The Effect of Polypropylene Fibers on Properties of Expansive Soil

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Abstract*: *Expansive soils pose problems in design, construction and maintenance of civil structures. Lot of research is going on to improve the properties of expansive soils. The experimental results gathered over the past years show the potential for use of different types of fiber in improving properties of expansive soils. In this investigation effect of randomly oriented polypropylene fibers on CBR value, UCS value and shear parameters using direct shear test is studied. Fiber content is varied from 0.0% to 0.4% in steps of 0.1% (F0-F4 samples). Results indicate improved soil properties. UCS value increases from 7.4% to 24.43%; CBR value increases 23.55% to 59.88% ; cohesion increases from 5.9% to 26.80% and angle of internal friction increases from 24.84% to 53.79% with increase of fiber content from 0.1% to 0.4% compared to 0.0% fiber content(F0 sample).

Index Terms*: *CBR value, Cohesion & angle of internal friction, Expansive Soil, Polypropylene fibers, UCS Value

I. INTRODUCTION

Expansive soils are the soils which require due concern by the geotechnical engineers. They can cause extensive damage to civil structures, if not adequately treated. Out of the many alternatives, recently attention is focused on soil reinforcement with different types of fibers. Lie et.al. [4], indicated that there were significant increases in shear strength, toughness and plasticity of a cohesive soil after reinforcement with discrete polypropylene fiber. Puppala and Musenda [8] investigated the influence of discrete and randomly oriented polypropylene fiber reinforcement on expansive soil stabilization. According to the results, fiber reinforcement enhanced the properties investigated. A.S.

Soganci [2] investigated the effects of discrete polypropylene fibers on UCS value and swell potential with fiber content of 0.5%, 0.75% and 1.0%. Investigation reported increase in UCS value and decrease in swell potential with increase of fiber content. Present investigation is carried out to establish the use fiber reinforcement in improving expansive soil properties.

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II. EXPERIMENTAL INVESTIGATION

A. Properties of Soil Polypropylene Fibers

The soil used for investigation is a typical black cotton soil collected from “Nerwada” near RGM College, and is shown in Fig 1. The soil is mixed thoroughly as per the “quartering or riffling” process. After thorough mixing the entire soil is passed through 4.75mm sieve.

Fig.1 Soil sample

Table.1 Sieve analysis observations

Sieve size (mm)	Soil retained (g)	Percent retained (%)	Cumulative percent retained (%)	Percent finer (%)
4.75	0	0	0	100
2.36	1	0.50	0.50	99.50
1.18	6	3.00	3.50	96.50
0.600	7	3.50	7.00	93.00
0.425	3	1.50	8.50	91.50
0.300	5	2.50	10.99	89.01
0.150	6	3.00	13.99	86.01
0.075	4.5	2.48	16.23	83.76
Pan	167.7	83.77	100	0

Wet sieve analysis is carried out on the black cotton soil and dry sieve analysis is carried out on the retained soil sample of wet sieve analysis.

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Sieve analysis observations are shown in Table.1. The Hydrometer analysis is performed on the soil passing through the 75µ sieve. Hydrometer analysis observations are shown in Table 2.

Table.2 Hydrometer Analysis

Particle size, D (mm)	$R_{c2}=R_t \pm C$	% Finer w.r.t mass taken F	% Finer w.r.t total mass
0.0409	29.0	99.06	82.91
0.0296	28.0	95.64	80.05
0.0216	26.0	88.81	74.33
0.0158	24.0	81.98	68.61
0.0116	21.0	71.73	60.03
0.0087	19.0	64.90	54.32
0.0064	16.0	54.65	45.70
0.0046	13.5	46.11	38.59
0.0033	11.5	39.28	32.80
0.0024	10.0	34.16	28.59
0.0017	8.5	29.03	24.29
0.0010	6.0	20.49	17.15

From sieve analysis and hydrometer analysis the grain size distribution curve is plotted and is shown in Fig 2.

