Application of Jute Fibers to Improve Sub Grade Characteristics of Silty-Clay Soil

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Abstract- A good network of roads in all the parts of country is the first step towards the infrastructure development of a nation. Road consists of upper part called pavement and the lower part called as sub grade. Sub grade is an integral structural element of pavement as all the loads coming on the pavement are ultimately bared by the sub grade (compacted soil). Load carrying and dispersion capacity of the sub grade plays an important role in civil engineering. In case of highways, if there is a weak sub grade it results in a greater pavement thickness and thereby increasing the pavement construction cost. In order to strength sub grade, there are many stabilizing techniques and materials available. Geo -textiles both natural and artificial are very helpful in improving the geotechnical properties of soil. Geo- textiles are used because of the various advantages like erosion control, a separation layer, drainage, support etc. Jute which is also a geo-textile is not only eco-friendly but also cheap and readily available can be used in road construction cost effectively. Jute fibers mixed randomly with the soil have a great impact on the improvement of sub grade characteristics seen over a decade. Keeping this in view, an experiment was conducted on the locally available soil reinforced with jute fibers. The percentage of jute fibers by dry weight of soil are taken as 0.2%, 0.4%, 0.6%, 1%, and length of jute fibers are taken as 30mm, 60mm, 90mm and diameter of 2mm. The laboratory values of plain soil and reinforced soil were determined. The effect of length of jute fibers was determined and it was found that the CBR value of soil increased with increase in length of jute fibers. It was also found that the CBR value of soil is maximum at fiber content of 0.6%, therefore optimum fiber content is 0.6%.

Key words: jute fibers, CBR test, soil, proctor test, USC test

I. INTRODUCTION

The biggest challenge in a developing country like India is that to build full road network system with limited financial resources. As such use of locally available materials can bring down the construction cost, if the local soil is not stable to bear the wheel loads, the properties of sub grade can be improved by soil stabilization techniques e.g. Use of geo grids, using randomly distributed jute fibers or waste plastic in the sub grade soil. A good network of roads in all the parts of country is the first step towards the infrastructure development of a nation. Road consists of upper part called pavement and the lower part called as sub grade. Sub grade is an integral structural element of pavement as all the loads coming on the pavement are ultimately bared by the sub grade (compacted soil). As we know that the sub grade should possess sufficient stability so that it can support pavement under adverse weather and loading conditions because if sub grade is weak formation of waves, corrugations, rutting and shoving occurs in pavements. Highway and geotech engineers have always been concerned about the improvement of soil sub grade. In case of highways, if there is a weak sub grade it results in a greater pavement thickness and thereby increasing the pavement construction cost.

Researches done more than over 25 years on the strength deformation behaviour of fiber reinforced soil have proved beyond doubt that overall engineering properties of soil is increased by the addition of fibers . Among the notable properties that improved are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. In the recent past fiber reinforced soil has been used in many countries and further research is in process to find out the hidden aspects of it. Fiber reinforcement is effective in all types of soil eg clay, silt and sand. The use of natural materials such as jute, coir, bamboo and sisal as reinforcing material has been used for a very long time and they are abundantly used in many counties like India, Philippines and Bangladesh etc. The main reason for which these materials are used is because there are very cheap and locally available and also they are biodegradable and hence do not create disposal problem in environment. Also processing of these materials into a usable form is an employment generation activity. Geo -textiles both natural and artificial are very helpful in improving the geotechnical properties of soil. Geo- textiles are used because of the various advantages like erosion control, a separation layer, drainage, support etc.

Jute which is also a geo-textile is not only eco-friendly but also cheap and readily available can be used in road construction cost effectively. Jute fibers mixed randomly with the soil have a great impact on the improvement of sub grade characteristics seen over a decade. Keeping this in view, an experiment was conducted on the locally available soil reinforced with jute fibers. The percentage of jute fibers by dry weight of soil are taken as 0.2%, 0.4%, 0.6%, 1%, and length of jute fibers are taken as 30mm, 60mm, 90mm and diameter of 2mm. The laboratory values of plain soil and reinforced soil were determined. The effect of length of jute fibers was determined and it was found that the CBR value of soil increased with increase in length of jute fibers.

