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Effect Lime and Recron Fibre on Geotechnical Properties of Black Cotton Soil

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Abstract: ***Clayey soils are considered as the weakest subgrade soil from civil engineering point of view under moist condition. These soils attract and absorb water and loses their strength. Because of this reason certain inherent properties of these clayey soils need modification for their bulk use in construction of highways, embankments etc. Recently, many synthetic fibres have emerged to strengthen soft soils. Synthetic fibres are low-cost materials, hydrophobic and chemically inert in nature which does not allow the absorption or reaction with soil moisture. The inclusion of synthetic fibres provides reinforcement to the soil and use of lime as a soil stabilizer in BC soil cut down the plasticity index and also increase its strength. For this an extensive laboratory test program was conducted to analyse the variation geotechnical properties of soil by changing the percentage of recron fibre at an optimum dose of lime. The laboratory tests include Atterberg Limit Test, Modified Proctor Test, Unconfined Compressive Strength Test and California Bearing Ratio Test. To conduct different tests on soil sample the proportion of lime is kept fixed and proportion of polyester recron fibre is varied from 0% to 1% by dry weight of soil sample for different lengths of fibre(6 mm, 12 mm & 18 mm separately). Optimum dose of lime is find out by plasticity index of BC soil mixed with varying percentages of lime (4%, 6%, 8% and 10%). Results of the experiments shows that with the increase in the appropriate percentage in recron fibre the Unconfined Compressive Strength and California Bearing Ratio increases. On increasing the length of Recron Fibre, the Unconfined Compressive Strength and California Bearing Ratio also increases. Combination of lime and recron fibre in BC soil give higher CBR value. Therefore it can be used in the improvement of Clayey Soil Subgrade in pavement design and in the construction of embankements.***

Index Terms: ***CBR, Unconfined Compression test, BC soil, Recron Fibre, Plasticity index***

I. INTRODUCTION

Black cotton soil is one of the major soil deposits of India. They exhibit a high rate of swelling and shrinkage when exposed to changes in moisture content and hence have been found to be most troublesome from engineering consideration. Black cotton soils experience periodic swelling and shrinkage with variation in water content. Such cyclic swell - shrinkage movements of ground causes considerable damage to the structures founded on them. In the design of highways, less CBR (California Bearing Ratio) value soils require high pavement thickness for particular design traffic, resulting in costly pavement composition. To overcome this problem associated with black cotton soil, soil stabilization using various conventional and non-conventional stabilizers are studied. These methods vary from replacing existing soil with good soil to methods that involve treatment of soil with chemical stabilizers that involve a complex process. The choice of a stabilizing method depends mainly on the type of soil and its properties.

Recently, many synthetic fibres have emerged to strengthen soft soils. Synthetic fibres are manufactured using plant materials and minerals: viscose comes from pine trees or petrochemicals, while acrylic, nylon, and polyester come from oil and coal. Synthetic fibres are low-cost materials, hydrophobic and chemically inert in nature which does not allow the absorption or reaction with soil moisture. The inclusion of synthetic fibres provides reinforcement to the soil. Use of lime as a soil stabilizer in BC soil cut down the plasticity index and also increase its strength. In this study combination of Polyester Recron Fibre (6mm, 12mm and 18 mm) and Lime are used to improve the properties of BC soil. Lime content is kept fixed and percentage of recron fibre is varied from 0% to 1% of weight of dry soil for different lengths of recron fibre. CBR (California Bearing Ratio) value and Unconfined Compression strength of BC soil mixed with lime and recron fibre is evaluated.

II. LITERATURE REVIEW

In recent years an increasing number of non- traditional have been developed for soil stabilizing purposes. These stabilizers are becoming popular due to their low cost, ease of application and short curing time. When these stabilizers applied to the appropriate soil and aggregates using the construction techniques can produce a dramatic improvement in its engineering properties.

Suthar M. and Aggarwal P. (2015) has conducted laboratory studies on the modification of clayey soil using lime and recron 3s fibre (6mm and 12mm) separately. A series of proctor compaction and CBR tests (un-soaked and soaked) was carried out on clayey and clayey soil mixed with lime in 2%, 4% and 6% by weight of dry soil. Recron 3s fibre are also mixed separately in quantity 0.3%, 0.5%, 1.0% 2.0% and 3.0% by weight of dry soil. CBR value of the clayey soil improved by 63.7% using lime and 10.9% and 11.2% using 6 mm and 12 mm long fibre respectively.

