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Experimental Investigation on Strength Characteristics of Sisal Fiber Reinforced Soil Stabilized With Sugar Cane Bagasse Ash

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Abstract: In many situations, soils cannot be used directly as road service layers, foundation layers and as a construction material; hence the properties of those soils should be changed. Expansive soils are one of those kinds of soils whose volume change takes place while it comes in contact with water. It expands during the rainy season due to intake of water and shrinks during summer season. The wetting and drying process of a sub-grade layer composed of black cotton (BC) soil result into failure of pavements in form of settlement and cracking. Therefore, prior to construction of a road on such sub-grade, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the engineering properties of the existing soil by stabilization. There are number of soil improvement techniques. These include stabilization of soil by lime, cement, lime and cement, bitumen, chemicals etc. sugar cane bagasse ash (SCBA) is also used to stabilize the black cotton soil. SCBA is abundantly available as industrial and Agricultural waste and is hazardous if not disposed scientifically. Pavement construction is one of the major area in which a large quantity of SCBA could be effectively utilized. The presence of small amount of fibres in soil enhances soil strength and reduces swell shrink behavior of soil. Using fibres reinforcement in sub grades can increase safety coefficient of embankment stability and also decrease displacements. Furthermore, if the weak sub grade is stabilized or reinforced, the crust thickness required will be less, which results in less repairs and overall economy.

The present work is aimed to assess the improvement in the strength and stability characteristics in soft Sub-grade soil by using the SCBA for the stabilization and then Sisal fibre as reinforcing material. Randomly distributed fibre reinforced soil technique is used to prepare the reinforced soil samples. In RDFRS technique the mixing of reinforcement in the soil is

Very easy and no special skill is required. The reinforcement is added by percentages of the weight of the BC soil sample and by following certain aspect ratio i.e. length/diameter (L/D) ratio. Attempt is made to determine optimum combination SCBA and fiber content for maximum gain in strength.

Keywords: BC Soil, SCBA, Sisal Fibre, OMC, MDD, CBR and Swelling.

I. INTRODUCTION

Black Cotton (B.C) soil is highly plastic clayey soil. In dry state, it is very stiff that clods may not be effortlessly pulverized to be treated for its use in road construction. This poses severe troubles when considered in respect to subsequent performance of road .In addition, the softened sub-grade has a tendency to up heave into the upper layers of pavement, mainly when sub-base consists of stone soling with lot of voids. Regular intrusion of soaked B.C soil perpetually leads to road failure. Roads resting on B.C soil base develop undulation on pavement top because of strength loss of sub-grade through softening at time of monsoons. Soaked laboratory CBR standards of B.C soil are usually found in range of 2 to 4%. Due to very small CBR values on sub-grade B.C soil, enormous pavement stratum is vital to design flexible pavement. Research & Development (R&D) efforts were made for a long time to advance strength characteristics of B.C soil with new technologies.

