STUDY ON STRENGTH BEHAVIOUR OF SOIL USING GEO-SYNTHETICS

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Abstract : The subgrade of any pavement layer plays vital role in load bearing capacity and support of traffic in the form of foundation. Geo-synthetics a newly emerging field in the civil engineering and other fields, offers great and good potential in various areas of application worldwide. It plays a significant part in modern pavement design and maintenance techniques. Ideal materials for super infrastructure works, roads, harbors and many others. It also plays an important role in the construction of highways with no additive layers, such as asphalt concrete or cement concrete, or in a subgrade layer which affects the bearing capacity of unbounded layers.

A huge variety of strengthening materials emerged have been developed for construction purposes, including metal strips, bar mats, geo-textile sheets, Geo-grids etc. Strengthening soil technologies has been widely used during the past few years in the construction of railway formation layer, highway embankments fill , heavy earth dams and retaining walls. As a reinforcing material the geo-synthetics are widely used in engineering practice to strengthen the foundation of structure, ground slope, road pavement layers, crushed-stone column etc. Pavement is a durable and hard crust layer constructed over the natural soil for the purpose of providing an even surface for the vehicles. In rigid or flexible pavement construction soil stabilization also deals with the construction practice. It shows the various means by which the stabilization response of different soils can be identified.

Key Words- Geo-synthetics, Strengthening, Stabilization, Technology, Subgrade layer.

1. INTRODUCTION

Development of roads is important as it provides access to various places of the country for improvement. Problems in road arises when laid on soft subgrade because of large deformations, however it may not be a viable option when it comes for low volume roads. In such situation, there is a possibility of utilizing the natural Geo-textiles instead of Geo-synthetics, as an economic alternate to overcome the problem. The coir is a naturally occurring fiber derived from the husk of coconut fruit. It is abundantly available at low cost in India. A large number of coir products are manufactured for various geotechnical applications in the form of grids, textiles, and mats. These applications include filtration and drainage application, reinforcement, erosion control, etc.

These products were found to last for as long as four to six years within the soil environment depending on the physical and chemical properties of the soil. When it is used as reinforcement, the coir layers can share the load with soil until its degradation thus increasing the load bearing capacity of the subgrades. The strength of subgrade soil increases in course of time as the soil undergoes consolidation induced by the traffic loads..For such applications, where the strength of subgrade increases with elapsed time, the natural reinforcement products are extremely suitable. The application of natural woven coir Geo-textiles for unpaved roads on soft subgrade performs satisfactorily. The use of blended Geo-textiles shows an increase in the CBR value as well as gives an even surface without significant marks of subsidence or rutting.

2. OBJECTIVES OF THE STUDY

The present study involves laboratory and site investigations on the use of geosynthetic material in sub grade soil

- To highlight the use of geosynthetic material
- To determine the difference in simple black cotton soil and reinforced black cotton soil
- To determine value of C.B.R for various quantities of geosynthetic material.
- To demonstrate advantages of using geosynthetic material.

3. WHY GEO-SYNTHETICS?

Geo-synthetics with high tensile strength used in combination with soil of high compressive strength have been found to be effective in the design of many civil engineering applications. The application of Geo-synthetics in the field of geotechnical, transportation, hydraulics, and geo-environmental engineering has been explained by many researchers.

The materials employed in the manufacture of Geo-synthetics square measure primarily artificial materials, generally, derived from crude oil oils, though rubber, fiberglass. Geo-synthetics could be a generic name representing a broad vary of plane merchandise factory made from compound materials. The foremost common ones square measure Geo-textiles, Geo-grids, Geo-nets, Geo-membranes and Geo-composites, that square measure employed in contact with soil, rock associate in Nursingd/or the other material as an integral a part of a artificial project, structure or system.

What is Geo-Synthetics?

The term ‘Geo-synthetics’ has 2 parts: ‘GEO’ touching on Associate in Nursing finish use related to rising the performance of applied science works involving earth/ground/soil. ‘SYNTHETICS’ touching on the very fact that the materials square measure virtually solely from artificial merchandise

Types

The various types of Geo-synthetics that are available in the market are named below:

1. Geo-textiles (GT). 2. Geo-grids (GG). 3. Geo-nets (GN). 4. Geo-membranes (GM).
5. Geo-synthetics clay liners (GCL). 6. Geo-pipe (GP). 7. Geo-foam (GF). 8. Geo-composite (GC).

