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Behavior of Fiber Reinforced Soil under Heavy and Light Compaction

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Abstract—*This paper presents the results of laboratory investigations conducted on two sands reinforced with randomly distributed jute fibres. The reinforced and unreinforced soil samples were subjected to Modified Proctor, Standard Proctor, CBR and Direct Shear tests. The main objective of this investigation had been focused on the strength behaviour of the soil reinforced with randomly included Jute fibre at different compaction efforts. The results indicate that Heavy Compaction increases the CBR value and Shear Strength of Jute fibre reinforced soil substantially than Light Compaction.*

Keywords: *Modified Proctor Test, Standard Proctor Test, Jute Fiber, Reinforcement.*

1. INTRODUCTION

The fundamentals of compaction of fine-grained soils are relatively new. R.R. Proctor in the early 1930's was building dams for the old Bureau of Waterworks and Supply in Los Angeles, and he developed the principles of compaction in a series of articles in Engineering News-Record. In his honor, the standard laboratory compaction test which he developed is commonly called the proctor test

The Modified Test was developed during World War II by the U.S. Army Corps of Engineering to better simulate the compaction required for airfields to support heavy aircraft. The point is that increasing the compactive effort tends to increase the maximum dry density, as expected, but also decrease the optimum water content (Holtz and Kovacs, 1981[1]; Lambe, 1979[2]). Bera et al. (2007[3]) presented the study on compaction characteristics of pond ash. It was found that the Light Compaction Test (Standard Test) could not reproduce the densities measured in the field under heavier loading conditions, and this led to the development of the Heavy Compaction Test (Modified Test).

The geotechnical properties of soil are dependent on the moisture and density at which the soil is compacted. Generally, a high level of compaction of soil enhances the geotechnical parameters of the soil, so that achieving the desired degree of relative compaction necessary to meet specified or desired properties of soil is very important.

2. MATERIALS USED FOR EXPERIMENTAL STUDY

The fine sand (Soil 1) and silty sand (Soil 2) were collected locally from village Dantali and Goner, Jaipur, Rajasthan, India respectively. Natural Jute fibers were also collected from local market. The particle size distribution curve for each soil type is shown in Figure 1. The physical properties of both the sands and fibres are given in Tables 1 and 2. Jute fibers used in small length of 5 mm, 10 mm and 15 mm are shown in Fig. 2.

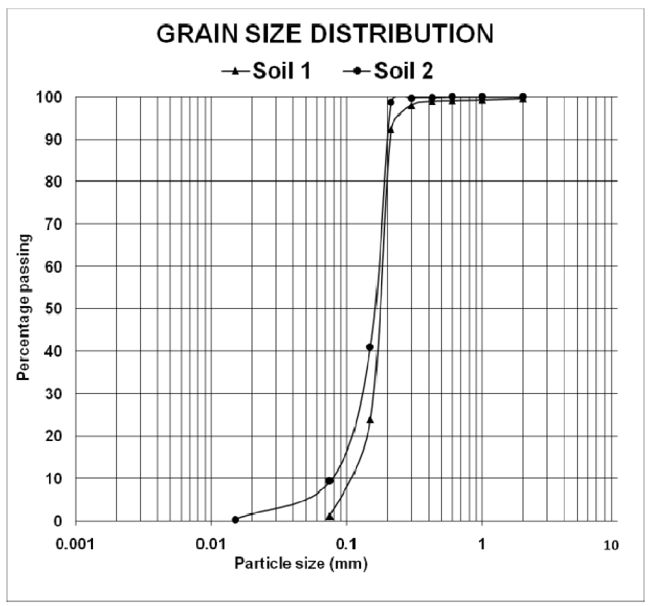

Fig. 1: Grain Size Distribution Curve for different types of sand

Table 1: Summary of Physical & Compaction Properties of Sands

Properties	Soil 1	Soil 2
Colour	**Brown**	**Whitish gray**
Classification (IS)	SP	SM
Specific Gravity	2.65	2.67
Coefficient of uniformity, Cu	1.72	2.60
Coefficient of curvature, Cc	1.36	1.43

Maximum dry density, γd , (g/cc)-Heavy compaction	1.72	1.74
Optimum moisture content, OMC, (%) -MPT	12.31	13.20
Maximum dry density, γd , (g/cc)-Light compaction	1.66	1.64
Optimum moisture content, OMC, (%) -SPT	12.89	15.20
Plastic Limit, PL (%)	NP	NP
Liquid Limit, LL (%)	23.4	24.8