1.1. Methodology

1. Identification of suitable site.
2. Collection of soil sample.
3. Determination of CBR and UCS values of soil.
4. Reinforcement of soil samples with 0.2%, 0.4%, 0.6% and 1.0% of lengths 30mm, 60mm and 90mm.
5. Determination of CBR and UCS values of reinforced soil.
6. Comparision of CBR and UCS values of reinforced and unreinforced soils.
7. Conclusion.

II. EXPERIMENTAL METHODOLOGY

2.1 Materials used

Soil: The soil used in the investigation is natural soil collected from district Shopian of Kashmir division. The soil was collected from a depth of 60cm below the top surface soil.

Jute fibers: The jute fibers used were obtained from the local market of diameter 2mm.They were cut into different lengths of 30mm, 60mm and 90mm.

The chemical composition of jute is as follows:

Cellulose = 59 - 61%
Hemi cellulose= 22 - 24%
Lignin= 12 - 14%
Fats and waxes = 1.0 - 1.4%
Nitrogenous matter = 1.6- 1.9 %
Ash content = 0.5 - 0.8 %
Pectin = 0.2 - 0.5 %

2.2 Tests carried out on soil samples:

Atterberg limits

a) Liquid limit:

The liquid limit of a soil is the moisture content expressed as the percentage of the weight of the oven- dried soil ,at the boundary between the liquid and plastic states of consistency .The moisture content of this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together ,for a distance of 1\2 in (12.7mm)along the bottom of a groove at standard dimensions separating the two halves , when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 inch (10mm) at the rate of two drops per second.

Fig -2: liquid limit apparatus

b) Plastic Limit

Water content at the boundary between plastic and semisolid state is called plastic limit. It is also the water content below which soil losses its plasticity and starts acting like a semi-solid and it begins to crumble when it is rolled into a thread of 3mm diameter.

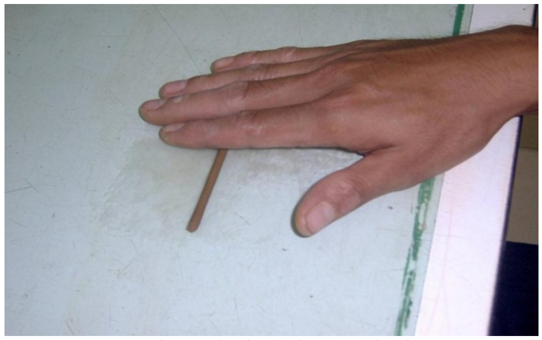


Fig -3: Plastic Limit Determination

Standard Proctor Test

In this method we determine the relationship between moisture content and dry density of reinforced soil compacted in a standard mould size with a 2.5 kg rammer dropped from a height of 30 cm.

California Bearing Ratio Test

California bearing ratio is the ratio of force unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm /min. The table step-up provides the standard loads used for assorted infiltration of a standard material with a 100% CBR nature. This standard burden is taking limestone as a standard material and its CBR estimate with infiltration of 2.5mm, 5mm, 7.5mm; 10mm are set as standard burden for the determination of CBR estimation.