For rectification of embankment performance problems produced by lack of strength or uniformity, entire pavement section would have to be replaced or either removed. Embankment that is to be built should be strong, uniform, durable, resilient and economical as possible. An economical embankment is one that performs well for many decades, present methods to help attain adequate stiffness, strength, and uniformity for a given embankment soil. The course of action initiates with a good soil survey at the site so that accurate designing and construction procedures can be included for the project. Efforts are therefore made to strengthen sub-grade soil through mechanical stabilization or soil-cement, lime-fly ash, soil-rice husk ash or geosynthetics to advance its performance and a latest technique is soil reinforcement. Soil reinforcement is reliable and efficient practice to enhance stability and strength of soil.Engineering and chemical properties of Indian ashes of various Industries tested at CRRI have been found to be favorable to construction of roads and embankments. Properties of SCBA from different Industries vary and therefore it is recommended that characterization of ash proposed to be used should be conducted to establish the design parameters. The significant properties of SCBA that must be considered when it is used for construction of road embankments are gradation, compaction characteristics, shear strength, compressibility and permeability properties. Individual SCBA particles are spherical in shape, generally solid, though sometimes hollow. SCBA possesses a silty texture and its specific gravity would be in the range of 2.2 to 2.4, which is less than natural soils. SCBA is a non- plastic material. Zach Thomas (2002) carried out the experiments to found out the effects of adding SCBA to soil were evaluated in some common soil tests. When SCBA and soil are mixed and compacted immediately, the SCBA causes the mixture to have a higher dry unit weight, by filling in voids with ash particles. Use of fiber inclusions to improve the properties of compacted soil is becoming increasingly common in geotechnical engineering projects. However, the technique requires extensive testing before it can be implemented. Gosavi et al, 2004, did an attempt to investigate the strength behavior of locally available BC Soil reinforced with randomly mixed (i) geotextile woven fabric and (ii) fibreglass. Results showed that there was an increase in the value of cohesion and slight decrease in the value of OMC with the addition of 2% of these fibres in black cotton soil. The trend was reverse with 3% addition of the fibres. CBR value of the black cotton soil also increased considerably due to the addition of the fibres in the soil. Literature survey was done related to the study which is given as: Santoni et al. (2001) laid full length pavement section over 1 % fiber reinforced sub-grade soil. The test track was tested using simulated C-130 aircraft and military cargo trucks. Rakesh et al. (1999) studied the characteristics of fibre reinforced sand by conducting CBR tests, triaxial tests and plate load tests. McGowan et al (1978) classified the reinforcement in to two major categories, namely the soil reinforced with ideally inextensible inclusions (like metal strips and bars) known as reinforced earth, and the soil reinforced with ideally extensible inclusion (natural and synthetic fibers, plant roots, polymeric fabric) known as Ply soil.

The effect of polymer fibre inclusion on plain SCBA was studied by Chakraborty and Dasgupta (1996)by conducting triaxial tests. The fiber content ranging from 0 to 4 % by weight of RHA was used with constant fibre aspect ratio of 30. The study indicates increase in friction angle. The study on soil SCBA mixture reinforced with 1% polyester fibres (20 mm length) was conducted by Kaniraj and Havanagi (2001), which indicated the combined effect of RHA and fibre on soil. Kaniraj and Gayatri (2003) indicated that 1% polyester fibers (6 mm length) increased strength of RHA and change their brittle failure into ductile one. Dhariwal, Ashok (2003) carried out performance studies on California bearing ratio values of SCBA reinforced with jute and nonwoven geo fibres. A review of the literature revealed that various laboratory investigations have been conducted independently either on SCBA/ lime stabilization of soil or fibre reinforced soil. Studies concerning RHA and lime utilization for soil stabilization have been conducted in the past years by many investigators like

A. Ankita Sonkaret al (2017)

The soil was examined for compaction test and unconfined compression test at four different fiber contents (0.25%, 0.5%, 1% and 1.25%).The Maximum Dry Density (MDD) of fiber stabilized soils goes on decreasing and Optimum Moisture Content (OMC) goes on increasing with increase in the percentage of fiber in soil. The result indicated that inclusion of palm fiber increases the ductility and strength of soil

B. Amrutha Mathew et al (2016)

California bearing ratio values increased with addition of optimum percentage of sisal fibre, bagasse ash and glass powder waste to the mixture of black cotton soil. The best result was obtained for mixture of black cotton soil and optimum dosage of 0.9% of sisal fibre, 7% bagasse ash and 14% glass powder waste

C. MayuraYeole and Dr. J.R. Patil (2013

executed a laboratory CBR test on granular soil in presence and in absence of geotextile which was located in 1 or 2 layer in the mould. Single layer of geotextile was placed at depth of (25, 50, 100 mm) from top of mould, the maximum CBR obtained was at 25mm and when the geotextile was located in 2 layers at { (25 &75 mm),(50 &75 mm), (50 &100 mm)} CBR was increased and it was maximum at 25 & 75mm geotextile layer by 38.21% when correlated to CBR with absence of geotextile.

