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Improvement of CBR Value of Soil Using Geogrids and Jute Fibers

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Abstract: In India, sub-grade of flexible pavement are generally constructed over naturally available soil strata. Often, these sub-grade have very low strength depending of the soil type in various reach of length of road construction. The California Bearing Ratio (CBR) is the test which helps to know the strength of such sub grades, if CBR value of respective sub grade soil is low, it needs to increase the thickness of pavement. Due to such challenges and unavailability of suitable sub-grade material research is required to find the economic method of converting locally available soil or problematic soil to suitable construction material. One of such methods is using, 'reinforcing' materials like 'Geogrid and natural Geotextiles (jute) in the sub grade layer to increase the strength. This paper presents Geosynthetics (geogrid and geotextile) as a tension material that has been used for the reinforcement of black cotton soil, alluvial soil, and sandy soil. Additionally, series of CBR tests were conducted to evaluate the effect of placing a layer of reinforcement horizontally at a depth of $1/3^{rd}$ of the height (125mm) of mould from the top surface of these soils. The test shows that the CBR of reinforced soil increases with the use of geogrid and natural geotextile (jute).

Keywords: California bearing ratio, Geogrid, Geotextile, Sub-Grade

1. Introduction

Geotechnical materials, such as soil and rocks, are the most fundamental construction materials encountered in the civil engineering projects. All the loads are eventually transferred to the shallow depths of soils or to the bedrocks at larger depths. Where the soil at shallow depth is weak, the loads are often transferred to the firm and strong deeper layers by using the deep foundation systems [1]. Few of the researchers have considered different ground improvement techniques, such as installation of stone columns [2], provision of geogrids [3] and using sand drains to enhance the settlement characteristics [4]. The major mechanism of working of these ground improvement techniques lies in the fact that soil soft soils, undergo large and long term settlement under working loads. These ground improvement techniques enhance the settlement and load settlement characteristics of the ground and therefore, improves the overall quality of the soil.

Additionally, several researchers have investigated the influence of partial saturation, or influence of matric suction on the shear strength characteristics of the soils have been extensively investigated in the literature. Studies are available in which the bearing capacity of shallow foundations are investigated in varying saturation conditions under static [5] and seismic loading conditions [6]. However, the influence of inclusion of Geogrids and Natural Geotextiles, such as Jute Fibers in enhancing the characteristics of the natural ground needs to be considered more explicitly.

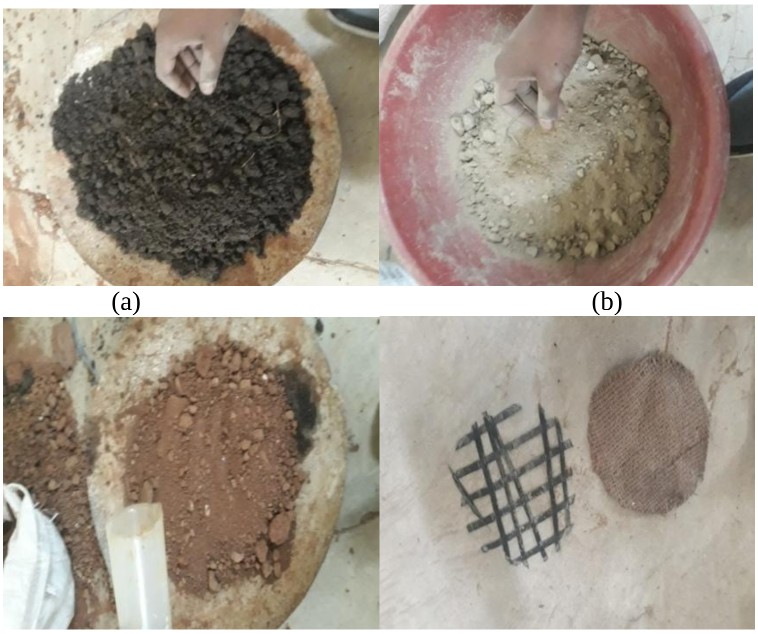
With rapid increase in urbanization, the traffic volumes and the need for enhanced transport infrastructure is very essential. In last few decades, the number of vehicles as well the axle loads on vehicles have increased significantly. In developing countries, such as India, this growth in transportation infrastructure has put tremendous effort on a geotechnical engineer to enhance the quality and strength of the subgrade soil. When sub-grade soil is soft or not capable of withstanding adequate traffic loads for an extended period due to environmental pressures or traffic, it results in deformation in the pavements. Although, few of the researchers have considered the influence of traffic load on the stability of embankments [7,8], the studies are limited in which the performance of the embankment has been studied considering the influence of natural or synthetic geogrids. The study indicates that CBR improvement sufficient to eliminate the need for a strong sub-grade in unpaved roads is achievable through the use of these geogrid and natural geotextiles (jute) [9,10,11,12].