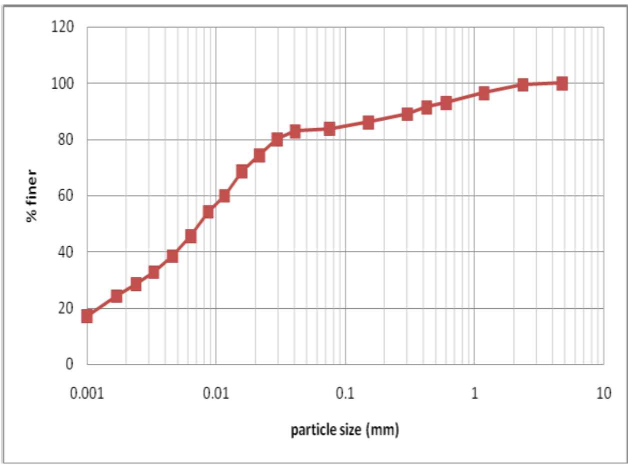

Fig.2 Grain size distribution curve for the soil sample

Physical properties of soil Liquid limit, plastic limit, specific gravity and free swell index are determined and are shown in Table 3. As per IS soil classification the soil is classified as Clay with High Compressibility with group symbol CH.

Table.3 Physical properties of soils

Property	Property Value
Specific gravity	2.413
Free swell index	37.8%
Liquid limit, w_L	61.0%
Plastic limit, w_P	30.0%
Plasticity Index=w_L-w_P	31.0%
Gravel	0%
Sand	16.24%
Silt	57.76%
Clay	26.00%
IS Classification	“CH- CLAY WITH HIGH COMPRESSIBILITY

B. Polypropylene Fibers

Polypropylene fibers, which are manufactured by Reliance Industries Ltd, are used in this investigation. Sample of polypropylene fibers are shown in Fig 3. Properties of polypropylene fibers used are shown in Table 4.

Fig.3 Polypropylene fibers

Table.4 Properties of polypropylene fibers

Index and strength parameters of PP-fiber	
Behavior parameters	Values
Fiber type	Single fiber
Unit weight	0.91 g/cm^3
Average diameter	0.034 mm
Average length	12 mm
Breaking tensile strength	350 MPa
Modulus of elasticity	3500 MPa
Fusion point	165 °C
Burning point	590 °C
Acid and alkali resistance	Very good
Dispersibility	Excellent

C. Proportion of Fibers

The proportion of polypropylene fibers considered for investigation is shown in Table 5. The proportions are designated as F0 to F4 based on variation of polypropylene from 0% to 0.4%.

Table.5 Proportions of Fibers

Proportion Designation	Proportion of Polypropylene as percentage of dry soil
F0	0.0
F1	0.1
F2	0.2
F3	0.3
F4	0.4

The fibers are mixed with soil uniformly before the addition of water to the soil. Soil mixed with fibers after addition of water is shown in Fig 4

Fig.4 Soil mixed with fiber

III. RESULTS & DISCUSSIONS

A. Compaction Test

Is Light Compaction test is done for F0 – F4 proportions to determine the Maximum dry density (MDD) and Optimum moisture content(OMC). Compaction test results are plotted and shown in Fig 5. Fig 6 shows the variation of MDD with variation % of fibers. It is observed that, as the fiber content increases MDD increases up to 0.2% and then decreases. Fig 7 shows the variation of OMC with variation of % of fibers. It is observed that with the increase of fiber content the OMC increases almost linearly.

