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ENHANCEMENT OF SHEAR STRENGTH PROPERTIES AND STABILITY OF SOIL BY USAGE OF PLASTIC STRIPS

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ABSTRACT - In a country like India where the natality rate is 3 per second, availability of proper land for shelter and clean drinking water is a bizarre demand and hence economic methods are more acceptable than healthier methods which in turn leads to excessive use of chemically manufactured plastics for all kind of day to day activities. The undesirable effects of plastic use which consecutively leads to pollution which must be eliminated or at least reduced. Rapid improvements in the engineering world have influenced a lifestyle of human beings in utmost extends but day to day activities of mankind are augmenting risk in the environment in the same proportion. Plastic wastes have become one of the major problems for the world. The harmful gas which is being produced during manufacturing and burning of plastics leads to carcinogenic pollutants. So, effective consumption of plastic waste in engineering application has become one of the challenging jobs for environmental, geotechnical engineers. 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.

Index terms: effectiveness, Fiber Reinforcement, Direct Shear Test, Plastic Waste, Shear Strength, Tri-axial Test, unsaturated soil

1. INTRODUCTION

SOIL forms the integral matrix of land segregated in a number of layers. Soil around the world are of various compositions and has varied physical, chemical and physiological properties which invariably comes into action when soil is subjected to external loads or pressure. Some of them may respond positively from engineering point of view and some may not. Positive response will be considered only when the mass is stable against normal and shear failures under loads. Due to scarcity of land in the present day the weak lands cannot be eliminated and must be put to use and hence the soil has to made capable enough to bear the incomings loads and external pressure. Thus stabilization of soil is an important task to be done before a construction is started. For this purpose, a number of research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement.

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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 behavior. 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.

Soil stabilization is a collective term for any physical, chemical, or biological method or any combination of such methods employed to improve certain properties of natural

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soil to make it serve adequately an intended engineering purpose. The basic principles of soil stabilization are:

- Evaluating the properties of given soil.
- Deciding the lacking property of soil and choose effective and economical method of soil stabilization.
- Designing the stabilized soil mix for intended stability and durability values.

Here, in this project, soil stabilization has been done with the help of randomly distributed polypropylene fibers. 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. TEST PROCEDURE

Two substantial quantity of soil samples has been collected from KIT campus construction site located at park circus and C.I.T campus at Madhyamgram respectively. Even before we check for the shear strength of the soil sample certain routine tests has to be carried out in order to classify the type of soil and its various geotechnical properties.

S. No.	**SAMPLE 1 (Park Circus)**	**Value**
1	Liquid Limit	28
2	Plasticity Index	6.32
3	Specific Gravity	2.72
4	Coefficient of uniformity (Cu)	1.362
5	Coefficient of Curvature (Cc)	0.037
6	Optimum Moisture Content	14 %
7	Maximum Dry Density	1.97
8	Classification of soil	ML
9	ML= Inorganic silt with low plasticity	
	SAMPLE 2 (Madhyamgram)	
S. No.	**Property of Soil**	**Value**
1	Liquid Limit	43.49
2	Plasticity Index	24.35
3	Specific Gravity	2.60
4	Coefficient of uniformity (Cu)	1.362
5	Coefficient of Curvature (Cc)	0.039
6	Optimum Moisture Content	18
7	Maximum Dry Density	1.98
8	Classification of soil	CL
9	CL= Clay with low plasticity	

Once the routine tests has been conducted each soil sample was divided into 4 main parts and 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 equation ($pf=W_f/W$) where, pf= ratio of fiber content, W_f = weight of the fiber, W = weight of the air-dried soil.

The different values of plastic content adopted in the present study for the percentage of fiber reinforcement are 0, 0.05, 0.15, and 0.25. The fibers were 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.

2.1. Direct Shear Test: The soil samples so prepared were placed in the shear mold of volume $90cm^3$ to carry out the 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 (ς) is applied to obtain one value of c and ϕ. The proving ring attached measures the load applied is of sensitivity 1 division = 3.82 N. 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: ($\tau = c + \varsigma * \tan\phi$)
After repeating the experiment for different normal loads (ς) we obtain a plot which normalized to a straight line with slope equal to angle of internal friction (ϕ) and intercept equal to the cohesion (c).

2.2. Tri – axial Test: After the preparation of remolded samples in cylindrical shapes the test is conducted till the specimen fails in shear. The specimen is not subjected to any horizontal confined forces. The unconsolidated, undrained shear strength of unconfined soil is determined in this experiment. 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 measurement respectively. The load was taken for different readings of strain dial gauge starting from ε = 0.005 and increasing by 0.005 at each step. The corrected cross-sectional (A') area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area as per following equations:
qu= load/corrected area (A')
qu- compressive stress
A'= cross-sectional area/ (1- ε)
The proving ring used for load measurement is of sensitivity 1 division =1.16N

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3. RESULTS & DISCUSSIONS

The entire test has been conducted in 2 parts. Each of the sample (maintaining the uniformity of geotechnical properties) has been subjected to direct shear test and tri-axial test consecutively and the results obtained are plotted in graphs in order to compare the different increments and decrements of the shear strength of reinforced soil mass with plastic.

