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SOIL STABILIZATION USING BAMBOO FIBRES

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Abstract:
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 with additives. The different types of method used for soil stabilization are: Soil stabilization with cement, Soil stabilization with lime, Soil stabilization using bitumen, Chemical stabilization and a new emerging technology of stabilization by Geo textiles and Geo synthetic fibers. In this study, we are making use of bamboo fibers as geo synthetic material for stabilization of soil. With the introduction of bamboo fibers to the soil the CBR values will improve and thickness of pavement layer also gets reduced. It also reduces the intensity of stress on subgrade. Bamboo fibers are such a geosynthetic material which is easily available, ecofriendly and also cost effective. With the application of soil stabilization method in construction the overall cost gets reduced when compared to the ordinary method of construction. The Highway Research Board (HRB) classification of the soil strata like black cotton soil and sedu soil is done using suitable sampling technique such as Core Cutter Method. To determine the characteristics like Grading by Sieve Analysis, Atterbergs Limits i.e Liquid limit using Cone Penetration Method and Cassagrande Method, Plastic limit by rolling the sample to 3mm diameter thread, Shrinkage limit using Shrinkage apparatus, Optimum Moisture Content and Maximum Dry Density uses Standard Proctor Test and also California Bearing Ratio by conducting CBR test. The MDD of the soil with addition of bamboo fibers by weight of soil is found to be increasing upto 0.75% after that it decreases and the corresponding OMC is decreased with addition of fibers. The shear strength of soil decreased substantially with addition of fibers. The CBR value of the soil increased substantially.

Key Words: Soil stabilization, Geosynthetic Material, Bamboo Fiber, Shrinkage Limit, Shear Strength.

I. INTRODUCTION

A developing country like India which has a large geographical area and population, demands vast infrastructure i.e. network of roads and buildings. Everywhere land is being utilized for various structures from ordinary house to sky scrapers, bridges to airports and from rural roads to expressways. Almost all the civil engineering structures are located on various soil strata. Soil can be defined as a material consisting of rock particles, sand, silt, and clay. It is formed by the gradual disintegration or decomposition of rocks due to natural processes that includes disintegration of rock due to stresses arising from expansion or contraction with temperature changes. Weathering and decomposition from chemical changes that occur when water, oxygen and carbon dioxide gradually combine with minerals within the rock formation, thus it is breaking down to sand, silt and clay. Transportation of soil materials by wind, water and ice forms different soil formations such as those found in river deltas, sand dunes and glacial deposits. Temperature, rainfall and drainage play important roles in the formation of soils as in the different climatic regions. Under different drainage regimes, different soils will be formed from the same original rock formation. In India, soils are classified into six groups namely alluvial soil, marine soil, laterite and lateritic deposits, expansive soils, sand dunes and boulder deposits. On an average 1 lakh sq.km area is covered by lateritic soil deposits, 3 lakh sq.km area is covered by black cotton soil, and

5 lakh sq.km area is covered by sand dunes. Encountering land having soft soil for construction leads to an attention towards adopting ground improvement techniques such as soil stabilization. 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 Geo textiles and Geo synthetic fibers. Geo synthetics are synthetic products made from various types of polymers which may be either Woven or Non-Woven. These are used to enhance the characteristics of soil and have provided a practical way of constructing civil engineering structures economically. In this study, we are making use of bamboo fibers as geo synthetic material for stabilization of soil. With the introduction of bamboo fibers to the soil the CBR values may improve and thickness of pavement layer also may get reduced. It may also reduce the intensity of stress on subgrade. Bamboo fibers is such a geosynthetic material which is easily available, eco-friendly and also cost effective. With the application of soil stabilization technique in construction process the overall cost may get reduced when compared to the ordinary method of construction. Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil to improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids.

Fig.1- Bamboo Fiber

Table 1 Physical properties of bamboo fiber

Bamboo fiber properties	**Values**
Density	0.6–1.1
Young's modulus (GPa)	11–17
Tensile strength (MPa)	140–230
Elongation (%)	16
Uniformity index (%)	92.7
Moisture (%)	6.5

existing ground surface. The collected soil was taken to the geotechnical engineering laboratory by a large polythene bag and dried in air for about 7 days.