Several design concepts for the stabilization of soil and improving the California bearing ratio(CBR) value are available in the literature. A series of small-scale laboratory tests are carried out to determine the improvement in the property of the soils. CBR tests are conducted by introducing geogrid and natural geotextile(jute) in the horizontal layer at a depth 1/3rd of the height of mould from the top surface of the soils. Further, geogrid and natural geotextile influences using the CBR are investigated in using these (black cotton, alluvial, and sandy soil) considered as soft sub-grade soil of the unpaved roads.

This paper aims to improve the California bearing ratio of black cotton soil, alluvial soil and sandy soil used as sub-grade soil in unpaved road construction by using two different types of reinforcement material namely geogrid and natural geotextile (jute).

2. Experimental investigations

Black cotton soil, alluvial soil, and sandy soil are considered as sub-grade materials in the experiments. Black cotton soil is collected from Rajmahal areas in Sahebganj district in Jharkhand whereas alluvial soil is collected from Patna in Bihar from the Ganga river plain. Sandy soil is collected from Baliapur region in Dhanbad district of Jharkhand. Industrial grade geogridswere procured from Ocean Global Pvt. Ltd. which is a geogrid manufacturing company based in New Delhi. Natural geotextile(jute) were extracted from gunny bags, used for rice packing. Various index properties and compaction properties are evaluated in the laboratory for all three types of soil are given in Table 1 and corresponding images are shown in Fig. 1. The geogrid and natural geotextile used in the experiment are also shown in Fig. 1. The properties obtained based on the laboratory experiments are shown in Table 2.



(a) (b) (c) (d)

Fig. 1. The different soils (a) Black Cotton (b) Alluvial (c) Sandy and (d) Geogrids considered

Table 1: Properties of the Black Cotton Soil, Alluvial soil and Sandy soil.

Parameters	Black Cotton Soil	Alluvial Soil	Sandy Soil
Colour	Black	Light Grey	Light Brown
Specific Gravity (G)	2.524	2.703	2.636
Liquid Limit (W_L)	47.3	29.01	30.15
Plastic Limit (W_P)	25.87	22.37	-
Plasticity Index (I_P)	21.43	7.44	-
Maximum Dry Density MDD (g/cc)	1.67	2.16	1.98
Optimum Moisture Content (OMC)%	21.3	11.2	10.93
California Bearing Ratio CBR %	4.81	6.2	7.51

Table 2: Properties of Reinforcing Materials

Parameters	Geogrid	Natural Geotextile (jute)
Material composition	Polypropylene	Natural Jute Fiber (woven)
Aperture Size (mm)	21x21	2x2
Thickness (mm)	1.5	2
Tensile Strength (kN/m)	4.00	2.81