D. M. Bagra (Aug 2013)

In this, experimental learning was executed out on nearby existing (Doimukh, Itanagar, Arunachal Pradesh, India) soil with reinforcement of Jute fibres. Here soil samples were formulated at its MDD analogous to its optimal moisture content in CBR mould with and without reinforcement. Percentage of Jute fibre by dry weight of soil - 0.25%, 0.5%, 0.75% and 1% was taken. In the current investigation lengths of fibres were taken as 30 mm, 60 mm and 90 mm and two dissimilar dia, 1mm and 2mm were considered for each fibre length. Test results indicate that CBR value of soil rises on inclusion of fibre content. It was also seen that on increasing diameter & length of fibre further raises CBR value of reinforced soil and this rise is substantial at fibre content of 1 % for 90 mm fibre length having diameter 2 mm. Thus there is considerable rise in CBR value of soil with reinforcement of Jute fibre and this rise in CBR value will significantly reduce pavement sub grade thickness.

E. Dr. P Senthil kumar& R. Rajkumar (2012)

Flourishing utilization of geosynthetics is guaranteed for a given geotechnical application, as it is compatible & effective to improve soil properties when appropriately placed. In his study, performance of woven and non-woven geotextile, interfaced between soft subgrade and unbound gravel in an unpaved flexible pavement system and is performed out experimentally, utilizing the CBR test arrangement. In order to assess out performance, reinforcement ratio is obtained based on CBR load – penetration relation of both soft subgrade-gravel and soft subgrade-geotextile-gravel, separately, for woven and nonwoven geotextile. Effect of introducing geotextile layer between subgrade soil and base course layer and found that resistance to penetration increases with introduction of geotextile layer.

Table 1 - Properties and Classification of BC Soil

SpecificGravity	2.58
Grain Size Distribution	
Sand(%)	8.0
SiltandClay (%)	92
Natural Moisture Content (%)	41
Maximum Dry Density (gm/cm^3)	1.56
O.M.C. (%)	18.60
Liquid Limit (%)	72
PlasticLimit (%)	29
Plasticity Index (%)	43
CBR (%)	1.67(Soaked)
ISClassification	CH

II. METHODOLOGY

In the present study, Sieve analysis, Specific Gravity Test, Consistency Indices Liquid Limit, Plastic Limit, and Plasticity Index Modified Proctor's Test, and California Bearing Ratio tests were conducted on the Black Cotton Soil first by mixing with varying percentage of SCBA to stabilize the soil and then the varying percent of RHA at which the maximum CBR is gained is selected for the next step of the experiment. The optimum percentage of fly ash at which maximum CBR is achieved is then selected and gets reinforced with varying percentage of Sisal fibre. Among these varyingPercentages of the reinforcement the optimum quantity of fibre required to get maximum strength are known.

Table 2-Combinations of materials and the tests

Materials combination	Tests conducted for all combination
Block Cotton Soil only Block Cotton Soil + SCBA Block Cotton Soil + SCBA + Sisal Fibre	Specific Gravity Consistency Indices Modified Proctor's Test (Heavy Compaction) CBR Test (Soaked)

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III. RESULTS

In the present study, Specific Gravity Test, Consistency Indices Liquid Limit, Plastic Limit ,and Plasticity Index, Modified Proctor's Test, and California Bearing Ratio (CBR) Tests were conducted on the Black Cotton first by mixing with varying percentage of SCBA to stabilize the soil. The optimum percentage of SCBA at which maximum CBR is achieved is then selected and gets reinforced with varying percentage of synthetic Sisal fibre. Among these varying percentages of there in for cement the optimum quantity of fibre required to get maximum strength is known. For better understanding of the experiment the results are presented in the graphical form and where possible in tabular forms. it is analyzed that the rate of increment in engineering properties of the mix or combination is high up to aspect ratio of 40, but after that the properties are getting lowering down to the before maintained aspect ratio. Thus, the outcome is that the aspect ratio of 40 is more suitable for the Sisal fibre used in the experiment and the fiber concentration at which highest result is obtained is 0.75 percent by weight of the sample.