3.1.1 Geo-textiles (GT)

Geo-textiles type one among the 2 largest teams of Geo-synthetics. Their rise in growth throughout the past 35years has been nothing wanting extraordinary. they're so textiles within the ancient sense, however they comprises artificial fibers instead of natural ones like cotton, wool, or silk. Thus, biodegradation and resultant short life isn't a drag (Fig.1). These artificial fibers are created into versatile, porous materials by normal weaving machinery or matted along during a random non-woven manner. Some also are unwoven. There are at-least a hundred specific application areas for Geo-textiles that are developed, however, the material invariably performs a minimum of one among four distinct functions: separation, reinforcement, filtration and/or drain.

3.1.2 Geo-grids (GG)

A geo-grid is geo-synthetic material used to reinforce soils and similar materials. Geo-grids are commonly used to reinforce retaining walls, as well as subbases or subsoils below roads or structures. Soils pull apart under tension. Compared to soil, geogrids are strong in tension (Fig.2). This fact allows them to transfer forces to a larger area of soil than would otherwise be the case. Geogrids are commonly made of polymer materials, such as polyester, polyvinyl alcohol, polyethylene or polypropylene. They may be woven or knitted from yarns, heat-welded from strips of material, or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid.

Fig.1 Geo-Textiles

Fig.2 Geo-Grids

3.1.3 Geo-nets (GN)

Geo-nets, also called geo-spacers, constitute another specialized phase inside the Geo-synthetics space. They are fashioned by a nonstop extrusion of parallel sets of chemical compound ribs at acute angles to one another (Fig.3). Once the ribs area unit opened, comparatively giant aperture area unit fashioned into a web like configuration. Two sorts area unit most typical, either biplanar or triplanar. Their style perform is totally inside the geographical region wherever they're wont to convey liquids of all sorts.

Fig.3 Geo-Nets

Fig.4 Geo-Membranes

3.1.4Geo-membranes (GM)

A geo-membrane is very low permeability synthetic membrane liner or barrier used with any geotechnical engineering related material so as to control fluid (or gas) migration in a human-made project, structure, or system (Fig.4) . Geomembranes are made from relatively thin continuous polymeric sheets, but they can also be made from the impregnation of geotextiles with asphalt, elastomers or polymer sprays, or as multilayered bitumen Geo-composites. Continuous polymer sheet geomembranes are, by far, the most common.

3.1.5Geo-synthetics clay liners (GCL)

Geosynthetic clay liners (GCLs) are factory manufactured hydraulic barriers consisting of a layer of bentonite or other very low-permeability material supported by geotextiles and/or geomembranes, mechanically held together by needling, stitching, or chemical adhesives (Fig.5). Due to environmental laws, any seepage from landfills must be collected and properly disposed off, otherwise contamination of the surrounding ground water could cause major environmental and/or ecological problems. The lower the hydraulic conductivity the more effective the GCL will be at retaining seepage inside of the landfill. Bentonite composed predominantly (>70%) of montmorillonite or other expansive clays, are preferred and most commonly used in GCLs. A general GCL construction would consist of two layers of geo-synthetics stitched together enclosing a layer of natural or processed sodium bentonite.

3.1.6 Geo-pipes (GP)

A plastic pipe placed beneath the ground surface and subsequently backfilled. Geo-pipes are perforated or solid-wall polymeric pipes used for drainage of liquids or gas including leachate or gas collection in landfill applications (Fig.6). In some cases the perforated pipe is wrapped with a geotextile filter.

Fig.5 Geo-Synthetic Clay Liners

Fig.6 Geo-Pipes

3.1.7 Geo-foams (GF)

Geo-foam could be a product created by a compound enlargement method leading to a foam consisting of the many closed, however gas stuffed cells. The skeletal nature of the cell walls is that the unexpanded compound material. Geo-foams is expanded polystyrene (EPS) or extruded polystyrene (XPS) manufactured into large lightweight blocks (Fig.7). The blocks vary in size but are often 2 m × 0.75 m × 0.75 m (6.6 ft × 2.5 ft × 2.5 ft). The primary function of Geo-foams is to provide a lightweight void fill below a highway, bridge approach, embankment or parking lot. EPS Geo-foams minimizes settlement on underground utilities. Geo-foams is also used in much broader applications, including lightweight fill, green roof fill, compressible inclusions, thermal insulation, and (when appropriately formed) drainage.