2.1 Sample Preparation

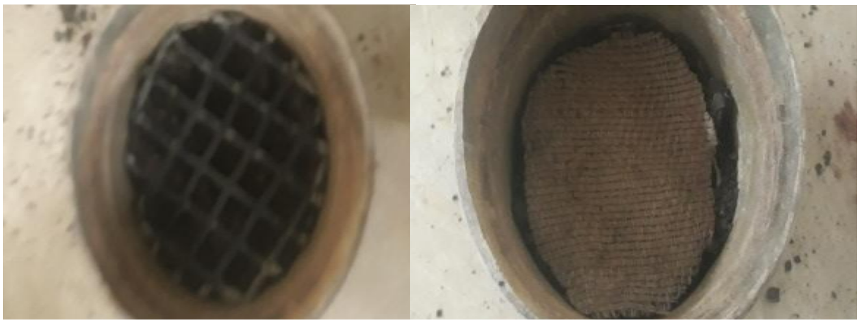
All the experiments are performed as per the standard procedure established by the American Society for testing and materials (ASTM 2006). California bearing ratio test is done as per IS:2720 (Part XVI – 1974). For the reinforced soil specimen, a single layer of reinforcement is cut in the form of a circular disc of a diameter of 146 mm i.e slightly less than the mould diameter of 150 mm and is placed at a depth of 1/3rd height of the mould height from the top surface of the compacted soil specimen.

The required quantity of dry soil and water for filling the mould is calculated based on the maximum dry density and optimum moisture content obtained from the standard proctor test. The soil is mixed thoroughly after adding the required amount of water corresponding to the optimum moisture content.

The soil is filled in the mould up to the mark where the reinforcing layer is to be placed and then compacted up to the desired level to get the required density. After compaction of the soil, reinforcement is placed inside the mould at the height of 1/3rd height of the mould from the top. Finally, the remaining soil is filled and compacted. The top soil surface of the mould is leveled. A filter paper and a perforated metallic disc with an adjustable stem along with an annular surcharge weight of 5 kg are then placed on top of the compacted soil specimen. The whole mould assembly is transferred to a soaking water tank filled with water.

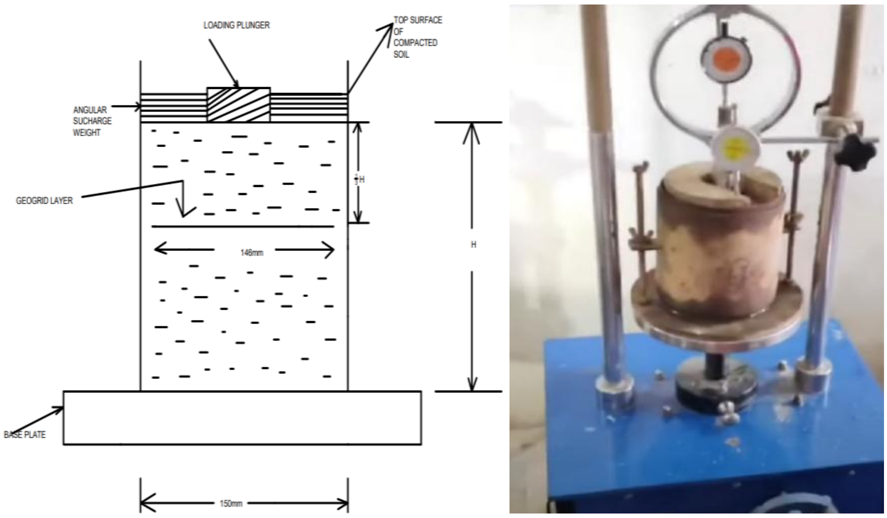
The mould assembly is left undisturbed for 96 hours in the soaking tank to allow the soaking of water in the specimen. After 96 hours of soaking the whole mould, assembly is transferred to a motorized loading frame to conduct the CBR test. Initially, a seating load of 4 kg is applied through the penetration plunger at the center of the specimen. The dial gauge is set to zero before the application of any further load. The load is then applied through the penetration plunger at a constant rate of strain (1.25 mm/minute) and the load is carefully recorded up to a total penetration of 12.5 mm.

