AN EXPERIMENTAL INVESTIGATION OF EFFECTIVENESS OF VARIOUS NATURAL FIBRES IN STABILIZATION OF SUBGRADE SOIL OF STATE HIGHWAY-168

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***Abstract*: The stability of any pavement depends upon the stability of its subgrade soil. Subgrade governs the performance, life span and effectiveness of the pavement. The entire load coming over the pavement is ultimately borne by the subgrade. Thus, the subgrade plays a very important role in the pavement design. Now-a-days, many techniques are used to stabilize the subgrade soil, use of natural fibres being one of them. Natural fibres are cheap, easily available and eco-friendly.**
A study was conducted to investigate the influence of randomly oriented natural fiber on soil strength parameter. Three type of natural waste fibres i.e., coir, jute and rubber fibers with varying doses (w/w) were used. Laboratory tests were carried out to evaluate the reinforcing effect of these natural fibres on the strength of the subgrade soil. Characterization of soil was carried out by grain size distribution and soil classification. For stabilized soil, the Atterberg limits, Unconfined Compressive Strength test and California Bearing Ratio tests were conducted in accordance with the standard procedures for different combination of soil and natural fibres.
Among the natural fibers used, jute fibre gave best improvement in strength of the subgrade soil. 1% w/w of jute fibre was found to be optimum ratio among the dose tried. 1.86 times increase in CBR value and 2.07 times increase in UCS was found compared to the virgin soil.

***Keywords*: Soil stabilization, Jute fibre, Coir fibre, Rubber fibre, California Bearing Ratio, UCS.**

2. INTRODUCTION

Generally, any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behaviour. Soil stabilization is the process which involves enhancing the physical properties of the soil in order to improve its strength, durability etc. by blending or mixing it with additives. The different types of methods used for soil stabilization are: Soil stabilization using cement, Soil stabilization using lime, Soil stabilization using bitumen, Chemical stabilization and a new emerging technology of stabilization that is stabilization of soil by using various natural fibres on stabilization of subgrade soil. Natural fibres are cheap, easily available and eco-friendly.

In this study, we are making use of three types of naturally available fibres i.e. jute, coir and rubber fibre with different aspect ratios were used with varying dosages for stabilization of soil.

3. MATERIAL USED

In this project the material used as stabilizer is jute and coir and rubber fibre. The test were conducted by adding jute and coir and rubber in varying percentages to the virgin soil. Also it is experimentally proved that the soil changes its property by adding jute and coir and rubber fibre as soil stabilizer.

1. Jute Fibre:-

Jute was collected from local market. Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. Jute is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. The Physical properties of the jute fibre that was used is given below in the table 3.2.

Table 3.1 Physical Properties of Jute: -

SR No.	Properties	Value
1	Specific Gravity	1.12
2	Cut Length	20-50mm
3	Diameter	2-3mm
4	Colour	Yellowish Brown
5	Aspect Ratio	10-25

2. Coir Fibre:-

These fibers are biodegradable and environmentally friendly. It has the greatest tearing strength among all natural fibers and retains this property in wet conditions. The Physical properties of the coir fibres used in the present study is as given below in the table 3.3.

Table 3.3 Physical Properties of Coir: -

SR No.	Properties	Value
1	Specific Gravity	0.71
2	Cut Length	20-50mm
3	Diameter	0.20-0.25mm
4	Colour	Brown
5	Aspect Ratio	100-250

3. Rubber Fibre:-

Rubber has an excellent and long flex life with high tensile strength and can come in a wide range of hardness for various applications. The Physical properties of therubbe fibres used in the present study is as given below in the table 3.4.

Table 3.4 Physical Properties of rubber: -

SR No.	Properties	Value
1	Specific Gravity	0.96
2	Cut Length	20-50mm
3	Diameter	2-3 mm
4	Colour	White
5	Aspect Ratio	300

