

# IMPROVEMENT IN CBR VALUE OF SOIL REINFORCED WITH JUTE FIBER

H. P. Singh<sup>1</sup>, M. Bagra<sup>2</sup>

Associate Professor, Department of Civil Eng., NERIST, Itanagar, A.P., India<sup>1</sup>

Research Scholar, Department of Civil Eng., NERIST, Itanagar, A.P., India<sup>2</sup>

**Abstract:** Use of natural fibre in civil engineering for improving soil properties is advantageous because they are cheap, locally available, biodegradable and eco-friendly. The natural fiber reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. Over the last decade the use of randomly distributed natural and synthetic fiber has recorded a tremendous increase. Keeping this in view an experimental study was conducted on locally available (Doimukh, Itanagar, Arunachal Pradesh, India) soil reinforced with Jute fiber. In this study the soil samples were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould with and without reinforcement. The percentage of Jute fiber by dry weight of soil was taken as 0.25%, 0.5%, 0.75% and 1%. In the present investigation the lengths of fiber was taken as 30 mm, 60 mm and 90 mm and two different diameters, 1 mm and 2 mm were considered for each fiber length. The laboratory CBR values of soil and soil reinforced with Jute fiber were determined. The effects of lengths and diameters of fiber on CBR value of soil were also investigated. Tests result indicates that CBR value of soil increases with the increase in fiber content. It was also observed that increasing the length and diameter of fiber further increases the CBR value of reinforced soil and this increase is substantial at fiber content of 1 % for 90 mm fiber length having diameter 2 mm.. Thus there is significant increase in CBR value of soil reinforced with Jute fiber and this increase in CBR value will substantially reduce the thickness of pavement subgrade.

**Keywords:** CBR value, Soil, Jute Fiber, Length, Diameter,

## I. INTRODUCTION

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. During last 25 years, much work has been done on strength deformation behaviour of fiber reinforced soil and it has been established beyond doubt that addition of fibre in soil improves the overall engineering performance of soil. Among the notable properties that improved are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. Fiber reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay). Use of natural material such as Jute, coir, sisal and bamboo, as reinforcing materials in soil is prevalent for a long time and they are abundantly used in many countries like India, Philippines, Bangladesh etc. The main advantages of these materials are they are locally available and are very cheap. They are biodegradable and hence do not create disposal problem in environment. Processing of these materials into a usable form is an employment generation activity in rural areas of these countries. If these materials are used effectively, the rural economy can get uplift and also the cost of construction can be reduced, if the material use leads to beneficial effects in engineering construction. Of all the natural fiber Jute has highest tensile strength and withstand rotting and heat (Sen and Reddy, 2011). Studies have also shown that durability of natural fiber can be improved using coating of fiber with Phenol and Bitumen which is easily available in these areas (Sivakumar Babu and Vasudevan 2008). Many studies have been conducted relating to the behaviour of soil reinforced with randomly distributed fiber. Gray and Ohashi (1983) conducted a series of direct shear tests on dry sand reinforced with different synthetic, natural and metallic fiber to evaluate the effects of parameters such as fiber orientation, fiber content, fiber area ratios, and fiber stiffness on contribution to shear strength. Based on the test results they concluded that an increase in shear strength is directly proportional to the fiber area ratios and shear strength envelopes for fiber-reinforced sand clearly shows the existence

