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Soil Stabilization using GEO Synthetic Materials (Bamboo Fibers)

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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 is such a geosynthetic material which is easily available, eco friendly 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 Casagrande Method, Plastic limit by rolling the sample to 3mm diameter thread, Shrinkage limit using Shrinkage apparatus, Optimum Moisture Content and Maximum Dry Density using Standard Proctor Test and also California Bearing Ratio by conducting CBR test. The pavement thickness was designed using pavement design catalogues published by IRC SP:20-2002.

Keywords-.Bamboo Fiber, Geosynthetic Material, Soil stabilization

1. 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 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. 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.

- If during the construction phase weak soil strata is encountered, the usual practice followed is replacing the weak soil with some other good quality soil. With the application of soil stabilization technique, the properties of the locally available soil (soil available at the site) can be enhanced and can be used effectively as the subgrade material without replacing it.
- The cost of preparing the subgrade by replacing the weak soil with a good quality soil is higher than that of preparing the subgrade by stabilizing the locally available soil using different stabilization techniques.
- The strength giving parameters of the soil can be effectively increased to a required amount by stabilization.
- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- Stabilization is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.
- It helps in reducing the soil volume change due to change in temperature or moisture content. However the soil stabilization has disadvantage like increase in cost of construction and difficulty in mixing the fibers with soil.
- 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.

Advantages of soil stabilizations areas follows:

- If during the construction phase weak soil strata is encountered, the usual practice followed is replacing the weak soil with some other good quality soil. With the application of soil stabilization technique, the properties of the locally available soil (soil available at the site) can be enhanced and can be used effectively as the subgrade material without replacing it.
- The cost of preparing the subgrade by replacing the weak soil with a good quality soil is higher than that of preparing the subgrade by stabilizing the locally available soil using different stabilization techniques.
- The strength giving parameters of the soil can be effectively increased to a required amount by stabilization.
- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft found.

2. LITERATURE REVIEW:

Sujitkawadeetal[1].,studied the effect of Lime and geo-grid on the properties of the soil. Their main objectives was to determine the properties of the soil before and after the addition of lime and geogrid to it. The different tests they conducted were natural moisture content determination, specific gravity, Atterbergs limits, Compaction test, Compressive Strength test. After studying and conducting the entire above test, the optimum lime content was found to be 15% and they concluded that there was a substantial increase in the compressive strength of the soil.

AyushMithal and Dr.ShalinuShukla[2].,studied the effectiveness of use of geo-textiles as reinforcement material for stabilization of soil for different engineering works. Their objectives were to study and introduce the properties of Geo-textiles (such as Physical property, Mechanical property, Hydraulic property, Endurance property and Durability property),Fibers of

Geo-textiles,(they are natural and synthetic fibers).Types of Geo-textiles, functions of Geo-textiles, application of geo-textiles and impact of geo-textiles on environment.They have concluded that, due to the versatility of functions of geo-textiles they can be used in many important civil engineering works. The use of geo-textiles not only reduces construction cost but also reduce maintenance cost.

Vegulla. Raghudeep et al[3]. , studied the effect of vitrified polish waste on the properties of the soil. Their objective was to check the reduction in pavement thickness due to increase in CBR because of addition of polish waste. They conducted the tests like Grain size distribution, Atterbegs limits, Compaction tests and CBR tests on soil alone and with addition of vitrified polish waste. They conducted that 10% addition of vitrified polish waste resulted in substantial increase in CBR value and significant reduction in pavements thickness was reported.

