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STABILIZATION OF SUBGRADE USING GEOSYNTHETICS (CASE STUDY- GEOTEXTILE) UNDER SOAKED CONDITION

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Abstract: Soil stabilization is a process of treating a soil to maintain, alter or improve the performance of the soil as a construction material and very importantly to minimize the cost of earthworks. In this study, the results of studies on the performance of non-woven geotextile within subgrade are carried out experimentally utilizing the California Bearing Ratio (CBR) testing arrangement. Three soil samples; (lateritic, clay and organic) were subjected to the following laboratory tests; Particle size analysis, Atterberg limit test, specific gravity test, Compaction test and CBR test. The result obtained from the Atterberg limit test shows that the liquid limits of lateritic and clay soils are higher than the standard set by the Federal Ministry of Works general specification (1997) for selection criteria of subgrade soils and are considered not good for subgrade soil, while organic soil with its liquid limit less than 35% has low plasticity. CBR tests were conducted with and without non-woven geotextiles in soaked condition with the non-woven geotextiles placed at depths H/4 from the top and bottom surfaces of the soil to determine the strength of the soil samples. CBR values are low for the unreinforced soil samples (2%- 6%) as when compared with the reinforced soil samples (3%-16%). It was found that non-woven geotextile placed at depth H/4 from the bottom surface showed higher CBR values (10.4%, 15.8% and 2.8%) than when placed at depth H/4 (8.94%, 13.7% and 2.45%) from the top surface which gives a clear indication that the presence of non-woven geotextiles influences the CBR of the soil. Thus, designers should consider the installation of geotextile to improve the CBR and reduce the layer thickness of pavements.
Keywords: Stabilization, geotextile, CBR, pavement, soil

1. INTRODUCTION

Pavements either bound or unbound are exposed to repeated, high and focused loads which can cause precipitate aging and failure of the road construction. Thus, roads should be constructed on strong native soil deposits and the behavior of road surface depends on the strength of the fill material and the subgrade below it (Maxwell, 2005).

In the construction of pavements, subgrade serves as the foundation for the pavement and for this purpose, an appropriate value of CBR is required in subgrade soil in order to ensure adequate strength to support the imposed traffic load. However, not all subgrades are able to meet up with this criterion because some have a considerably low and thus inappropriate CBR values. Subgrade supports the pavement to carry load and hence should have adequate strength regardless adverse conditions such has high rainfall and flooding. Natural soil is of limited strength in many locations around the globe and weaker soil subgrade increases the pavement thickness, thereby adding to cost. Increase in the moisture content below or up to the point of saturation decreases the shear strength of the subgrade soil by reducing the amount of contact and interlock of the aggregates thereby leading to rutting in road pavements (Ampadu, 2007). When excavation and replacement of those soils is not cost effective, soil stabilization may be necessary to provide a working platform so that the base course gravel layer can be properly constructed and overall rutting reduced. Geosynthetics are planar polymeric materials that have been extensively used in these situations (i.e. subgrade stabilization) to reinforce and or separate the surrounding soils (Maxwell, 2005). A geosynthetic has been defined by the American Society for Testing and Materials (ASTM) D4439 (2001) Committee D35 on Geosynthetics as "a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system." Geosynthetics have been found to be a cost effective alternative to improve poor sub-soils in adverse locations, especially in situations where there may be non-uniform quality and/or non-availability of desired soils with applications in almost all geotechnical engineering projects such as airport and highway pavements.

The geosynthetics that are routinely used in the transportation industry are geotextiles, geogrids, geomembranes, erosion control blankets and materials, geosynthetic clay liners, geocomposite drainage materials and geonets. The major functions of geosynthetic materials in relation with transportation engineering are separation, reinforcement, filtration, drainage and acting as a liquid barrier (Khodaii, 2009), but in the asphalt layer if properly installed they mainly function as fluid barrier, cushion, and reinforcement. In providing reinforcement, the geosynthetic material structurally strengthens the pavement section by changing the response of the pavement to loading. In providing separation, it prevents contamination of an aggregate layer by the underlying subgrade and hence maintains a clean interface. In providing filtration and drainage, it aids in improving subsurface drainage and allows the rapid dissipation of excess subgrade pore pressures caused by traffic loading (Barksdale, 2006).