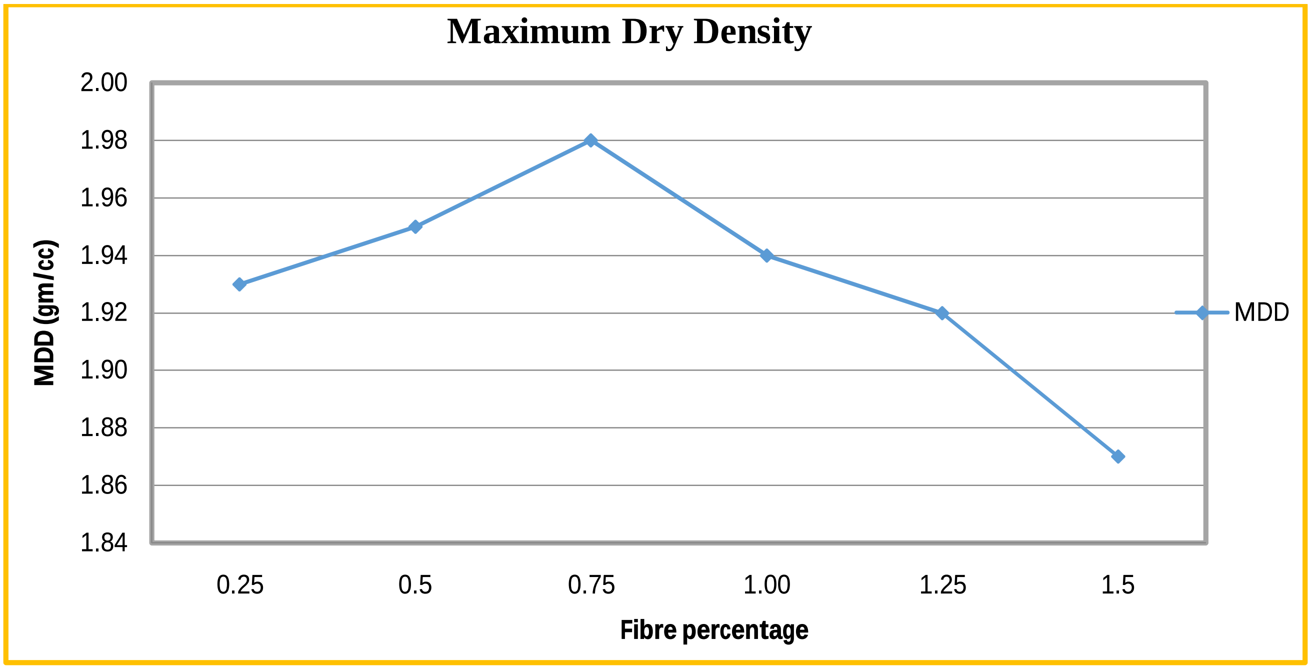

Figure1–MDD graph for Black Cotton Soil

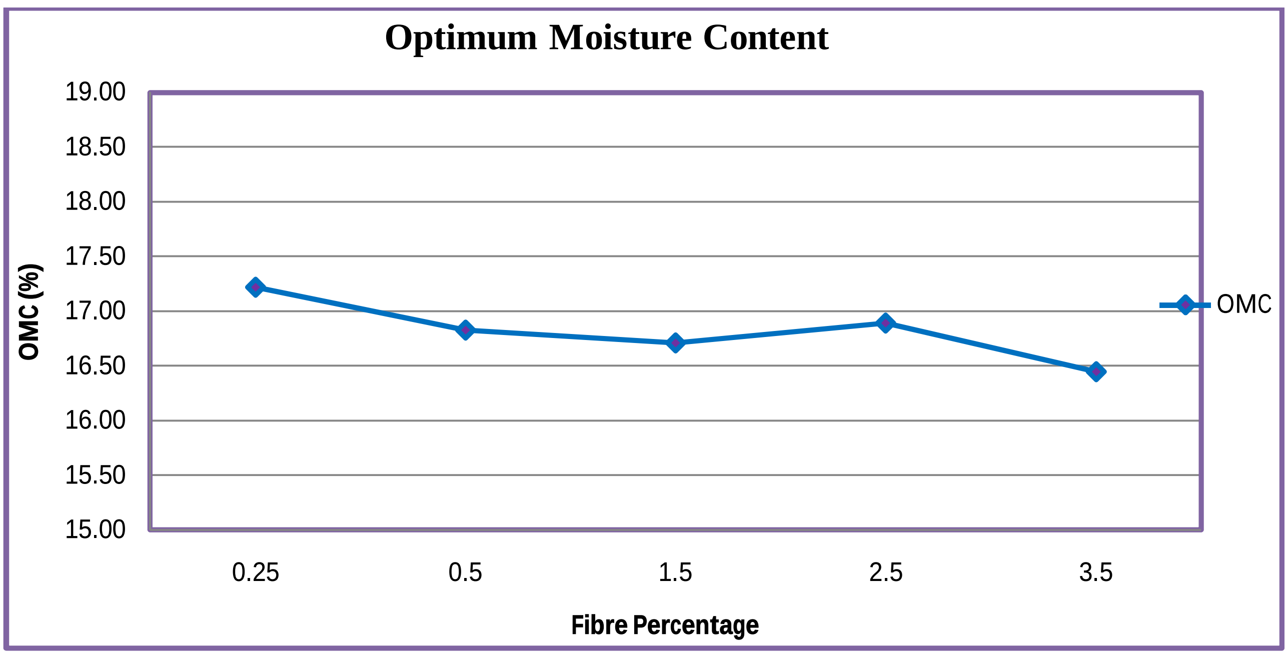

Figure2 – OMC graph for Black Cotton Soil