HarshitaBairagi et al[5].,studied the effectiveness of jute fibers in controlling the swelling behavior of black cotton soil measured in lab with and without use of randomly reinforced jute fibers in the soil. Their objectives were to determine the CBR values and unconfined compressive strength of the soil. The different tests conducted were sieve analysis, Atterbergs limits, differential swelling test, proctor test, CBR test and unconfined compression test. From the test they concluded that there was a substantial increase in shrinkage limit, optimum moisture, dry density, CBR value and shear strength of the soil and also the addition of jute fibers to black cotton soil decreased the swelling behavior. soil. Their objectives were to determine the CBR values and unconfined compressive strength of the soil. The different tests conducted were sieve analysis, Atterbergs limits, differential swelling test, proctor test, CBR test and unconfined compression test. From the test they concluded that there was a substantial increase in shrinkage limit, optimum moisture, dry density, CBR value and shear strength of the soil and also the addition of jute fibers to black cotton soild increased the swelling behavior.

3. EXPERIMENTAL WORK:

The following tests are used in soil stabilization:

- Wet sieve analysis
- Liquid limit test (Casagrande test)
- Using Cone Pentration test
- Plastic limit test(Atterbergs limit)
- Shrinkage limit
- Compaction test(Proctor test)
- Unconfined compression test
- CBR test

Wet Sieve Analysis:

General

The grain size distribution is found by mechanical analysis. If the percentage fines are more there is a need to conduct wet sieve analysis.

Apparatus

The different apparatus used for test were, sieves confirming to IS:460(part I)- 1978, 4.75mm,2mm,425μ,75μ.Oven to maintain temperature between105˚C to110˚C,trays or buckets, brushes, mechanical sieve shaker.

Liquid Limit Test:

General

In order to study the liquid limit of soil Casagrande test was conducted. Liquid limit is generally determined by the mechanical method using Casagrande's apparatus or the standard liquid limit test apparatus. As per this method the liquid limit is defined as the moisture content at which 25 blows or drops in standard liquid limit apparatus will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.

Apparatus

Standard liquid limit apparatus is a mechanical device, consisting of a cup and arrangement for raising and dropping through a specified height of 10mm. There are two standard grooving tools. Other apparatus required include spatula, evaporating dish, moisture containers, balance of capacity 200 grams and sensitivity to 0.01 g and thermostatically controlled drying oven to maintain 105˚C to 110˚C.

Using Cone Penetration Method

General

Another method used for testing liquid limit of soil is cone penetration method. From the cone penetration method, liquid limit of a soil is defined as the water content in the soil sample when the depth of the penetration of the standard cone is 20 mm. The depths up to which the standard metal cone penetrates into samples of soil paste prepared with different water contents in 5 sec are measured.

Apparatus

Penetration cone of standard apex angle and weight, cylindrical cup, balance of sensitive to 0.01g and drying oven maintained at105˚C to 110˚C.

Plastic Limit Test:

General

In order to study the atterbergs limit it is important to conduct plastic limit test. Plastic limit (PL) is the water content at which the soil rolled into thread of smallest diameter possible starts crumbling and has a diameter of 3mm

Apparatus

Evaporating dish of about 120 mm diameter, spatula, ground glass plate, moisture containers, rod of 3 mm diameter, balance sensitivity to 0.01g, drying oven controlled at temperature105˚C to 110˚C.

Shrinkage Limit Test:

General

Shrinkage limit (SL) in a remoulded soil sample is the maximum water content, expressed as a percentage of oven dry weight, at which any further reduction in water content will not cause decrease in volume or shrinkage of the soil sample.

Apparatus

Evaporating dish, shrinkage dish of diameter 45mm and height 15mm (both internal), spatula, straight edge, glass cup 50-60mm in internal diameter and 25 mm height, two glass plates of size 75 mm x 75 mm, one plane and the other having three metal prongs. Other equipment needed are 25 ml graduated jar to read 0.2 ml, balance sensitive to 0.01g, mercury sufficient to fill the glass cup and a desiccator.

Compaction Test:

General

The Standard Proctor Test is conducted to study the density of soil and its corresponding optimum moisture content. Compaction of soil is a mechanical process by which the soil particles are constrained to be packed more closely together by reducing the air voids. Soil compaction causes decrease in air voids and consequently an increase in dry density. This may result in increase in shearing strength.