Bamboo fiber

Bamboo, a perennial grass, is one of the rapid thriving grasses, which belongs to family of poaceae/graminae. Bamboo fiber is a regenerated cellulosic fiber produced from bamboo. It is a common fact that bamboo can grow naturally without using any pesticide. The root rhizomes of bamboo are tremendous soil binders which can prevent erosion. Bamboo fiber is s a satisfactory fiber for incorporation into the cement matrix. Bamboo fiber is a higher degree of water retainer and also rich in micronutrients. Repeated technological analysis has proved that this kind of fiber has a thinness degree and whiteness degree close to normal finely bleached viscose and has a strong durability, stability and tenacity. Physical properties of bamboo fiber are given in Table 1. A typical view of Jute fiber is shown in Fig. 1.

II. OBJECTIVES OF THE WORK

- To categorize the clayey soil namely black cotton soil and sedu soil as per Highway Research Board classification.
- To analyze the characteristics of soil for different concentrations of Geo synthetic material (Bamboo fibers) mixed with it.
- The design of flexible pavement without Geo synthetic material and with the optimum concentration of the geo synthetic material mixed with the above soil as per IRC SP:20- 2002.
- Estimation and costing of the flexible pavement for unit length as per SR 2016-17.

III. EXPERIMENTAL WORK

The collected samples were brought to the laboratory and spraded it over the floor to get air dry soil samples. After drying the soil was broken and grinding by using wooden hammer as fine as possible without applying unnecessary force. The soil powder was passed through #40 standard sieves. Air dry soil powder free from foreign materials. Various index properties of soil such as moisture content, specific gravity, GS, liquid limit, WL, plastic limit, WP, shrinkage limit, WS, plasticity index, IP, Shrinkage ratio, SR, grain size distribution, pH were determined. The index properties of the organic soil were determined according to ASTM D2976-15. Typical soil properties are given in Table 2. Standard Proctor compaction tests were carried out to determine the optimum.

Table-2 Typical Soil Properties

Name ofthe experiment	Experimental results
Specific gravity GS	2.43
Water content, W (%) W (%)	86..38
	79.98
Atterberg's limit test Liquid limit, WL (%) WL (%)	
	58.87
Plastic limit, W (%) WP (%)	
	26.96
Shrinkage limit, WS (%) WS (%)	
	21.11
Plasticity index, IP (%) IP (%)	1.19
Shrinkage ratio, SR SR	
	2%
Sieve analysis Percentage of gravel	
	43.0%
Percentage of sand	
	55.0%
Percentage of silt and clay	
	40.5%
Sedimentation analysis Percentage of silt	14.5%
Percentage of clay	34.76
Organic content (%)	6.42
PH	
	OH
Classification USCS AASHTO OH	

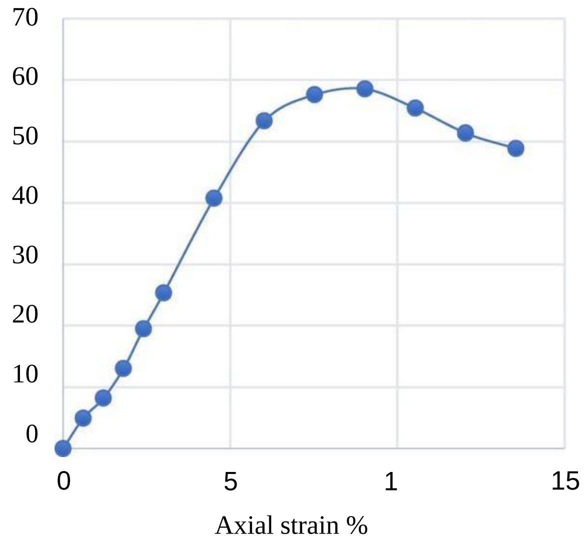

Fig. 2 Unconfined compressive test

moisture content (OMC) and maximum dry density (MDD) of soil sample according to ASTM D698-12e2 [35]. Dry density versus water content graphs is shown in Fig. 2. From the dry density and moisture content relationship, optimum moisture content (OMC) and maximum dry density (MDD) were determined. Cylindrical samples having a diameter of 38 mm and height of 76 mm, used in the unconfined compressive strength (UCS) test, were prepared at their corresponding optimum moisture content and maxi- mum dry density by static compaction. The unconfined compressive strength of the soil samples was assessed according to ASTM D5102-09. The unconfined compressive:-

Table 3 Experimental results of mechanical properties for unreinforced soil sample

