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Laboratory Study on Geotextile Reinforced Soil for Poor Subgrade

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ABSTRACT: *Many pavements have become deteriorated within their design life due to sudden fall in subgrade strength as a result of unforeseen rise in the moisture content of the subgrade which may be due to a rise in ground water level (GWL) or water seeping through cracks on road pavement. Geosynthetic materials have been found worthy to be a good means of reinforcing subgrade by increasing the useful life of a pavement or substantially decreasing the thickness of the base course. Three different soil samples were obtained and were compacted according to West African Standard and CBR tests were carried out without reinforcement (geotextile) and also by placing geotextiles at various depths within the soil mass in single layers. Then the effect of the geosynthetic material (geotextile) was observed. The results show that the strength of the subgrade (laterite) is considerably lowered with increased moisture content; and the introduction of geotextile as reinforcement in the soil substantially increase the soil at all levels ($^2/_5$, $^3/_5$, $^4/_5$) with the maximum increase in strength observed to occur at 3/5 level from the base of the compacted soil.*

Keywords: Geosynthetic, Geotextile and Subgrade

INTRODUCTION

Laterite is the product of intensive weathering that occurs under tropical and subtropical climatic condition resulting in the accumulation of hydrated iron and aluminum oxides (Agarawal et al, 2011); it is a soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidizing and leaching conditions. It forms in tropical and subtropical regions where the climate is humid. Lateritic soils may contain clay minerals; but they tend to be silica-poor, for silica is leached out by waters passing through the soil. Typical Laterite is porous and claylike. It contains the iron oxide minerals goethite, $HFeO_2$; Lepidocrocite, FeO (OH); and Hematite, Fe_2O_3. It also contains titanium oxides and hydrated oxides of aluminum, the most common and abundant of which is gibbsite, $Al_2O_3{\cdot}3H_2O$. The aluminum-rich representative of Laterite is bauxite (Alexander, 1992.)

Some laterites are found to have a pozzolanic reaction when mixed with lime (which can be explained by the high clay content), producing hard and durable building materials (e.g. stabilized blocks). Soft occurrences tend to harden on exposure to air, which is why blocks have traditionally (e.g. in India) been cut in situ, allowed to harden and then used for masonry wall construction (hence the name was derived from "later", the Latin word for "brick") (Ayyappan *et al*,2008). The darker the laterite, the harder, heavier and more resistant to moisture it is.

In the construction of pavements, Laterite is widely used as subgrade which serves the purpose of a foundation for the pavement. 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 laterite are able to meet up with this criterion because some have a considerably low and thus inappropriate CBR value. Hence, something is needed to reinforce the poor laterite to salvage the uneconomic excessively thick pavement's base course and land wastage. (Al-Qadi *et al*, 2002)

Geosynthetics are synthetic materials manufactured from polymers made from polyethylene, polypropylene or polyester they are applied to take on geotechnical engineering problems (Ghosh *et al*, 2013). Depending on the type in use, geosynthetics are applied in various capacities that have to do with the earth. They serve functions like filtration, protection of slopes and embankments in pavements, subsurface erosion, separation of layers, erosion control, soil reinforcement, etc. Types of Geosynthetics include: geotextile, geogrid, geonet, geomembrane, geofoam, geocell, etc.; they are employed in different situations.