Geotextiles are permeable fibrous structures used for filtration, drainage, separation, reinforcement and stabilization in civil engineering applications and are broadly classified into woven, nonwoven and knitted structures; employed according to the performance requirement. The beneficial property of the woven structure in terms of reinforcement, is that stress can be absorbed by the warp and weft yarns and hence by fibres, without much mechanical elongation. Needle-punched nonwoven fabrics are made from blended webs of continuous or staple filaments that are passed through banks of multiple reciprocating barbed needles. The fabrics derive mechanical coherence from the entangling of fibres caused by the barbs on the reciprocating needles; these fabrics thus resemble wool felts. Needle-punched geotextiles are relatively open and porous structures with high permeability, high elongation and conformability, while knitted geotextiles are strong but generally very extensible (Denton and Daniels, 2007). All road systems, whether temporary or permanent, ultimately derive their strength and support from the subgrade and the misconception in conventional layered roadway designs, such as AASHTO, is that respective layers of various pavement components will remain unchanged over the existing subgrade throughout the service life of the pavement. Changes in load and environment cause pavement system failures to occur at the aggregate base subgrade interface. This is a result of the intrusion of low strength subgrade material into the aggregate base and base materials into the subgrade (Giroud and Han, 2011). Research programmes have largely concentrated on unpaved roads and have been able to identify benefits in terms of either reduced plastic deformation or the ability to have reduced aggregate thickness (Potter and Currer, 2010).

Technique of improving the soil with geotextile increases the stiffness and load carrying capacity of the soil through fractional interaction between the soil and geotextile material. The load coming on the road crust is transferred to the underlying soil and if the soil supporting the road crust is weaker, the crust thickness of road increases, which leads to more cost of construction and most likely road pavement failures in the nearest future, but with the application of geotextile, it helps reduce cost of bringing in earth materials from a borrow pit, rather the initial earth materials found on the construction site is used for the road pavement (Olaniyan and Akolade, 2014). The primary function of geotextile is used as pavements reinforcement, in which the geotextile mechanically improves the engineering properties of the pavement system (Woods and Adcox, 2006). The stabilization of subgrade with and without non-woven geotextile under soaked condition was conducted using California Bearing Ratio (CBR) test to ascertain the improvement it would have on the subgrade soils.

2. EXPERIMENTAL PROCEDURE

— Materials

Soil samples; lateritic and clay collected from Ogbondoroko borrow pit in Asa Local Government Area (LGA) located on latitudes 8°00' and 9°10' North of the equator and longitudes 2°45' and 4°15' East of the Greenwich Meridian (Ajibade, 2006) and organic soils collected from Sobi in Moro LGA located between latitudes 7°45'N and 9°30'N and longitudes 2°30'E and 6°25'E (Akangbe et al, 2013) both in Ilorin, Kwara State labeled (A, B and C) respectively were collected and used for experiment while the non-woven geotextile was gotten from Maccaferri Nigeria Limited, Port-Harcourt. The soil samples were gotten in polythene to prevent loss of moisture to the atmosphere.