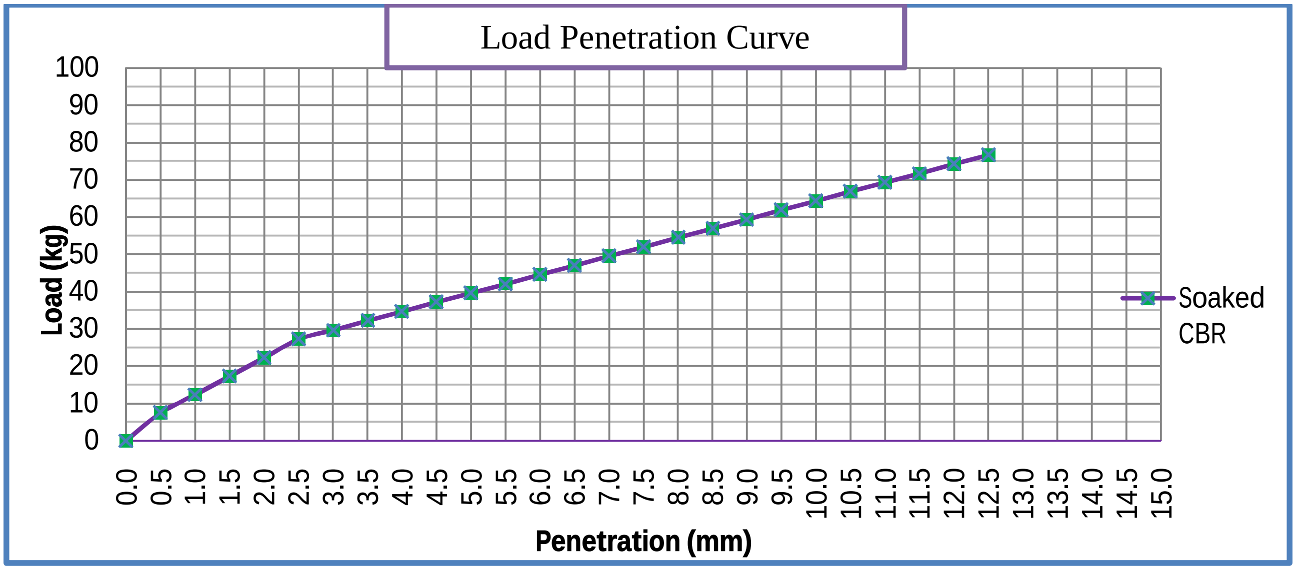

Figure3 – CBRGraphplotted forBlack Cotton Soil

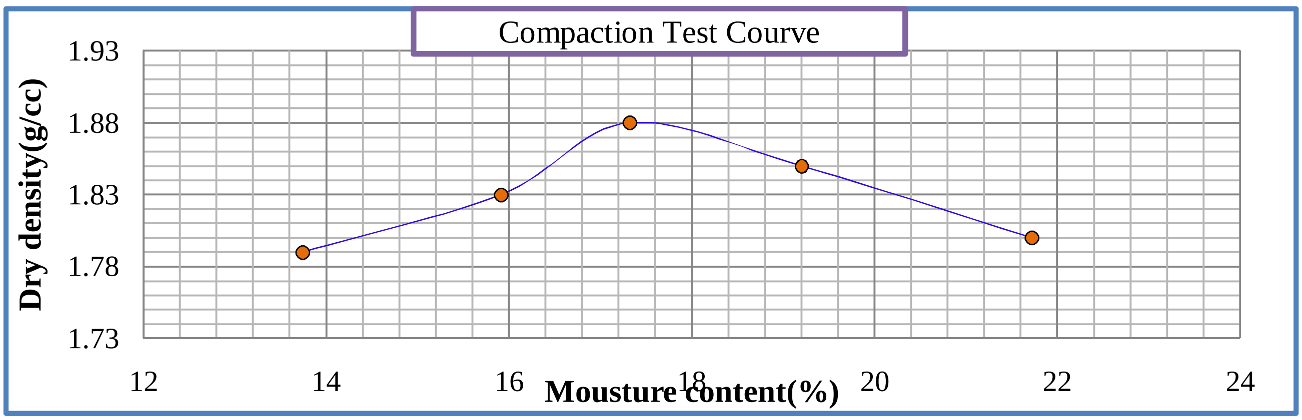

Figure-4MDD and OMC for BC Soil+20% SCBA

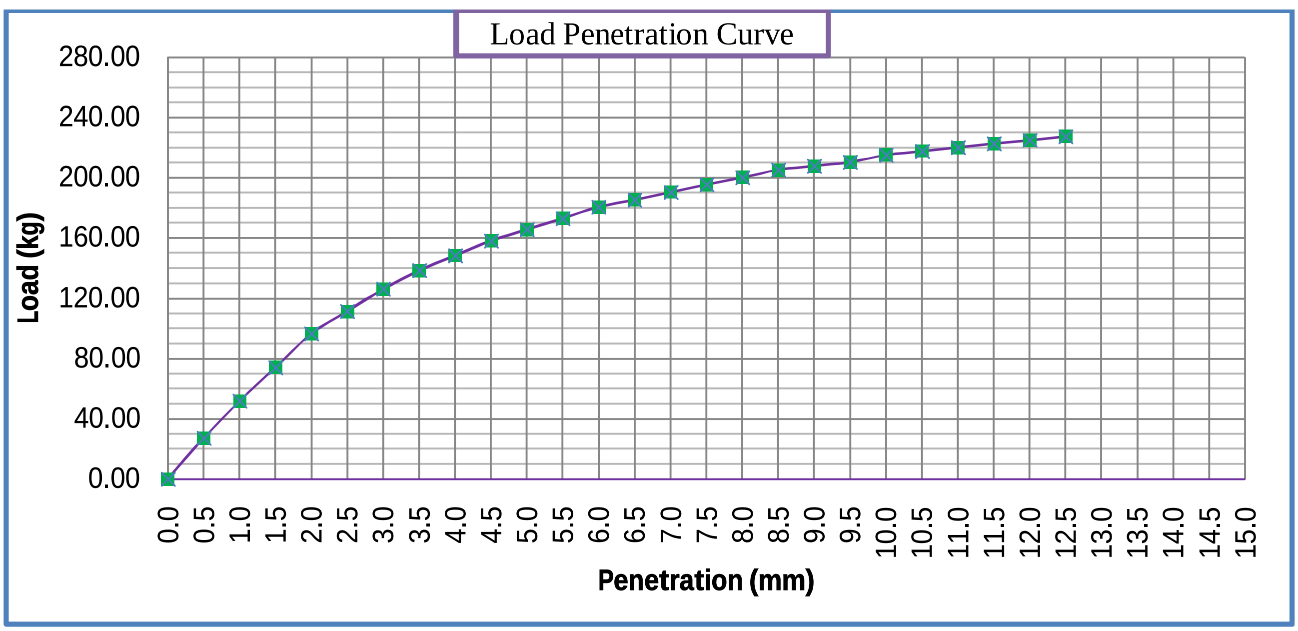