Finally, load–Penetration curves are drawn for each case. The correction is applied to the load – Penetration curves where ever required using the standard procedure. This process is followed for all three types of soil considered in this investigation. The position of geogrid during the test has been shown in Fig. 2. Similarly, the schematics of the test setup as well as the picture of the actual test setup has been shown in Fig. 3.



(a) (b)

Fig. 2. Position of (a) Geogrid and (b) Natural Geotextile (Jute) in the CBR Mould



(a) (b)

Fig. 3. Experimental Test Setup (a) Schematics and (b) Actual

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3. Results and Discussions

In the present study, Black cotton soil, alluvial soil, sandy soil and two types of reinforcement materials namely- geogrid and natural geotextile(jute) are used for the investigation. CBR tests were conducted for both unreinforced as well as reinforced cases under soaked conditions. For the reinforced case a single layer of reinforcement is placed at a depth of 1/3rd height of the mould from the top soil surface. The CBR value of soil increases with the inclusion of reinforcement.

The load settlement curve obtained from the CBR test is shown in Fig 4, 5 and 6 for Black cotton soil, Alluvial Soil and Sandy Soil respectively for both reinforced as well as unreinforced cases.

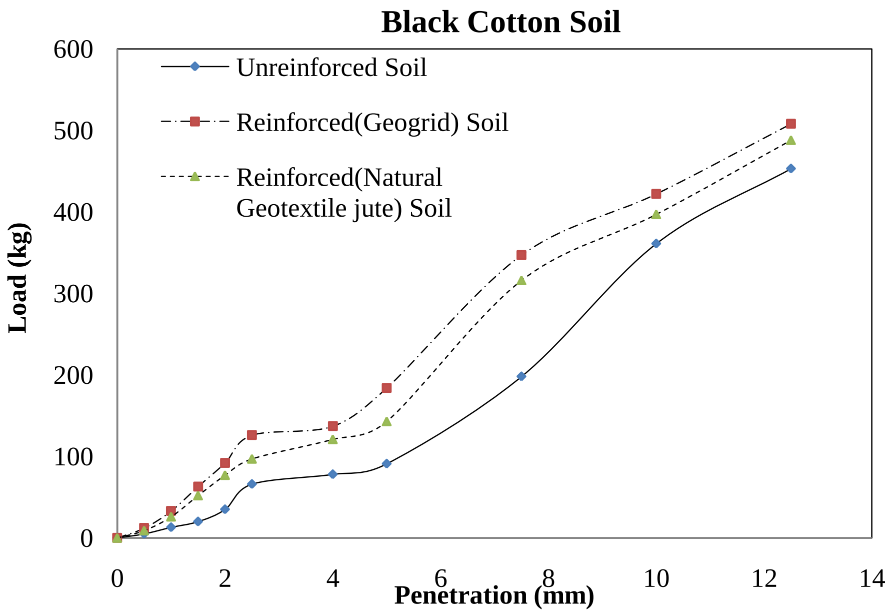

Fig. 4. Load penetration curves obtained for Black Cotton soil for both reinforced and unreinforced cases.

