

# Soil Stabilization Using Polypropylene Fiber Materials

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**ABSTRACT:** The main objective of this study is to investigate the use of polypropylene fibre materials in geotechnical applications and to evaluate the effects of polypropylene fibres 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 samples and inferences are drawn towards the usability and effectiveness of fibre reinforcement at various percentages (0, 0.05, 0.015, and 0.025) as a replacement for deep foundation or raft foundation, as a cost effective approach.

**KEYWORDS:** polypropylene fiber, direct shear test, unconfined compression test, fiber reinforcement

## 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. 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 favour. 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. It is very expensive to replace the inferior soil entirely soil and hence, soil stabilization is the thing to look for in these cases

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.
- It is also used to provide more stability to the soil in slopes or other such places. Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

## II. METHODS

**Mechanical method of Stabilization** In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

- i. Additive method of stabilization

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It refers to the addition of manufactured products into the soil, which in proper quantities enhances the quality of the soil. Materials such as cement, lime, bitumen, fly ash etc. are used as chemical additives. Sometimes different fibers are also used as reinforcements in the soil. The addition of these fibers takes place by two methods;

- a) Oriented fiber reinforcement  
The fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.
- b) Random fiber reinforcement  
This arrangement has discrete fibers distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties. Randomly distributed fibers have some advantages over the systematically distributed fibers. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur in the other case and provides ductility to the of soil.

## MATERIALS

- A) Sample1
- B) Sample 2
- C) Reinforcement material (polypropylene fiber)

### Index and strength parameters of PP-fiber

Behaviour parameters	Values
Fiber type	Single fiber
Unit weight	0.91g/cm <sup>3</sup>
Average diameter	0.034mm
Average length	12mm
Breaking tensile strength	350MPa
Modulus of elasticity	3500MPa
Burning point	590 <sup>0</sup> C
Acidic and alkali resistance	Very good



FIGURE 1 Polypropylene fiber

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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 here in decided by the following equation

Where

$$\rho_f = \frac{W_f}{W}$$

$\rho_f$  = ratio of fiber content

$W_f$  = 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.

### III. RESULT AND DISCUSSION

#### RESULTS

	Soil sample	
	Sample 1	Sample 2
<b>Specific gravity G</b>	<b>2.72</b>	<b>2.60</b>
<b>Coefficient of uniformity</b>	<b>1.462</b>	<b>1.362</b>
<b>Liquid limit LL</b>	<b>28.90</b>	<b>43.91</b>
<b>Plastic limit PL</b>	<b>22.58</b>	<b>19.56</b>
<b>Plasticity index PI</b>	<b>6.32</b>	<b>24.35</b>

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<b>OMC %</b>	<b>12.6</b>	<b>17.02</b>
<b>MDD (g/cc)</b>	<b>1.91</b>	<b>1.96</b>
<b>Direct shear without reinforcement</b>	<b>C= 0.325kg/cm<sup>2</sup></b>	<b>C=0.31513kg/cm<sup>2</sup></b>
	<b>Ø=47.72°</b>	<b>Ø=27.28°</b>
<b>Unconfined compression test</b>	<b>0.0562MPa</b>	<b>0.0692MPa</b>

### Direct shear test

Sample ID		Unreinforced	0.05% of reinforcement	0.15% of reinforcement	0.25% of reinforcement
Sample1	C(kg/cm <sup>2</sup> )	0.325	0.3575	0.3747	0.3887
	Ø	47.72°	48.101°	48.245°	48.357°
Sample 2	C(kg/cm <sup>2</sup> )	0.315	0.4732	0.504	0.5375
	Ø	27.28°	29.02°	29.95°	32°

### Unconfined compression test

Sample ID	Unreinforced	0.05% of reinforcement	0.15% of reinforcement	0.25% of reinforcement
Sample 1(MPa)	0.0562	0.0631	0.0637	0.0643
Sample 2(MPa)	0.0692	0.0938	0.0965	0.1037

## DISCUSSION

Inferences from Direct Shear Test

Soil sample-1

- Cohesion value increases from 0.325 kg/cm<sup>2</sup> to 0.3887 kg/cm<sup>2</sup>, a net 19.6%
- The increment graph shows a gradual decline in slope.
- The angle of internal friction increases from 47.72 to 48.483 degrees, a net1.59%