Table 2 Summary of Physical Properties of Fibers

Tests	Jute Fiber
Density (g/cc)	1.47
Diameter (mm)	0.02 – 0.03
Length (mm)	5, 10, 15
% fiber by weight of the dry sand	0.5, 1.0, 1.5, 2

Fig. 2: View of Jute Fibers cut into pieces of definite length

3. EXPERIMENTAL SETUP AND TEST PROGRAM

The laboratory investigations carried out include Heavy Compaction, Light Compaction, CBR and Direct Shear Tests on both reinforced and unreinforced soil types. The optimum fibre content 1.5% of the dry unit weight of the soil and optimum fibre length 5mm was arrived, based on test results of CBR and Direct Shear Tests conducted with various combinations of fibre contents of 0.5, 1.0, 1.5 and 2.0 % by weight of the dry sand and various fibre lengths of 5 mm, 10 mm and 15 mm . The fibers-as-solid principle is followed to define dry density in this study. However, a slight decrease in dry unit weight is observed with an increase of fibre content. Similar results have been observed by Nataraj and McManis (1997)[4], Maher and Ho (1964)[5]. Three specimens were prepared and used for each type of test. The average result of three specimens were reported and used for the analysis.

Heavy Compaction Test

The aim of the Proctor test (moisture-density test) was to determine the optimum moisture contents (OMC) and maximum dry densities (MDD) of both untreated compacted and treated fiber reinforced soil-mixtures. In order to obtain these parameters, Heavy Compaction Test was employed for the mentioned mixture proportions as per IS: 2720 (Part 8)[6]. The results for OMC and MDD for raw soil 1 and soil 2 are as shown in Fig. 3 and Fig. 4 respectively.

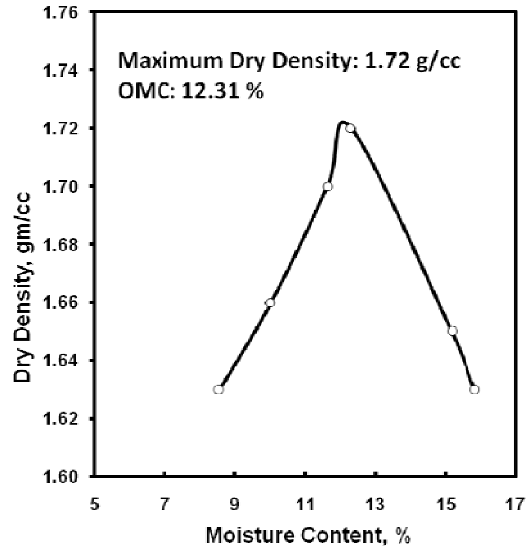

Fig. 3: Modified Proctor Test Result for Soil 1

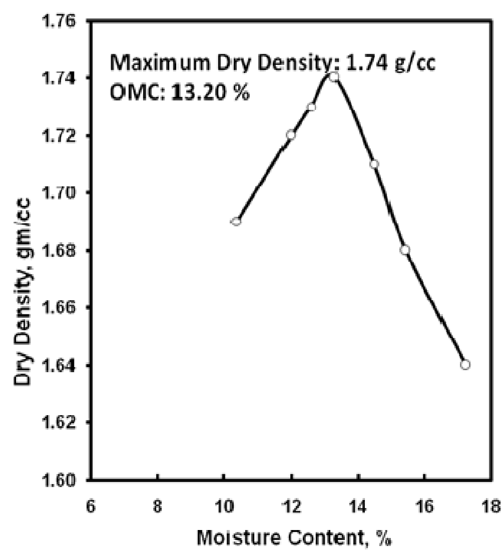

Fig. 4: Modified Proctor Test Result for Soil 2

IS:2720(Part 8) recommends that a mould of 1000 ml capacity having an internal diameter of 100 mm and an internal effective height of 127.5 mm should be used. The rammer has a mass of 4.9 Kg with a drop of 450 mm. In this test, sample is compacted at various water contents in five layers. Each layer is given 25 blows. Fig. 7 shows the test equipment set up.

Light Compaction Test

IS Light Compaction Tests were carried out on raw soil 1 and soil 2 and optimized fibre reinforced soil1 and soil 2 with fibre content 1.5% and fibre length 5mm in accordance with the procedure laid in IS:2720 (Part VII)[7] so as to study their moisture – density relationship. The results for OMC and MDD for raw soil 1 and soil 2 are as shown in Fig. 5 and Fig. 6 respectively.