Geotextiles are continuous sheets of woven, nonwoven, knitted or stitch-bonded fibers or yarns. The sheets are flexible and permeable and generally have the appearance of a fabric (Palmeira *et al*, 2008). Geogrids, also a member of the geosynthetic family, used within a pavement system perform two of the primary functions of Geosynthetics: separation and reinforcements; although they are most applied as reinforcements. Due to the large aperture size associated with most commercial geogrid products, geogrids are typically not used for achieving separation of dissimilar material. An example of a situation where separation is needed is when the subgrade soil has a high percentage of its grains passing through sieve #200 (75 microns), i.e. above 35%. The ability of a geogrid to separate two materials is a function of the gradations of the two materials and is generally outside the specifications for typical pavement materials. However, geogrids can theoretically provide some measure of separation, albeit limited. For this reason, separation is a secondary function of geogrids used in pavements. The primary function of geogrids used pavements in reinforcement, in which the geogrid mechanically improves the strength of the subgrade. Reinforcing weaker soils using geosynthetics like geogrids to improve its strength is considered to be of great importance in many civil engineering projects. This is particularly popular in road construction. Subgrade soil, its properties like permeability and strength are vital to the design of pavement structures. Subgrade supports the pavement to carry load and hence should have adequate strength. Weaker soil sub-grade increases the pavement thickness, thereby adding to cost. Natural soil is of limited strength in many places. Geo-synthetics, in this study, geo-grids are used to improve the strength of the subgrade and reduce the pavement thickness.

MATERIALS AND METHODS

Collection of samples

Soil samples were collected from three different locations within Ogbomosho (named Sample A, Sample B and Sample C). After soil samples have been collected and they are moved carefully to the laboratory in black air-tight cellophane bags to preserve the natural state of the samples. The collection of samples from a burrow pit was done with mechanical auger dug to approximate depth of 1m to get an undisturbed soil sample.

Straw (which is produced by a mixer of straw and a loosely woven net of biodegradable string) was also sourced for as geotextiles material used for this study.

Sieve Analysis

This is done in order to determine the particle size distribution of the soil sample being collected.

Determination of Liquid Limit of the Sample

This test is being carried out to determine the liquid limit of the air-dried soil.

Determination of the Plastic Limit of Soil

This test was carried out in order to determine the lowest moisture content at which the soil is plastic

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Determination of Plasticity Index

The plasticity index (PL) was calculated from the equation:

$$PI = LL - PL$$

Where:

PI is the plasticity index

LL is the liquid limit of the soil sample

PL is the plastic limit of the soil sample

The numerical difference calculated was reported as the plasticity index (PL) except when the plastic limit cannot be determined or when the plastic limit is equal to or greater than the liquid limit, the material will be reported as non-plastic (NP).

Determination of Dry Density or Moisture Content Relationship (Compaction)

This was done to determine the optimum moisture content (OMC) and maximum dry density (MDD). This test covers the determination of the mass of dry soil per cubic meter when the soil was compacted in a specific manner over a range of moisture content including the maximum mass of dry per cubic meter.

The obtained dry densities were plotted against the corresponding moisture content for each sample. The optimum moisture content (OMC) and maximum dry density (MDD) of the soil were obtained from the graph.

Determination of the California Bearing Ratio

This test was carried to determine the California Bearing Ratio (CBR) of a soil. This was obtained by measuring the relationship between force and penetration when a cylindrical plunger of cross-sectional area of 1935mmSqr is made to penetrate the soil at a given rate at any value of penetration, the ratio of the force to a standard force is defined as the California bearing ratio (CBR).

Determination of California Bearing Ratio of Geotextile Stabilized soil

This was done to determine the effect of geotextile on the soil to be stabilized. This is obtained by measuring the relationship between force and penetration when a cylindrical plunger of cross-sectional area of 1935mm^2 is made to penetrate the soil at a given rate at any value of penetration, the ratio of the force to a standard force is defined as the California bearing ratio (CBR).
The soil sample was air dried; an oven may be used for drying provided the temperature does not exceed 60 degrees Celsius. The soil was then thoroughly broken up so as to avoid reduction of the natural size of the individual particles. The sample was sieved and much coarse particles discarded. A separate batch of material was used for each test specimen. Geotextile are placed at differentiated compacted levels 1, 3 and 1&3 respectively to ascertain the best layers in which the geotextile materials is most effective. The moulds were assembled and compaction of the specimen sample was done. A sufficient number of test specimens were compacted over a range of moisture content to establish optimum water content and maximum density.
The geotexiles material were arranged in layer of 1st layer at 0.2H, 2nd layer at 0.4H, 3rd layer at 0.6H and 4th layer at 0.8H, where: H is the total thickness of layer

RESULTS AND DISCUSSION

Result of Sieve Analysis

The result of the sieve analysis of the sample (natural soil) is presented in Table 1. It shows the percentage of different sieve size, in order to ascertain the percentage of silt, sand and gravel in this residual lateritic clay and its gradation as well. It also helps in AASHTO classification of the soil.