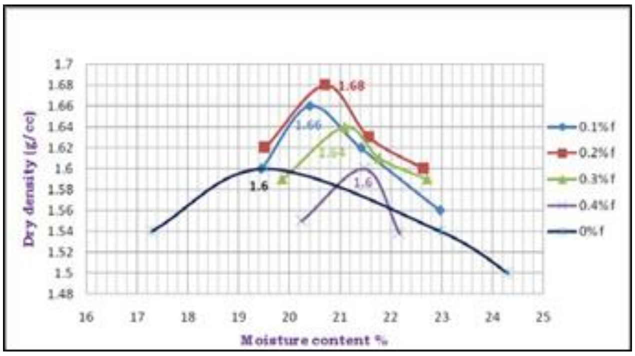

Fig.5 Compaction curves for soil mixed with different % of fibers

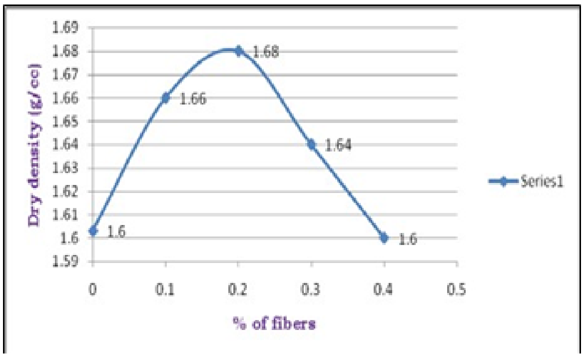

Fig.6 Variation of MDD with variation % of fibers

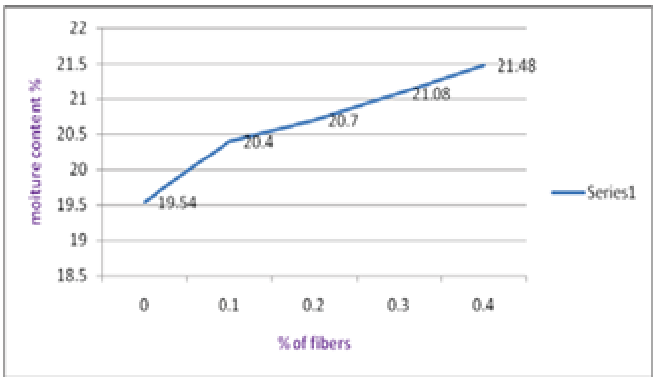

Fig.7 Variation of OMC with variation % of fibers

B. Direct Shear Test

Samples are prepared for F0 – F4 by mixing fiber with dry soil as per the proportion, added respective OMC water content obtained from compaction test and compacted the sample using IS light compaction in 2250 cm^3 IS standard mould. Then direct shear test specimens with size 60x60x25 mm are extracted from the mould using sample extractor. Then the specimens are tested in direct shear apparatus at 1.25 mm/min shear loading rate. Table 6 shows the maximum shear stress values and corresponding normal stress values at failure for F0 – F4samples. Mohr Coulomb failure envelope is plotted for F0 – F4 samples and is shown in Fig 8. From the Fig 8, slope-intercept equations for F0 - F4 samples in the form $y = mx + c$ is obtained, where 'c' is the cohesion value & 'm' represents the slope of the line from which angle of internal friction is calculated.

Table.6 Maximum shear stress values and corresponding normal stress values at failure for F0 – F4 samples

Sample	% fibers	Maximum Shear Stress (N/mm^2)		
		σ1=0.1 (N/mm^2)	σ1=0.2 (N/mm^2)	σ1=0.3 (N/mm^2)
F0	0	0.099	0.1192	0.1566
F1	0.1	0.11	0.14	0.183
F2	0.2	0.12	0.159	0.203
F3	0.3	0.129	0.161	0.216
F4	0.4	0.136	0.168	0.228

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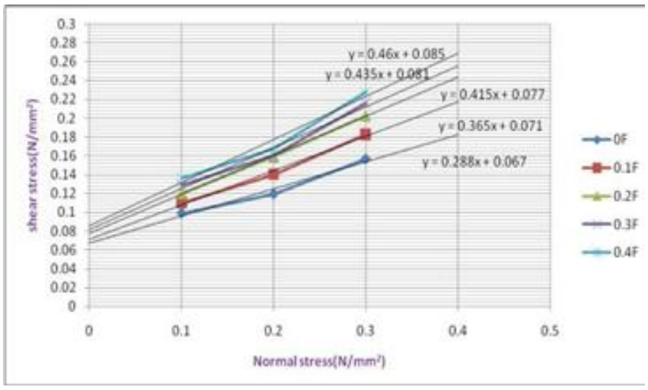

Fig.8 Mohr Coulomb failure envelope for F0- F4 samples

The cohesion 'c' and angle of internal friction 'Φ' for F0 – F4 samples are shown in Table 7. It is observed that, with the increase of percentage of fibers from 0.1 % to 0.4 % in the soil the cohesion and angle of internal friction increases from 5.9% to 26.80% and 24.84% to 53.79% respectively compared to F0sample.