Name ofthe experiment
1. Unconfined compression test UCS = 58.52 kPa
2. Compaction test Maximum dry density (MDD) = 21.15 kN/m3
3. Optimum moisture content (OMC) = 15.90%

strengths (UCS) values of specimens were determined from deviator stress versus axial strain curves (Fig. 3). Experimental results of Mechanical properties for unreinforced soil sample is given in Table 3. CBR test value for unsoaked and soaked environments were ascertained for normal soil (0% bamboo fiber) and reinforced soil for different proportions of bamboo fiber (Fig. 4a) such as 0.20, 0.4, 0.60, 0.80, 1.00, 1.20 and 1.40% by waterless weight of ordinary soil. To determine CBR value first of all empty mold was taken (Fig. 4b) and weighted. After that sample was taken in CBR mould having 150 mm diameter and 175 mm high with removable perforated base plate. Then the soil was compacted with 5 layers by 56 blows (Fig. 4c) according to ASTM D 1557 [37]. After that the top surface of the specimen in the CBR mould was made level and (Fig. 4d) a filter paper and a perforated metallic disc was positioned over the specimen. With spacer disc settled inside the CBR mould, the effective length leftovers only 127.3 mm and the net volume is 2237 cm3. A surcharge load of 4.5 kg was placed on the surface of the compacted specimens. Two types of tests were run, unsoaked and soaked. For soaked CBR test, CBR mould was transferred to a tank containing water for soaking of the sample (Fig. 4e). After 96 h (i.e. 4 days) of soaking, all the CBR mould was taken out from water and the top surface of sample was left uncovered to air for half an hour. CBR mould along with soaked soil sample and unsoaked soil sample were transported to a motorized loading frame for testing (Fig. 4f). A strain rate of 1.20 mm/min was used for all the tests, and all the specimens were tested in a similar manner. A series of unsoaked and soaked laboratory CBR tests were performed on plain soil and fiber reinforced soil accordance with ASTMD 1883.

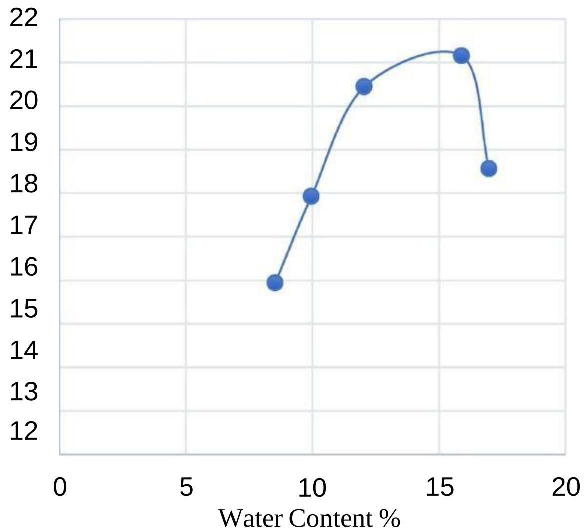

Fig.3 Compaction test graph

Fig.4 a. Reinforcement. **b.**Testapparatus.**C.** Compaction in5layers.**d.**Topsurface leveling.**e.**Soaked condition. **f.** Loading frame