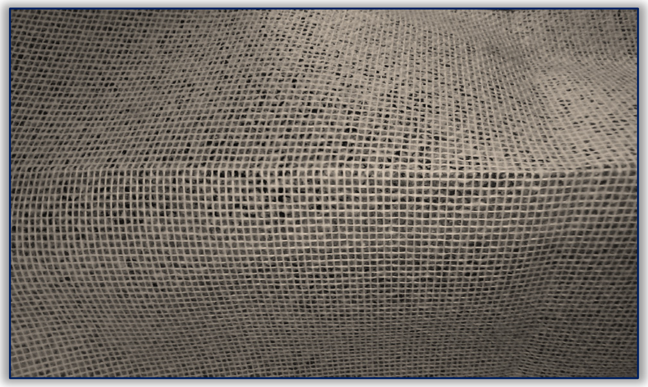

Figure 1: Sample of the non-woven geotextile material used

— Test Procedure

Analyses were carried out in order to ascertain the preliminary and engineering (strength) tests of the samples. The laboratory analysis was performed according to British Standard methods of test for soil for civil engineering purposes (BS 1377: Part 1-9, 2000). The physical tests carried out on the soil samples are grain size analysis, Atterberg limits and specific gravity while the engineering (strength) tests performed are compaction test to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soil and California Bearing Ratio (CBR) test to determine the maximum penetration load that the samples could withstand before deformation under soaked conditions with the non-woven geotextile reinforced in the soil samples at depths H/4 from the top and bottom surfaces of the soil in the CBR mould as shown in Figure 2 and the soaked CBR values were obtained after the soil samples has been soaked for 48 hours (2 days). The load values corresponding to penetrations 0.25mm, 0.5mm, 1.0mm, 1.5mm, 2.0mm, 2.5mm, 3.0mm, 4.0mm, 5.0mm, 6.0mm, 7.5mm and 8.00mm were noted. Furthermore, in order to evaluate the performance and to quantify the amount of increase in the penetration resistance, the reinforcement ratio was taken into consideration based on the CBR load-penetration relation of both soil samples and soil non-woven geotextile samples. The reinforcement ratio (Koerner, 2001) at a particular penetration is:

$$\text{Reinforcement ratio} = \frac{\text{Load with geotextile}}{\text{Load without geotextile}} \quad (1)$$

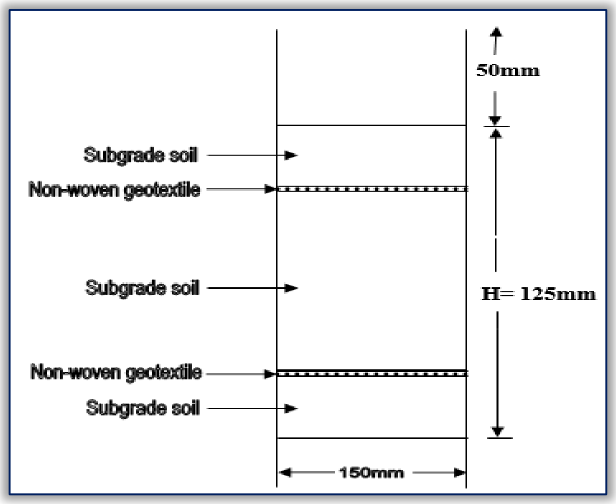

Figure 2: Cross-sectional diagram showing the subgrade soil and non-woven geotextile layers

3. RESULTS AND DISCUSSION

The summary of the results of the preliminary tests (grain size analysis, specific gravity and Atterbergs limit tests) as well as the engineering (strength) test (Compaction and California Bearing Ratio tests) are presented in Tables 1 – 3 and Figures 3 – 5.

— Preliminary Test

Grain size analysis test was a procedure used in the experiment to assess the particle size distribution of the soil samples of a granular material. Samples A, B and C according to British International Standard are considered as silty gravel with sand (GM), well-graded gravel with clay and sand (GC) (or silty clay and sand) and well-graded gravel with sand (GW) respectively.

The Atterberg limit test shows that samples A, B and C have liquid limits of 35.5%, 43.5% and 23% with plasticity index of 15.3%, 14.1% respectively indicating that samples A and B have intermediate plasticity while sample C without plastic limit and plasticity index due to its non-plastic nature has low plasticity.