Figure 5 – CBRGraph plotfor 20% SCBA+ B.C Soil

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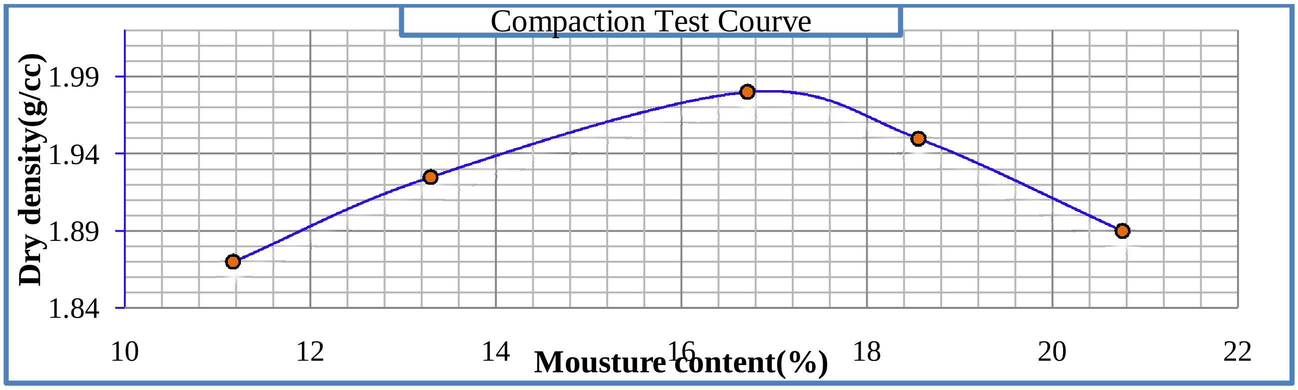