Apparatus

Mould of capacity 1000 cm3 with diameter of 100 mm and height 127.3 mm, metal rammer of 50 mm diameter, 2.6 kg weight with a free drop of 310 mm, IS sieve 4.75 mm. Other accessories like moisture containers, spatula, trowel, balances of capacity 10kg and 200g,drying oven, measuring cylinder.

Unconfined Compression Test:

General

The shear strength of the soil is determined by conducting unconfined compression test. Unconfined compression tests are carried out on cohesive soil specimen. The test maybe considered as a special case of the tri axial compression test when the lateral confining pressure σ3 is equal to 0. Therefore, the cylindrical test specimen may be directly placed in a compression testing machine and the compressive load applied.

Apparatus

Strain controlled compression testing machine with proving ring assembly to measure load applied, dial gauge to measure deformation and moulds and tools to prepare test specimen.

California Bearing Ratio (CBR) Test:

General

The CBR test denotes a measure of resistance to penetration of a soil or flexible pavement material, of standard plunger under controlled test conditions.

Apparatus

CBR test equipment consists of a motorised loading machine fitted with the plunger which penetrates at the specified rate into the test specimen placed in the CBR mould. Hollow cylindrical mould of inner diameter 150 mm and height 175 mm, spacer disc, compaction rammer of 4.89kg with a drop of 450mm, metal weights i.e., two discs weighing 2.5 kg each. Other accessories like IS sieve 19 mm, tray, mixing bowl, straight edge, filter paper, weight balance, measuring jar.

3. RESULTS & DISCUSSIONS:

Atterbergs Limit:

Liquid limit: Wet sieve analysis of Black cotton soil collected from Murkwad was carried out in order to classify the soil. The following observations were made:

Sample taken [passing 4.75mm sieve before washing] = 200 g Sample retained on 0.075mm sieve after washing and drying=115g Sample passed through0.075mm sieve after washing=85g ,42.5%.

Sl. No.	IS sieve size	Partcle size	Mass	%Mass of retained (M1/M)*100	Cumulative % retained, C	Cumulative % N=100-C
1	2.000	2.000	0	0.00	0.00	100.00
2	1.000	1.000	06	05.22	5.22	94.78
3	0.600	0.600	37	32.17	37.39	62.61
4	0.425	0.425	09	07.83	45.22	54.78
5	0.300	0.300	15	13.04	58.26	41.74
6	0.212	0.212	17	14.78	73.04	26.96
7	0.150	0.150	00	0.00	73.04	26.96
8	0.075	0.075	29	25.22	98.26	01.74
9	Pan	0	0	0.00	98.26	01.74

Table1: Sieve analysis of Black cotton soil

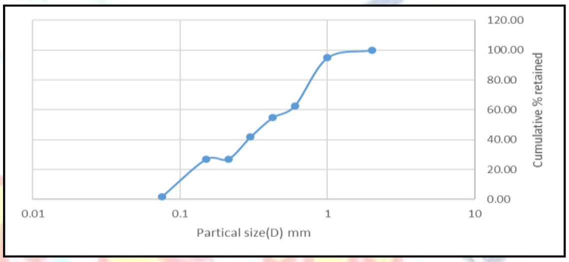

Fig1: Particle size distribution curve of Black cotton soil

Plastic limit:

Cone Penetration Test:

Sample Taken [passing through=425μ]=150g

Trail No.	Water Content,%	Water Amount, ml	Penetration ,mm
1	50	75	16
2	55	82.5	17
3	60	90	20
4	65	97.5	35
5	70	105	44

Table2: Liquid limit test on Black cotton soil using cone penetration method

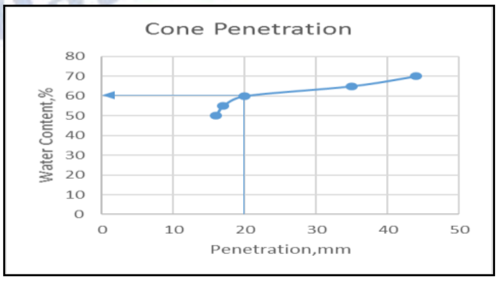

Fig2: Liquid Limit curve (Cone Penetration)

Liquid limit as obtained from graph=**60%** (corresponding to 20mm penetration).