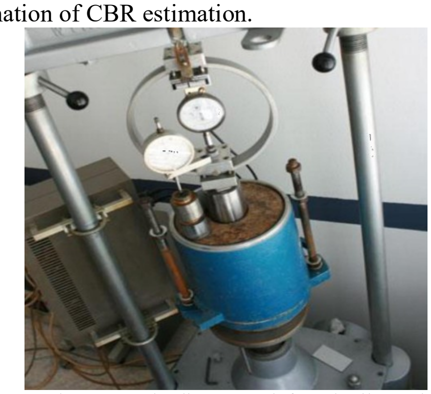


Fig -4: CBR loading on a reinforced soil sample

III. RESULTS

Liquid Limit

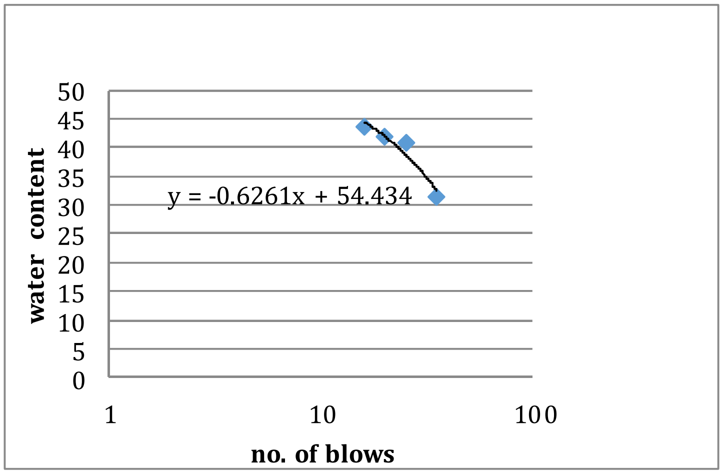


Chart -1: Flow chart

At 25 blows

LL= - (0.6261x25) + 54.434

= 38.7815%

Plastic Limit

Weight of moist soil sample = 29.76 gm

Weight of soil sample after oven drying = 24 gm

I_p = (LL-PL)

= 14.7815%

Compaction Test

Table 1: Compaction Test Data

Water Content (w) (%)	Bulk Density(ρ) (gm/cm^3)	Dry Density; $\rho_d = \rho/(1+w)$
8	1.7712	1.640
12	1.8704	1.671
14	1.9266	1.690
16	1.9720	1.700
18	2.0119	1.705
20	2.0900	1.701
22	2.0618	1.690
24	2.0770	1.675

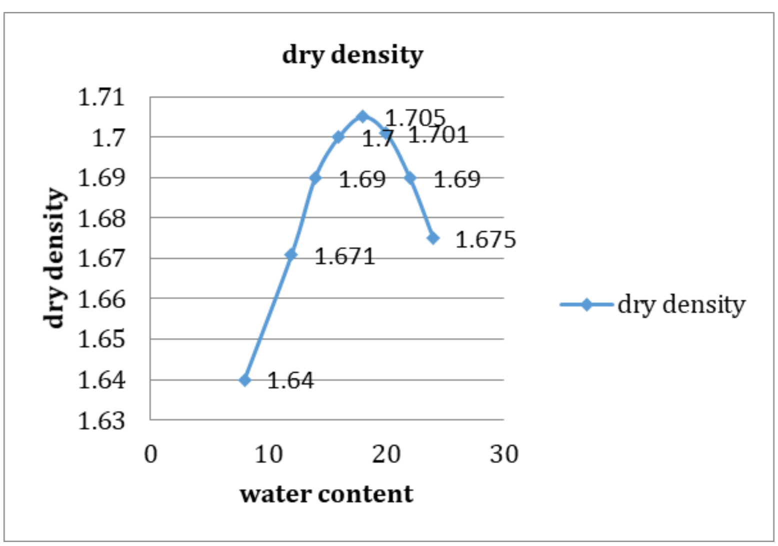


Chart -2: Compaction Curve

From the compaction curve plotted in chart-2, the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil sample are found to be at 18% and 1.705 gm/cm^3 respectively.