3.1 Direct Shear Test:

3.1.1. Sample 1

Normal Stress (kg/cm^2)	Shear stress (kg/cm^2) for different plastic reinforcement			
	0%	0.05%	0.15%	0.25%
0.5	0.59	0.83	0.85	0.86
1	0.91	1.31	1.32	1.34
1.5	1.14	1.75	1.79	1.82
2	1.27	2.25	2.27	2.29

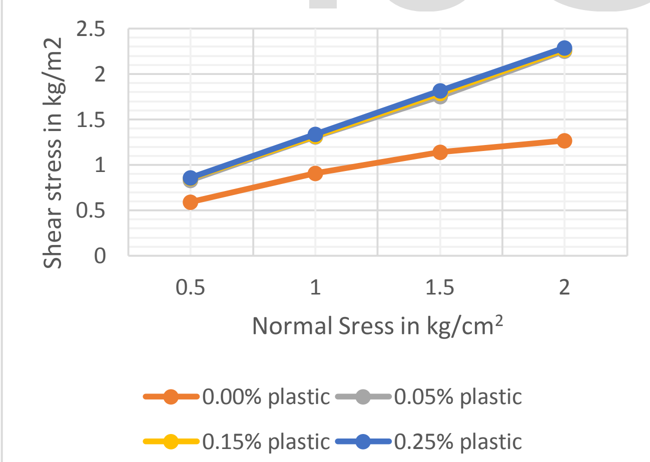


fig1: representaion of shear stress to corresponding normal stress at different reinforcements

Results from figure 1	Reinforcements with plastic variation			
	0.0%	0.05%	0.15%	0.2%
Cohesion (c) kg/cm2	0.325	0.3575	0.3747	0.3887
Angle of friction(φ)	47.72o	48.81 o	48.26 o	48.43 o

3.1.2. Sample 2

	Shear stress (kg/cm2) for different plastic reinforcement			
	0%	0.05%	0.15%	0.25%
0.5	0.58	0.72	0.788	0.85
1	0.82	0.96	1.083	1.17
1.5	1.05	1.22	1.378	1.5
2	1.28	1.42	1.651	1.79

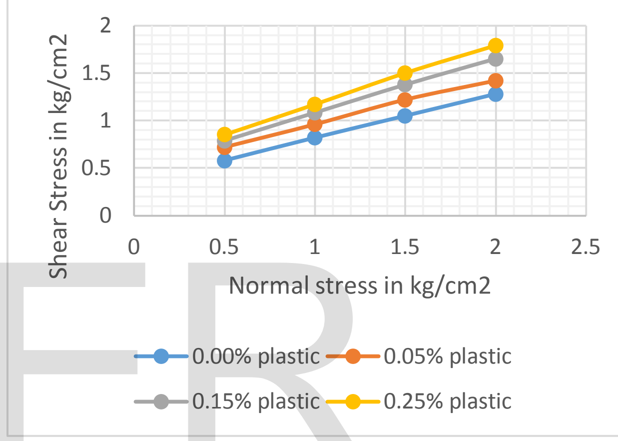


fig 2: representaion of shear test to corresponding normal stress atdifferent reinforcements

Results from figure 2	Reinforcements with plastic variation			
	0.0%	0.05%	0.15%	0.2%
Cohesion (c) kg/cm2	0.352	0.473	0.504	0.537
Angle of friction(φ)	27.82 o	29.02 o	29.95	32 o

From the above study we find the increments achieved in cohesion, angle of friction and shear stress.

Reinforcement %	Increments in c and φ value			
	Sample 1		Sample 2	
	c	φ	c	φ
0%	0%	0%	0%	0%
0.05%	10%	0.8%	34.7%	4.31%
0.15%	4.8%	0.31%	6.09%	3.2 %
0.25%	3.73%	0.47%	7.07%	6.84%

Hence we can say for 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

Axial Strain	Axial stress (kg/cm2) for different plastic reinforcement			
	0%	0.05%	0.15%	0.25%
0.0033	0.0207	0.0284	0.0277	0.0302
0.0067	0.0349	0.0382	0.0417	0.0406
0.0100	0.0462	0.0544	0.0550	0.0550
0.0133	0.0530	0.0594	0.0612	0.0612
0.0167	0.0567	0.0631	0.0639	0.0643
0.0200	0.0536	0.0605	0.0593	0.0611
0.0233	0.0487	0.0551	0.0527	0.0533

