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Stabilization of Soil Subgrade Using Natural Geosynthetics for Flexible Pavements.

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ABSTRACT

The quality of a pavement depends on the strength of its sub-grade, improving the quality of natural weak subgrade to enhance its strength and load bearing capacity is essential. If the natural soil is very soft it needs some improvement to act as a sub-grade. It is therefore, needed to replace the natural soil by stabilization with improved strength and compressibility characteristics. The Experimental works have been carried out with natural geosynthetics material like Jute Fiber individually mixed with soil and also in combination with different percentage of Hydrated Lime with several mix proportions to study improvement of weak road subgrade. 1, 2, 3 and 4 percentages of Jute Fiber were mixed with soil and stabilized with 1, 2, 3 and 4 percentage of lime is tested for California Bearing Ratio (CBR). The study reveals that the CBR value increases with the increase in Jute Fiber and Lime reaches to a desirable CBR value for subgrade of pavement. Normally soaked CBR value is considered for pavement design. Experimentally it is found that the addition of Jute Fiber with Lime in the soil results in the improvement of soaked CBR value from 2.23 % to 8.10 %. The maximum CBR is obtained while using 3% Jute Fiber and 3% Lime with the natural soil.

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Introduction:

Geosynthetics include a large variety of products composed of polymers and are designed to enhance geotechnical and transportation projects. Geosynthetics perform at least one of five functions: separation, reinforcement, filtration, drainage, and containment.

The potentiality of Jute Fiber as a good source of high technological materials in road construction is the subject of this study. India is the world largest producer of jute, and Jute is one of the most affordable natural fibers and extracted by steeping the plant in water, until the bark is sufficiently softened by retting, to allow separation of fiber. Besides these, in order to enhance the engineering properties soil can be reinforced with jute fiber. Jute fiber is preferable because of durability, high tensile strength and capability to withstand rutting and heat, porous texture which gives it good drainage and filtration properties. Emerging trend of using in soil stabilizing or soil strengthening is being working out all over the world in present days. Moreover, jute is locally available, cheap, eco-friendly and biodegradable and it can be utilized in several other applications.

Lime's dominant construction use today is in soil stabilization for roads, airfields, building foundation and earthen dams, where it upgrades low quality soils into usable base and sub base materials. It is also used as an additive in asphalt, in which it improves the cohesion of asphalt, reduces "stripping" and retards ageing process. Lime is routinely used as a soil modification agent to improve the performance of sub grade soils with the primary goal of reducing volume change. Effective mixing of lime and soil is critical to ensuring that the expected improvements occur throughout the soil mass. Lime also decreases the apparent amount of fines in a soil by causing flocculation and agglomeration of the clay particles (Little 1995). This results in an increase in the

percentage of sand and silt size particles as measured by standard grain size distribution methods.

Using some of these waste materials in construction practice will reduce the problem in a great extent. Present study concentrates on how Jute Fiber can be used in construction of roads, step by step procedure of various tests to be conducted on the experimental model section of road block.

Experimental Methodology:

All the tests of soil before and after stabilization with different mixtures of jute fiber and lime will be carried out as per the Indian standard. For laboratory tests specimens of soil with and without admixtures has to be prepared by thoroughly mixing the required quantity of soil and stabilizers in pre-selected proportions in dry state and then required quantity of water was added and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures. To maintain the homogeneity and uniformity of mix proportions, the California Bearing Ratio tests has to be performed for soaked conditions, so as to ensure uniformity in proportion of materials and water content. The 1%, 2%, 3%, and 4%, proportions may be used in cases of lime and 1%, 2%, 3%, and 4% for jute fiber. They will be mixed with original soil individually and also in combination of both the admixtures and laboratory results has to be analysed according Indian standardization of design criteria.

Objectives:

1. To evaluate the effectiveness of use of jute fiber with Lime in enhancing the performance of flexible pavements.
2. To study the load bearing capacity & stability of the sub grade layers.
3. To find out the best possible design mix proportion of soil and admixtures which gives maximum strength of stabilized soil compared to that of the original soil.

Materials Used:

The materials used in the present investigation were Natural Jute Fiber, Hydrated Lime and locally available soil.