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of a threshold confining stress below which the fiber tries to slip or pull out. Various types of randomly distributed elements such as polymeric mesh elements (Andrews et.al, 1986), synthetic fiber (Gray and Al Refeai 1986, Mahar and Gray 1990, Ranjan et. al, 1996, Charan 1995, Consoli et al., 2002, Michalowski and Cermak, 2003, Gosavi et al., 2004, Yetimoglu and Inanir 2005, Rao et al., 2006, Chandra et al. 2008 and Singh 2011) metallic fiber (Fatani et al.1999) and discontinuous multioriented polypropylene elements (Lawton et.al, 1993) have been used to reinforce soil and it has been shown that the addition of randomly distributed elements to soils contributes to the increase in strength and stiffness. Lekha (2004) and Vishnudas et al. (2006) have presented a few case studies of construction and performance monitoring of coir geotextile reinforced bunds and suggested that the use of coir is a cost effective ecohydrological measure compared to stone-pitching and other stabilization measures used in the protection of slopes and bunds in rural areas. Sivakumar Babu and Vasudevan (2008) and Singh et.al (2011) studied the strength and stiffness response of soil reinforced with coir-fiber. Singh and Yachang (2012) used the Jute Geotextile sheets to improve the laboratory CBR value of fly ash. Based on the experimental results they found that stress-strain behaviour of soil is improved by inclusion of coir-fiber into the soil and Jute Geotextile sheets improves the California Bearing Ratio (CBR) value of fly ash significantly. They further concluded that the deviator stress at failure is increased up to 3.5 times over the plain soil. They also observed that stiffness modulus of reinforced soil increases considerably which can reduce the immediate settlement of soil significantly.

Aggarwal and Sharma (2010) studied the application of Jute fiber in the improvement of subgrade characteristics. From this study it was concluded that Jute fiber reinforcement reduces the maximum dry density and increases the optimum moisture content of the subgrade soil. The CBR value of the subgrade soil increases up to 250% with the inclusion of bitumen coated Jute fiber.

A recent study revealed that greenhouse gas emission by Jute is negative whereas all other synthetic fiber possesses a net GHG emission. This negative emission by Jute attribute to make Jute products attractive as GHG emission is a matter of great concern under the Kyoto Protocol and all developed countries are to demonstrate commitment by way of reduction of GHGs.

This paper presents the influence of Jute fiber on the CBR value of Itanagar, Arunachal Pradesh, India soil which is a typical soil and is normally used in the construction of embankments and pavement subgrade in tropical countries such as India. A number of CBR value tests have been conducted on soil and soil reinforced with varying amount of Jute fiber. The effects of different lengths and diameters of Jute fiber on CBR value of reinforced soil have also been investigated and results were compared with that of unreinforced soil.

## II. MATERIALS AND TEST PROCEDURE

### A. Soil

The soil used in this study was collected from the site of Doimukh RCC Bridge constructed on Dikrong River near Itanagar, Arunachal Pradesh, India. The various index properties and compaction properties (maximum dry density and optimum moisture content) of soil were determined in the laboratory which is given in Table 1. The grain size distribution curve of soil is shown in Fig.1.

# International Journal of Innovative Research in Science, Engineering and Technology

(ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 8, August 2013

### B. Reinforcement

The reinforcing material used in this study is Natural Jute fiber of diameters 1 mm and 2mm. The length of fiber corresponding to each diameter of fiber was taken as 30 mm, 60 mm and 90 mm. A typical view of Jute fiber is shown in Fig. 2.

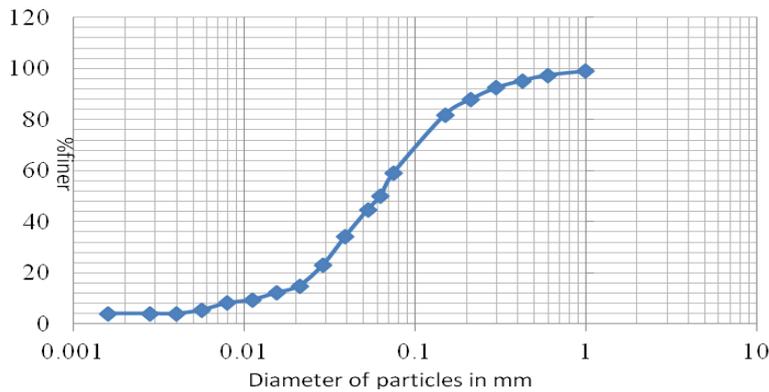


Fig. 1: Particle Size Distribution Curve of Soil

Table I: Index and Compaction Properties of Soil.