Table 7: Cohesion & angle of internal friction values F0 – F4 samples

Sample	% of fibers	Cohesion 'c' (N/mm^2)	% increase in'c' compared toF0	Angle of internal friction, 'Φ'	% increase in'Φ' compared toF0
F0	0	0.067	-	16.06^o	-
F1	0.1	0.071	5.9	20.05^o	24.84
F2	0.2	0.077	14.9	22.53^o	40.28
F3	0.3	0.081	20.89	23.50^o	46.32
F4	0.4	0.085	26.80	24.70^o	53.79

C. Unconfined Compressive Strength(UCS)

Samples are prepared for F0 – F4 by mixing fiber with dry soil as per the proportion, added respective OMC water content obtained from compaction test and compacted the sample using IS light compaction in 2250 cm^3 IS standard mould. Then UCS test specimens with size 38x76 mm are extracted from the mould using sample extractor. Then the specimens are tested in UCS apparatus. Table 8 shows UCS test results. Graph plotted between compressive stress and displacement for F0- F4 samples is shown in Fig 9. Table 9 shows the UCS values for F0 – F4 samples. Fig 10 shows the variation of UCS with different proportions of fibers. It is observed that with the increase of fiber content the UCS increases linearly. With the increase of fiber content from 0.1% to 0.4% the UCS increases from 7.4% to 24.43% compared to F0 sample.

Table 8: Compressive stress vs displacement for F0 – F4 samples

Deformation/ Displacement (mm)	Compressive stress values at different % of fiber content				
	0%	0.1%	0.2%	0.3%	0.4%
0	0	0	0	0	0
0.5	0.013	0.015	0.015	0.0195	0.0244
1	0.026	0.0265	0.0287	0.03	0.0331
1.5	0.035	0.038	0.0395	0.0438	0.0483
2	0.0458	0.048	0.048	0.0545	0.0567
3	0.062	0.0646	0.066	0.0709	0.071
4	0.072	0.077	0.0786	0.0848	0.0892
5	0.0796	0.0838	0.088	0.0878	0.0943
7	0.0835	0.0897	0.0938	0.0995	0.1039
11	0.0358	0.052	0.061	0.0726	0.0769

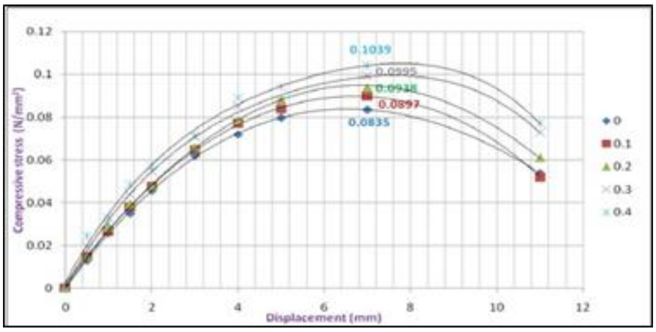

Fig. 9 Compressive Stress vs Displacement for F0 – F4 samples

Table.9 UCS values F0 – F4 samples

Sample	% of fibers	UCS	% increase in UCS compared to F0
F0	0	0.0835	-
F1	0.1	0.0897	7.4
F2	0.2	0.0938	12.33
F3	0.3	0.0995	19.16
F4	0.4	0.1039	24.43

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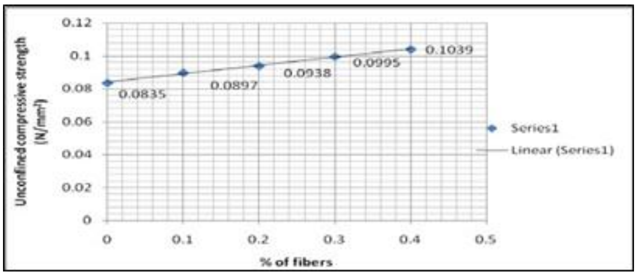

Fig 10: Variation of UCS with % of fiber mixed in soil

D. California Bearing Ratio(CBR) TEST

Samples are prepared for F0 – F4 by mixing fiber with dry soil as per the proportion, added respective OMC water content obtained from compaction test and compacted the sample using IS light compaction in CBR mould. Unsoaked CBR test is performed with surcharge of 2.5 kg based the procedure stated in SP36.