Soil:

Soil used in the present investigation has been collected from an excavation site near Vasanthpura, Bangalore, India. On visual inspection it was found to be reddish brown soil and from HRB classification it is found to be of category A-4(Silty soil with moderately plastic in nature). Evaluated properties of the soil are shown in table below. Based on Liquid Limit, Plasticity Index and Unified Soil Classification system the soil may be classified as SM (Sandy Silt and Silty sand mixtures)

Table 1: characteristics of soil

Sl. No	Characteristics	Value
1	Specific Gravity	2.4
2	Liquid Limit (%)	17.30
3	Plastic limit (%)	14
4	Plasticity Index (%)	3.3
5	Classification of soil	A-4
6	Maximum Dry Density (gm/cc)	1.72
7	Optimum Moisture Content (%)	16
8	Unsoaked CBR (%)	1.87
9	Soaked CBR (%)	2.23

Lime:

Lime possesses good plasticity and is easy to work and stiffens easily and is resistant to moisture, even it has excellent cementitious property. Lime shrinkage on drying is small because of its high water retentivity. Some of chemical constituents are listed below table 2.

Table 2: Chemical constituents of Lime

Constituents	Weight (%)
SiO2	4.11
Al2 O3	3.11
Fe_2 O3	2.70
Ca CO_3	3.80
CaO	63.70
$CaSO_4$	19.26
MgO	1.62
Loss on ignition	1.70

Jute Fiber:

Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced from plants in the genus Corchorus, which was once classified with the family Tiliaceae, more recently with Malvaceae, and has now been reclassified as belonging to the family Sparrmanniaceae. The primary source of the fiber is Corchorus olitorius, but it is considered inferior to Corchorus capsularis." Jute" is the name of the plant or fiber that is used to make gunny cloth.

Figure 1: View of Jute fiber

The jute fibre used was procured from the local market. The diameter of the jute fibre used was 2mm. Jute fibres are generally available in the threaded form. These are mechanically woven fibres with very fine threads. Following are the advantages of jute geotextile

1. Abundant availability
2. High moisture/water absorbing capacity. Jute Geotextile can absorb moisture/water up to about 5 times its dry weight.
3. High initial strength.

Jute fiber for the present investigation was obtained from a local Jute Pragnya RT Nagar, Bangalore, India.

Table 3: Components of Jute fiber

Sl. No	Components	% present in Jute Fiber
1.	Cellulose	65.2
2.	Hemi-Cellulose	22.2
3.	Lignin	12.5
4.	Water Soluble Matter	1.5
5.	Fat and Wax	0.6

Experimental Work:

Detailed experimental study was under taken to investigate the characteristics and behavior of typical locally available soil mixed with lime and jute fiber in different percentage and in several combinations from the view point of applicability of such materials in road subgrade. Even experimental works have been done to investigate the behavior of soils with and without adding admixtures.

Routine tests were carried out for characterization such as Liquid Limit, Plastic Limit and strength properties for unstabilized soil and the relevant IS code followed for experimental work have been listed in table 4

Table 4: Relevant IS Code followed for Experimental Work

Sl. No	Name of Tests	Relevant IS code followed
1	Specific Gravity	IS : 2720, Part-3, 1980
2	Atterberg Limits	IS : 2720, Part -5,1985
3	Classification and Identification of soil	IS : 2720, Part-1498,1970
4	Grain size analysis	IS : 2720, Part-4,1985
5	Water content determination	IS : 2720, Part -2, 1973
6	Laboratory CBR	IS :2720, Part-16,1979

All the tests of original soil were carried out as per the standard practice as laid out in the relevant IS code of practice. For tests of specimens of mixed/stabilized soils, specimens were prepared by thoroughly mixing the required quantity of soil and stabilizers in preselected proportion in dry state and then required quantity of water was sprinkled and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures.

For laboratory CBR tests, specimens were prepared in the CBR mould as per the standard practice and then it was submerged for four days for soaked tests.

For *Atterberg's limit* test on mixed soils, specimens were prepared by mixing soil and stabilizers in dry state as per the preselected proportions thoroughly and then water was added as per the standard practice. To investigate the effect of mixing jute fiber and lime combination with the original soil to be used for construction of road subgrade, Jute Fiber was mixed in various proportions of 1%, 2%, 3%, 4% and lime in the proportions of 1%, 2%, 3%, 4%. To determine the moisture content dry density relationship, CBR of stabilized soil, Standard Proctor Test (IS 2720, Part-7, 1980) was carried out. Specimens for CBR tests were compacted at moisture content equal to Optimum Moisture Content and the results are tabulated in table 5.

Table 5: Consistency limits for soil with varying percentage of Lime and Jute Fiber

SOIL (%)	LIME (%)	Jute fiber (%)	L.L (%)	P.L (%)	P.I (%)
100	0	0	17.30	14	3.3
98	1	1	20.65	14.93	5.72
96	2	2	24	15.86	8.14
94	3	3	29.013	21.964	7.049
92	4	4	30.594	27.556	3.038

Standard Proctor Test:

Standard proctor test have been conducted to determine the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. Thus, the routine laboratory tests with different mix proportions involves conducting Standard Proctor Test as per IS: 2700(Part-VII), 1980/87 on both unstabilized and stabilized soil mixes to determine their individual OMC and MDD and the results are tabulated in table 6.