1	Specific Gravity (G)		2.60
2	Liquid Limit, LL (%)		26
3	Plastic Limit, PL (%)		NP
4	Particle Size Distribution Curve	Gravel Size (> 4.75 mm)	0
		Sand Size (0.075- 4.75 mm)	44 %
		Silt Size (0.002-0.075 mm)	52 %
		Clay Size (<0.002 mm)	4 %
5	Co-efficient of uniformity ( $C_u$ )		8
6	Co-efficient of curvature ( $C_c$ )		1.53
7	Maximum Dry Density, $\gamma_d$ (kN/m <sup>3</sup> )		17.30
8	Optimum Moisture Content, OMC (%)		16.45



Fig. 2: View of Jute Fiber (D = 2mm, L = 30 mm)

# International Journal of Innovative Research in Science, Engineering and Technology

(ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 8, August 2013

## C. Test Procedure

The soil samples of unreinforced and reinforced soil for CBR test were prepared as per standard procedure. The desired amount of oven dried ( $100-105^{\circ}\text{C}$ ) soil was taken and mixed thoroughly with water corresponding to its optimum moisture content (OMC) in the CBR mould having 150 mm diameter and 175 mm high with detachable perforated base plate (IS:2720-XVI). The soil was then compacted to its maximum dry density obtained by laboratory standard Proctor test. For the preparation of soil samples of reinforced soil the desired amount of fiber was mixed in dry state before the addition of water and then compacted to same Proctor density as per IS: 2720, Part VII- (1974). The top surface of the specimen in the CBR mould was made level and a filter paper and a perforated metallic disc were placed over the specimen. With spacer disc placed inside the mould, the effective height remains only 127.3 mm and the net capacity is  $2250\text{ cm}^3$ . The CBR mould along with compacted soil and surcharge load of 5 kg was then transferred to a tank containing water for soaking of the sample. After 4 days (i.e. 96 hours) of soaking, the mould assembly was taken out from water and the top surface of sample was left exposed to air for half an hour. The CBR mould along with soaked soil sample was brought to a motorized loading frame for testing. The CBR values of the test samples of unreinforced and reinforced soil were determined corresponding to plunger penetrations of 2.5 mm and 5 mm as per the standard procedure laid down in IS: 2720, Part XVI (1965).

## III. TEST RESULTS AND DISCUSSIONS

The CBR values of soil and soil reinforced with different combinations of Jute fiber determined in the laboratory are shown in Table 3. The interpretation of tests result such as effects of fiber content, length of fiber and diameter of fiber on CBR value of soil have been discussed in the following sections.

### A. Effect of fiber content

Results of CBR tests carried out at different fiber content varying from 0 % to 1 % by dry weight of soil are shown in columns 3 and 5 of Table 3, for different fiber lengths and fiber diameters. It is clear from the tests results that the CBR value of soil increases as the fiber content increases. This aspect can be observed for all the fiber lengths (30 mm, 60 mm and 90 mm) and fiber diameters (1 mm and 2 mm). Results show that maximum increase in CBR value was 3 times (200 %) over that of plain soil at a fiber content of 1 %, for fiber having length of 90 mm and diameter of 2 mm. The minimum increase in CBR value was observed as 1.16 times (15.62 %) over that of plain soil at a fiber content of 0.25 %, for fiber having length of 30 mm and diameter of 1 mm. Similar trend was observed by Sivakumar Babu and Vasudevan (2008), Singh et al. (2011), Singh (2011) and Singh (2012) with the natural and geosynthetic fiber reinforced soil and fly ash. This is due to reason that randomly oriented discrete inclusions incorporated into soil mass improves its load deformation behaviour by interacting with the soil particles mechanically through surface friction and also by interlocking. The function of bond or interlock is to transfer the stress from soil to the discrete inclusion by mobilising the tensile strength of discrete inclusion. Thus, fibre reinforcement works as frictional and tension resistance element. Further, addition of Jute fiber makes the soil a composite material whose strength and stiffness is greater than that of unreinforced soil. The strength and stiffness of reinforced soil increases with the increase in fiber content and may be due to this reason also the CBR value of reinforced soil was observed to be greater than that of unreinforced soil. The optimum fiber content corresponding to maximum improvement in CBR value is found to be 1 %. It was difficult to prepare the identical samples (at constant dry density) of reinforced soil beyond 1 % of fiber content and hence in the present study the maximum fiber content was considered to be 1 % by dry weight of soil.