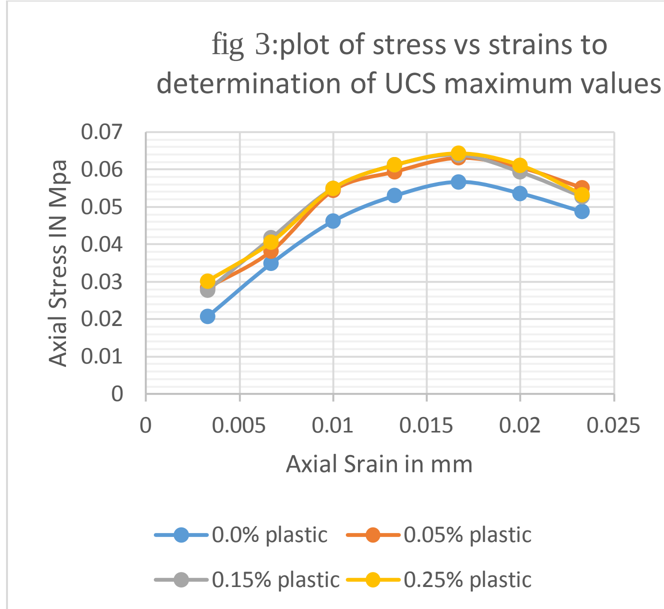
reinforcement is marginal.

In sample 2 the cohesion value increases from 0.3513 kg/cm2

Values of max UCS in (MPa)	Reinforcements with plastic variation exhibiting the increment			
	0.0%	0.05%	0.15%	0.25%
	0.0562	0.0631	0.0637	0.0643
Increment in strength	0%	11.68%	1.36%	0.62%

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 graph for ϕ shows a variation in slope- alternate rise and fall. The increment in shear strength of soil due to reinforcement is **substantial**.



3.2. Tri-Axial Test

3.2.1. Sample 1

3.2.2. Sample 2

Axial Strain	Axial stress (kg/cm^2) for different plastic reinforcement			
	0%	0.05%	0.15%	0.25%
0.0033	0.0248	0.0372	0.0408	0.0449
0.0067	0.0459	0.0617	0.0635	0.0659
0.0100	0.0597	0.076	0.0849	0.0884
0.0133	0.0663	0.0897	0.0919	0.0972
0.0167	0.0689	0.0938	0.0961	0.1037
0.0200	0.0662	0.0893	0.0927	0.0979
0.0233	0.0613	0.0814	0.0871	0.09

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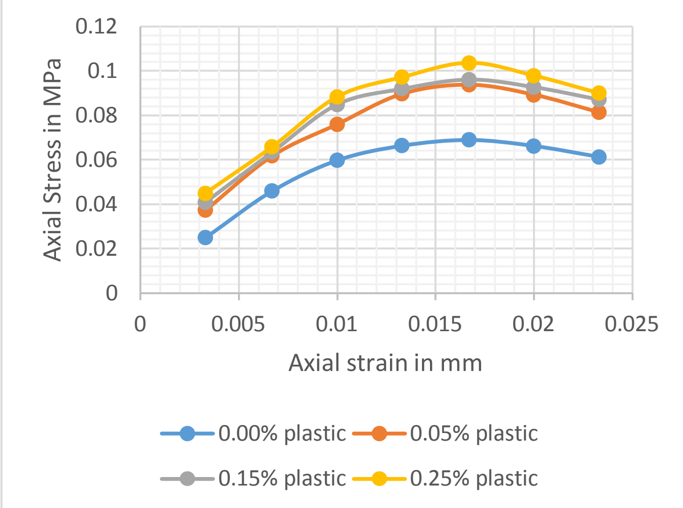

fig 4:plot of stress vs strain to determine the maximum values of UCS

Values of max UCS in (MPa)	Reinforcements with plastic variation exhibiting the increment			
	0.0%	0.05%	0.15%	0.25%
	0.0689	0.0938	0.0961	0.1037
Increment in strength	0%	35.84%	2.87%	7.46%

Hence from the resultants of fig 3 and fig 4 it can easily be deduced that for sample 1 UCS value increases from 0.0643 MPa to 0.0562 MPa, a net **14.4% and** for sample 2 UCS value increases from 0.0692 MPa to 0.1037 MPa, a net **49.8%.**

4. CONCLUSION

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

4.1. 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 (illustrated above). The increase in the internal angle of friction (ϕ) was found to be 0.8%, 0.31% and 0. 47% respectively (illustrated in figure- 27). 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.

4.2. 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 (illustrated). This increment is not substantial and applying it for soils similar to soil sample- 1 is not effective.

4.3. The shear strength parameters of soil sample- 2 were determined by direct shear test. Figure- 26 illustrates 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. It has been seen 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 0.5375 kg/cm2 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.

4.4. 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.

4.5. 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 mostly in clayey type soils where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy.

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