Table 1: Summary of preliminary test results

Particulars	Sample A	Sample B	Sample C
BIS Classification	GM	GC	GW
Liquid limit (%)	35.50	43.50	23.00
Plastic limit (%)	20.20	29.40	-
Plasticity index (%)	15.30	14.10	-
Specific gravity (g)	2.70	2.63	1.98

Table 2: Summary of compaction test result

Particulars	Sample A	Sample B	Sample C
O.M.C (%)	14.50	12.00	11.50
M.D.D (g/cm^3)	1.35	1.39	1.44

The specific gravities for samples A, B and C are 2.70, 2.63 and 1.98 respectively which shows that these values fall within the range for lateritic (2.50 – 2.75), clay (2.60 – 2.90) and sample C having the presence of organic substances.

— Engineering Test

The summary of the compaction test is shown in Table 2. The test was performed to determine the relationship between the Optimum Moisture Content (O.M.C) and Maximum Dry Density (M.D.D) of the soils for a specified compactive effort and the maximum amount of water needed to enhance the strength or load-carrying capacity of the soil was determined.

Table 3: Summary of the CBR values (Soaked condition)

Soil samples	Without non-woven geotextile		CBR value (%)	With non-woven geotextile		CBR value (%)
	2.5mm	5.0mm		2.5mm	5.0mm	
Sample A	2.8	3.2	3.2	9.6	9.7	10.0
Sample B	5.2	6.0	6.0	15.8	13.8	16.0
Sample C	1.4	1.5	2.0	2.8	2.6	3.0

Table 3 and Figures 3 and 4 shows the summary of the CBR test results. There was a considerable increase in the CBR values after the inclusion of the non-woven geotextiles than the CBR values before the inclusion of the non-woven geotextiles. It can be clearly seen from Figure 4 that due to the placement of non-woven geotextile, the CBR values increases irrespective of the placement depth. It is observed that though the CBR values were increased in all cases, the percentage increase was found to be much higher when non-woven geotextile was placed at H/4 depth in the top and bottom regions for sample B but performs best at H/4 depth from the bottom region. The reason for this could be attributed to the fact that the depth through which the effective pressure bulb passes is a function of the diameter of the plunger and if the non-woven geotextile is inserted at depths lower than the depth of pressure bulb, significant improvement can be witnessed.