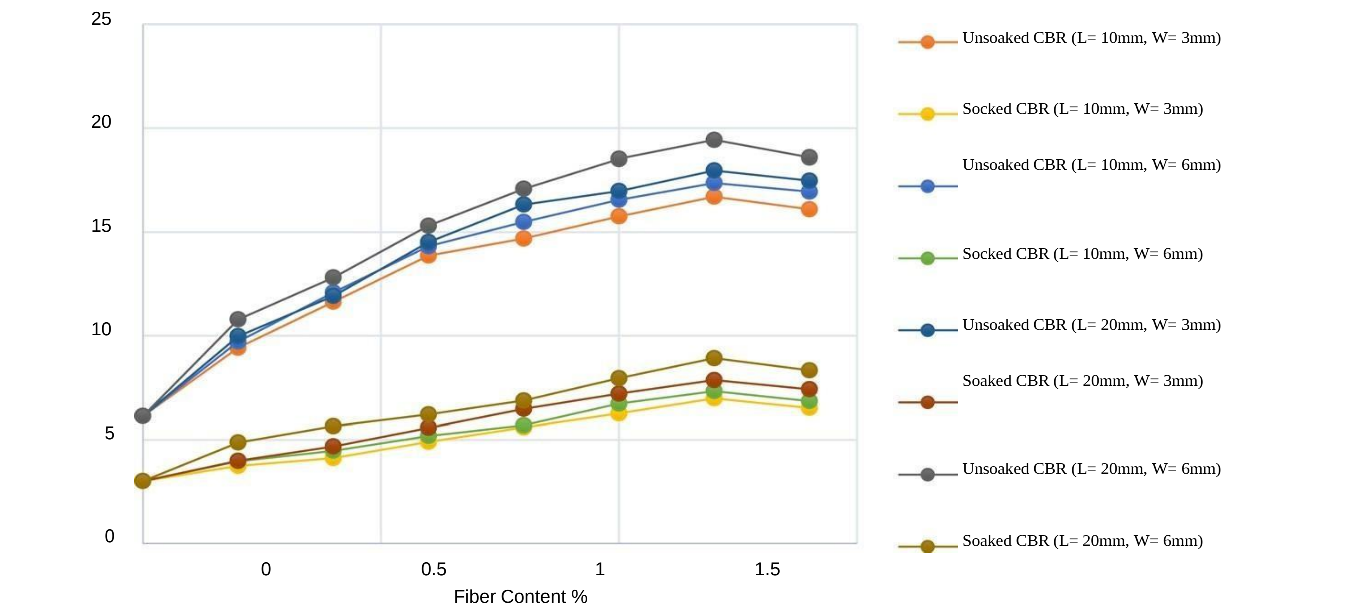

Fig. 5 Variation of CBR value for bamboo fiber at different (content, length and diameter)

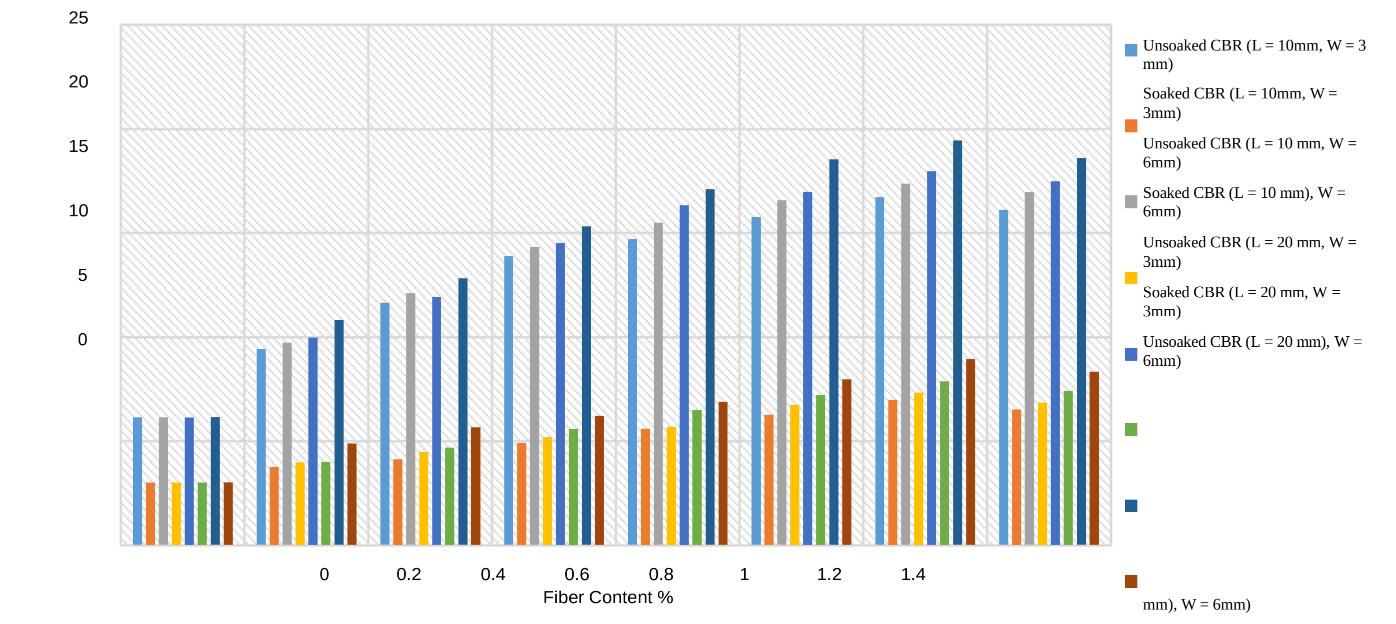

Fig.6 Comparison of CBRvalue

IV. RESULTS AND DISCUSSION

The unsoaked and soaked CBR values of ordinary soil and soil strengthened with varying percentages, length and diameter of bamboo fiber determined in the laboratory are shown in Tables 4 and 5. Figures 5 and 6 represents the variation and comparison of unsoaked and soaked CBR test value respectively for different content, length and diameter of bamboo fiber. The clarification of tests results such as effects of bamboo fiber content, length of bamboo fiber and diameter of bamboo fiber on CBR value for both soaked and unsoaked condition of soil have been discussed in the subsequent sections.

