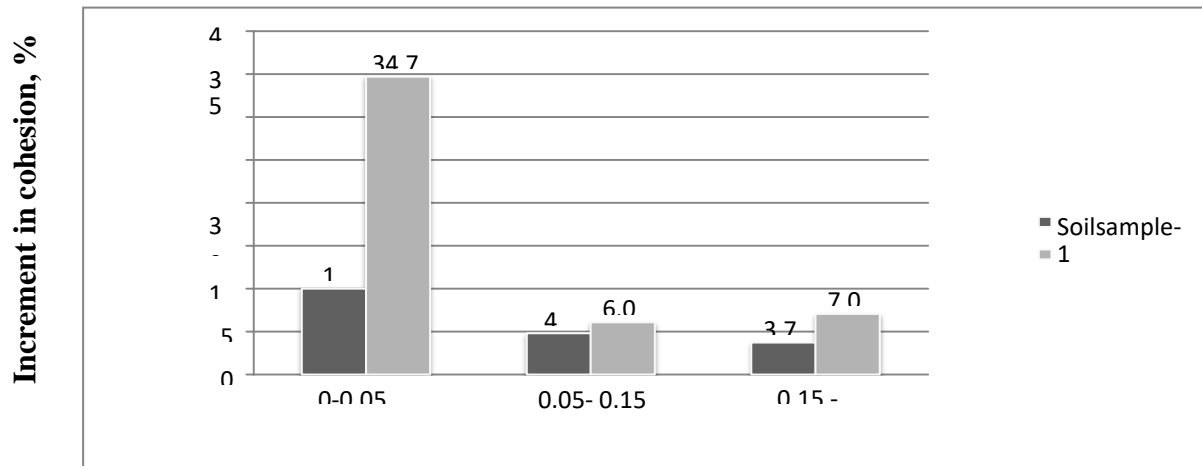
Volume of shear Box	90cm ³
Maximum dry density of soil	1.91gm/cc
Optimum moisture content of soil	12.6%
Weight of the soil to be filled in the shear box	1.91x90=171.9gm

Weight of water to be added	$(12.6/100) \times 171.9 = 21.66\text{gm}$
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Soil sample 2:-

- Cohesion value increases from 0.3513 kg/cm² to 0.5375 kg/cm², a net 53.0%
- The increment graph for cohesion shows a gradual decline in slope.
- The angle of internal friction increases from 27.82 to 32 degrees a net 15.02%
- The increment graph for ϕ shows a variation in slope-alternate rise and fall.
- The increment in shear strength of soil due to reinforcement is substantial.

Comparison of shear parameters between soil sample-1 and soil sample-2



V. CONCLUSION

On the basis of present experimental study, the following conclusions are drawn:

Based on direct shear test on soil sample- 1, with fiber reinforcement of 0.05%, 0.15% and 0.25%, the increase in cohesion was found to be 10%, 4.8% and 3.73% respectively. The increase in the internal angle of friction (ϕ) was found to be 0.8%, 0.31% and 0.47% respectively. Since the increase in the values of c and ϕ were observed to be 19.6%, from 0.325kg/cm² to 0.3887kg/cm² and 1.59%, from 47.72 to 48.483 degrees respectively, for such as soil, randomly distributed PET waste is not recommended.

The shear strength parameters of soil sample- 2 were determined by direct shear test shows that the increase in the value of cohesion for fiber reinforcement of 0.05%, 0.15% and 0.25% are 34.7%, 6.09% and 7.07% respectively. Figure 27 illustrates that the increase in the internal angle of friction (ϕ) was found to be 0.8%, 0.31% and 0.47% respectively. Thus, a net increase in the values of c and ϕ were observed to be 53%, from 0.3513 kg/cm² to 0.5375kg/cm² and 15.02%, from 27.82 to 32 degrees. Therefore, the uses of polypropylene fiber are in forcemeat for soils likes oil sample-2is recommended

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