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Effect of Soil Type on Efficiency of Recycled Jute Fibre as Natural Reinforcing Material

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Abstract **-** A developing nation like India is on a fast infrastructure buildup trajectory and we need to find suitability of different recyclable materials for construction and/or stabilization purpose. One such recyclable materials is jute which is produced in large quantity in the country annually. Primary objective of the study is to understand the suitability of jute fibre extracted from used gunny bags for strengthening of different soil types for various geotechnical applications. The extracted fibres are trimmed to different lengths of 5, 10 and 15mm and mixed in 0.5, 1, 1.5, 2 and 2.5% proportions based on dry mass of soil. Effect of the length and proportion of fibre in mixture with different type of soil is studied with regards to compaction characteristics and shear strength parameters. The study reveals that maximum dry density is attained for 10mm fibre mixed in 0.5%. The highest increment in shear strength is attained for 5mm fibre mixed in 1.5% proportion for sands and for clays, the undrained cohesion increases for all fibre lengths mixed in 0.25% proportion.

Keywords**:** jute fibre, sand, clay, recycled material, soil improvement

1. Introduction

As long as sustainable building practises are on the global agenda, it is crucial to employ recyclable materials in a way that ensures the performance of the resulting structure and/or soil-material mixture is at the appropriate level. According to past research [1–5], industrial by-products and fibres can cause significant changes in properties of sands and clays such as density, strength characteristics, acidity, and so on. It is preferable to use and dispose of these products elsewhere rather than on land. The benefits of employing waste materials include lower costs and the creation of a new solution for waste management. Focus of present study is on effectiveness of used jute fibre as India is one of the largest producers of jute in the world [6] and hence a large quantity of recyclable jute is available once the primary products like yarns, sacks, carpets, etc. serve their life. The approach aligns with the Goals 9 and 11 of United Nations Sustainable Development Goals (SDG), where all the countries are encouraged to strive towards a sustainable environment by promoting cities for a more efficient management of natural resources [7].

In the current investigation, sandy and clayey soil is combined with natural fibres from old gunny sacks. A series of compaction, DST and UCS tests have been performed on the soil-fibre mix to determine the optimal length and proportion of fibre in the soil.

2. Materials

2.1. Soil

In order to understand the suitability of soil type for strengthening with fibre addition, two soil types are taken for the study. The two soil types are sand and clay. Physical properties of the soil are determined for classification and results are summarized in Table 1. Indian codal provisions are followed for the determination of specific gravity [8], sieve analysis [9] and Atterberg limits [10]. Sand is uniformly graded, while clay used for the study is highly plastic in nature [11].

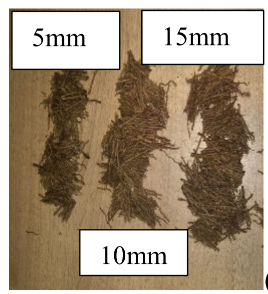
Table 1: Physical properties of the soils.

Type	G	D_{10} (mm)	C_u	C_c	w_L (%)	w_P (%)	PI (%)	Classification
Sand	2.62	0.04	1.149	0.532	NP	NP	NP	SP
Clay	2.713				53.04	24.33	28.71	CH

2.2. Fibre

The fibers used in the study are extracted from locally available used jute bags (see Fig. 1a). The jute bags are soaked in water for 24hours and dried, then fibers are extracted and cut into lengths of 5mm, 10mm and 20mm (see Fig. 1b). The specific gravity of the fiber is determined by the Archimedes principle, using soybean oil instead of water and the value comes out to be 1.59.


(a)



(b)

Fig. 1: (a) Used gunny bags and (b) Fibre of lengths 5, 10 and 15mm

3. Testing Methodology

In order to understand the behaviour of soil-fibre mixture for engineering purpose, three type of tests are performed, i.e. Compaction test [12], DST [13]and UCS [14]. The tests are performed following Indian codal provisions. The trimmed fibres are mixed in five proportions of 0.5, 1, 1.5, 2 and 2.5% for sand (see Fig. 2a), while for clay, the fibres are mixed in proportions of 0.5, 1 and 1.5% (see Fig. 2b). The difference in mix proportion for the two soil types is due to more fibre proportion required for coarse grained sand to mobilize better compressibility and higher shear strength, as compared to the fine grained clay.

Effect of fibre addition on the compaction behaviour is determined using light compaction test. The shear strength testing is carried for samples prepared at the MDD and OMC obtained from compaction tests. The three normal stresses during DST for sand are 0.65, 1.15 and 1.65 kg/cm². Shear strength of clay with varying proportions of fibre is determined using [14] while for sands, same is determined using [13]. Results of the tests on natural soil is presented in Table 2. It has to be noted that UCS indicates undrained cohesion which is relevant for cohesive soil like clay, while DST indicates drained strength parameters, which is relevant for cohesion-less soil like sand.