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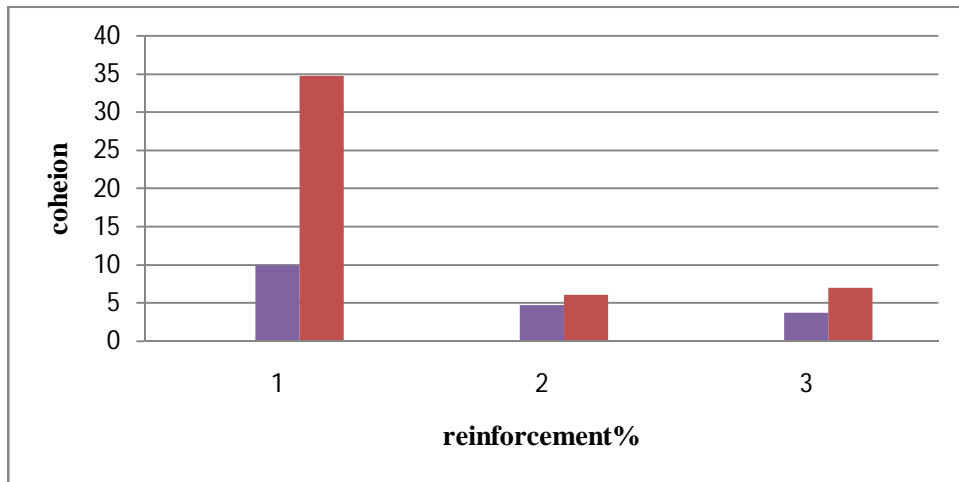
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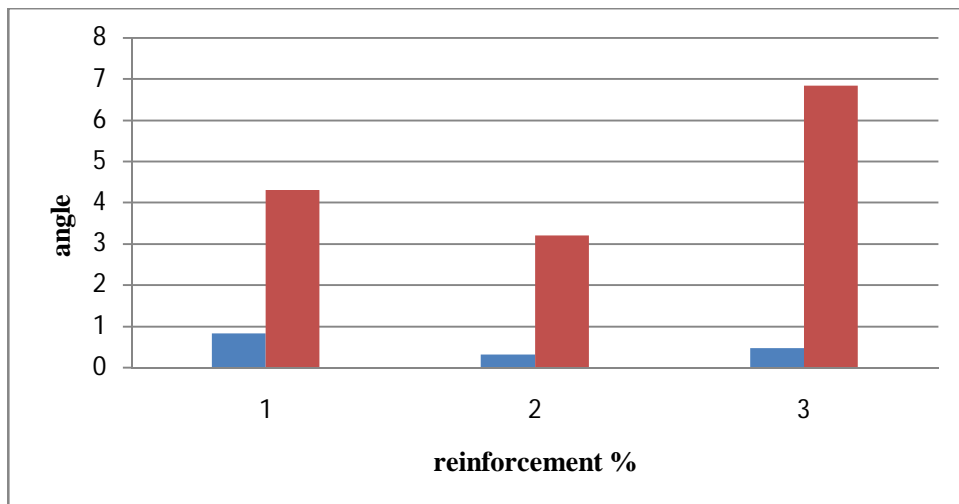
- The increment in shear strength of soil due to reinforcement is marginal

### Soil sample-2

- Cohesion value increases from 0.3513kg/cm<sup>2</sup> to 0.5375kg/cm<sup>2</sup>, 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 32degrees, a net 15.02%
- The increment graph for  $\phi$  shows a variation in slope-alternate rise and fall.
- The increment in shear strength of soil due to reinforcement is substantial



Comparison of cohesion values between soil sample-1 and soil sample-2



Comparison of  $\phi$  values between soil sample-1 and soil sample-2

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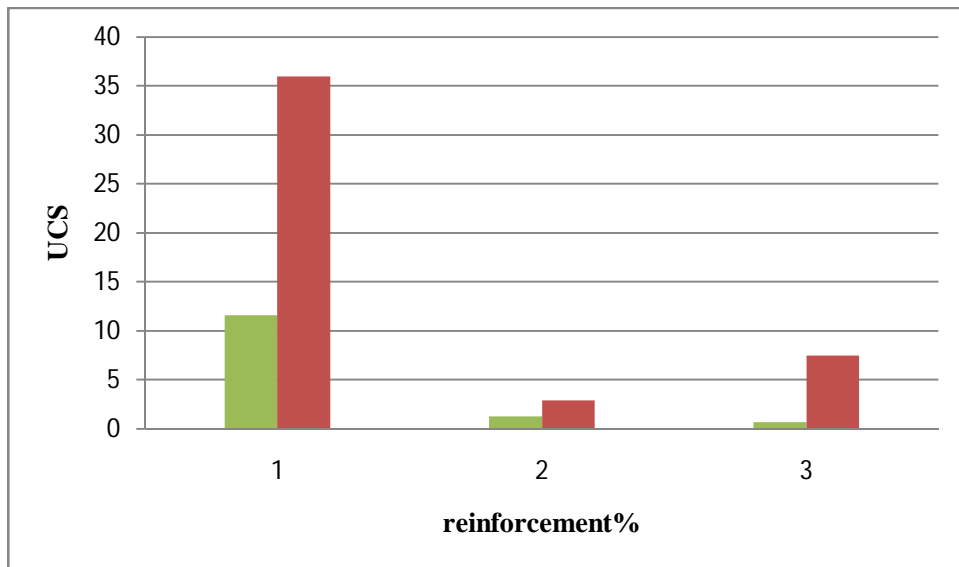
## Inferences from Unconfined Compression Test

### Sample -1

- UCS value increases from 0.0643 MPa to 0.0562MPa, a net 14.4%.
- The slope of increment graph is continuously decreasing with an initially steep slope.

### Soil sample-2

- UCS value increases from 0.0692 MPa to 0.1037 MPa, a net 49.8%.
- The slope of the increment graph varies with alternate rise and fall.



Comparison between soil sample-1 and soil sample-2 for UCS

## IV. CONCLUSIONS

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

1. Based on direct shear test on soil sample1, 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 (illustrated in figure25). The increase in the internal angle of friction ( $\phi$ ) was found to be 0.8%, 0.31% and 0.47% respectively. Since the net increase in the values of  $c$  and  $\phi$  were observed to be 19.6%, from 0.325 kg/cm<sup>2</sup> to 0.3887 kg/cm<sup>2</sup> 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 sample1 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 sample1 is not effective.
3. The shear strength parameters of soil sample2 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. Figure illustrates that the increase in the internal angle of friction ( $\phi$ ) was found to be 0.8%, 0.31% and 0.47% respectively. Thus, a net increase in the values of  $c$  and  $\phi$  were observed to be 53%, from 0.3513 kg/cm<sup>2</sup> to 0.5375 kg/cm<sup>2</sup> 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 values of unconfined compressive strength show a net increment of 49.8% from 0.0692 MPa to 0.1037 MPa. This also supports the previous conclusion that use of polypropylene fibers for reinforcing soils like soil sample-2 is recommended.

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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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