CBR of unreinforced soil

Table 2: CBR Test of Data of Unreinforced Soil Sample

Penetration (mm)	Load dial readings (divisions)	Load(Kg)
0.0	0	0
0.5	0.7499	5
1.0	1.4999	10
1.5	2.0998	14
2.0	2.6998	18
3.0	3.4498	23
4.0	4.1997	28
5.0	4.6497	31
7.5	5.6997	38
10.0	6.7496	45
12.5	7.4996	50

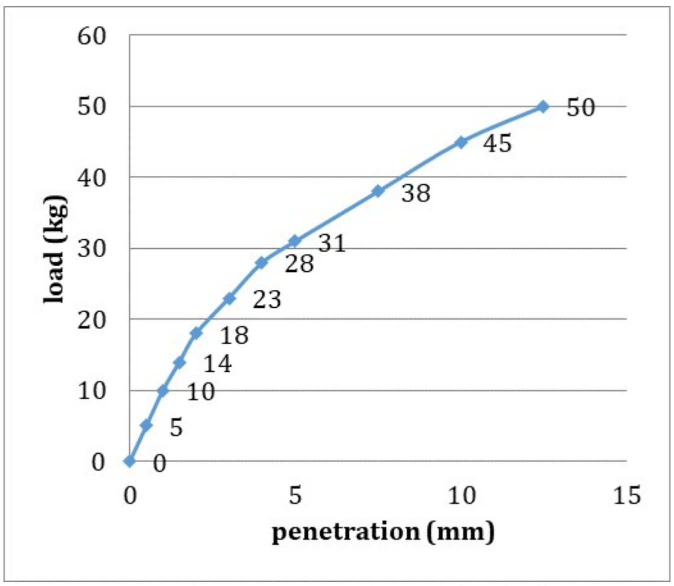


Chart -3: CBR Curve for Unreinforced Soil

At 2.5mm, CBR value = 1.5%
At 5mm, CBR value = 1.5%

CBR of soil reinforced with jute fiber length 30mm

CBR test conducted on the soil reinforced with jute fibers of length 30mm with different percentages of 0.2%, 0.4%, 0.6% and 1.0%.The results are tabulated below.

Table 3: CBR test data of reinforced soil (fiber length=30mm)

Penetration (mm)	**Load(Kg)**				
	Fiber content=0%	**Fiber content=0.2%**	**Fiber content=0.4%**	**Fiber content=0.6%**	**Fiber content=1.0%**
0.0	0	0	0	0	0
0.5	5	9	13	15	14
1.0	10	16	22	22	23
1.5	14	24	30	31	32
2.0	18	30	37	39	39
3.0	23	41	51	55	52
4.0	28	52	59	64	61
5.0	31	59	64	69	68
7.5	38	75	75	81	78
10.0	45	92	83	90	85
12.5	50	100	91	101	89

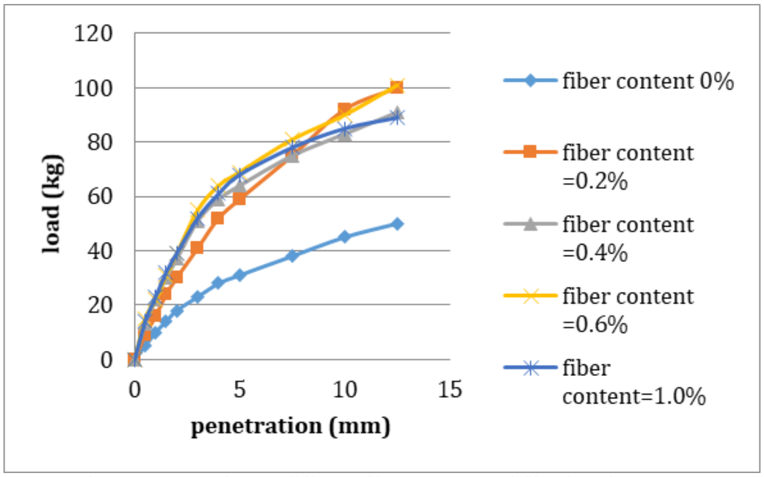


Chart -4: CBR values at different fiber contents and fiber length= 30mm

CBR of soil reinforced with jute fiber length 60mm

CBR test conducted on the soil reinforced with jute fibers of length 60mm with different percentages of 0.2%, 0.4%, 0.6% and 1.0%.The results are tabulated below.