### B. Effect of length of fiber

It is observed from Table 3 that the CBR value of soil reinforced with same fiber content and of same fiber diameter increases with the increase in length of fiber. For instance the CBR values of soil reinforced with fiber length of 30 mm, 60 mm and 90 mm at 1 % fiber having diameter 1 mm are 10.89 %, 12.67 % and 17.04 % respectively. This aspect can be observed for all other fiber content (0.25 %, 0.5 %, and 0.75 %) and fiber diameter (2 mm) also. Similar trend was observed by Sivakumar Babu and Vasudevan (2008) also in case of coir fibre reinforced soil. This is attributed to the fact that for shorter fibers, the area in contact with soil is comparatively less and hence there is a less improvement in strength and stiffness of soil.

# International Journal of Innovative Research in Science, Engineering and Technology

(ISO 3297: 2007 Certified Organization)

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### C. Effect of diameter of fiber

It is clear from the tests results of Table 3 that the CBR value of soil reinforced with Jute fiber increases with the increase in fiber diameter. For instance the CBR value of soil reinforced with Jute fiber of 1 mm diameter and 30 mm length is 7.0 % at fibre content of 0.25%. When the diameter of fiber is increased from 1 mm to 2 mm, the CBR value of reinforced soil increases from 7.0 % to 7.33 % for the same fiber content (0.25 %) and same fiber length (30 mm). Similarly the CBR values of soil reinforced with fiber contents of 0.5 %, 0.75 % and 1 % for fiber lengths of 60 mm increases from 11.73%, 12.00 % and 12.67% to 11.90%, 12.40% and 13.60% respectively for increase in diameter of fiber from 1 mm to 2 mm. The substantial increase in CBR value of soil due to increase in fiber diameter is about 7 % for fiber length of 90 mm corresponding to 1% of fiber content. Similar trend was observed by Sivakumar Babu and Vasudevan (2008) also. This is attributed to the fact that due to increase in diameter of fiber increases the pull out resistance of fiber. In addition, large diameters fibers are capable of sharing more stresses induced in the soil specimens.

Table III: CBR Value of Soil Reinforced with Jute Fiber.

Length Of Jute Fibre (mm)	Percentage of Fiber by Dry Weight of Soil	Fiber Diameter 1mm		Fiber Diameter 2 mm.	
		CBR Value (%)	% increase in CBR value	CBR Value (%)	% increase in CBR Value
30	0%	6.08%	-	6.08%	-
	0.25%	7.03%	15.62%	7.33%	20.55%
	0.50%	10.16%	67.10%	10.35%	70.23%
	0.75%	10.50%	72.69%	10.58%	74.13%
	1%	10.89%	79.11%	11.12%	82.89%
60	0%	6.08%	-	6.08%	-
	0.25%	11.49%	88.98%	11.56%	90.13%
	0.50%	11.73%	92.92%	11.90%	95.72%
	0.75%	12.00%	97.36%	12.40%	103.94%
	1%	12.67%	108.38%	13.60%	123.68%
90	0%	6.08%	-	6.08%	-
	0.25%	13.21%	117.26%	13.53%	122.53%
	0.50%	13.70%	125.32%	13.70%	125.32%
	0.75%	14.66%	141.11%	15.22%	150.32%
	1%	17.04%	180.26%	18.27%	200.49%

## IV. CONCLUSIONS

Based on the present investigation it is concluded that CBR value of soil increases with the inclusion of Jute fiber. When the Jute fiber content is increases, the CBR value of soil is further increases and this increase is substantial at fiber content of 1 %.

It was also found that preparation of identical soil samples for CBR test beyond 1 % of fiber content is not possible and optimum fiber content was found to be 1 % by dry weight of soil.

It is also concluded that there is significant effects of length and diameter of fiber on the CBR value of soil.

The CBR value of soil increases with the increase in length and diameter of fiber.

The maximum increase in CBR value was found to be more than 200 % over that of plain soil at fiber content of 1 % for fiber having diameter 2 mm and length 90 mm

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Vol. 2, Issue 8, August 2013

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