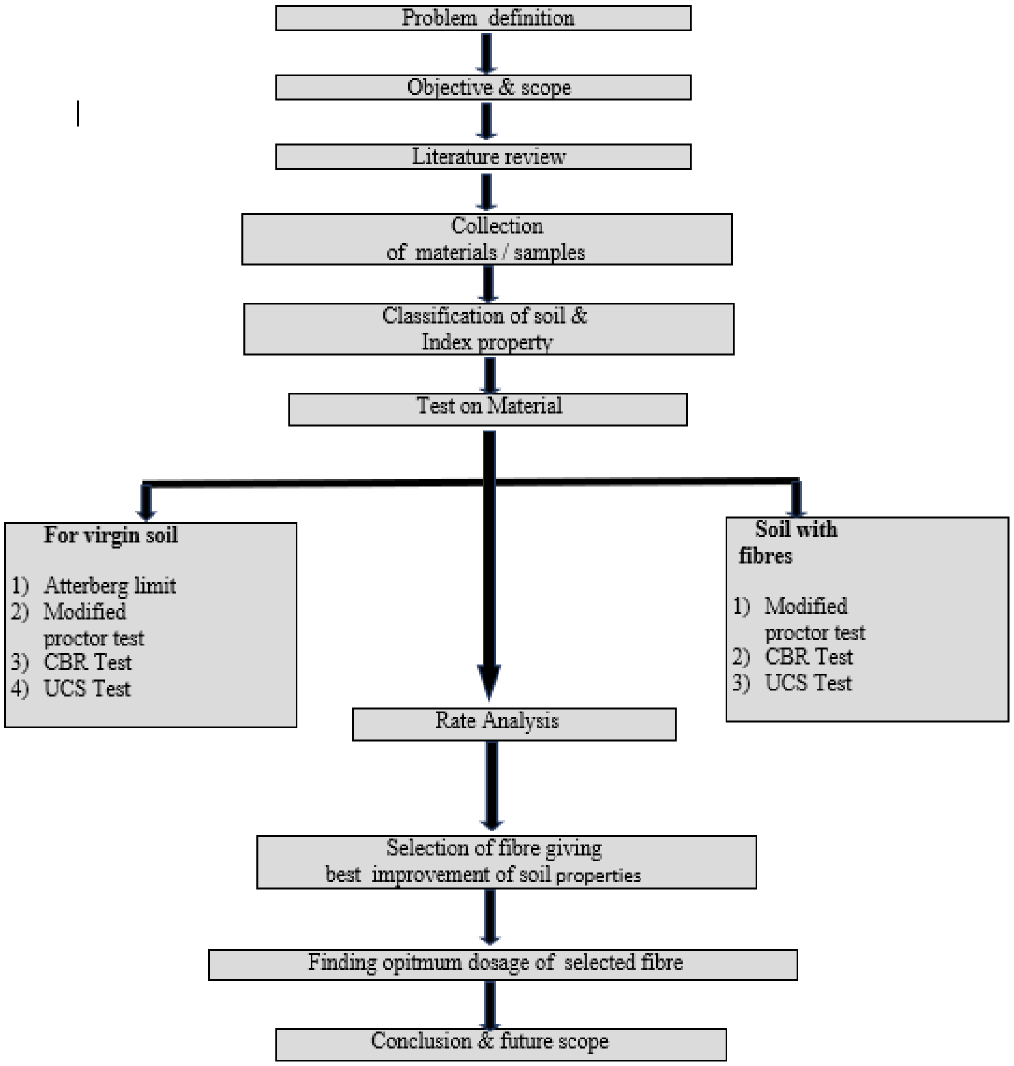
4. Virgin Soil :-

The soil sample was collect from a place on Hazira-Sayan Highway which is State Highway No – 168 at a depth of 2m below the ground surface. The soil was initially allowed to dry for 2 days and the dried soil was thoroughly grinded. The grinded soil was allowed to pass through 4.75mm IS sieve and this soil was used for the present study. These soil Physical properties given by Table 3.1.

Table 3.1Physical Properties of Virgin soil : -

SR No.	Properties	Value
1	Specific Gravity	2.7
2	Liquid limit (%)	66
3	Plastic limit (%)	32
4	Plasticity index	34
5	MDD (KN/m^3)	1.73
6	OMC (%)	18.64
7	CBR Value % (soaked)	0.622
8	Free swell index	110
9	IS Classification	CH

❖ **METHODOLOGY**



4. RESULT ANALYSIS

4.1 LABORATORY INVESTIGATION OF NATURAL SUBGRADE SOIL (VIRGIN SOIL)

The results of the various laboratory experiments done on the virgin soil has been discussed below

4.1.1 GRAIN SIZE DISTRIBUTION:-

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used to determine suitability of soil for road construction. Information obtained from grain size analysis can be used to predict soil water movement. Table 4.1 gives the result of grain size distribution of the virgin soil.

Table 4.1 Grain size distribution

Sr. No	**Grain size analysis**				
	Gravel	C.S	M.S	F.S	S+C
1.	0	0	1	2	97

4.1.2 ATTERBERG LIMIT:-

The tests were carried out according to IS: 2720 (part 5). The results of liquid limit and plasticity index are given in table 4.2 below.

Table 4.2 Atterberg Limit

Sr. No	**Consistency Limits**		
	Liquid Limit	Plastic Limit	Plasticity Index
	(%)	(%)	(%)
1.	66	32	34