Table 4: CBR test data of reinforced soil (fiber length=60mm)

Penetration (mm)	**Load(Kg)**				
	Fiber content=0%	**Fiber content=0.2%**	**Fiber content=0.4%**	**Fiber content=0.6%**	**Fiber content=1.0%**
0.0	0	0	0	0	0
0.5	5	14	15	14	14
1.0	10	20	23	24	24
1.5	14	28	31	32	32
2.0	18	36	39	41	41
3.0	23	44	49	55	53
4.0	28	52	58	64	61
5.0	31	59	64	71	69
7.5	38	70	75	85	84
10.0	45	82	83	98	96
12.5	50	90	91	105	103

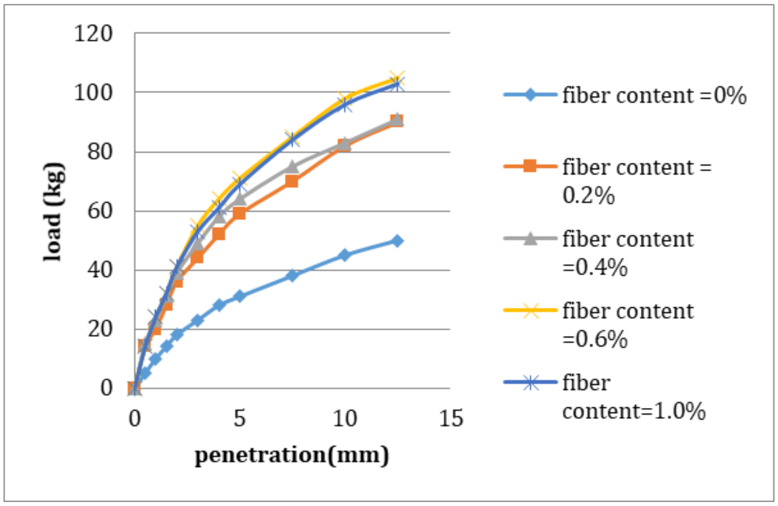


Chart -5: CBR values at different fiber contents and fiber length= 60mm

CBR of soil reinforced with jute fiber length 90mm

CBR test conducted on the soil reinforced with jute fibers of length 90mm with different percentages of 0.2%, 0.4%, 0.6% and 1.0%.The results are tabulated below.

Table 5: CBR test data of reinforced soil (fiber length=90mm)

Penetration (mm)	Load(Kg)				
	Fiber content=0%	**Fiber content=0.2%**	**Fiber content=0.4%**	**Fiber content=0.6%**	**Fiber content=1.0%**
0.0	0	0	0	0	0
0.5	5	14	18	18	17
1.0	10	24	27	29	27
1.5	14	30	34	38	35
2.0	18	37	42	47	44
3.0	23	48	56	61	60
4.0	28	58	64	71	72
5.0	31	63	73	79	77
7.5	38	71	89	94	92
10.0	45	77	95	100	99
12.5	50	82	99	105	104