Fig.7 Geo-Foams

Fig.8 Geo-Composites

3.1.8 Geo-composite (GC)

Geo-composite is combination of various Geosynthetics materials like Geo-textile, Geo-net, Geo-membrane, Geo-grid bounded in such a way that specific applications are addressed in the optimal manner, mini-mum lost, less time and minimum labours force and are waving basic functions separation, reinforcement, filtration, drainage and containment(Fig.8). Geo-composite used as barriers or separation layers to separate and contain polluted Soil or waste and avoid migration of pollutants to the surrounding soil or waste and avoid migration of pollutants to the surrounding soil or water. They can be mounted on solid frames to build below ground physical barriers i.e. separation walls. In railways applications, geocomposites can replace the sand layers separating the track ballast from the foundation, performing the same function of stopping the upward migration of Fines.

3.2 Properties

Geo-synthetics are usually supposed to have the following three basic kinds of properties:
1) Strength properties
2) Resistance properties
3) Permeability properties

3.2.1Strength properties

It must be tough to with stand the stresses during the installation process. Properties concerned are:

- Tensile strength
- Burst strength
- Grab strength
- Tear strength
- Resistance to ultraviolet light degradation for two weeks exposure with negligible strength loss

3.2.2 Resistance properties

It must be strong enough to withstand static and dynamic loads, high pore pressure and severe abrasive action to which it is subjected during its life span. The properties concerned are:

- Puncture resistance
- Abrasion resistance
- Elongation resistance

3.2.3 Permeability properties

It must be resistant to excessive clogging and blinding, allowing water to pass freely across and within the plane of the geotextile. At the same time, it must be capable of filtering out and retaining fines in the subgrade. The properties concerned are:

- Cross plane permeability
- In plane permeability
- Apparent opening size

3.3. Experimental Programme

3.1 Soils used in the project

Some major kinds of soils that are encountered are:
(i) Black cotton soil – marshy regions, dried up river or lake beds, etc.
(ii) Marine clay – river delta, high rainfall zones, d/s of erosion prone areas.
(iii) Granular soil– Desert regions, coastal areas, etc.
(iv) Red laterite soil – Plateaus, boulder regions.
Black cotton soils are expansive in nature and tend to shrink in dry seasons while in wet seasons they expand highly depending on the mineral present in it. It has weak strength
Properties like the load bearing capacity. This is an adverse property for the construction of pavement and so the soil needs to be assessed for the various engineering properties including the depth of the layer to compensate the amount of expansion and shrinkage.
Marine clay also belongs to the family of pure clays but has fine sand embedded into it. This might have happened due to the exposure of clayey soils to desert winds and eroded soils. These sand grains have acted as coarse aggregate as in concrete and strengthened the soil to some extent but are still not good enough for engineering applications. Expansion behavior is reduced as compared to that of clays.
Red laterite soils possess good strength properties but when exposed to high moisture, these also behave like clay and may cause the failure of pavements and so need the assessment for strength behavior. From literature survey we found that expansive nature is not as extreme as in clays.

4. RESEARCH METHODOLOGY

The aim of doing this work is to highlight the use of geosynthetics for improving the strength and stability of sub grade soil. A geosynthetic material can be natural or synthetic and are added to soil to increase its performance. It is found that addition of geosynthetic increases the stability of roads where bearing capacity of soil is low. Geosynthetic materials are framed into textile, raft, mat, cell and membrane. Modern geosynthetic material don’t usually decay under biological and chemical processes which is useful in construction of road and its maintenance.