Kumar A. et al (2006) in their research on "Compressive strength of fibre reinforced highly compressible clay",

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mixed polyester fibre with soft clay soil to investigate the relative strength gain in terms of unconfined compression. Samples were tested in unconfined compression with 0%, 0.5%, 1.0%, 1.5% and 2.0% plain and crimped polyester fibres. It was observed that unconfined compressive strength of clay increases with the addition of fibres.

Dhar S. and Hussain M. (2018) studies the effect of lime and discrete plastic fibre on the strength and stiffness behaviour of a clayey soil. A series of unconfined compressive strength (UCS), split-tensile strength (STS) and California bearing ratio (CBR) tests are performed on clayey soil with different percentage of lime (i.e. 3%, 5% and 9% by dry weight of soil) and fibre (i.e. 0.5%, 1%, 1.5% and 2% by dry weight of soil) at different curing periods (i.e. 7, 14 and 28 days). The results show that the addition of lime improved the compressive and tensile strength of the soil up to 5% of lime beyond which it decreases. The role of fibre on lime-stabilised soil is found to be more significant than that of fibre-reinforced soil. The inclusion of fibre within lime stabilised soil helps to increase the peak axial stress, achieve the residual strength, increase the modulus of elasticity and toughness, and change the failure mode of lime-stabilised soil from completely brittle to ductile

Nguyen G. et al (2015) has done soil improvement using polyester fibres of length 70mm mixed in soil SC as random reinforcement in the amount of 0.5%, 1.0% and 1.5%. Improvement of soil was measured by direct shear tests, using a shear box of size 0.3m x 0.3m x 0.15m. It will be shown that for tested soil, the optimal amount of fibres is 1.0% when the increase of angle of internal friction was up to 6.0o (from 45.3o to 51.3o) and an increase of cohesion was up to 17.5kPa (from 0 kPa to 17.5 kPa) in comparison with soil without fibres.

Tiwari U. et al (2018) conducted an experimental program to study the effect caused by the action of lime on the geotechnical characteristics of expansive subgrade soils. Expansive soil treated with varying percentages of lime, 0, 3, 6, 9, and 12 per cent were studied. It was found that the optimum dosage of lime at 12% mixed with soil in significant improvement in strength and durability and reduction in swelling and plasticity properties.

Maheshwari K.V. et al (2013) used clayey soil as subsoil below footing reinforced with randomly distributed fibres and conducted a series of laboratory model footing tests. The dosages of 12 mm length polyester fibres were taken as 0.25%, 0.50% and 1.00%. The results of load settlement curve of the model footing test on un-reinforced soil and soil reinforced with various amount and depths of fibre reinforced soil were recorded.

III. MATERIAL

A. Black Cotton (BC) Soil

The soil is collected from the college campus in front of Civil Department MANIT, Bhopal. According to IS (Indian Standards) soil classification, the soil was classified as Clay with high compressibility (CH). The geotechnical properties of BC soil was determined in the laboratory as per IS test procedure and tabulated in Table 1

Table 1: Properties of BC soil

S. No.	Properties of untreated soil	Value
1.	Consistency Limits Liquid limit (%) Plastic Limit (%) Plasticity index (%)	 50.00 31.00 19.00
2.	Differential Free Swell (%)	51.00
3.	Specific Gravity	2.69
4.	IS Soil Classification	CH
5.	Standard Proctor Test Maximum Dry Density (g/cc) Optimum moisture content (%)	 1.61 20
6.	Modified Proctor Test Maximum Dry Density (g/cc) Optimum moisture content (%)	 1.75 17
7.	Unconfined Compressive Strength (KN/m^2)	260.60
8.	California Bearing Ratio CBR Un soaked (%) CBR Soaked (%)	 11.60 1.82

B. Polyester Recron Fibre

Polyester staple hollow Recron 3S fibre 6 mm (CT2012), 12 mm (CT2024) and 18 mm (CT2436) long are used in this study. The fibres are purchased from FIBRECON MARKETING, KOLKATA. Figure 3.2 shows the loose 6 mm, 12 mm and 18 mm fibre. The properties of fibre are shown in Table 2:-