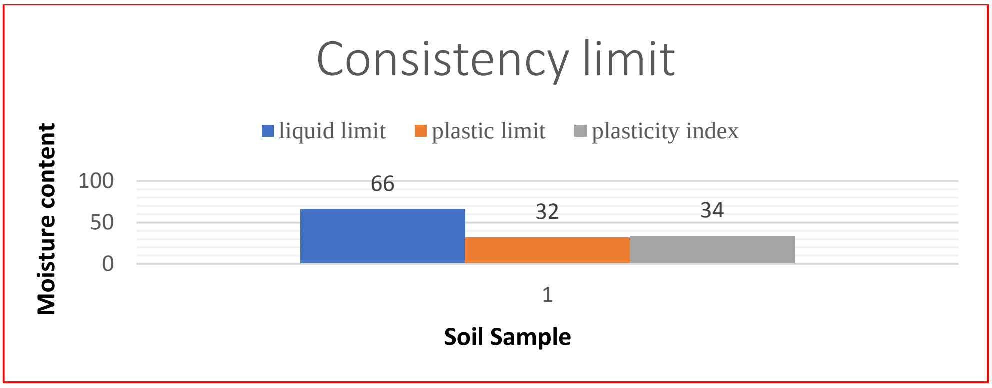


Figure 4.1 Consistency limit

➢ Atterberg's limits tests were performed on the soil samples. The results obtained were as follows; the Liquid limit (LL), Plastic limit (PL) and Plasticity index (PI) were found to be 66%, 32% and 34% respectively. The results are shown in figure 4.1.

4.1.3 MODIFIED PROCTOR TEST:-

Compaction characteristics were studied by Standard and modified proctor test. The test helps to determine the maximum dry density and optimum moisture content of the specimen. The compaction test was carried out according to IS: 2720 (part 8).
Optimum moisture content and maximum dry density for soils were obtained from the respective compaction curves. MDD and OMC for selected soil samples are as shown in the table 4.3.

Table 4.3 Modified proctor test

Sr. No	Optimum Moisture Content	Maximum Dry Density
	(%)	(KN/m^3)
1.	18.64	1.73

As seen from figure 4.2, the maximum dry density (MDD) obtained was 1.73(KN/m^3) and the corresponding optimum moisture content (OMC) was found to be 18.64%.

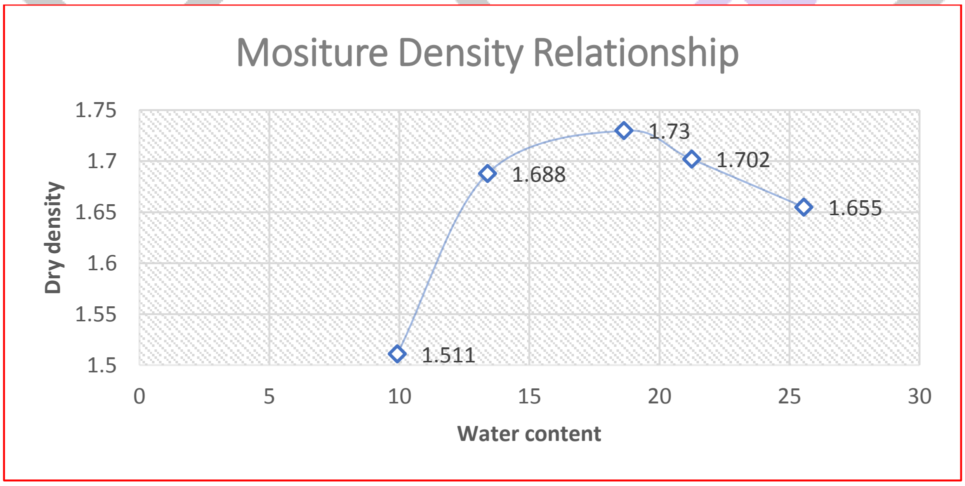


Figure 4.2 Mositure density relationship

4.1.4 CALIFORNIA BEARING RATIO:-

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The CBR test was done for both soaked and un-soaked conditions. The soak CBR test was carried out after the submergence of sample in water for 4 days in accordance to IS: 2720 (part 16).The test results are presented in table 4.4. The results of the un-soaked sample are given in table 4.5.

Table 4.4 CBR Test (soaked)

Sr.No	CBR Value (%) (Soaked)	
	2.5	**5.0**
1.	0.622	1.11

➢ The CBR value for the soaked soil samples obtained at 2.5mm penetration was 0.622% while that at 5mm penetration the CBR value was 1.11%. The results are shown in figure 4.3.

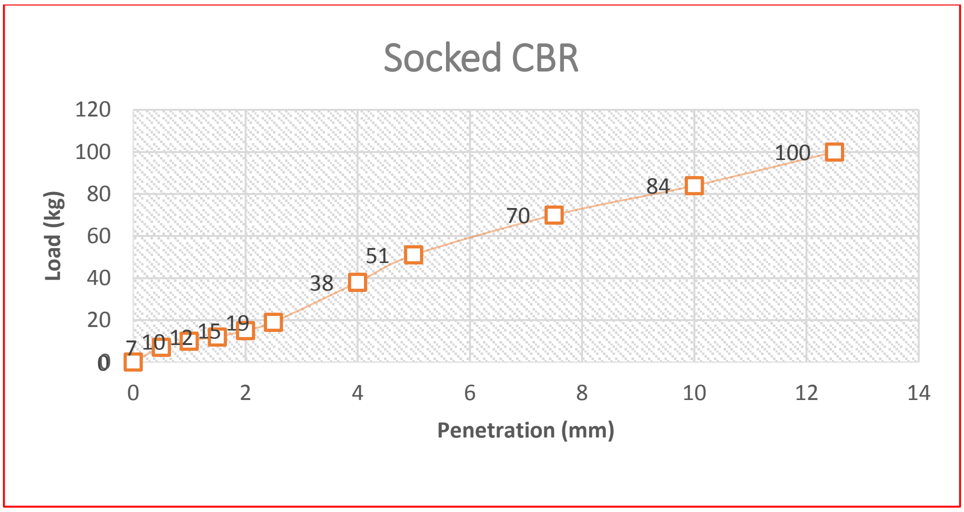


Figure 4.3 Soaked CBR Value

Table 4.5 CBR Test (Unsoaked)