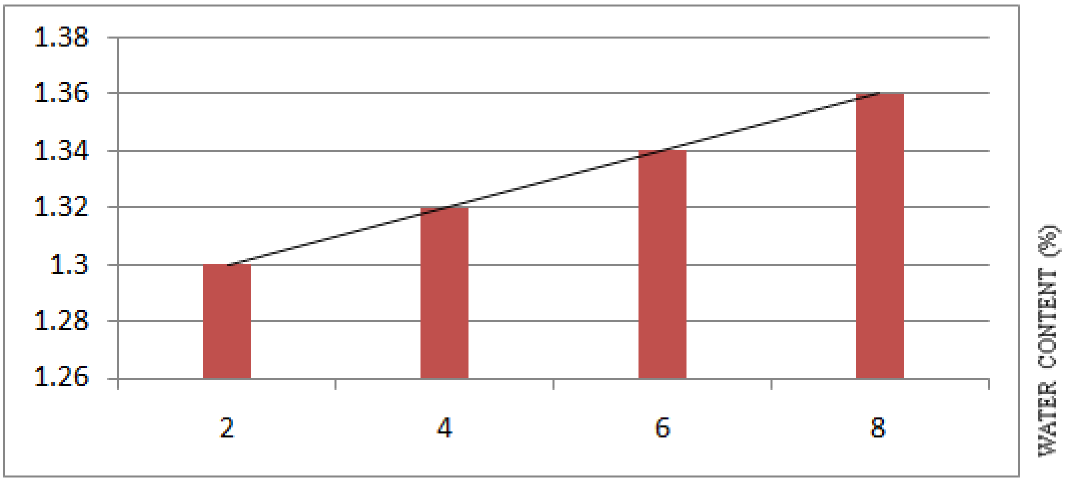
5. DIFFERENT LAB TEST FOR GEO SYNTHECTICS

5.1 Proctors Compaction Test

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

TABLE 1
PROCTORS COMPACTION TEST

SL.NO	DESCRIPTION	1	2	3	4
1	Mass of compacted wet soil + mould(g)	6218	6423	6384	6541
2	Mass of wet soil (WL)	1.7kg	1.8kg	1.9kg	2.0kg
3	Bulkdensity $\gamma f=\frac{WL*1000}{V}$	1.73	1.83	1.93	2.03
4	Water content (%)	2%	4%	6%	8%
5	Dry density(g/cc)	1.3	1.32	1.34	1.36



GRAPH 1: PROCTORS COMPACTION TEST

From graph, Optimum moisture content = 8%.

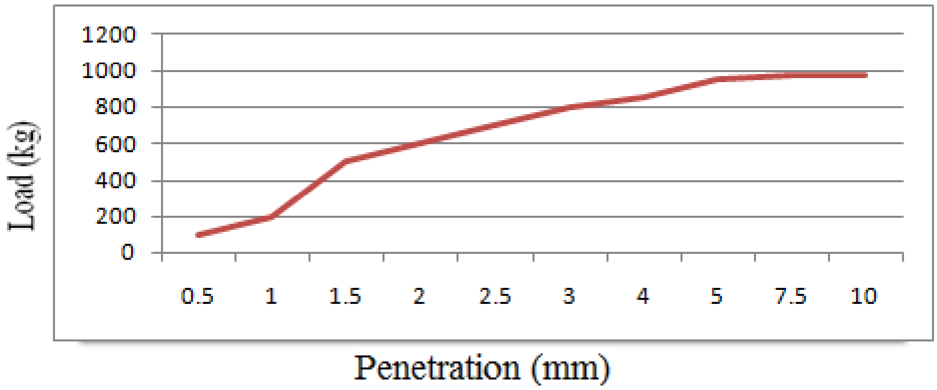
5.2 California Bearing Ratio Test

The California Bearing Ratio (CBR) test is a penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

TABLE 2
California Bearing Ratio Test Using Gravel Soil

Readings	Penetration (MM)	Corrected Load(kg)
9.39	0	0
9.89	0.5	1363.59
10.39	1	1020.24
10.89	1.5	480.69
11.39	2	13.83.21
11.89	2.5	274.68
12.39	3	578.79
13.39	4	824.04
14.39	5	1128.15
16.89	7.5	441.45

GRAPH 3: CALIFORNIA BEARING RATIO TEST USING GRAVEL SOIL



From graph:
For 2.5mm, CBR Value = 49.63%
For 5mm, CBR Value = 41.85%
It shows the value of 2.5mm is greater than 5mm.
Then the CBR value = 49.63%= 50 (Approx).

The following observation using geotextile in gravel soil by three layers confirms the strength mobilization principle of the geotextile in general which emphasized that the strength mobilization of reinforcing geotextile materials material very much depends on the range of CBR of soil sample. The smaller the soil sample CBR the more effective the strength mobilization effects of geotextile material in general.