Figure6- MDD and OMC for BC Soil+20% SCBA and 0.75 % Sisalfibre (Aspect ratio-40)

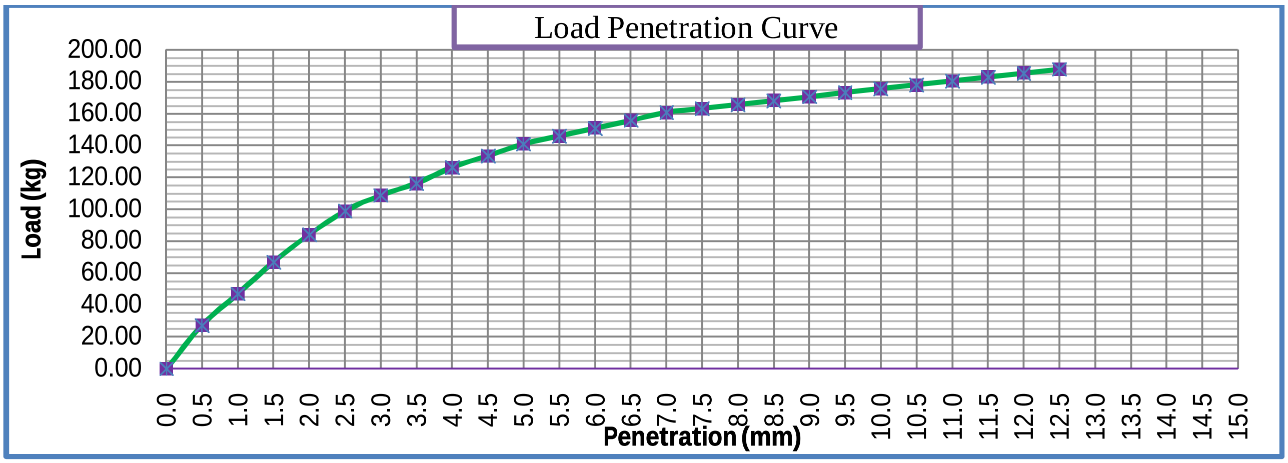

Figure 7 – CBRGraph plotfor0.75% Sisal Fibre(L/D-40)with 20 percentSCBAin B.C. Soil