Sr.No	CBR Value (%) (Unsoaked)	
	2.5	**5.0**
1.	15.92	14.21

The CBR value for the unsoaked soil samples obtained at 2.5mm penetration was 15.92% while that at 5mm penetration the CBR value was 14.21%. The results are shown in figure 4.4.

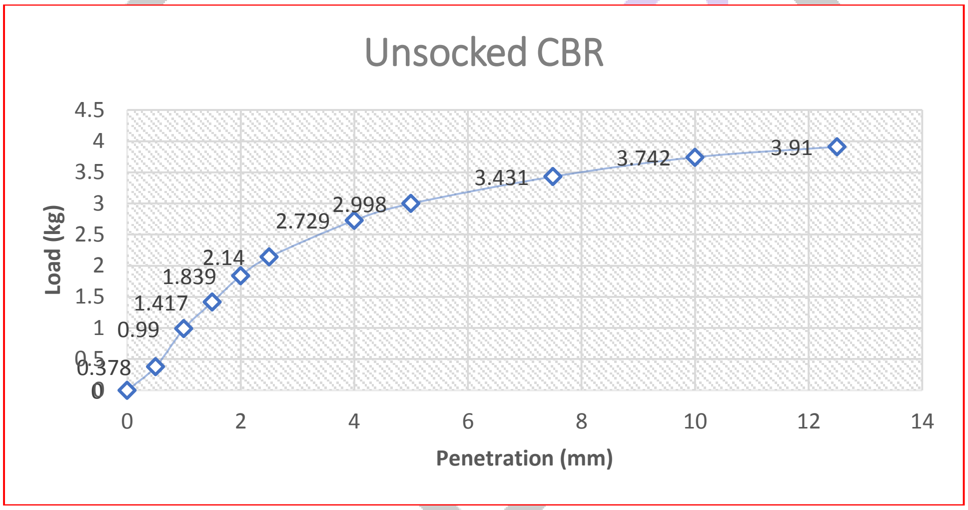


Figure 4.4 Unsoaked CBR Value

4.1.5 UNCONFINED COMPRESSION TEST:-

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. As seen from the figure 4.5, the maximum compressive strength was obtained for the virgin soil was 0.346 KN/m^2.

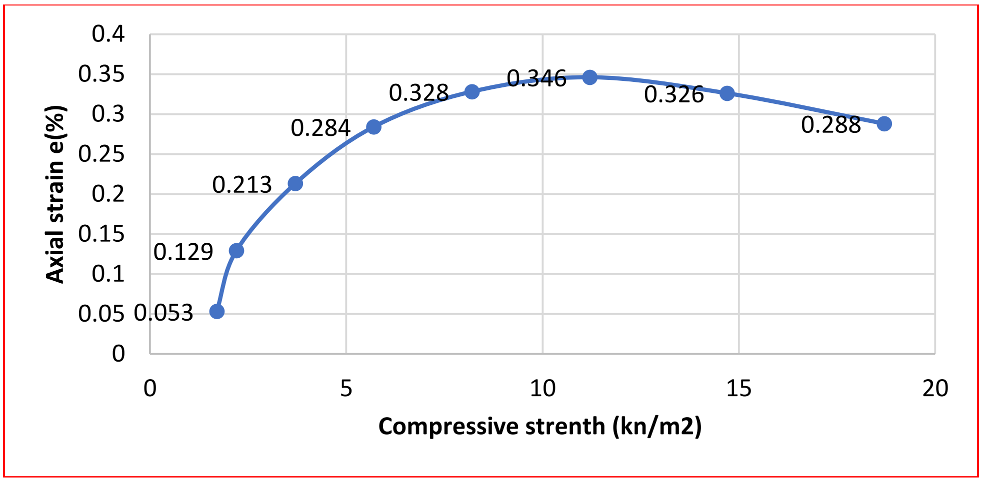


Figure 4.5 UCS Test

4.1.6 FREE SWELL TEST:-

Free Swell Index is the increase in volume of a soil, without any external constraints, on submergence in water. A free swell test is commonly used for identifying expansive clays and to predict the swelling potential. Free Swell Index of the soil was investigated according to IS: 2720 (part 40). The results are presented in table 4.6.