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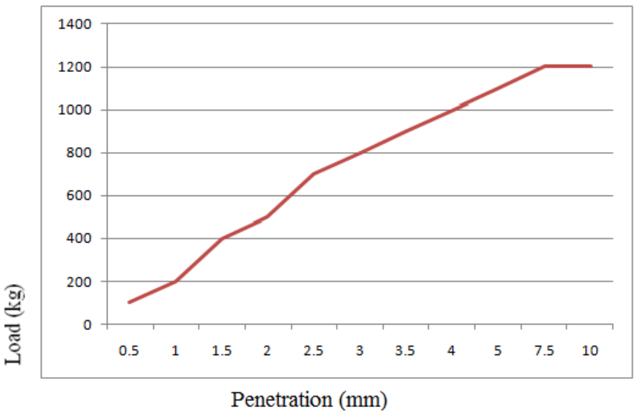
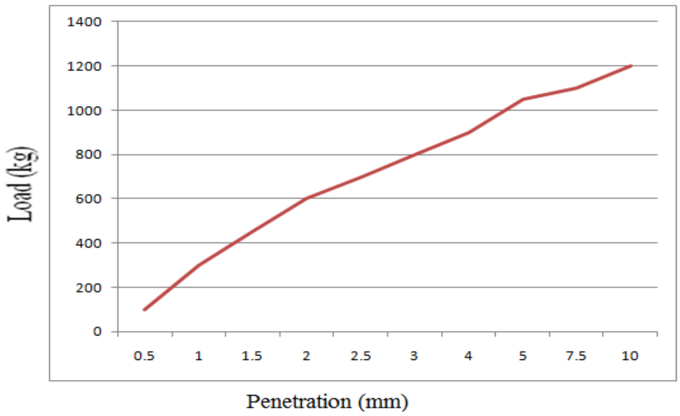
TABLE 3

USING GEOTEXTILE IN GRAVEL SOIL

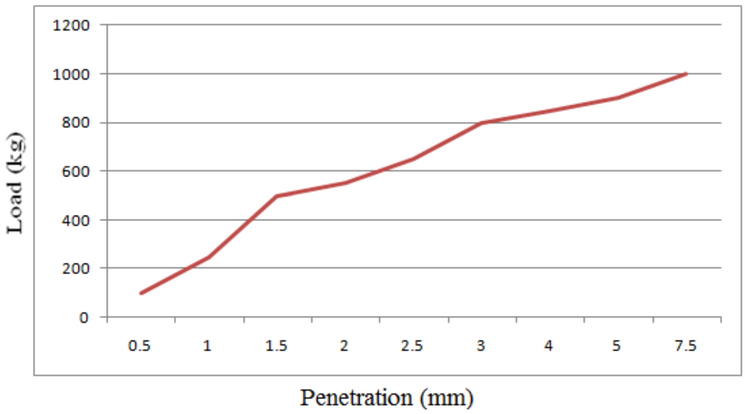
NUMBER OF GEOTEXTILE LAYER	GRAVEL SOIL
ONE LAYER (BOTTOM)	57%
ONE LAYER(MIDDLE)	54%
ONE LAYER(TOP)	50%



GRAPH 3: CBR USING GEOTEXTILE BOTTOM LAYER



GRAPH 4: CBR USING GEOTEXTILE MIDDLE LAYER



GRAPH 5: CBR USING GEOTEXTILE TOP LAYER

5.3 Direct Shear Test

A direct shear test is a laboratory or field test used by geotechnical engineers to measure the shear strength properties of soil or rock material, or of discontinuities in soil or rock masses.

TABLE 4
DIRECT SHEAR TEST READING IN GRAVEL SOIL

Sl.no	Normal Stress (Kg/Cm²)	Shear Load				Shear Stress (N/Cm²)	
		Without Geo-Textile		With Geo-Textile		Without Geo-Textile	With Geo-Textile
		Div	N	Div	N		
1	0.5	18	52.2	29	84.1	1.45	2.33
2	1.0	30	87	35	101.5	2.41	2.81
3	1.5	41	118.7	42	121.8	3.30	3.38
4	2.0	52	150.8	54	156.6	4.18	4.35
5	2.5	61	176.9	63	182.7	4.91	5.075

Size of Shear box = 6×6cm =36cm²
Using gravel soil, Shear Stress =1.45N/cm²
Using Gravel Soil with Geosynthetics,
Shear Stress = 2.33N/cm²

6. FUNCTIONS OF GEO-SYNTHECTICS

A paved road section with the location of possible geosynthetic layers and the various functions that these geosynthetics can fulfill. These functions include:

Separation: The geosynthetic, placed between two dissimilar materials, maintains the integrity and functionality of the two materials. It may also involve providing long-term stress relief. Key design properties to perform this function include those used to characterize the survivability of the geosynthetic during installation.