Casagrande Method:

Sample Taken [passing through=425μ]=150g

Trial No.	Water Content %	Water Amount, ml	No. of Blows
1	50.00	75.0	108
2	54.33	81.5	25
3	55.00	82.5	20
4	60.00	90.0	4

Table3: Liquid limit test on black cotton soil

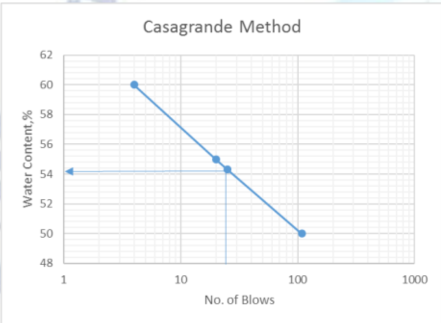

Fig3:Liquid Limit curve (Casagrande's method)

Liquid limit as obtained from graph = **54.33%** (corresponding to 25 blows).

Plastic Limit test:

Trial Number	1
Container No.	GT-19
Mass of empty container, M_1g	32.15
Mass of container + wet soil,M_2g	47.15
Mass of container + dry soil,M_3g	44.50
Mass of water=M_w=M_2-M_3	02.65
Mass of dry soil=M_d= M_3-M_1 g	12.35
Plastic Limit,%W_p=(M_w/M_d)*100	21.46

Table4: Plastic limit test on Black cotton soil

Plasticity Index:

Soil Sample-1

$I_p=W_L-W_P$=60– 21.46 =**38.36%**

Shrinkage limit:

Sl. No	a)Volume of wet soil pat(V)c.c.	
1	Shrinkage dish No.	1
2	Fibre added,%	0
3	Mass of empty porcelain weighting dish, M1gms	166
4	mass of mercury weighing dish + mercury filling the shrinkage dish, M2gms	460
5	Mass of mercury filling the dish M_3= (M_2-M_1)gms	294
6	Volume of wet soil pat,V=(M3/13.6)cc	21.618
	b)Mass of wet dry soil pat and its water-content	
7	Mass of empty shrinkage dish, M4gms	37
8	Mass of shrinkage dish + wet soil, M5gm as	71
9	Mass of shrinkage dish +dry soil, M6g m as	57
10	Mass of water Mw=(M5-M6) gms	14
11	Mass of dry soil, Md=(M6-M4) gms	20
12	Water content, w=(Mw/Md)	0.700
	c)Volume of dry soil pat(Vd)cc	
13	mass of mercury weighing dish + mercury displacement by dry soil pat, M7gms	333
14	Massofmercurydisplacedbydrysoilpat,M8=(M7-M1)gms	167
15	Volume of dry soil pat,Vd=(M8/13.6)cc	12.279
	d)Calculation	
16	Shrinkage Limit(%)Ws=(w-{V-Vd/Md})*100	23.309

Table5: Shrinkage limit test on Black cotton soil

Standard Proctor Test:

Sample taken [passing 4.75mm sieve before washing]=2500g Volume of Mold =1000cc.