Table 4.6 Free Swell Test

Sr. No	F.S.I
1.	110

4.2 LABORATORY INVESTIGATION OF NATURAL TREATED SOIL:-

To improve geotechnical properties of the virgin soil it was mixed with different proportion of selected natural fibres i.e. coir, jute and rubber. The degree of improvement in OMC, MDD, CBR value and UCS compared to virgin soil was used as the base for selection of the best suitable fibre and also the optimum dose of the selected fibre.

4.2.1 EFFECT OF ADDITION OF NATURAL FIBRE ON OMC AND MDD:-

The modified Proctor test was carried out for the virgin soil as well as the mixture of virgin soil and the natural fibres. A constant dose of 2% (w/w) was selected for all the three fibres. The results obtained are as shown in the table 4.7.

Table 4.7 Modified Proctor Test result

Sr.No	Material	OMC	MDD
		(%)	(KN/m^3)
1	Virgin soil	18.64	1.73
2	Coir	17.82	2.197
3	Jute	21.657	2.149
4	Rubber	19.623	2.28

As seen from **table 4.7,** maximum dry density (MDD) and optimum moisture content (OMC) of the virgin soil is lower than obtained for the soil mixed with 2% fibre . These shows that addition of this natural fibre improves the OMC as well as MDD of the virgin soil. Highest increase in OMC (16.18%) was obtained for the jut fibre, while the highest improvement in MDD (31.79%) was found to be for the rubber fibre. The moisture density relationship for all the four cases i.e. the virgin soil and virgin soil with fibres is shown in figure 4.6

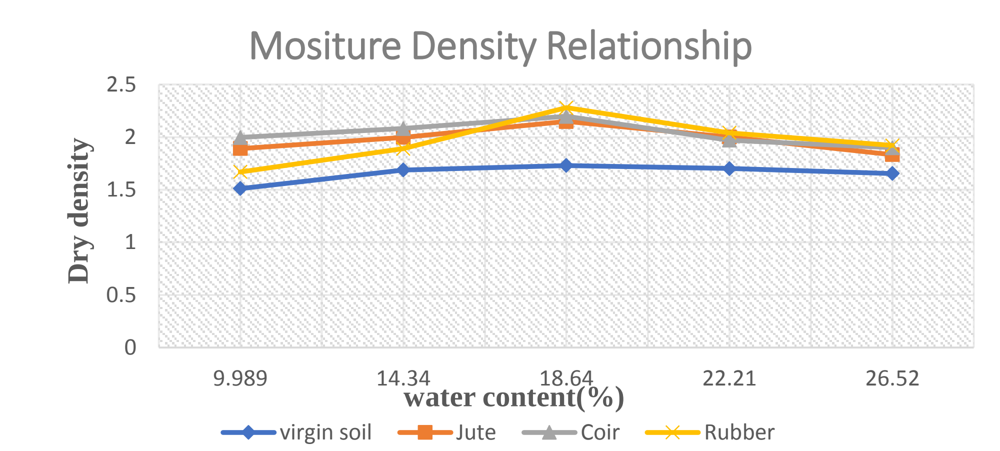


Figure 4.6 Moisture Density Relationship for different fibre

4.2.2 EFFECT OF ADDITION OF NATURAL FIBRE ON C.B.R VALUE:-

➢ As the unsoaked C.B.R value is generally very high in black cotton soil, the CBR test was done only for the soaked condition. The CBR value obtained for virgin soil as well the soil reinforced with natural fibres are shown in table 4.8

Table 4.8 CBR value for virgin as well as reinforced soil

	Material	**CBR Value (%) (Soaked)**	
		2.5	**5.0**
1	Virgin soil	0.622	1.112
2	Coir	1.334	1.588
3	Jute	1.517	1.986
4	Rubber	0.716	1.283

As seen from **table 4.8, the CBR value at 2.55 and 5mm penetration** for the virgin soil is lower than obtained for the soil mixed with 2% fibre . This shows that addition of this natural fibre improves the CBR value of the virgin soil. It can also be seen that improvement in the CBR value when rubber fibres were used was not very significant compared to the other fibres. Jute gave about 143% improvement in CBR value at 2.5 mm penetration while 78 % improvement at 5 mm penetration. Similarly coir gave 114 % improvement in CBR value at 2.5 mm penetration while 43 % improvement at 5 mm penetration. This improvement in the CBR value can be attributed to the reinforcing effect of this fibre. In case of the rubber, as its surface was smooth proper bonding between the soil and the fibre was not as good as compare to other two fibre. This may have resulted in the lower CBR values when rubber was used as compared to coir and jute fibre. The figure 4.7 shows the effect of fibres on the CBR values.