Table 2: Properties of Polyester recron fibre

Type	Hollow
Shape	Hollow elliptical
Diameter	40-45 microns
Tensile strength	≥450 mpa
Length of fibre	6/12/18 mm
Specific Gravity	1.31-1.41
Elongation	≥ 35%
Melting point (^{0}C)	250-265

Fig.1: 6mm, 12mm and 18mm Polyester Recron Fibre

C. Lime

The lime was purchased from the local market of Bhopal @ Rs 60 per bag of 10 Kg. Hydrated lime is used in this study having following properties shown in the Table 3

Table 3: Properties of lime

Type of lime	Hydrated lime
Specific Gravity	2.4-2.5
Color	White

Fig.2: Hydrated Lime used in this study

IV. TESTING PROGRAMME

Atterberg's Limits Tests was performed on untreated BC soil and BC soil mixed with varying percentage of lime (4%, 6%, 8% and 10%) to determine plasticity index of treated BC soil in accordance to IS 2720 Part 5 – 1985. Optimum dose of lime was find out by plasticity index of treated BC soil. Modified Proctor Test was carried on untreated BC soil. BC soil was treated with optimum dose of lime and varying percentages of Recron Fibre(0.3%, 0.5%, 0.8% and 1%) as per IS 2720 (Part 8)-1983, value of maximum dry density (MDD) and optimum moisture content (OMC) were determined. Treated BC soil with lime and Recron Fibre was tested for Unconfined Compression Strength (UCS) as per IS 2720 (Part-10):1991 and for Soaked- California Bearing Ratio (CBR) value as per IS: 2720 (Part 16)-1979.

V. RESULTS AND DISCUSSIONS

A. Effect of Lime on Plasticity Index

Liquid Limit and Plastic Limit tests were conducted on untreated BC soil and BC soil mixed varying percentage of Lime. Liquid Limit of Treated BC soil decreases up to optimum content of lime and then increases on further increase in lime content. Plastic Limit of treated BC soil increases with increase in lime content. Therefore Plasticity Index (PI) of BC soil decreases from 19% to 8.05% up to optimum percentage (8%) of lime and then increases. The variation of Liquid Limit, Plastic Limit and Plasticity Index of BC soil treated with varying percentages of Lime are shown in the figure 3

Table 4: Soil treated with different percentage of lime

S.No.	Atterberg's LimitS	Untreated Soil	4% Lime	6% Lime	8% Lime	10% Lime
1.	Liquid Limit(LL)	50.00	45.00	43.00	**41.00**	42.00
2.	Plastic Limit(PL)	31.00	32.50	32.80	**32.95**	33.10
3.	Plasticity Index(PI)	19.00	12.50	10.20	**8.05**	8.90

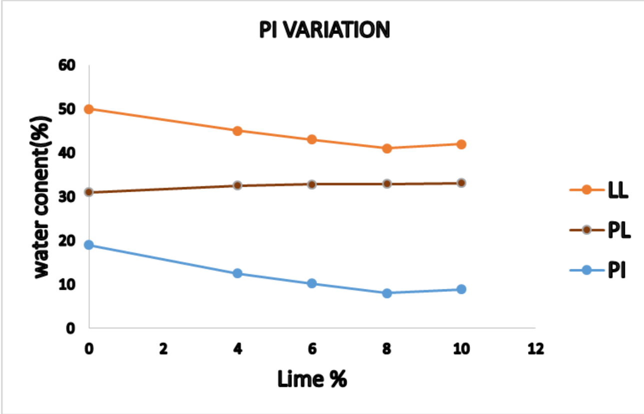

Fig.3: Variation of LL, PL and PI with varying percentages of lime

B. Modified Proctor Test Results

Compaction test is performed on virgin soil as well as soil mixed with varying percentage (0.3%, 0.5%, 0.8% and 1%) and varying length (6mm, 12mm and 18mm separately) of polyester recron fibre at a fixed dose of lime (8%) and graphs is plotted for Water content versus Dry density.