Trials	1	2	3	4
Mass of Empty mould, m_1(g)	3686.00	3686.00	3686.00	3690.00
Mass of mould + Compacted soil, m_2(g)	5358.00	5390.00	5421.00	5430.00

Mass of Compacted soil, $M=m_2-m_1(g)$	1672.00	1704.00	1735.00	1740.00
Bulk density, $\Upsilon_b=(M/V)$g/cc	1.67	1.70	1.74	1.74
Container number	2	3	4	GT-24
Water added	0.22	0.24	0.26	0.28
Mass of container,M1(g)	29.50	22.50	16.00	29.50
Mass of container + Wet soil, M2(g)	102.00	113.50	78.00	96.50
Mass of container +Dry soil, M3(g)	92.00	99.00	67.00	84.00
Mass of Water, Mw=M2-M3(g)	10.00	14.50	11.00	12.50
Mass of Dry soil, Md=M3-M1(g)	62.50	76.50	51.00	54.50
Water content, w=(Mw/Md)*100	0.160	0.190	0.216	0.229
Dry Density, $\Upsilon_d=\Upsilon_b/(1+w)$g/cc	1.370	1.374	1.377	1.359

Table6: Standard Proctor Test on Black cotton soil

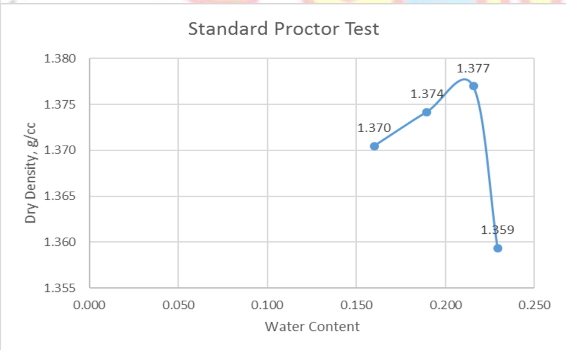

Fig6:Compaction Curve for Black cotton soil

OMC as obtained from graph=21.4%

MDD as obtained from graph =1.378 g/cc.

Unconfined Compression Test: In UCS test following observations made:

OMC=21.40%, h=7.8cm, d=3.8cm, h1=7.1cm, d1=3.8cm load per div=3.417N◎ =58◎ ◎

Table7: Unconfined Compression Test on Black cotton soil

Dial gau ge rea	Strain (ϵ)	Provingri ng readin g (Trial	Provingri ng readin g (Trial	Avg Provin gring readin	Correcteda rea	Load (N)	Axial Str ess (M

din g		1)	2)	g			pa)
0	0.00	0.0	0.0	0.0	11.34	0.00	0.00
50	0.06	2.6	0.4	1.5	11.34	5.13	0.45
100	0.13	4.2	1.4	2.8	11.34	9.57	0.84
150	0.19	4.4	3.4	3.9	11.34	13.33	1.18
200	0.26	4.0	4.4	4.2	11.34	14.35	1.27
250	0.32	4.0	4.3	4.15	11.34	14.18	1.25

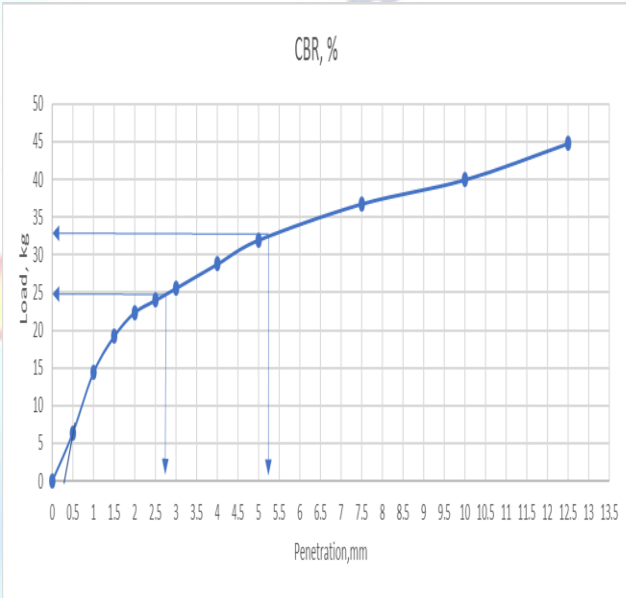

Fig:7 UCS Curve for Black cotton soil

California Bearing Ratio(CBR) Test:

The water added was equal to OMC=21.40%

Table8: California Bearing Ratio (CBR)Test on Black cotton soil

Penetration (mm)	Trial1	Division	Load(kg)
0	0	0	0
0.5	0.8	4	6.4
1	1.8	9	14.4
1.5	2.4	12	19.2
2	2.8	14	22.4
2.5	3	15	24
3	3.2	16	25.6
4	3.6	18	28.8
5	4	20	32

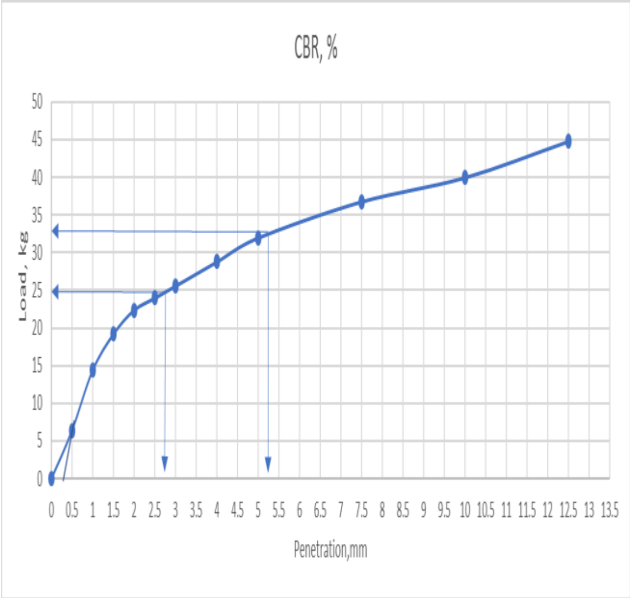

Fig8: CBR Curve for Black cotton soil

Atterbergs Limit (sedu soil):

Liquid limit: Cone Penetration Test

Sample Taken[passing through=425μ]=150g

Trial No.	**Water Conent ,%**	**Water Amount,ml**	**Penetration, mm**
1	30	45	14
2	32	48	16
3	34	51	17
4	36	54	19
5	40	60	48

Table9: Liquid limit test on Sedu soil using cone penetration method

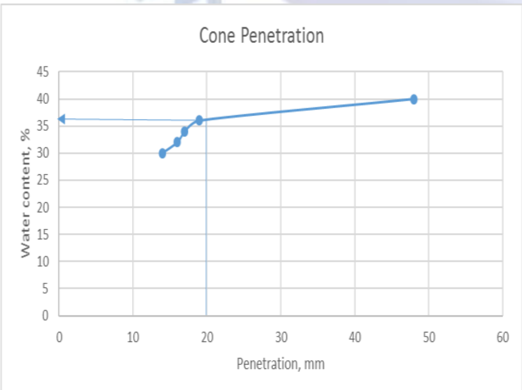

Fig9: Liquid Limit curve(Cone Penetration)

Liquid limit as obtained from graph= **36.5%** (corresponding to 20mm penetration).

Standard proctor test:

Sample taken [passing 4.75mm sieve before washing]=2500g Volume of Mold =1000 cc.

Trials	**1**	**2**	**3**	**4**
Mass of Empty mould, m_1(g)	4420	4420	4420	4420
Mass of mould + Compacted soil, m_2(g)	6325	6450	6510	6430
Mass of Compacted soil, $M=m_2-m_1$(g)	1905	2030	2040	2010
Bulk density, Υ_b=(M/V)g/cc	1.905	2.03	2.04	2.01
Container number	1	2	3	4
Water added	0.12	0.14	0.16	0.18
Mass of container, M_1(g)	30.5	30	33	16
Mass of container + Wet soil, M_2(g)	135	118	119	120
Mass of container +Dry soil, M_3(g)	104.5	88	86	104
Mass of Water, $M_w=M_2-M_3$(g)	10	10.5	11	15
Mass of Dry soil, $M_d=M_3-M_1$(g)	94.5	77.5	75	89
Water content, $w=(M_w/M_d)*100$	0.106	0.135	0.147	0.169
Dry Density, $\Upsilon_d=\Upsilon_b/(1+w)$g/cc	1.723	1.788	1.779	1.720