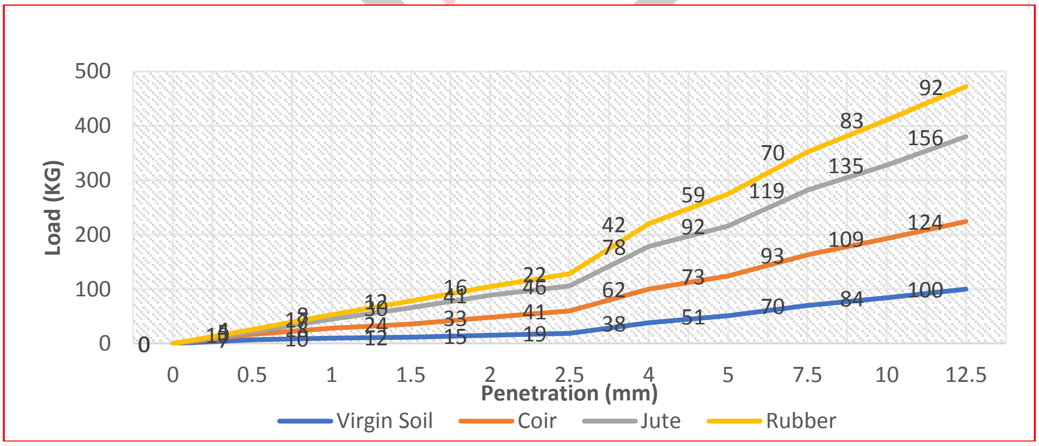


Figure 4.7 CBR Value for different fibre

4.2.3 EFFECT OF ADDITION OF NATURAL FIBRE ON UNCONFIRMED COMPRESSIVE STRENGTH

As seen from **table 4.9,** the unconfined compressive strength of the virgin soil is lower than obtained for the soil mixed with 2% fibre. UCS of the reinforced soil sample improved by around 76%, 79% and 50% respectively for coir, jute and rubber. Highest increase in the UCS was found to be for the jute fibre. As discuss in section 4.2.2, the weak bonding between the soil and the rubber due to its smoothness may have resulted in the lowest improvement of the UCS among all the fibres. Figure 4.8 shows the result of UCS test for all the

Table 4.9 Unconfirmed compressive strength test analysis

Sr. No	Material	UCS Value (kg/cm^2)
1	Virgin soil	0.346
2	Coir	0.609
3	Jute	0.621
4	Rubber	0.52

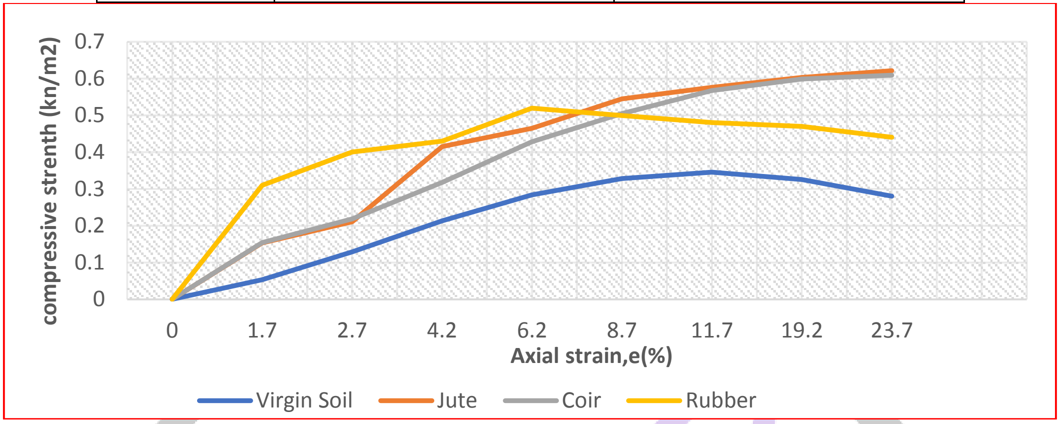


Figure 4.8 UCS Test for different fibre

4.3 SELECTION OF FIBRE BEST SUITABLE FOR IMPROVEMENT OF SOIL :-

Table 4.10 shows the effect of addition of the natural fibres (2%) on the engineering properties of the soil. As seen from the table as well as in the previous section Jute fibre have maximum improvement in the CBR value (143%) and the UCS (79%). Hence it was selected for further studies.

Table 4.10 Effect of addition of natural fibre on the engineering properties of the soil

SR.NO	MATERIAL	OMC (%)	MDD(KN/m^2)	CBR	UCS
1	Virgin soil	18.64	1.73	0.622	0.346
2	Coir	17.82	2.197	1.334	0.609
3	Jute	21.657	2.149	1.517	0.621
4	Rubber	19.623	2.28	0.716	0.520

4.3.1 EFFECT OF THE DOSE (% WEIGHT) OF THE JUTE ON THE SOIL STABILIZATION:-

As discussed in the previous section, jute fibre gave the maximum improvement in the CBR value and UCS. Hence to study the effect of the dose of jute on the improvement of soil properties, experiments with varying percentages of jute fibre were done. The doses used were 0.5%, 1%, 1.5 and 2%. OMD, OMC, CBR and UCS were determined for all the doses to determine the optimum concentration of the jute fibre to be used for stabilization of the subgrade.

