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Stabilization of Waste Soil at Karur Dump Yard by using Polypropylene Fiber

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***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 polypropylene fibers on shear strength of unsaturated soil by carrying out direct shear tests and unconfined compression tests 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 replacement for deep foundation or raft foundation, as a cost effective approach.*

***Keywords:** polypropylene fibers, direct shear tests and unconfined compression tests, cost effective approach.*

I. INTRODUCTION

For any land-based structure, the foundation is very important and has to be strong to 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 behaviour. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work. From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength etc., some of these methods were so effective that their buildings and roads still exist.

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.

II. SCOPE OF WORK

The experimental work consists of the following steps:

1. Specific gravity of soil
2. Determination of soil index properties (Atterberg Limits)
   i) Liquid limit by Casagrande's apparatus
   ii) Plastic limit
3. Particle size distribution by sieve analysis
4. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
5. Preparation of reinforced soil samples.
6. Determination of the shear strength by:
   i) Direct shear test (DST) ii) Unconfined compression test (UCS)

III. MATERIALS AND PROPERTIES

- Soil sample-1
  Location: Karur - Arasu colony Dump Yard-1
- Soil sample- 2
  Location: Karur - Arasu colony Dump Yard-2
- Reinforcement: Short PP (polypropylene) fiber

TABLE-1 Index and Strength Parameters of PP-Fibre

Behaviour parameters	values
Fibre type	Single fibre
Unit weight	$0.91 gm/cm^3$
Average diameter	0.034mm
Average Length	12mm
Breaking tensile strength	350Mpa
Modulus of elasticity	3500Mpa
Fusion Point	165^oC
Burning Point	$590\ ^oC$
Acid and alkali resistance	Very Good
Dispersibility	Excellent

3.1 Preparation of samples

Following steps are carried out while mixing the fiber to the soil. All the soil samples are compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests. Content of fiber in the soils is herein decided by the following equation:

$$\rho_f=(W_f/W) \qquad \text{----------- (1)}$$

Where, ρf= ratio of fiber content
Wf = weight of the fiber
W = weight of the air-dried soil

- The different values adopted in the present study for the percentage of fiber reinforcement are 0, 0.05, 0.15, and 0.25.
- In the preparation of samples, if fiber is not used then, the air-dried soil was mixed with an amount of water that depends on the OMC of the soil.

If fiber reinforcement was used, the adopted content of fibers was first mixed into the air-dried soil in small increments by hand, making sure that all the fibers were mixed thoroughly, so that a fairly homogenous mixture is obtained, and then the required water was added.

IV. TEST PROCEDURE

4.1 Specific gravity of the soil

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water.

$$\text{Specific Gravity } G = \frac{W2-W1}{(W4-W1 - W3-W2)}$$

W1- Weight of bottle in gms
W2- Weight of bottle + Dry soil in gms
W3- Weight of bottle + Soil + Water
W4- Weight of bottle + Water

Specific gravity is always measured in room temperature and reported to the nearest 0.1.

4.2 Liquid limit

The Casagrande tool cuts a groove of size 2mm wide at the bottom and 11 mm wide at the top and 8 mm high. The number of blows used for the two soil samples to come in contact is noted down. Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate. Liquid limit corresponds to 25 blows from the graph.

4.3 Plastic limit

This is determined by rolling out soil till its diameter reaches approximately 3 mm and measuring water content for the soil which crumbles on reaching this diameter. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

$$I_p = w_L - w_P$$

wL-Liquidlimit
wP- Plasticlimit

4.4 Particle size distribution

The results from sieve analysis of the soil when plotted on a semi-log graph with particle diameter or the sieve size as the abscissa with logarithmic axis and the percentage passing as the ordinate gives a clear idea about the particle size distribution. From the help of this curve, D10 and D60 are determined. This D10 is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D10 and D60 gives the uniformity coefficient (Cu) which in turn is a measure of the particle size range.

4.5 Proctor compaction test

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. The experimental setup consists of (i) cylindrical metal mould (internal diameter- 10.15 cm and internal height-11.7 cm), (ii) detachable base plate, (iii) collar (5 cm effective height), (iv) rammer (2.5 kg). Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD. The equations used in this experiment are as follows:

Wet density = weight of wet soil in mould gms/ volume of mould cc
Moisture content % = (weight of water gms/ weight of dry soil gms) x 100
Dry density γd (gm/cc) = wet density/(1+moisture content) x100

4.6 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. This load when divided with the area gives the shear strength 'τ' for that particular normal load. The equation goes as follows:

$$\tau = c + \sigma * \tan(\varphi)$$

After repeating the experiment for different normal loads (ς) 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.