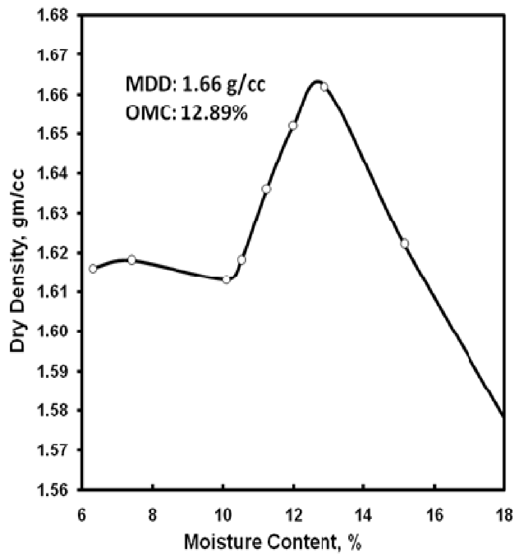

Fig. 5: Standard Proctor Test Result for Soil 1

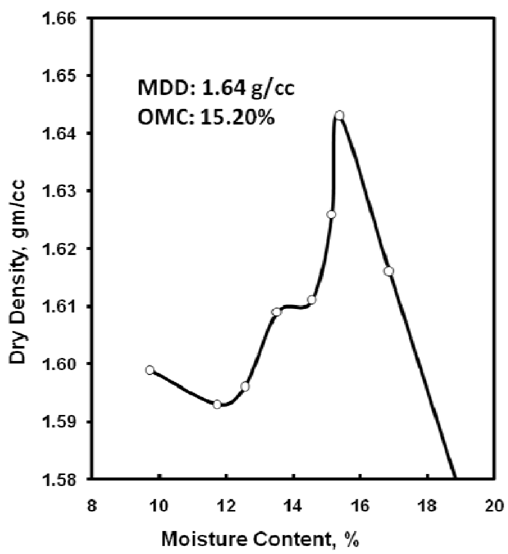

Fig. 6: Standard Proctor Test Result for Soil 2

IS:2720 recommends that a mould of 1000 ml capacity having an internal diameter of 100 mm and an internal effective height of 127.5 mm should be used. The rammer has a mass of 2.6 Kg with a drop of 310 mm. In this test, sample is compacted at various water contents in three layers. Each layer is given 25 blows. Fig. 7 shows the test equipment set up.

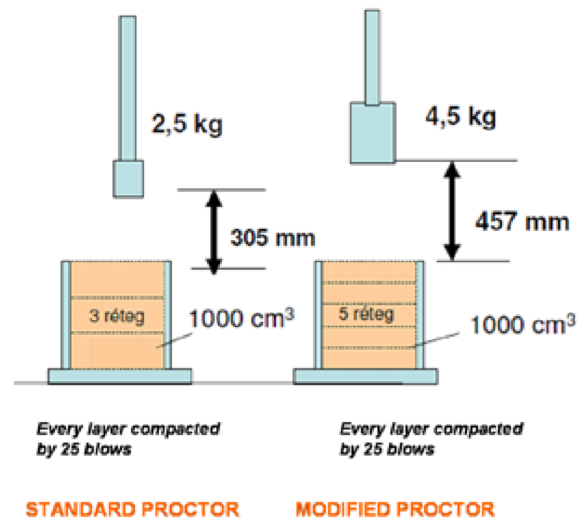

Fig. 7; Light and Heavy Compaction Test Equipment

Direct Shear Test

Specimens prepared using heavy and light compaction tests for raw and fibre reinforced soil 1 and soil 2 were tested in a 60x60 mm square shear box at normal stresses of 0.5, 1.0 and 1.5 Kg/cm^2 and sheared at a rate of 1.25 mm/minute according to IS:2720 (Part 13)[8] and results of peak friction angle and cohesion are compared.

CBR Test

IS:2720-16[9] recommends that a mould of 2250 ml capacity having an internal diameter of 150 mm and an internal effective height of 175 mm should be used. The test specimens were prepared using heavy and light compaction tests for raw and fibre reinforced soil 1 and soil 2 and results are compared for unsoaked and soaked CBR.

4. TEST RESULTS AND DISCUSSIONS

Heavy Compaction vs Light Compaction

The specimens for CBR and Direct Shear Test were prepared at OMC using heavy and light compaction for both the two types of sands mixed with fibers of different sizes and proportions by weight of dry sand for each mix. The effect of compaction on CBR and φ value are discussed below.

(I) The effect of Compaction on the Shear Strength for different types of sand

The peak shear strength, T (Kg/cm^2) of unreinforced and reinforced soils at normal stress (σ) of 0.5, 1.0 and 1.5 Kg/cm^2 for different compaction efforts in terms of total stresses and the extent of strength improvement are summarized in Table 3. It can be seen that MPT values are 23% and 5% higher for raw soil 1 and 2, 40% and 20% higher for optimized fibre reinforced soil 1 and 2, than the corresponding SPT values at 1.5 Kg/cm^2 normal stress.