a) ***Modified Proctor test results mixed with 6mm/12mm/18mm long recron fibre and lime***

Results of Modified Proctor Test of BC soil mixed with 6mm, 12mm and 18mm recron fibre and lime are presented in Fig. 4, Fig. 5 and Fig. 6

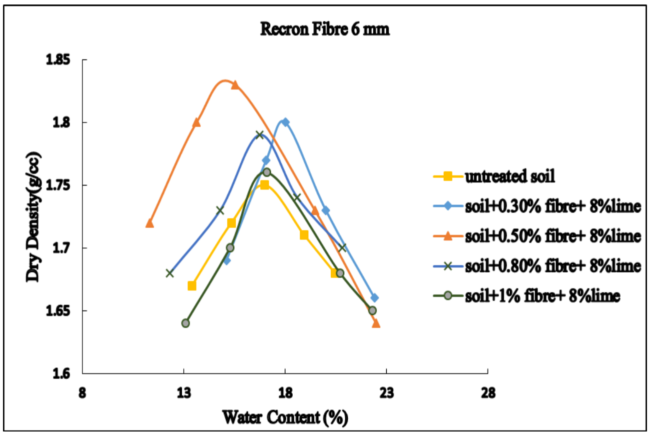

Fig. 4: Results of Modified Proctor Test of BC soil mixed with 6mm long recron fibre and lime

Fig4 shows that on addition of 6 mm recron fibre and lime increase the MDD of the BC soil up to 0.5% recron fibre and thereafter MDD decreases on further addition of recron fibre. MDD of soil varies from 1.75 g/cc to 1.83 g/cc (at 0.5%). While OMC of soil on addition of 6 mm recron fibre and lime varies from 15.52% to 18.0% with no set pattern.

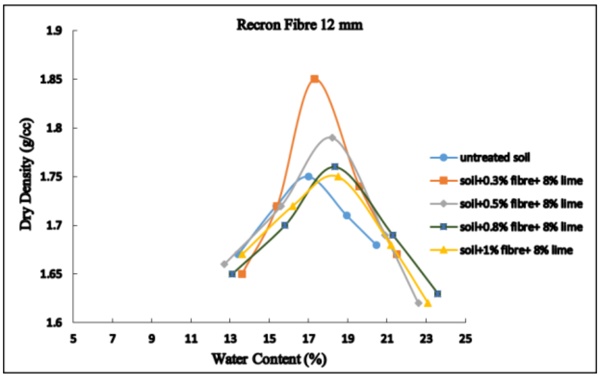

Fig. 5: Results of Modified Proctor Test of BC soil mixed with 12mm long recron fibre and lime

Fig.5 shows that on addition of 0.3%, 0.5%, 0.8%, 1% (by dry weight of soil) 12 mm long recron fibre with 8% (by dry weight of soil) lime in BC soil, the MDD initially increases from 1.75 g/cc to 1.85 g/cc (at 0.3% fibre) and then decreases with further increase in fibre content. OMC varies from 17.0% to 18.50% with no set pattern.

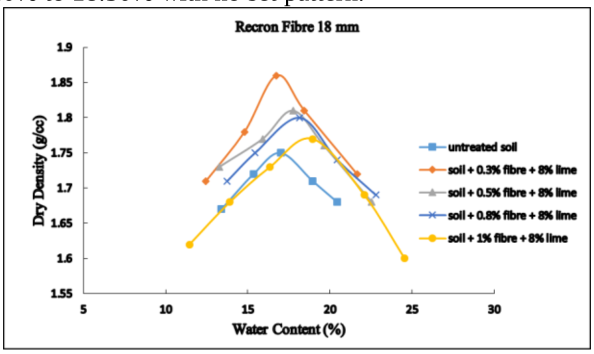

Fig. 6: Results of Modified Proctor Test of BC soil mixed with 18mm long recron fibre and lime

Fig.6 shows that on addition of 0.3%, 0.5%, 0.8%, 1% (by dry weight of soil) 18 mm long recron fibre with 8% (by dry weight of soil) lime in BC soil, the MDD initially increases from 1.75 g/cc to 1.86 g/cc (at 0.3% fibre) and then decreases with further increase in fibre content. OMC varies from 16.75% to 18.95% with no set pattern.