The Optimal moisture content and Maximum dry density for normal soil were:

- *Optimum Moisture Content =16 %*
- *Maximum Dry Density =1.72 g/ cm^3*

Table 6: Compaction characteristics of soil with varying percentage of Lime and Jute fiber

Soil (%)	Lime (%)	Jute Fiber (%)	O M C (%)	M D D (g/cc)
100	0	0	16	1.72
98	1	1	19	1.58
96	2	2	24	1.47
94	3	3	27	1.45
92	4	4	27	1.41

CBR Test for soil and soil mixed with admixtures:

California Bearing ratio is a penetration test used for evaluation of mechanical strength of road subgrades and base courses. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area and the test results are tabulated in table 7.

Table 7: CBR test results for soaked condition.

Sl No	Soil %	Lime %	Jute fiber %	CBR soaked %
1	100	0	0	2.23
2	98	1	1	3.95
3	96	2	2	5.27
4	94	3	3	8.10
5	92	4	4	4.58

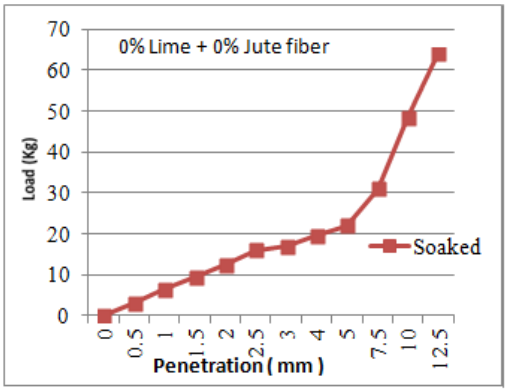

Fig. 2a: CBR for Normal soil

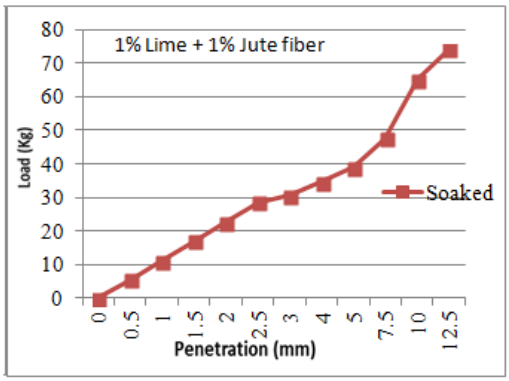

Fig. 2b: CBR for 1%Lime + 1% Jute Fiber

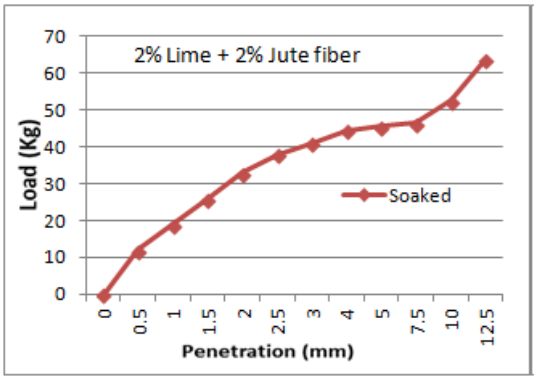

Fig. 2c: CBR for 2%Lime + 2% Jute Fiber

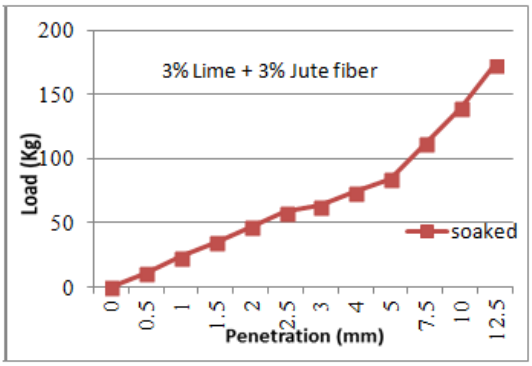

Fig. 2d: CBR for 3%Lime + 3% Jute Fiber

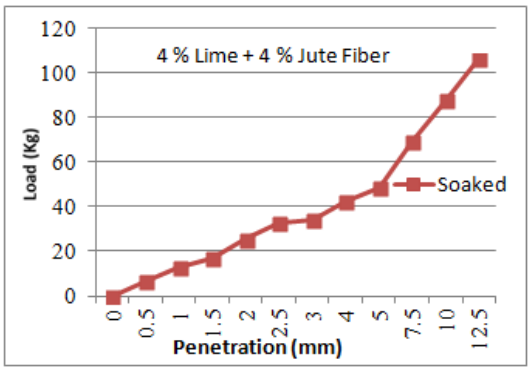

Fig. 2e: CBR for 4%Lime + 4% Jute Fiber

Results and Discussion:

Effects of Jute Fiber and Lime on Compaction Characteristics of soil:

The results indicated in Table 6 with increase in lime content, OMC of the soil lime mix increases gradually with same compactive effort. While the virgin soil has an OMC of 16% addition of 1% lime and 1% Jute Fiber with soil raise the OMC to 19% and an addition of 2% lime and 2% Jute fibre raise the OMC of mixed soil up to 24%.