Table.10 CBR values for F0 – F4 samples

Sample	%of fibers	CBR	% increase in CBR compared to F0
F0	0	12.14	-
F1	0.1	15.00	23.55
F2	0.2	16.82	38.55
F3	0.3	17.68	45.63
F4	0.4	19.41	59.88

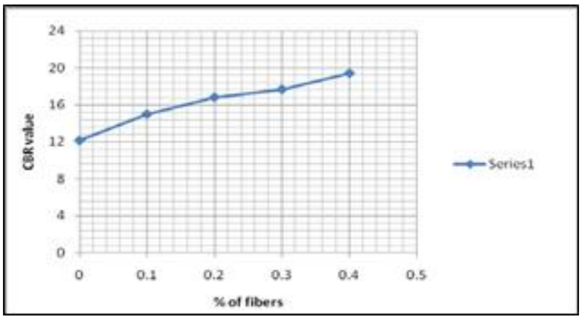

Fig. 11Variation of CBR value at with % of fibers mixed soil

Table 10 shows CBR values for F0 – F4 samples. Fig11 shows the variation of CBR value with different proportions of fiber mixed soil. It is observed with the increase of % fiber content the CBR value increases approximately linearly. With the increase of fiber content from 0.1% to 0.4% the CBR value increases from 23.55% to 59.88% when compared to 0% fiber content (F0 sample).

IV. CONCLUSION

1) OMC of the soil is gradually increased from 19.54% to 21.48% with inclusion of fibers from 0% to0.4%.
2) MDD increases from 1.6 gm/cc for 0% to maximum value of 1.68 g/cc for 0.2% and then decreases to 1.6 g/cc for 0.4% fibers addition.
3) With the increase of percentage of fibers from 0.1 % to 0.4 % in the soil the cohesion and angle of internal friction increases from 5.9% to 26.80% and 24.84% to 53.79% respectively compared to F0sample.
4) With the increase of fiber content from 0.1% to 0.4% the UCS increases from 7.4% to 24.43% compared to F0 sample.
5) With the increase of fiber content from 0.1% to 0.4% the CBR value increases from 23.55% to 59.88% when compared to 0% fiber content (F0sample).
6) Polypropylene fibers can used an alternative to enhance the expansive soil properties.

REFERENCES

1. Arpan Sen, Rishabh Kashyap ,under the guidance of Prof N. Roy " Soil stabilization using waste fiber materials" Thesis of project in NIT Rourkela
2. A. S. Soğancı "The Effect of Polypropylene Fiber in the Stabilization of Expansive Soils", World Academy of Science, Engineering and Technology International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering Vol:9, No:8, 2015
3. D.E. Jones and W. G. Holtz, Expansive Soils - The Hidden Disaster, Civil Engineering, 1973; 43(8),49-51.
4. G. X. Wu, "The research of enforcing role on glass fiber to stabilizing soil of cement-fly ash". Journal of Heilongjiang Institute of Science,2002; 12 (3),24-27.
5. J. Prabakar and R. S. Sridhar, "Effect of random inclusion of sisal fiber on strength behavior of soil". Construction and Building Materials 2002; 16, 123-131.
6. Mamta Mishra*, U. K. Maheshwari and N. K. Saxena, " Improving Strength of Soil using Fiber and Fly ash". International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 10 |Oct-2016
7. Puppala and C. Musenda, "Effects of Fiber Reinforcement on Strength and Volume Change in Expansive Soils". Journal of the Transportation Research board, 2007; 134-140
8. Shukla Devdatt1, Rajan Shikha2 Saxena A.K.3, Jha A.K.4, "Soil Stabilization Using Coconut Coir Fibre". International Journal for Research in Applied Science & Engineering Technology (IJRASET),Volume 3 Issue IX, September2015
9. Y. Cai, B. Shi, C. W. W. Ng and C. S. Tang, "Effect of polypropylene fiber and lime admixture on engineering properties of clay soil". Eng. Geol. (Amsterdam), 2006, 87, 230-240.