C. Unconfined Compression Strength Test Results

Unconfined Compression Test was performed on virgin soil as well as soil mixed with varying percentage (0.3%, 0.5%, 0.8% and 1.0%) and varying size length (6mm, 12mm and 18mm) of polyester recron fibre at a fixed dose of lime (8%). UCS Test was also performed at a curing period of 3 days and 7 days. It is observed that by addition of 6 mm recron fibre(0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime(8% by dry weight of soil) in BC soil, the UCS value initially increases from 260.60 KN/m2 to 735.08 KN/m2 (up to 0.5% fibre) and with further increase in fibre content it starts decreasing. The UCS value of soil also increases with increase in the curing period. Fig. 7 shows the percentage increase in UCS value of treated soil with respect to untreated soil at different curing for 6 mm long recron fibre.

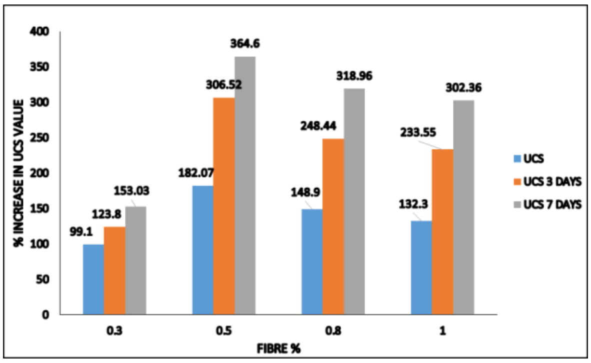

Fig. 7: Variation of UCS value at different curing period with varying percentages of 6 mm long recron fibre

It is observed that by addition of 12 mm recron fibre (0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime (8% by dry weight of soil) in BC soil, the UCS value initially increases from 260.60 KN/m2 to 1621.86 KN/m2 (up to 0.3% fibre) and with further increase in fibre content it starts decreasing. Fig. 8 shows the percentage increase in UCS value of treated soil with respect to untreated soil at different curing for 12 mm long recron fibre.

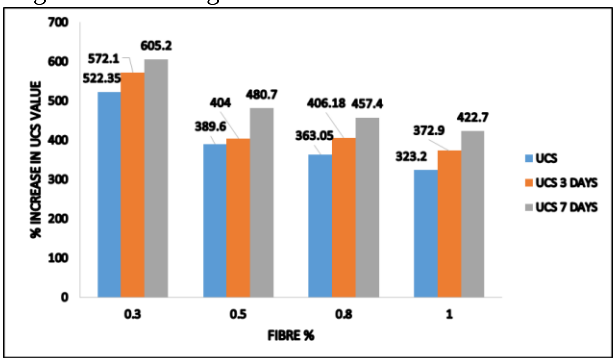

Fig. 8: Variation of UCS value at different curing period with varying percentages of 12 mm long recron fibre

It is observed that by addition of 18 mm recron fibre (0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime (8% by dry weight of soil) in BC soil, the UCS value initially increases from 260.60 KN/m2 to 2183.62 KN/m2 (up to 0.3% fibre) and with further increase in fibre content it starts decreasing. Fig. 9 shows the percentage increase in UCS value of treated soil with respect to untreated soil at different curing for 18 mm long recron fibre.

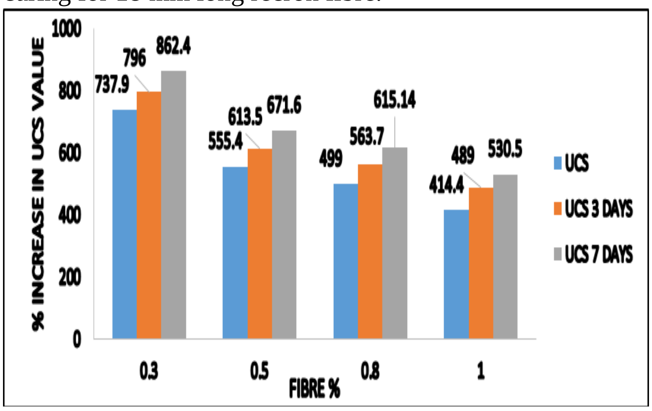

Fig. 9: Variation of UCS value at different curing period with varying percentages of 18 mm long recron fibre

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D. California Bearing Ratio Test under Soaked Condition Results

The CBR tests are performed on untreated as well as treated soil with varying percentage(0.3%, 0.5%, 0.8% and 1.0%) and varying size length(6mm, 12mm and 18mm) of polyester recron fibre at a fixed dose of lime(8%).