Filtration: The geosynthetic allows liquid flow across its plane, while retaining fine particles on its upstream side. Key design properties to fulfill this function include the geosynthetic permittivity (cross-plane hydraulic conductivity per unit thickness) and measures of the geosynthetic pore-size distribution (e.g. apparent opening size).

Reinforcement: The geosynthetic develops tensile forces intended to maintain or improve the stability of the soil geosynthetic composite. A key design property to carry out this function is the geosynthetic tensile strength.

Stiffening: The geosynthetic develops tensile forces intended to control the deformations in the soil-geosynthetic composite. Key design properties to accomplish this function include those used to quantify the stiffness of the soil-geosynthetic composite.

Drainage: The geosynthetic allows liquid (or gas) flow within the plane of its structure. A key design property to quantify this function is the geosynthetic transmissivity (in-plane hydraulic conductivity integrated over thickness).

Hydraulic/Gas Barrier: The geosynthetic minimizes the cross-plane flow, providing containment of liquids or gasses. Key design properties to fulfill this function include those used to characterize the long-term durability of the geosynthetic material.

Protection: The geosynthetic provides a cushion above or below other material (e.g. a geo-membrane) in order to minimize damage during placement of overlying materials. Key design properties to quantify this function include those used to characterize the puncture resistance of the geosynthetic material.

7. APPLICATION OF GEO-SYNTHECTICS

The procedure for testing remains a similar for each the cases except the addition of geo-synthetic layers into the soil whereas compacting at totally different heights of the soil within the mould. The geotextile and therefore the geogrid were take circular items that will match specifically into the mould while not. Layers were placed higher than of the primary and therefore the third layer whereas compacting the soil which might grow to be top of second layer and fourth layer when inverting the mould for cosmic microwave background testing and CBR test was conducted.

8. FUTURE SCOPE OF THE WORK

It is expected that the use of geosynthetics will become increasingly routine, and that geosynthetics will be the standard material of choice for several applications. It can be used in environmental engineering for landfill projects. It can also be applied in railway construction which includes anti filtration, anti-seepage, drainage, protection and reinforcement needle punched staple fiber nonwovens were used as filtration for subgrades.

Only Laboratory model plate load tests were performed to investigate (i) the effect of woven coir Geo-textiles and hand knotted nettings on the pressure versus settlement behaviour of loose sand bed, (ii) the degree of improvement obtained using sand-coir fiber composite in the form of columnar reinforcement on soft clay bed. All the results presented have scale effects and hence can be considered to be only qualitative in nature. Large scale field tests are needed to quantify the strength improvement ratio for a given set of values of variables considered in the present study.

9. CONCLUSION

An in-situ method of stabilization using geogrid in the form of geogrid cell was established and the improvement in the bearing capacity is observed from both the experimental and numerical study. The findings of the study are summarized below.

- The ultimate bearing capacity of the reinforced soil increases with decrease in vertical spacing between the geogrid cages.
- The maximum percentage increase in the bearing capacity of the reinforced soil is observed as 50% for Geo-grids placed at 5cm spacing and 29% for Geo-grids placed at 20cm spacing.
- The increase in the load carrying capacity of the reinforced soil is due to the additional adhesive shear resistance mobilized between reinforcement.
- The results of FEM analysis agrees well with the results of model tests conducted.

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

1. According to the Highway Research Board classification, the black cotton soil sample has been categorized as A-7-6 (4.549)
2. There is substantial increase in MDD with increase in addition of fibers upto 0.75% by weight beyond which it decreased.
3. There is substantial decrease in OMC with increase in addition of fibers.
4. 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.
5. 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 resistance 1% of fibers (by weight of soil) can be considered as the optimum fiber content.
6. 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.
7. The percentage increase in CBR value after stabilizing it with optimum percentage of fibers is 197.25%.
8. In the case of sedu soil there is substantial increase in MDD with increase in addition of fibers.
9. 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.
10. 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.

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