Table 3. Peak Shear Strength, T (Kg/cm^2) of sands from Direct Shear Test – UU at different compaction efforts

Optimum Fiber Length & Content	σ Kg/cm^2	Soil 1		Soil 2	
		MPT	SPT	MPT	SPT
Unreinfo-rced	0.5	0.41	0.38	0.38	0.34
	1.0	0.77	0.57	0.59	0.56
	1.5	1.06	0.86	0.86	0.82
Reinforc-ed 5 mm 1.5%	0.5	0.68	047	0.50	0.47
	1.0	1.17	0.82	0.89	0.78
	1.5	1.78	1.27	1.34	1.12

(II) The effect of Compaction on φ (°) value

Direct Shear Tests were conducted on specimens prepared from light compaction and heavy compaction efforts and test results are given in table 4. From test results it is evident that heavy compaction increases the φ value of unreinforced and optimized reinforced sand 26% and 21% respectively for soil 1, 12% and 15% respectively for soil 2, than the corresponding light compaction values. Similar results were observed by, Kulhar and Raisinghani, 2017[10].

Table 4: Summary of Results of CBR tests and DST at different compaction efforts (Heavy Compaction vs Light Compaction)

Optimum Fiber Length & Content	Parti-cular	Soil 1		Soil 2	
		MPT	**SPT**	**MPT**	**SPT**
Unreinfo-rced	OMC %	12.31	12.89	13.20	15.20
	MDD g/cc	1.72	1.66	1.74	1.64
	Unsoake d CBR	39.8	29.7	38.6	31.6
	Soaked CBR	37.4	22.3	28.6	23.7
	φ value	34°	27°	28°	25°
Reinforc-ed 5 mm 1.5%	Unsoake d CBR	79.1	43.0	79.6	41.4
	Soaked CBR	74.3	38.5	75.2	36.1
	φ value	47°	39°	40°	35°

(III) The effect of Compaction on CBR (%) value

CBR tests were conducted using light compaction and heavy compaction efforts and test results are given in table 4. From test results it is evident that heavy compaction increases the Soaked CBR value of unreinforced and optimized fiber reinforced sand 68% and 93% respectively for soil 1, 21% and 108% respectively for soil 2, than the corresponding light compaction values. Similar results were observed by, Kulhar and Raisinghani, 2017[11].

(VI) The effect of compaction on MDD and OMC of sand

From Table 4, it is evident that Modified Proctor Testing typically requires a lower moisture content for achieving maximum dry density and the corresponding dry density is higher than value from Light Compaction. An increase in compaction energy results in closer packing of particles resulting in an increase in dry density where as the optimum moisture content decreases.

(V) Effect of inclusion of Jute fibers with sand on Modified Proctor Tests

The results of Heavy Compaction effect in CBR tests on sands mixed with varying proportion of Jute fibers of different lengths are given in Table 5. The results show that as the fiber content and fiber length increases, the maximum dry density (MDD) decreases for both sands.

Table 5: Variation of MDD (g/cc) with Fiber Content in CBR Test using MPT

Fiber leng-th	% of Fiber	Soil 1		Soil 2	
		Un-soaked CBR	**Soaked CBR**	**Un-soaked CBR**	**Soaked CBR**
	0.0 %	1.715	1.698	1.735	1.668
5 mm	0.5 %	1.706	1.693	1.725	1.664
	1.0 %	1.698	1.687	1.686	1.659
	1.5 %	1.682	1.670	1.681	1.651
	2.0 %	1.658	1.647	1.656	1.633
10 mm	0.5 %	1.697	1.689	1.706	1.660
	1.0 %	1.689	1.680	1.678	1.654
	1.5 %	1.671	1.662	1.667	1.641
	2.0 %	1.648	1.643	1.639	1.630
15 mm	0.5 %	1.691	1.682	1.698	1.655
	1.0 %	1.680	1.671	1.665	1.647
	1.5 %	1.661	1.651	1.655	1.630
	2.0 %	1.634	1.629	1.628	1.617

5. CONCLUSIONS

For the sands used, MDD value decreases with the increase of randomly mixed jute fiber content within the range tested in the investigation. Modified Proctor Testing typically requires a lower moisture content for achieving maximum dry density than value from Light Compaction. Heavy Compaction increases the peak friction angle and CBR values of Jute fiber reinforced sand considerably than Light Compaction.

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