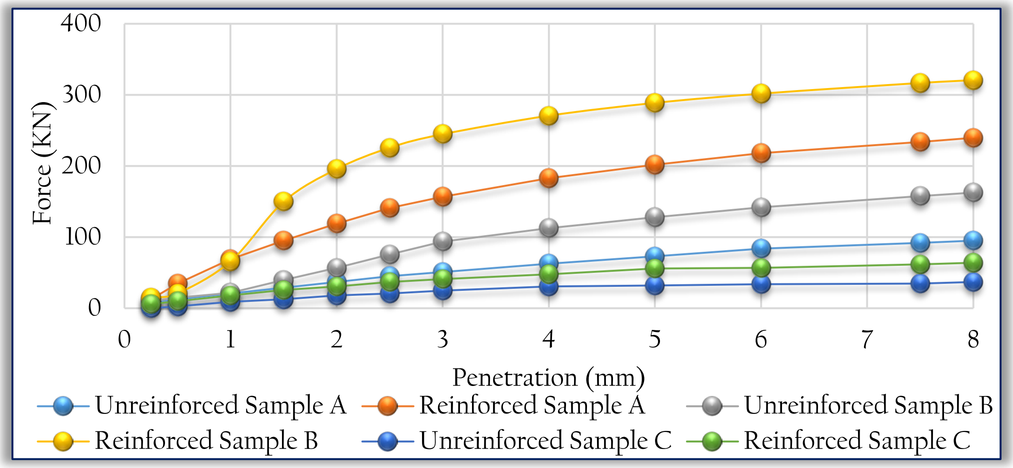

Figure 3: Graph of CBR Values for reinforced and unreinforced soil samples

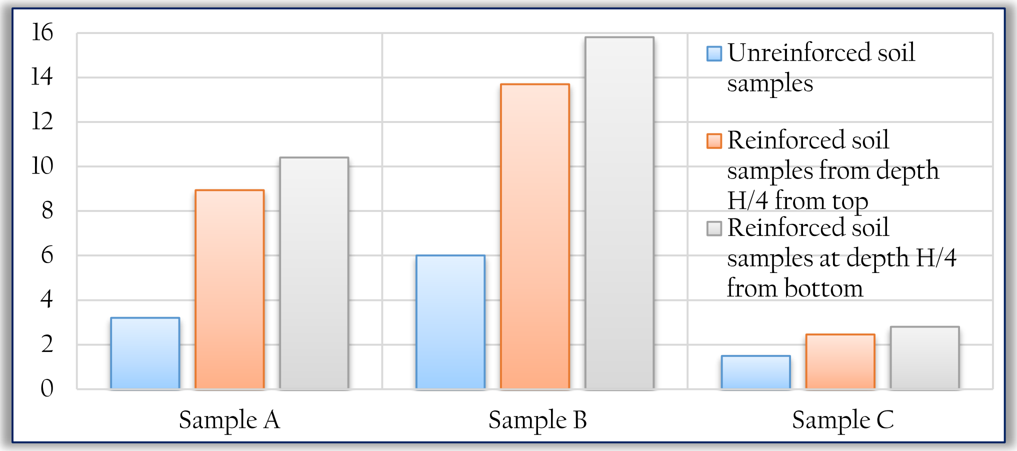

Figure 4: Effect of unreinforced and reinforced soil samples at depths H/4 from top and bottom surfaces in the CBR mould

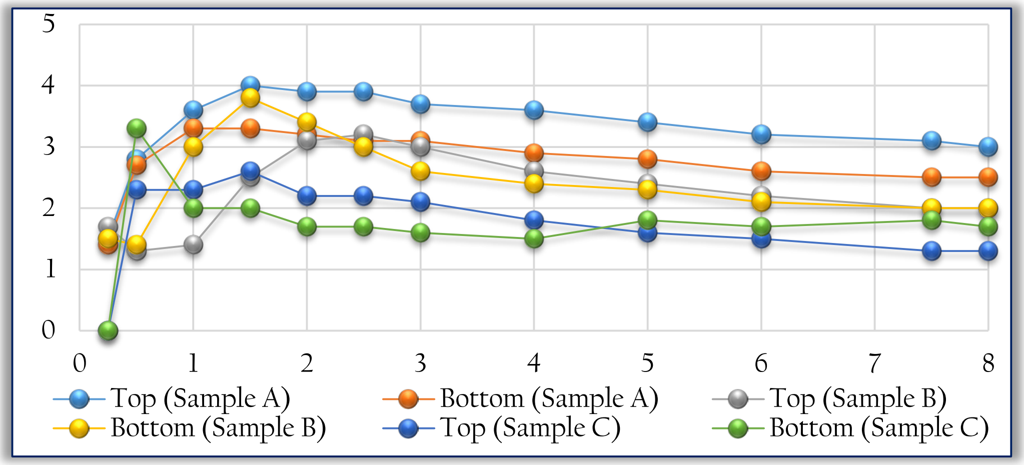

Figure 5: Variation of reinforcement ratio for soaked CBR values

Also, Figure 5 shows that reinforcement ratio is more than one for samples A and B, which indicate that the introduction of non-woven geotextile offers good resistance even to lower penetration unlike for sample C which has its reinforcement ratio less than one in some of the penetrations as this will not offer good resistance to lower penetration. Hence the use of non-woven geotextile is most advantageous in an unpaved road with soft subgrade at higher penetration (that is, higher traffic volume).