It is observed that by addition of 6 mm recron fibre(0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime(8% by dry weight of soil) in BC soil, the CBR value of soil increases up to 0.5% from 1.82% to 6.204% then it starts decreasing with further increase in fibre content. There is a maximum 240.90% increase in CBR value with respect to CBR value of untreated soil. Fig. 10 shows the percentage increase in CBR value of treated soil with respect to CBR value of untreated soil.

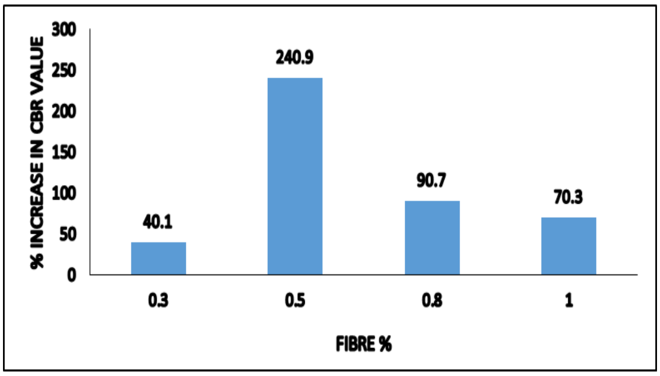

Fig. 10: Percentage change in Soaked CBR versus varying percentage of 6 mm long recron fibre

It is observed that by addition of 12 mm recron fibre (0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime (8% by dry weight of soil) in BC soil, the CBR value of soil increases up to 0.3% from 1.82% to 6.56% then it starts decreasing with further increase in fibre content. There is maximum 260.40% increase in CBR value with respect to CBR value of untreated soil. Fig. 11 shows the percentage increase in CBR value of treated soil with respect to CBR value of untreated soil for 12 mm long recron fibre.

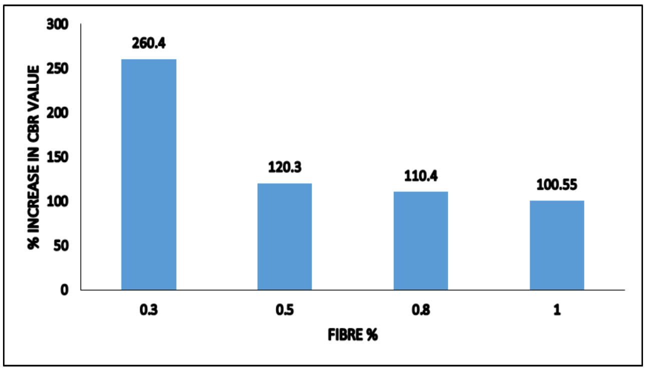

Fig. 11: Percentage change in Soaked CBR versus varying percentage of 12 mm long recron fibre

It is observed that by addition of 12 mm recron fibre (0.3%, 0.5%, 0.8% and 1.0% by weight of dry soil) and lime (8% by dry weight of soil) in BC soil, the CBR value of soil increases up to 0.3% from 1.82% to 6.56% then it starts decreasing with further increase in fibre content. There is maximum 260.40% increase in CBR value with respect to CBR value of untreated soil. Fig. 12 shows the percentage increase in CBR value of treated soil with respect to CBR value of untreated soil for 18 mm long recron fibre.