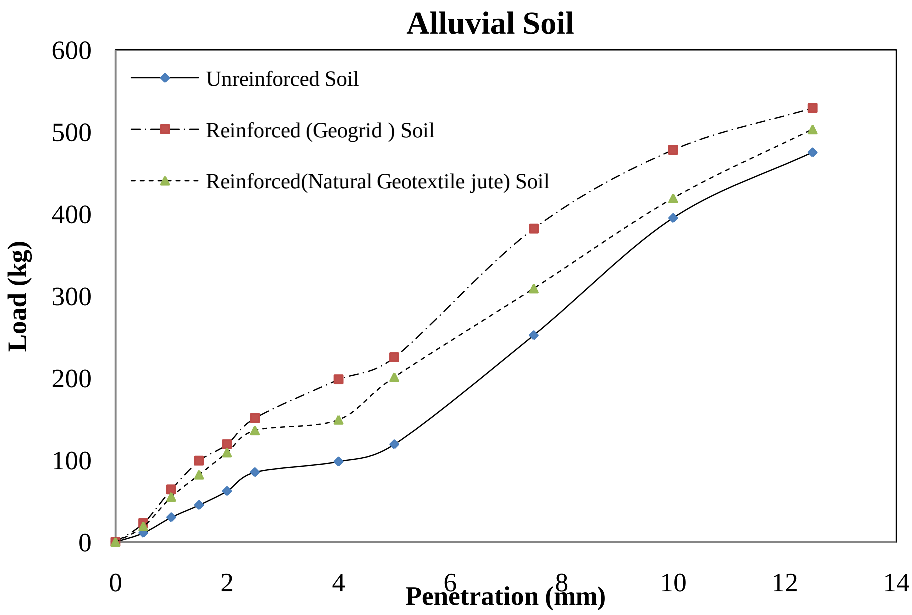

Fig. 5. Load penetration curves obtained for Alluvial soil for both reinforced and unreinforced cases.

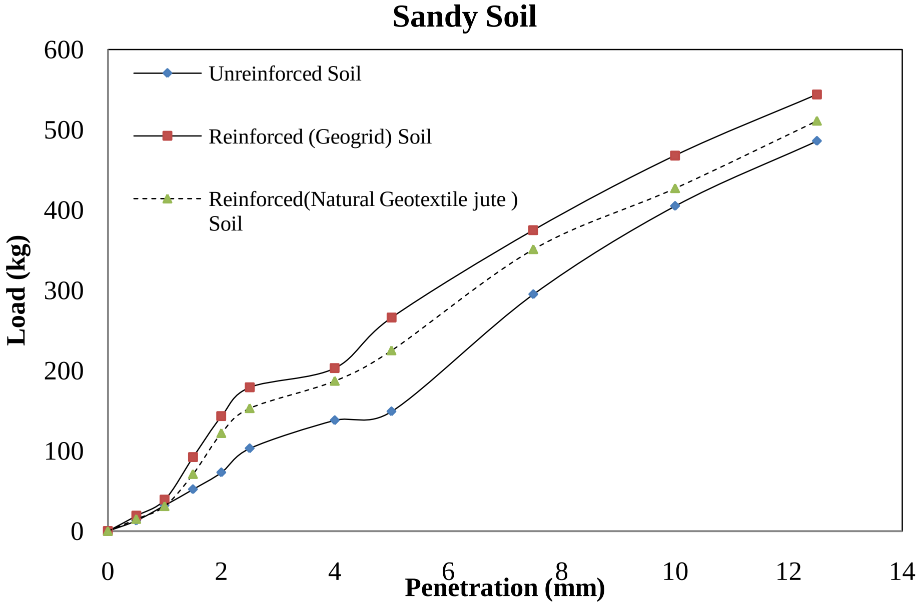

Fig. 6. Load penetration curves obtained for Sandy soil for both reinforced and unreinforced cases.

From Fig. 4, 5 and 6, it could be seen that the load–penetration behavior of black cotton soil, alluvial soil and sandy soil improves when reinforcement is geogrid and natural geotextile(jute). CBR values of the unreinforced black cotton soil corresponding to 2.5 mm and 5.0 mm are found to be 4.81% and 4.42%, the value is increased to 9.19% and 8.95% when geogrid is used as reinforcement i.e 91.06% rise in CBR value. But when the reinforcement is changed to natural geotextile(jute), the CBR value increased to 7.08% and 6.95% which is 47.19% of the unreinforced black cotton soil. For alluvial soil CBR values of unreinforced soil corresponding to 2.5 mm and 5.0 mm are found to be 6.2% and 5.79% which increased to 11.02% and 10.94% when geogrid is used as reinforcement is 77.74% rise in CBR value. When natural geotextile(jute) is used the CBR values are increased to 9.92% and 9.78% i.e value increased to 60% from the initial value. Similarly for sandy soil CBR values of the unreinforced soil corresponding to 2.5 mm and 5.0 mm are found to be 7.51% and 7.25% increased to 13.06% and 12.94 % in geogrid reinforcement and 11.16% to 10.94% in a natural geotextile(jute). Which is 73.90% rise in geogrid and 48.60% in natural geotextile(jute). Based on these observations it can be concluded that the placement of a horizontal layer of reinforcement can effectively increase the CBR value of the soil.