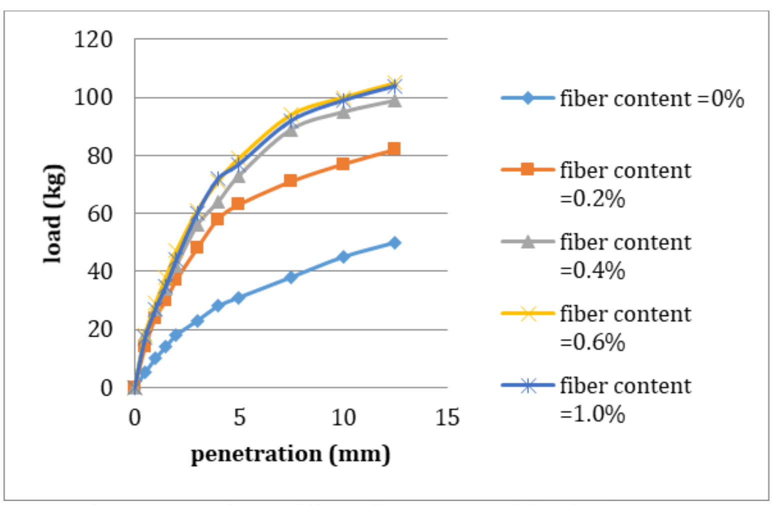
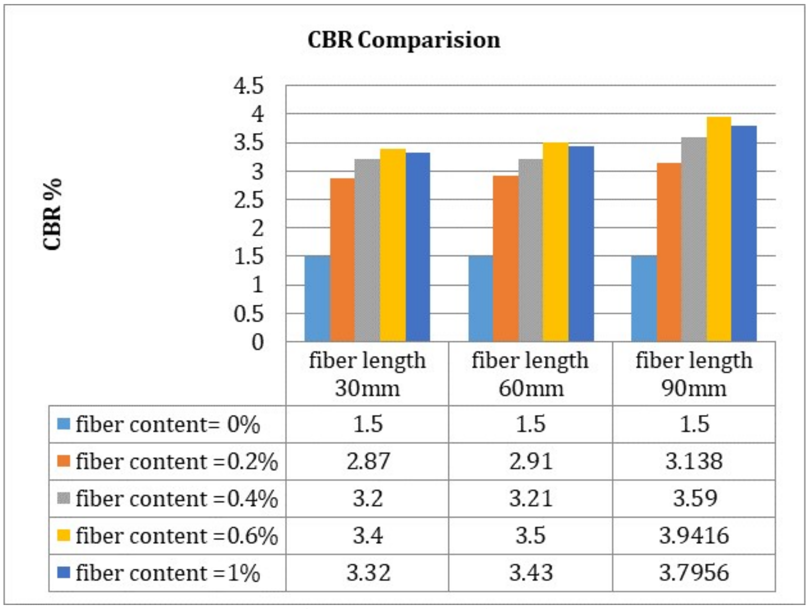


Chart -6: CBR values at different fiber contents and fiber length= 90mm

Comparison of CBR at different fiber contents



	fiber length 30mm	fiber length 60mm	fiber length 90mm
fiber content= 0%	1.5	1.5	1.5
fiber content =0.2%	2.87	2.91	3.138
fiber content =0.4%	3.2	3.21	3.59
fiber content =0.6%	3.4	3.5	3.9416
fiber content =1%	3.32	3.43	3.7956

Chart -7: CBR comparison

IV. CONCLUSIONS

A series of CBR tests were conducted in the present study. From the experimental observations, the following conclusions can be drawn.

Based on the present investigation it is concluded that CBR value of soil increases with the inclusion of Jute fibre. When the Jute fibre content is increased, the CBR value of soil further increases and this increase is substantial at fibre content of 0.6%. The optimum fibre content was found to be 0.6% by dry weight of soil. It is also concluded that there is significant effects of length of fibre on the CBR value of soil. The CBR value of soil increases with the increase in length of fibre. The maximum increase in CBR value was found to be more than 15% over that of plain soil at fibre content 0.6% for fibre having diameter 2mm and length 90 mm. It has been concluded that reinforcement of soil using jute-geotextiles is economically advantageous as it is cheap and locally available material. Compared to existing methods of soil reinforcement which have practical difficulties in the field, the application of jute-geotextile is easier. The jute-geotextile reinforcement is a superior solution for the construction of low volume roads on weak sub-grades.

Authors' contribution

Uzma Ashraf and Faiza Manzoor conceived of the presented idea, developed the theory and performed the computations. They also verified the analytical methods. Faiza Manzoor encouraged Uzma Ashraf to investigate the effect of 2mm dia fibre and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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