(a)


(b)

Fig. 2: Sample preparation for (a) Compaction test and (b) UCS

Table 2: Engineering properties of the soils in focus.

Type	c (kg/cm^2)	Φ'(°)	MDD (g/cc)	OMC (%)
Sand	0	36.36	1.763	17.85
Clay	0.61	0	1.61	21.3

4. Results and Discussions

The compaction curves (see Fig. 3) show the variation of dry density with water content for both soil types mixed with varying proportions of fibre. Results from the compaction and shear strength parameter tests are summarized in Table 3. The prefix represent the soil type, while the suffix and subscript represent the fibre and fibre proportion, respectively. For example, $SF_{0.5}$ represent results for a mixture with sand and 0.5% fibre. Similarly, other notations are to be interpreted. The results are discussed from three aspects, (i) effect of fibre length, (ii) effect of fibre proportion, and (iii) effect of soil type.

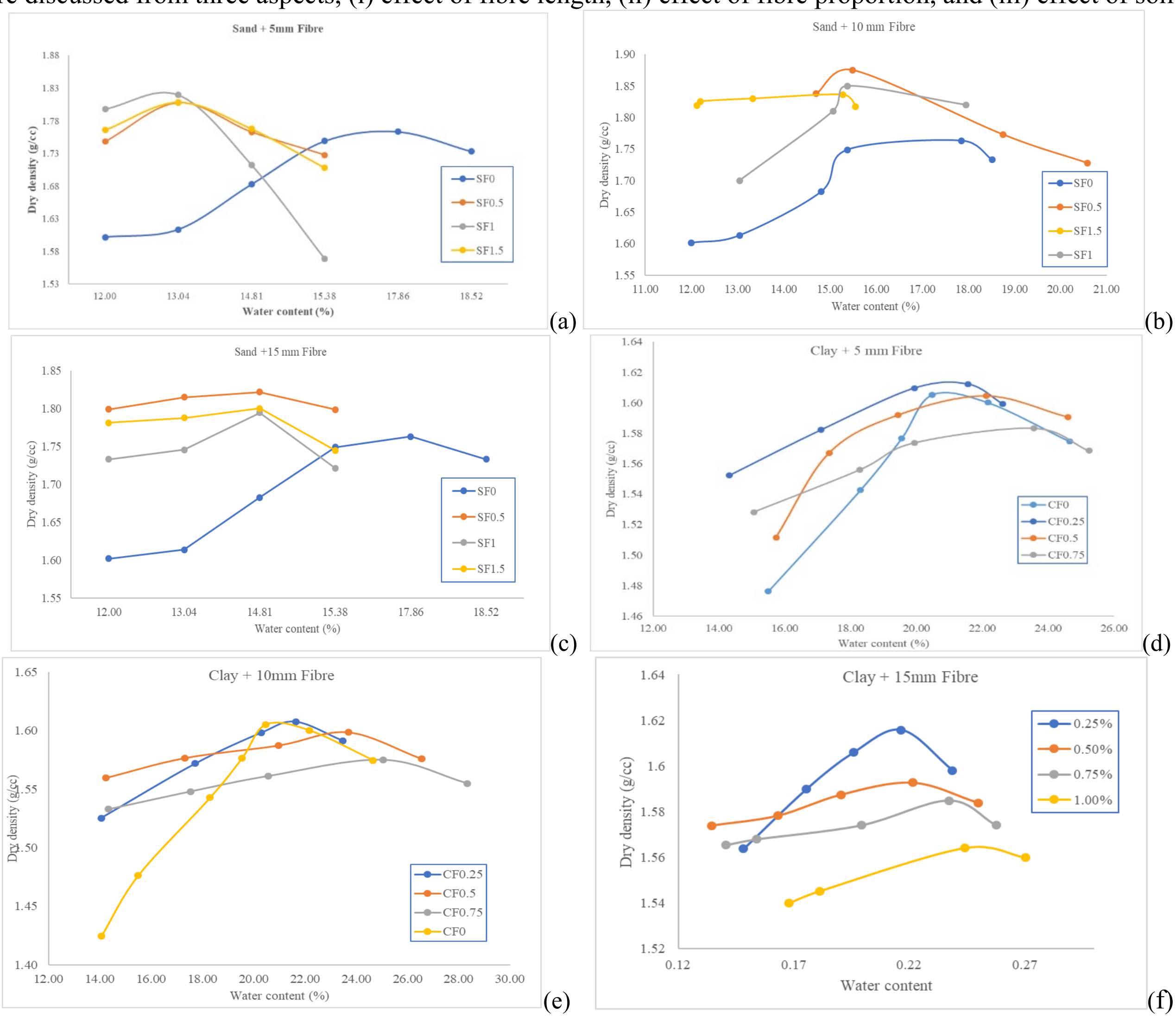


Fig.3: Compaction curve of soil mixed with different lengths of fibre (a) Sand + Fibre 5mm, (b) Sand + Fibre 10mm, (c) Sand + Fibre 15mm, (d) Clay + Fibre 5mm, (e) Clay + Fibre 10mm and (f) Clay + Fibre 15mm.