(1) EFFECT OF DOSE VARIATION OF JUTE FIBRE ON OMC AND MDD:-

The modified proctor test was performed for all the doses to observe the change in maximum dry density (MDD) and optimum moisture content (OMC). Figure 4.9 and 4.10 shows the effect of dose variation of jute fibre on OMC and MDD. As seen from figure 4.9 OMC increase with increase in the percentage of jute the OMC increase which maximum OMC of 21.66% observed at 2% dose. About 16 % increase in OMC was found at 2% compared to virgin soil. Similar observations were also made for the OMD except for the dose of 1.5% were there was a slight dip in the MDD. Increase in MDD was at 24 % at 2% jute compared to virgin soil.

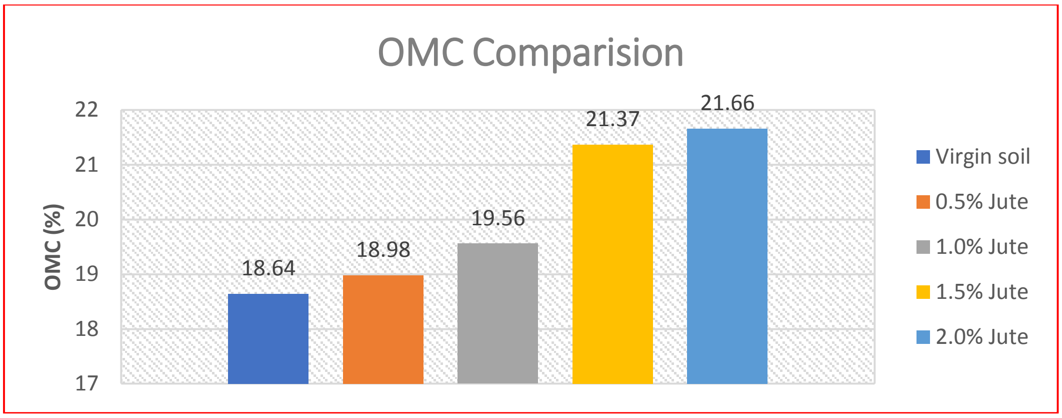


Figure 4.9 Effect of dose of jute fibre on OMC

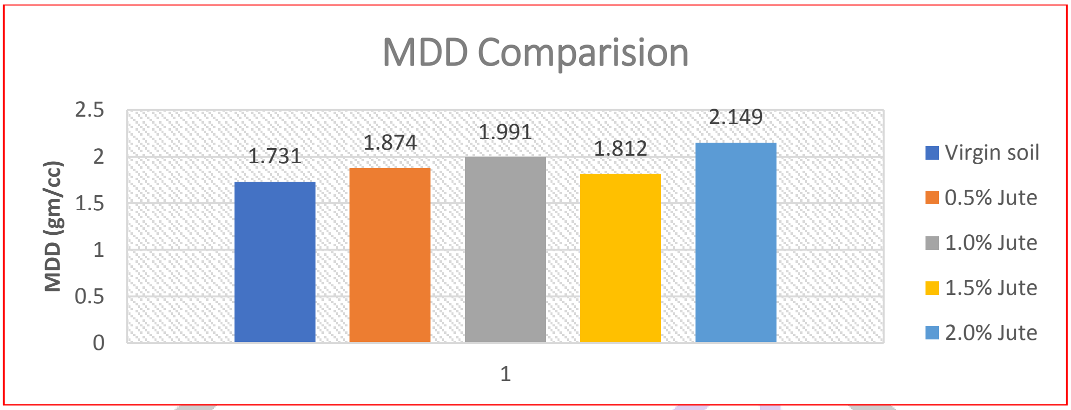


Figure 4.10 Effect of dose of jute fibre on MDD

(1) EFFECT OF DOSE VARIATION OF JUTE FIBRE ON CBR VALUE:-

California Bearing Ratio tests were conducted (as per IS 2720 (Part 16):1987) on soil samples. For this test, the observations were observed at 2.5mm penetration and at 5mm penetration. Figure 4.11 shows the variation in the CBR values at different doses of jute fibre at 2.5 mm and 5 mm penetration. It could be seen that the CBR values obtained at both the penetration for all the dose of jute fibres are higher than virgin soil. It could also be seen that the CBR value first increase up to 1% dose and then deceases. It gave almost similar results at 1.5 and 2% dose. At 1% dose the increase in CBR value was found to be 186 %.