Table10: Standard Proctor Test on Sedu soil+0.25% Bamboo Fibers

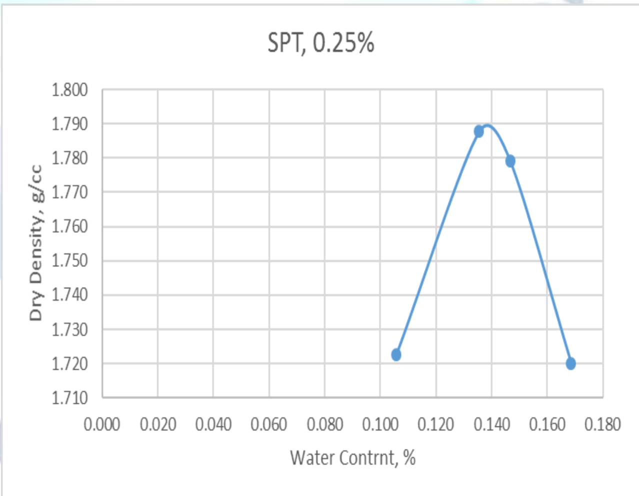

Fig10: Compaction CurveforSedusoil+0.25%fibers

OMC as obtained from graph=13.5%

MDD as obtained from graph=1.788g/cc

Unconfined Compression Test:

Black cotton soil added with fibers 0.75% by weight the following observations were made: weight of sample=250 g

OMC= 17.2% h =7.9cm,d =3.8cm,h_1=7.5cm,d_1=3.9cm,f =58°

Load per div=3.417 N

Dial gauge reading	Strain (ϵ)	Provingring reading	Provingring reading	Avg. Provingring reading	Corrected area	load(N)	Axial Stress (Mpa)
0	0.000	0.0	0.0	0.0	11.34114948	0.000	0.000
50	0.063	1.6	1.5	1.55	11.34114948	5.296	0.467
100	0.127	3.0	2.2	2.60	11.34114948	8.884	0.783
150	0.190	3.6	2.6	3.10	11.34114948	10.593	0.934
200	0.253	4.0	3.0	3.50	11.34114948	11.960	1.055
250	0.316	4.6	3.4	4.00	11.34114948	13.668	1.205
300	0.380	5.0	4.2	4.60	11.34114948	15.718	1.386
350	0.443	5.4	4.6	5.00	11.34114948	17.085	1.506
400	0.506	5.8	4.8	5.30	11.34114948	18.110	1.597
450	0.570	6.0	5.2	5.60	11.34114948	19.135	1.687
500	0.633	6.0	5.6	5.80	11.34114948	19.819	1.747
550	0.696	6.2	6.0	6.1	11.34114948	20.844	1.838
600	0.759	6.2	6.2	6.2	11.34114948	21.185	1.868
650	0.823	6.2	6.2	6.2	11.34114948	21.185	1.868

Table11: Unconfined Compression Test on Black cotton soil + 0.75% fiber

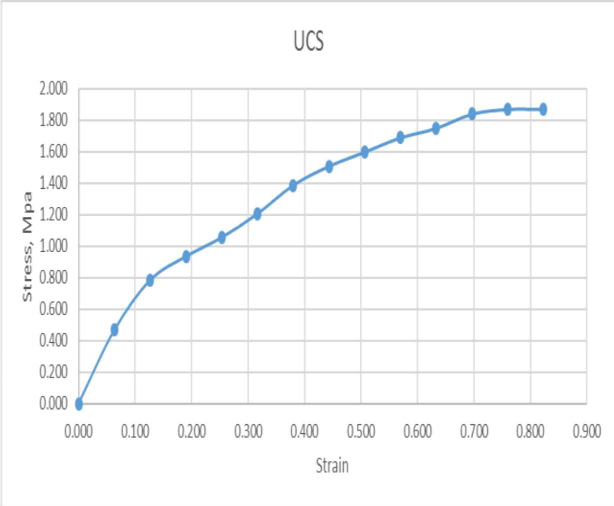

Fig11: Compaction Curve for Black cotton soil + 0.75%fibers

Caifornia Bearing Ratio (CBR) Test:

Black cotton soil added with fibers 0.25% by weight the following observations were made: OMC=20.1%.

Penetration (mm)	Trials	Division	Load(kg)
0	0	0	0
0.5	2	10	16
1	3.6	18	28.8
1.5	4.6	23	36.8
2	5.4	27	43.2
2.5	6	30	48
3	6.4	32	51.2
4	7.2	36	57.6
5	7.8	39	62.4
7.5	8.8	44	70.4
10	9.4	47	75.2
12.5	10	50	80

Table12: CBR Test on Black cotton soil + 0.25% fiber

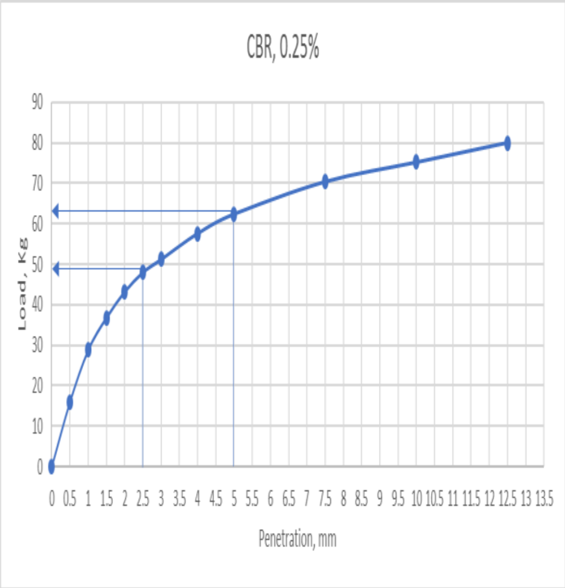

Fig12: CBR Curve for Black cotton soil + 0.25% fibers

Load as obtained from graph at 2.5 mm penetration = 48 kg CBR of Specimen=(48/1370) *100=3.49%

Load as obtained from graph at 5 mm penetration = 62.4 kg CBR of Specimen=(62.4/2055) *100=3.02%

CONCLUSIONS:

On the basis of present experimental study, the following conclusions are drawn:

- According to the Highway Research Board classification, the black cotton soil sample has been categorized as A-7-6 (4.549)
- There is substantial increase in MDD with increase in addition of fibers upto 0.75% by weight beyond which it decreased.
- There is substantial decrease in OMC with increase in addition of fibers.
- In unconfined compression test it was observed that the shear strength of the soil has increased with the increase in percentage of bamboo fibers, when compared to that of shear strength of soil tested without fiber.
- The shear strength of the soil is maximum when 1% (by weight of soil) of bamboo fibers is added to it. Hence in order to obtain higher shear resistance1% of fibers (by weight of soil) can be considered as the optimum fiber content.
- The California bearing ratio (CBR) of the soil alone is obtained as 1.82% and it increased to 5.41% after stabilizing it with optimum percentage of bamboo fibers.
- The percentage increase in CBR value after stabilizing it with optimum percentage of fibersis197.25%.
- In the case of sedu soil there is substantial increase in MDD with increase in addition of fibers.
- In unconfined compression test it was observed that the shear strength of the soil has decreased with the increase in percentage of bamboo fibers, when compared to that of shear strength of soil tested without fiber.
- The California bearing ratio (CBR) of the soil alone is obtained as 4.28%and there substantial increase in CBR value with addition of fibers.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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