Table 3: Shear strength parameters of the soil–fibre mixtures in focus.

Fibre length (mm) length(mm)	Mixture	c* (kg/cm^2)	Φ_d*(°)	MDD (g/cc)	OMC (%)
0	SF_0	0	38.31	1.76	17.86
5	$SF_{0.5}$	0.25	34.95	1.81	17.14
	SF_1	0.2	41.67	1.82	16.17
	$SF_{1.5}$	0.22	48.51	1.81	14.71
	SF_2	0.08	38.31	1.77	16.05
	$SF_{2.5}$	0.39	37.64	1.73	16.25
10	$SF_{0.5}$	0.15	41.12	1.88	15.49
	SF_1	0.2	43.68	1.85	15.64
	$SF_{1.5}$	0.08	43.01	1.84	15.29
	SF_2	0.06	38.01	1.75	17.03
	$SF_{2.5}$	0.08	29.57	1.74	17.14
15	$SF_{0.5}$	0.08	23.52	1.82	17.14
	SF_1	0.09	25.54	1.79	17.14
	$SF_{1.5}$	0.16	24.87	1.8	16.67
	SF_2	-	-	1.82	17.67
	$SF_{2.5}$	-	-	1.75	18.42
0	CF_0	0.61	-	1.61	21.3
5	$CF_{0.25}$	0.83	-	1.61	21.76
	$CF_{0.50}$	0.74	-	1.59	22.7
	$CF_{0.75}$	0.56	-	1.58	23.78
10	$CF_{0.25}$	0.88	-	1.61	21.63
	$CF_{0.50}$	0.78	-	1.59	22.21
	$CF_{0.75}$	0.74	-	1.58	23.59
15	$CF_{0.25}$	0.74	-	1.61	21.65
	$CF_{0.50}$	0.77	-	1.59	22.15
	$CF_{0.75}$	0.70	-	1.58	23.8

** c- cohesion, Φ_d – angle of internal friction*

4.1 Effect of fibre proportion

It is observed from Table 3 that for a specific soil type and fibre length, the compaction characteristics and shear strength is enhanced till an optimal proportion of fibres in the mixture. For 5mm fibre mixed with sand, the MDD increases till 1% fibre proportion, while the corresponding OMC decreases. For the same case, the shear strength parameters c and Φ_d, increase by 8.8% till 1% and by 26.6% till 1.5% fibre proportion. At larger fibre length of 10mm, the highest MDD is achieved at 0.5%, while maximum increment in c and Φ_d is observed till 1% fibre proportion. Similar trend is observed for 15mm fibre lengths. This indicates reduced efficiency of fibre inclusion beyond 1% in case of sand. This is probably due to inadequate mobility between sand and fibres to all for denser packing in presence of increased fibre content.

In case of clays, the MDD reduces with addition of fibre content and the OMC simultaneously increase. This is probably due to an increased surface area available in the mixture to absorb water. However, the undrained cohesion increases with addition of fibre for all mix proportions with maximum being observed for 0.25%.

4.2 Effect of fibre length

Another observation we can deduce from the results in Table 3, is that the engineering performance of soil-fibre mix enhances only for smaller fibre lengths, i.e. for 5 and 10mm. the reduced efficiency is easily noticeable in case of sands, while for clays, such inference cannot be made.

4.3 Effect of soil type

Comparing the properties of natural soil, we observe that the MDD of sand is more than that of clay, while OMC is lower. Addition of fibre seems to be more beneficial for sands as compared to clays, in case of compaction characteristics. While, the shear strength properties of both soil types are enhanced with the presence of fibres. This is probably due to more stress being required to break the soil-fibre bonds and/or fibre-fibre bonds.

5. Conclusion

In the present study, effect of length and proportion of recycled jute fibres in mixture with different type of soil is studied with regards to compaction characteristics and shear strength parameters. The conclusions can be summarized as follows:

- For sands mixed with 5mm fibre, maximum MDD is obtained for 1% fibres in the mixture. While for longer fibres, the MDD is obtained earlier at 0.5%. This indicates the compaction characteristics depending on total surface area of fibre.
- For clays, the compaction characteristics reduce with fibre addition irrespective of length and mix proportion.
- For sands, increment in shear strength parameters is observed for all cases, with maximum increment for 1.5% addition of 5mm fibre.
- For clays undrained cohesion increases with addition of fibre for all mix proportions with maximum being observed for 0.25%.

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