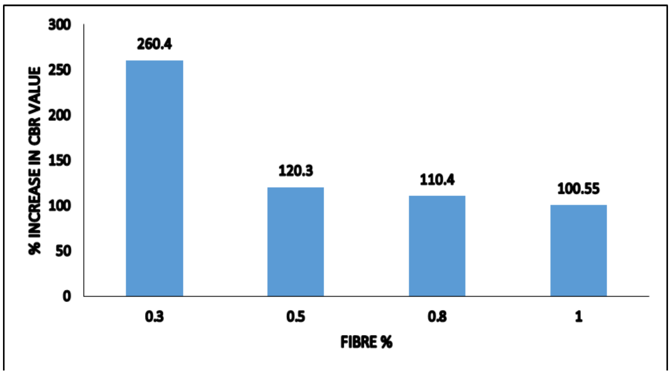

Fig. 12: Percentage change in Soaked CBR versus varying percentage of 18 mm long recron fibre

VI. CONCLUSIONS

On the basis of the results obtained from the experiments performed in the laboratory following conclusions are made:-

- Plasticity index of BC soil decreases on the addition of lime and shows an optimum value at lime content of 8% of the dry weight of soil. Its value decreases from 19% to 8.05%.
- On addition of 6 mm recron fibre and lime increase the MDD of the BC soil up to 0.5% recron fibre and thereafter MDD decreases on further addition of recron fibre.
- On addition of Recron Fibre (12 mm and 18 mm both separately) with Lime increases the MDD of the BC soil up to 0.3% recron fibre and thereafter MDD decreases on further addition of recron fibre.
- On addition of a varying percentage of 6 mm recron fibre and fixed percentage of lime increases the UCS value of BC soil from 260.60 KN/m^2 to 735.08 KN/m^2 up to 0.5% of recron fibre and thereafter on further addition of recron fibre UCS value of soil decreases. The UCS value of soil also increases with the increase in the curing period. For optimum percentage of 6 mm recron fibre i.e. 0.5% the UCS value increases from 735.08 KN/m^2 to 1210.57 KN/m^2 at 7 days. There is a maximum 182% increase in UCS value of BC soil at with respect to the UCS value of untreated soil.
- On addition of a varying percentage of 12 mm recron fibre and fixed percentage of lime increases the UCS value of BC soil from 260.60 KN/m^2 to 1621.86 KN/m^2 up to 0.3% of recron fibre and thereafter on further addition of recron fibre UCS value of soil decreases. The UCS value of soil also increases with the increase in curing period. For optimum percentage of 12 mm recron fibre i.e. 0.3% the UCS value increase from 1621.86 KN/m^2 to 1837.70 KN/m^2 at 7 days. There is maximum 522% increase in UCS value of BC soil with respect to the UCS value of untreated soil.
- On addition of varying percentage of 18 mm recron fibre and fixed percentage of lime increases the UCS value of BC soil from 260.60 KN/m^2 to 2183.62 KN/m^2 up to 0.3% of recron fibre and thereafter on further addition of recron fibre UCS value of soil decreases.

The UCS value of soil also increases with the increase in the curing period. For the optimum percentage of 18 mm recron fibre i.e. 0.3% the UCS value increase from 2183.62 KN/m^2 to 2507.92 KN/m^2 at 7 days. There is a maximum 737% increase in UCS value of BC soil with respect to the UCS value of untreated soil

- As the length of recron fibre increases, the UCS value of BC soil also increases.
- On addition of a varying percentage of 6 mm recron fibre and optimum percentage of lime, the CBR

Value under soaked condition increases from 1.82% to 6.32% up to 0.5% of recron fibre and thereafter CBR value of soil decreases on further addition of fibre. There is a maximum 240% increase in CBR value of BC soil with respect to CBR value of untreated soil.

- On addition of a varying percentage of 12 mm recron fibre and optimum percentage of lime, the CBR value under soaked condition increases from 1.82% to 6.56% up to 0.3% of recron fibre and thereafter CBR value of soil decreases on further addition of fibre. There is a maximum 260% increase in CBR value of BC soil with respect to CBR value of untreated soil.
- On addition of a varying percentage of 18 mm recron fibre and optimum percentage of lime, the CBR value under soaked condition increases from 1.82% to 7.30% up to 0.3% of recron fibre and thereafter CBR value of soil decreases on further addition of fibre. There is a maximum 301% increase in CBR value of BC soil with respect to CBR value of untreated soil.
- CBR value of BC soil increases with the increase in the length of the recron fibre.

Hence, combination of lime and recron fibre can be used to improve the strength properties like CBR value and UCS value of the BC soil. Combination of lime and recron fibre in BC soil give higher CBR value. Therefore it can be used in the improvement of Clayey Soil Subgrade in pavement design.

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