Table- 3 Combined results for B.C. Soil with SCBA

Properties	B.C.Soil	10%SCBA + B.C.Soil	20%SCBA + B.C.Soil	30%SCBA + B.C.Soil	40%SCBA + B.C.Soil
SpecificGravity	2.58	2.53	2.46	2.37	2.23
LiquidLimit(%)	72.00	58.00	52.50	48.60	45.00
PlasticLimit(%)	29.00	25.00	23.50	21.70	20.10
PlasticityIndex(%)	43.00	33.00	29.00	26.90	24.90
MDD (gm/cc)	1.56	1.82	1.88	1.85	1.81
O.M.C. (%)	18.60	16.74	17.32	17.43	17.88
CBR %(Soaked)	1.67	4.63	4.87	3.56	3.33

Table- 4 Combined results for BC Soil, SCBA with SISAL fibre

Properties	20%SCBA + B.C.Soil+ 0.75 Sisal Fibre Percentage					
	0.25% Sisal Fibre	0.5% Sisal Fibre	0.75% Sisal Fibre	1.00% Sisal Fibre	1.25% Sisal Fibre	1.50% Sisal Fibre
M.D.D.(gm/cc)	1.93	1.95	1.98	1.94	1.92	1.87
O.M.C. (%)	17.22	16.83	16.71	16.89	16.45	16.87
CBR%(Soaked)	6.67	6.92	7.22	6.44	6.33	6.22

Table- 5.Combined results for varying fibre concentration with 20 percent SCBA and Clayey Soil at fibre aspect ratio (L/D)of40

Properties	20%SCBA + B.C Soil+ 0.75 Sisal Fibre Percentage					
	0.25% Fibre	0.50% Fibre	0.75% Fibre	1.00% Fibre	1.25% Fibre	1.50 % Fibre
M.D.D. (gm/cc)	1.93	1.95	1.98	1.94	1.92	1.87
O.M.C. (%)	17.22	16.83	16.71	16.89	16.45	16.87
CBR(%) (Soaked)	6.67	6.92	7.22	6.44	6.33	6.22

After analysis of Table 4.17, it is concluded that maximum favorable changes in engineering properties of SCBA–fibre–soilmixis achieved at fibre concentration of 0.75 percent by weightofsampleatanaspectratioof40.Variation in CBR value is remarkable which increased from 1.67to7.22,which are about more than 4times superior than initial CBR of B.C Soil. Takingtheoptimalcombinationof0.75%sisal with20%SCBA and remaining B.C Soil, one more experiment is performed to study effect of providing this combination at certain depth only and remaining depth is of Soil and 20 percent SCBA mix without fibre. For that purpose the dept his segregated into5equivalentparts, eachofdepth1/5andthenthevariation in properties is studied. Results are also shown in tabular outline in Table.

IV. CONCLUSION

In the present research work, black cotton soil of Bhopal, which is highly compressible in nature is mixed with the varying percentages of SCBA (sugarcane bag assess which is utilized in this project is taken from Shakti Rice Mill Pvt Ltd Mandidip (M.P). ranging from 10 % to 40 % by weight of soil and changes on behavior of soil is studied including soaked CBR. The combination of soil and optimum percentage of SCBA mixed soil is added with varying percentage of Sisal fiber of 0.40 mm diameter. The percentage of fiber content

varied from 0.25 % to 1.50 % on different aspect ratios of 20, 40, 60 and 80 and soaked CBR value in each case was determined. The percentage of fiber giving maximum strength

at specific aspect ratio is identified and termed as optimum percentage of Sisal fibre, When the soil is mixed with optimum quantity of SCBA and Sisal fibre of 0.40 mm diameter at different aspect ratio and fiber content the results obtained are :-

I. At aspect ratio of 40 with 0.75 % fibre content in 20 % SCBA mixed soil, the maximum value of CBR is achieved which is 7.22. It is 4.24 times greater than the CBR value of raw soil.

ii. Irrespective of the aspect ratio, the soaked CBR value of the SCBA mixed soil increases up to 0.75 % Sisal fibre content and after this value it starts decreasing.

Thus for the black cotton soil used in the present study, the optimum quantity of SCBA and Sisal Fibre are 20% and 0.75 % (at aspect ratio of 40) respectively for achieving maximum soaked CBR.

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