The increase in OMC with increased lime and Jute fibre content is in agreement with most of the researchers in this area. The possible cause of increased water demand with increased lime content may be the requirement of more water for the dissociation of lime

into Ca and OH ions to supply more Ca ions for the cation exchange reaction.

It can be seen from the results of table 6 with the increase in lime and Jute Fiber contents MDD decreases gradually. While the virgin soil has the MDD of 1.72 gm/cc an addition of 1% lime and 1% Jute Fiber reduces the MDD to 1.58 gm/cc and addition of 2% lime and 2% Jute Fiber further reduces the MDD of mixed soil to 1.47 gm/cc. The decrease results from the flocculation and agglomeration of clay particles caused by cation exchange reaction leading to corresponding decrease in dry density. The decrease in the MDD of the lime treated soil is reflective of the increased resistance offered by the flocculated soil structure to the compactive effort. This agrees with the findings of the other investigators of this area.

Effect of Jute fibre and Lime addition on strength characteristics of soil:

From figure 2a, 2b, 2c, 2d, 2e shows that the variation of CBR of soil- lime and Jute Fiber combination for soaked condition. From curve, we see that for 1% jute fibre and 1% lime addition, the CBR value for soaked conditions increase gradually to a value slightly more than those of 0% jute fiber content .But at 2% jute fiber and 3% jute fiber content for soaked CBR reach to a peak value of 5.27% and 8.10% respectively and thereafter CBR value continue to drop with further addition of jute fiber. This suggests that for each given percentage of lime content, there exists an optimum amount of jute fiber which gives maximum value CBR. This enhances the lime pozzolanic reaction and as a result CBR value increases. But further addition of jute fiber at 4% with lime content 4% , manifests as free fiber which is in excess of jute fiber required for lime pozzolanic reaction and this additional jute occupies the space in between the soil particles in the specimen and thus reduces the bond and CBR value of the soil jute fiber lime mixture.

From the above discussion an inference may be drawn that with the increase in admixtures content CBR values for soaked conditions increases .Out of the above discussed four cases, we seen that the combination of 3% lime and 3% Jute Fiber gives the highest value of CBR of 8.10 % for soaked condition, so it is increased compared to that of original soil.

Conclusion:

General increase in OMC and decrease in MDD was found when Jute Fiber was added with Lime. Addition of Jute Fiber with lime found to improve the soil strength characteristics substantially. This is due to the increased pozzolonic activities in presence of lime and Jute Fiber. Based on the present investigation, it is concluded that CBR value of soil increases with the inclusion of jute fibre and Lime. When the jute fibre content is increased, the CBR value of soil further increases and this increase is remarkable at fibre content of 3%. The maximum increase in CBR value was found to be more than 360 % over that of plain soil at mix proportion of 94% of plain soil, 3% of fiber content and 3% of Lime content. It has been concluded that reinforcement of soil using jute-geotextile 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 natural jutegeotextile reinforcement is a superior solution for the construction of low volume roads on weak subgrades.

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Biography:

Naveen Kumar A.B was born in Hassan, India, in 1988. He received the B.E. degree in Civil Engineering from the Visvesvaraya Technological University, India, in 2009, and the M.Tech. Degrees in Highway Technology from the R.V College of Engineering(RVCE) Bangalore, India, in 2012 and pursuing his Ph.D. Degree from the Visvesvaraya Technological University, India, In 2009, he joined the Department of Civil Engineering, in KS Polytechnic, India as a Lecturer, and he was an Assistant Professor, in Yellamma Dasappa Institute of Technology from 2012 to 2014, later he joined as an Assistant Professor in S.J.B Institute of Technology (SJBIT), Bangalore, India from 2014 to 2016. Currently he is working as a Faculty Member in Civil Engineering Department, Mettu University, Mettu, Ethiopia. His current research interests include stabilization of flexible pavement layers, Transportation Engineering, Traffic Engineering, Railway Engineering, utilization of recycled materials for road construction. He has published research articles in reputed national and international journals and also presented research papers in various conferences. He is a Life Member for reputed journals like IJMER and etc. He got the best Academic Performer Awards also.