Effect of bamboo fiber content CBR value

CBR tests carried out for different Bamboo fiber dosage varying such as 0, 0.2, 0.4, 0.6, 1.0, 1.20, 1.40% by waterless weight of normal soil are given in Tables 4 and 5 for different length and diameters of bamboo fiber. Figure 5 illustrates that the CBR value increases with increases in bamboo fiber content up to 1.2% and beyond this gradual decrement was occurred. This aspect can be observed for all the fiber lengths (10 and 20 mm) and fiber diameters (3 and 6 mm). For instance, unsoaked and soaked CBR value for 10 mm length with 3 mm diameter was found 16.71 and 6.98% respectively at 1.2%
bamboo fiber content which is 2.73 and 2.32 times greater than the unreinforced soil. Some researchers were observed similar trend by using natural or geosynthetic fiber and ash for soil improvement. This may have occurred due to randomly inclusion of bamboo fiber in normal soil. This randomly oriented bamboo fiber has capability to make combined form with soil mass. This systematized form is mainly responsible for development of its load deformation behavior by mechanical interaction of soil particle with fiber by surface abrasion as well as interlocking. This interlock or interconnect mainly transmit stress from soil to the discrete inclusion by mobilizing the tensile strength of fiber initiated. In this way fiber reinforcement performs like a tension and frictional inhibitor component. Furthermore, soil become a composite material due to addition of fiber and its toughness and strength is higher than ordinary soil. This may have the real reason that CBR value of reinforced soil was seen higher than normal soil. The most appropriate percentage of coir fiber respect to the highest CBR value was established 1.2% by anhydrous weight of normal soil sample.

Effect of length of bamboo fiber

In this research two types of bamboo fiber length (10 and 20 mm) were used. From Fig. 5 it is clearly seen that unsoaked and soaked CBR value of soil increases with increase in bamboo fiber length for same fiber content and of same fiber diameter. For instance, unsoaked and soaked CBR values of soil reinforced with bamboo fiber length of 10 mm at 1.2% fiber dosages having diameter 3 mm are 16.71 and 6.98% respectively. When fiber length increased 10 mm to 20 mm then unsoaked and soaked CBR value were observed 17.97 and 7.86% respectively for same fiber content and diameter of bamboo fiber. This is attributed to the fact that for smaller fibers, the area in contact with soil is comparatively less and hence there is a less improvement in strength and stiffness of soil.

Effect of diameter of bamboo fiber

In this investigation two types of bamboo fiber diameter (3 and 6 mm) were used. Figure.5 illustrates that experimental unsoaked and soaked CBR value of soil reinforced with bamboo fiber increases with the increase in bamboo fiber diameter. For instance, unsoaked and soaked CBR value of soil reinforced with bamboo fiber for 10 mm length and 3 mm diameter is found 16.71 and 6.98% respectively at bamboo fiber content of 1.2%. When the diameter of fiber is increased from 3 to 6 mm, the unsoaked and soaked CBR value of reinforced soil increases up to 17.37 and 7.33% respectively for the same fiber content and same fiber length. This is imposed to the datum that due to increase in diameter of fiber increases the pull out resistance of fiber. Additionally, large diameters fibers are proficient of distribution more stresses initiated in the soil specimens.

V. Conclusion

Based on the current investigation and study it is concluded that both unsoaked and soaked California Bearing Ratio (CBR) value of soil increases due to the addition of bam- boo fiber. When bamboo fiber quantity is increases, unsoaked and soaked California Bearing Ratio (CBR) value of soil are considerable increase and this increase is occurred up to 1.2% of bamboo fiber dosage. It is observed that the preparation of identical soil samples for soaked and unsoaked CBR test beyond 1.2% of bamboo fiber dosage is not feasible and optimal proportion of bamboo fiber is found 1.2% by waterless weight of ordinary soil. It is also explored that there is highly impacts of length and diameter of bamboo fiber on the unsoaked and soaked CBR test value of normal soil. The unsoaked and soaked CBR test value of soil increases with the increase in bamboo fiber length and diameter. In addition, bamboo fiber makes the soil an amalgamate lements whose stiffness and strength is better than that of ordinary soil. Moreover, bamboo fibers are helpful natural biodegradable and environmental friendly material, for the construction of high-rise buildings construction, oil storing tanks, long span bridges, harbors, port structures, embankments for flood protection and barrages in a profitable way since they are relatively inexpensive than polymeric alternates.

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