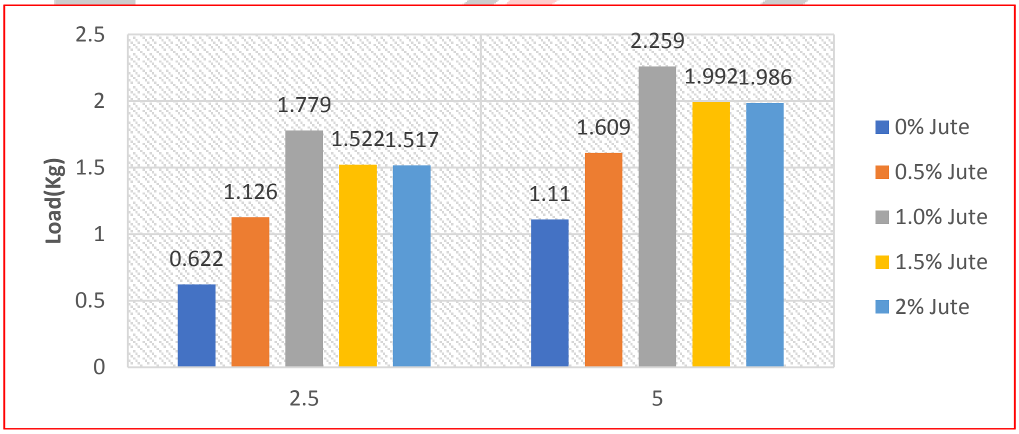


Figure 4.11 Comparison of CBR values for different percentages of jute fibre

(2) EFFECT OF DOSE VARIATION OF JUTE FIBRE UNCONFIRMED COMPRESSIVE STRENGTH TEST:

The unconfined compression test was conducted according to IS 2720 part X. Figure 4.12 shows the variation in the unconfined compressive strength at different doses of jute fibre. It could be seen that the UCS values obtained for all the dose of jute fibres are higher than virgin soil. It could also be seen that the UCS first increase up to 1% dose and then deceases. At 1% dose the increase in UCS value was found to be 207 %.

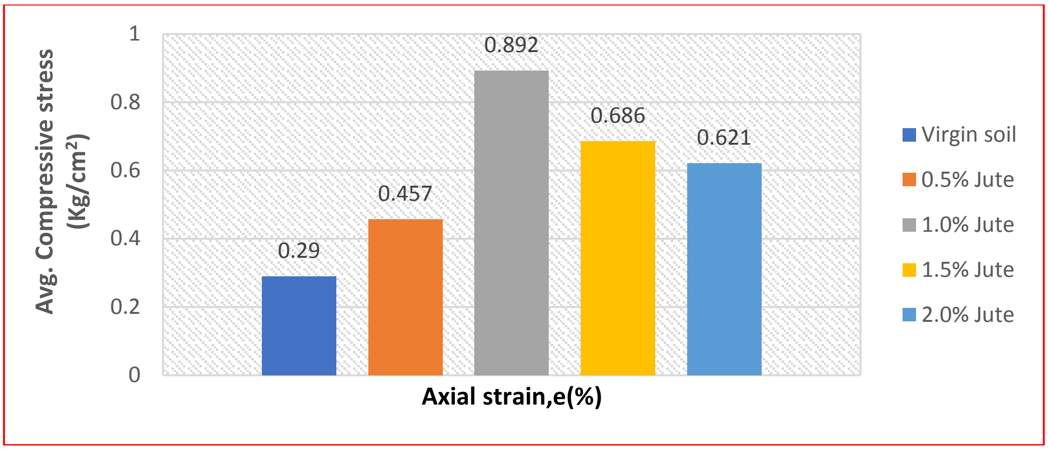


Figure 4.12 Comparison of the unconfined compressive strength for different percentage of jute fibres

5. CONCLUSION

The main objective of this study was to evaluate the effect of the addition of various natural fibres like coir, jute and rubber available as waste materials on the physical and engineering properties of the soil. The results obtained in this study indicate that these fibres can indeed provide a cost effective and environmental friendly method of subgrade soil stabilization. Apart from this main outcome of the study some important conclusion which can be drawn are mentioned below.

1. According to IS code 1498:1970, Indian Soil Classification the type of soil in the study area was found to be inorganic highly plastic clays (CH).
2. Addition of these natural fibres (2% w/w) improves MDD of the virgin soil. The highest improvement in MDD (31.79%) was found to be for the rubber fibre.
3. CBR value for the soil reinforced with all the three fibres was greater than virgin soil. The improvement in the CBR value when rubber fibres were used was not very significant, but it was very significant for other two fibres. Jute gave about 143% while coir gave 114 % improvement in CBR value. This shows that these fibres can provide an economical method for stabilization of black cotton soil. Overall economy can also be achieved as there would be reduction in the pavement thickness requirement due to improved CBR value.
4. The unconfined compressive strength for the soil reinforced with all the three fibres was greater than the virgin soil. UCS of the reinforced soil sample improved by around 76%, 79% and 50% respectively for coir, jute and rubber.
5. Jute fibre gave highest improvement in the CBR value and UCS.
6. Among the dose of jute fibre used, 1% (w/w) gave better results. At 1% dose the increase in CBR value was found to be 186 % while that in UCS was 207%.

❖ FUTURE SCOPE:-

Recommendation for the future work based on this study areas under

1. Economic evaluation of the subgrade soil stabilization by jute fibre can be done and cost saving compared to the chemical stabilization can be done.
2. Effectiveness of other natural fibres/industrial waste in subgrade soil stabilization can be explored.

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