4. DESIGN FOR PAVEMENT THICKNESS

The structural capacity of flexible pavements is attained by combined action of the different layers of the pavement. The load is directly applied on the wearing course and it gets dispersed with depth in the base, subbase and subgrade layers and then ultimately to the ground. Since the stress induced by traffic load is highest at the top, the quality of top and upper layer materials is better and the subgrade layer is responsible for transferring the load from above layers to the ground. Flexible pavements are designed in such a way that the load transmitted to the subgrade does not exceed its bearing capacity.

Consequently, the thickness of layers (subbase and base course) varies with CBR of soil and it affects the cost of pavement. For instance, using curve A with the lowest traffic volume from Figure 6, it shows that sample B having CBR values of 16% when reinforced with non-woven geotextile and 6% when unreinforced with non-woven geotextile in its soaked condition has pavement thicknesses of 12cm and 20cm respectively which indicates that increase in the CBR values leads to decrease in the pavement layer thicknesses thereby reducing the cost of road construction.

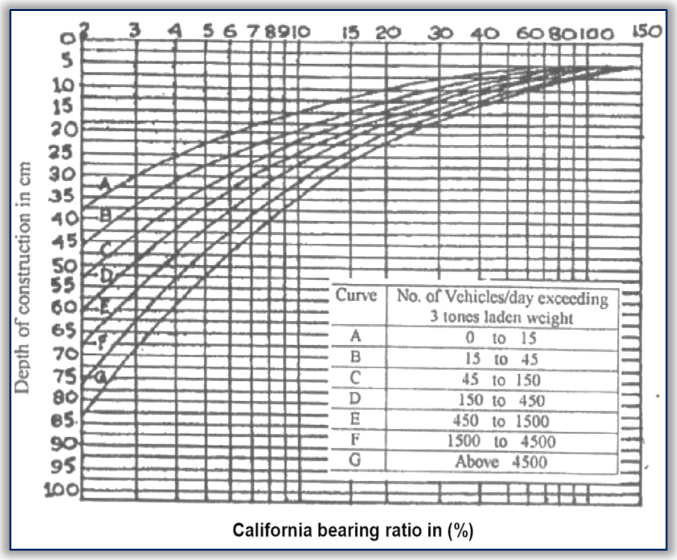

Figure 6: CBR-Depth relationship (Woods and Adcox, 2006)

5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn from the study:

- The consistency limit parameters of the soil samples reveal that samples A and B which have liquid limits of 35.5% and 43.5% respectively are higher than the standard set by the Federal Ministry of Works general specification (1997) for selection criteria of subgrade soils and are considered not good for subgrade soil while sample C which has liquid limit as low as 23% is considered good for subgrade soil.
- The soaked CBR values of samples A, B and C when reinforced with non-woven geotextile are 10%, 16% and 3% respectively, while their corresponding values without non-woven geotextile are 3%, 6% and 2% respectively. These indicate that the reinforced samples A and B are suitable for subgrade stabilization as set by the Nigerian Standard of soil classification for roads and bridges, Federal Ministry of Works general specification (1997) criteria for subgrade soils and Design Guide for improved quality of roadway Subgrades and Subbases Iowa Highway Research Board (IHRB Project TR-525).
- It can also be deduced that there exists interaction between the soil and non-woven geotextile as interfacing soil with a non-woven geotextile material increases the penetration resistance and hence the CBR in soaked condition. Thus, since subgrade CBR is taken as the criterion for the design of flexible pavements, the thickness of the component layers (subbase and base course) will be reduced when the subgrade CBR is high, thereby reducing the cost of road construction.

After the test results had been analysed, the following were recommended:

- When designing roads for flexible pavements, designers should consider the installation of geotextile to improve the California Bearing Ratio, reduce thickness of layers and increase structural number of pavements.
- Engineers should consider using the geotextile for the compaction test to ascertain whether it would have an effect on the optimum moisture content and dry density of the soil samples.
- Geosynthetics provides the answer to most of our environmental problems of slope failures, erosion menace, failures of structures which include our road ways and foundation failures. It should, therefore be used to enhance the performance of a subgrade material in a pavement system.

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