As per IRC: 37 – 2018, The thickness of the pavement may be calculated by considering the design traffic factor of the cumulative standard axle as 40 msa (million standar axle) and the corresponding CBR value of these soils with reinforcement and without reinforcement is adopted. The thickness of Reinforced and Unreinforced soil has been shown in Fig. 7. Also, based on the calculations, the reduction of pavement thickness is given below in Table 3.

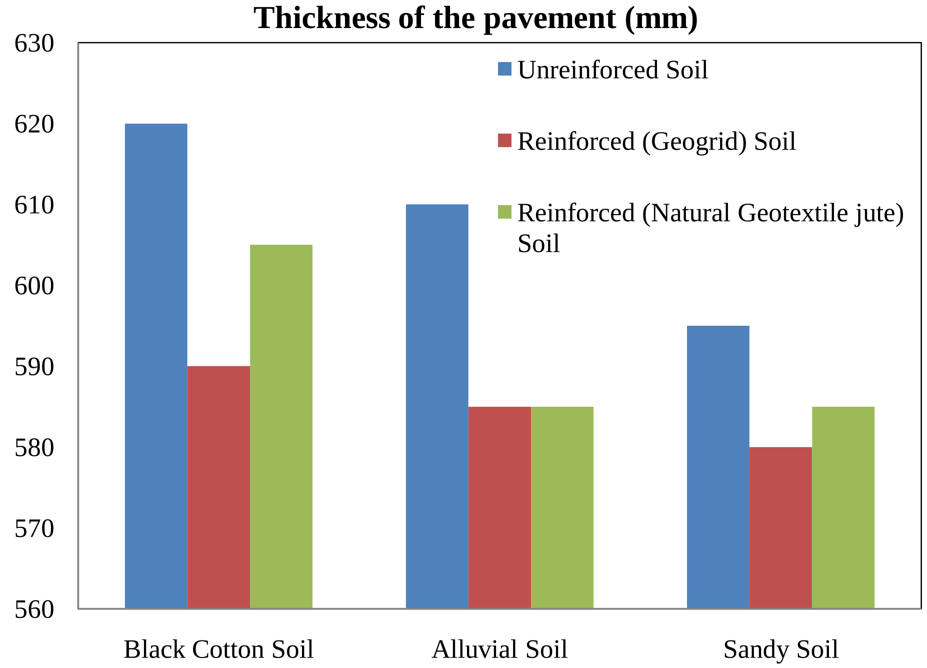

Fig. 7. Thickness of the pavement with reinforced and Unreinforced soil

Table 3 Reduction of the thickness of the pavement

Parameters	Black Cotton Soil	Alluvial Soil	Sandy Soil
Reinforced (Geogrid) Soil	5.08%	4.27%	2.58%
Reinforced (Natural Geotextile jute) Soil	2.47%	4.27%	1.70%

4. Conclusion

The following conclusion can be drawn from the present investigation.

- The inclusion of a single layer of reinforcement in soils improves the CBR Value and therefore the strength of the soils.
- It implies that geogrid and natural geotextile(jute) reinforced soils in various earthen structures will perform better than unreinforced ones.
- Natural geotextile(jute) gives slightly less CBR value than Geogrid so on low-budget roads like a rural roads we can use natural geotextile(jute) in place of geogrid.
- The thickness of the sub-grade layer also reduces by using this type of reinforcement which saves cost and time of the construction.

5. Acknowledgements

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