4.7 Unconfined compression test

This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined soil. The unconfined compressive strength (qu) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compressive test. The experimental setup constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge starting from $\varepsilon = 0.005$ and increasing by 0.005 at each step. The corrected cross-sectional area was calculated by dividing the area by $(1- \varepsilon)$ and then the compressive stress for each step was calculated by dividing the load with the corrected area.

V. RESULTS AND DISCUSSIONS

5.1 INDEX PROPERTIES

The index properties includes Specific Gravity, Liquid limit, Plastic limit, Uniformity Coefficient, Optimum Moisture content, Max dry density etc., The index properties obtained from the tests for sample 1 and sample 2 are listed in the table below

TABLE-2 Index properties of Soil

Index Properties	Sample-1	Sample-2
Specific Gravity	2.72	2.60
Liquid limit	28.90%	43.49%
Plastic limit	22.58%	19.56%
Uniformity Coefficient	1.362%	1.348%
Optimum Moisture Content	12.6%	17.02%
Maximum Dry Density	1.91g/cc	1.96g/cc

The Shear strength properties includes cohesion, Angle of internal friction, unconfined compression strength are determined by direct shear and unconfined compression strength test. The shear strength parameters obtained from the tests for sample 1 and sample 2 for unreinforced soil and reinforced soil of various percentages of reinforcement such as 0.05%, 0.1%, 0.15%, 0.2%, 0.25% are listed in the table below

TABLE-3 Shear strength properties

Parameters	Sample-1				Sample-2			
	0%	0.05 %	0.15 %	0.25 %	0%	0.05 %	0.1%	0.15 %
Cohesion (kg/cm^2)	0.32 5	0.36	0.37	0.39	0.35	0.47	0.50	0.54
Angle of Internal friction	47.7^o	48.1^o	48.3 ^{o}	48.5^o	27.8^o	29.02 ^{o}	29.9 5^o	32^o
Unconfined Compression Strength (kPa)	56.2	63.1	63.7	64.3	69.2	93.8	96.5	103. 7

5.2 DISCUSSIONS

5.2.1 Inferences from Direct Shear Test

Soil sample- 1

- Cohesion value increases from 0.325 kg/cm2 to 0.3887 kg/cm2, a net **19.6%**
- The angle of internal friction increases from 47.72 to 48.483 degrees, a net **1.59%**
- The increment in shear strength of soil due to reinforcement is **marginal**.

Soil sample- 2

- Cohesion value increases from 0.3513 kg/cm2 to 0.5375 kg/cm2, a net **53.0%**
- The angle of internal friction increases from 27.82 to 32 degrees, a net **15.02%**
- The increment in shear strength of soil due to reinforcement is **substantial**

5.2.2 Inferences from Unconfined Compression Test

Soil sample- 1

- UCS value increases from 0.0643 MPa to 0.0562 MPa, a net **14.4%**

Soil sample- 2

- UCS value increases from 0.0692 MPa to 0.1037 MPa, a net **49.8%**

VI. CONCLUSION

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

1. 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 net increase in the values of c and φ were observed to be 19.6%, from 0.325 kg/cm2 to 0.3887 kg/cm2 and 1.59%, from 47.72 to 48.483 degrees respectively, for such a soil, randomly distributed polypropylene fiber reinforcement is not recommended.
2. The results from the UCS test for soil sample- 1 are also similar, for reinforcements of 0.05%, 0.15% and 0.25%, the increase in unconfined compressive strength from the initial value are 11.68%, 1.26% and 0.62% respectively.This increment is not substantial and applying it for soils similar to soil sample-1 is not effective.
3. The shear strength parameters of soil sample- 2 were determined by direct shear test. 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. 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/cm^2 to 0.5375 kg/cm^2 and 15.02%, from 27.82 to 32 degrees. Therefore, the use of polypropylene fiber as reinforcement for soils like soil sample- 2 is recommended.
4. On comparing the results from UCS test of soil sample- 2, it is found that the value of unconfined compressive strength shows a net increment of 49.8% from 0.0692 MPa to 0.1037. This also supports the previous conclusion that use of polypropylene fibers for reinforcing soils like soil sample- 2 is recommended.
5. Overall it can be concluded that fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soils where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy.

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