Atterberg limits test
The natural moisture content and the Atterberg limits of the soil samples and are were determined and the result is employed in the classification of the soil samples together with the result of the particle size analysis. The soil AASHTO classification is shown in Table 1. Liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. This shows that samples A and B have intermediate plasticity while sample C has low plasticity.

Table 1 Atterberg Limits and AASHTO Classification of the Soil Samples

Soil sample	%passing sieve #200	L.L	P.L	P.I	G.I	Major Division	Typical name	AASHTO symbol
A	25.7	37.2	28.2	9.0	0	Granular	Silty gravel and sand	A-2-4 (0)
B	36.9	45.0	25.95	19.05	2	Silty-clay	Clayey soil	A-7-6 (2)
C	34.2	32.0	19.0	13	1	Granular	Clayey gravel and sand	A-2-6 (1)

California Bearing Ratio (CBR)

Soaked samples

The soil samples were soaked for 48 hours after which the CBR values were determined when the samples were not reinforced as well as when they are reinforced with geotextiles embedded at varying levels within the soil per time. The penetrations and their respective forces on plunger are presented from Figure 1-12

$$\text{CBR} = (\text{Test load}/\text{standard load}) \times 100$$

Standard load for 2.5 mm penetration = 13.24 kN

Standard load for 5.0 mm penetration = 19.96 kN

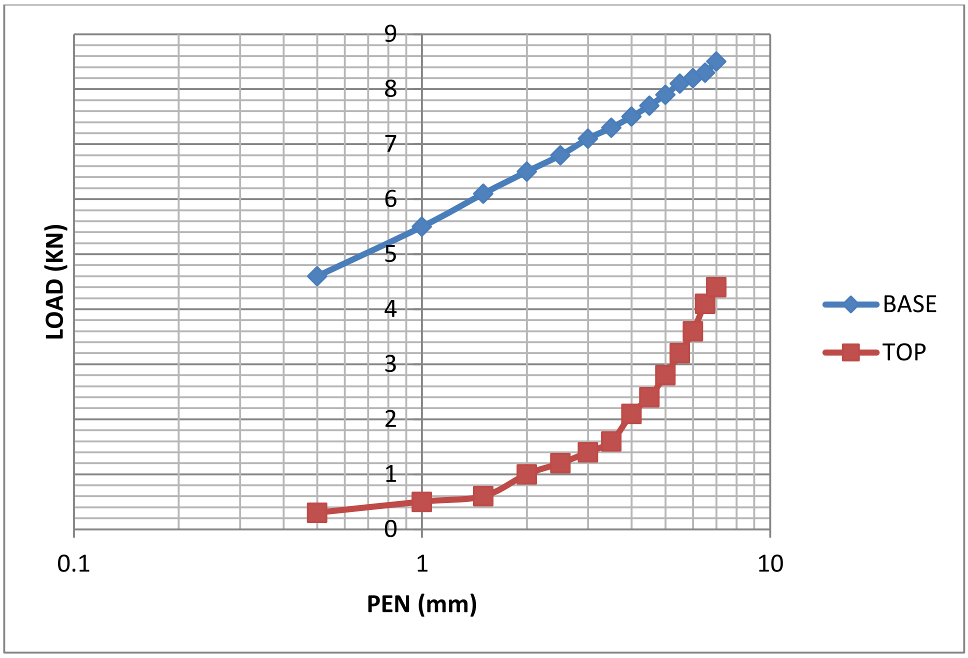

Figure 1 Shows the Zero (0) layer of Geotextile in Sample A

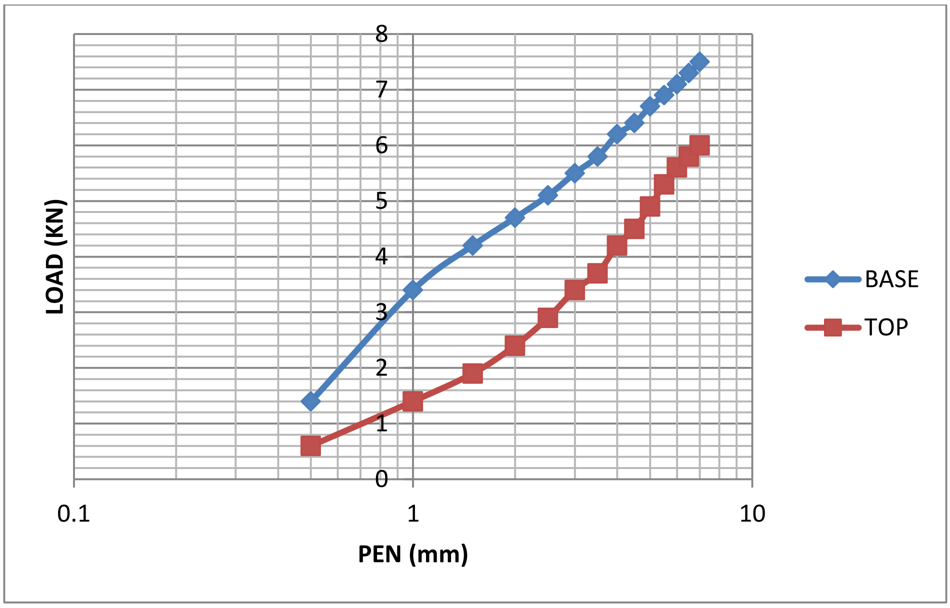

Figure 2 Shows the 1st layer of Geotextile in Sample A

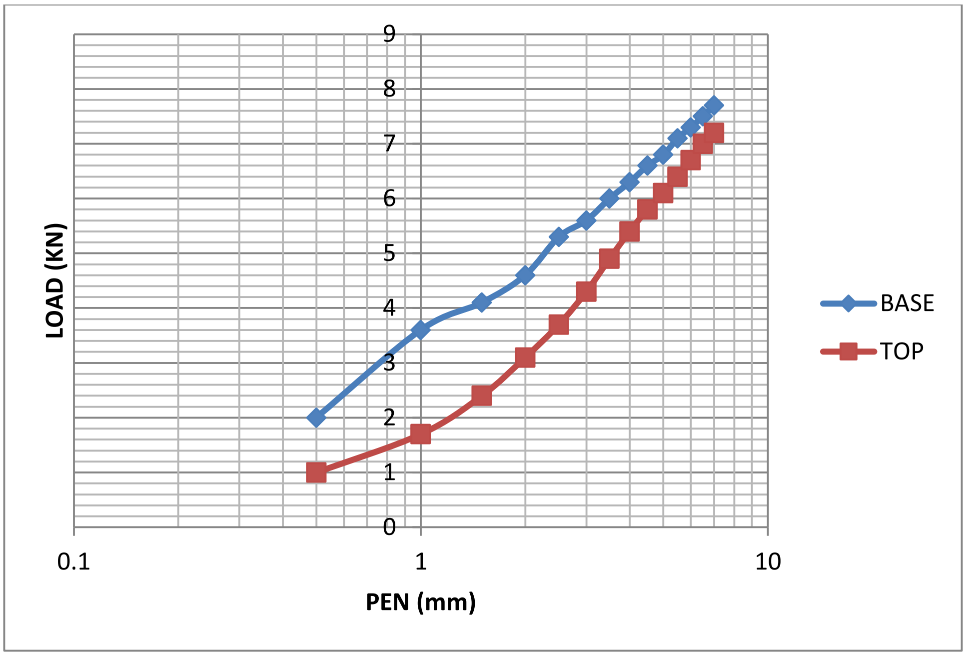

Figure 3 Shows the 3rd layer of Geotextile in Sample A

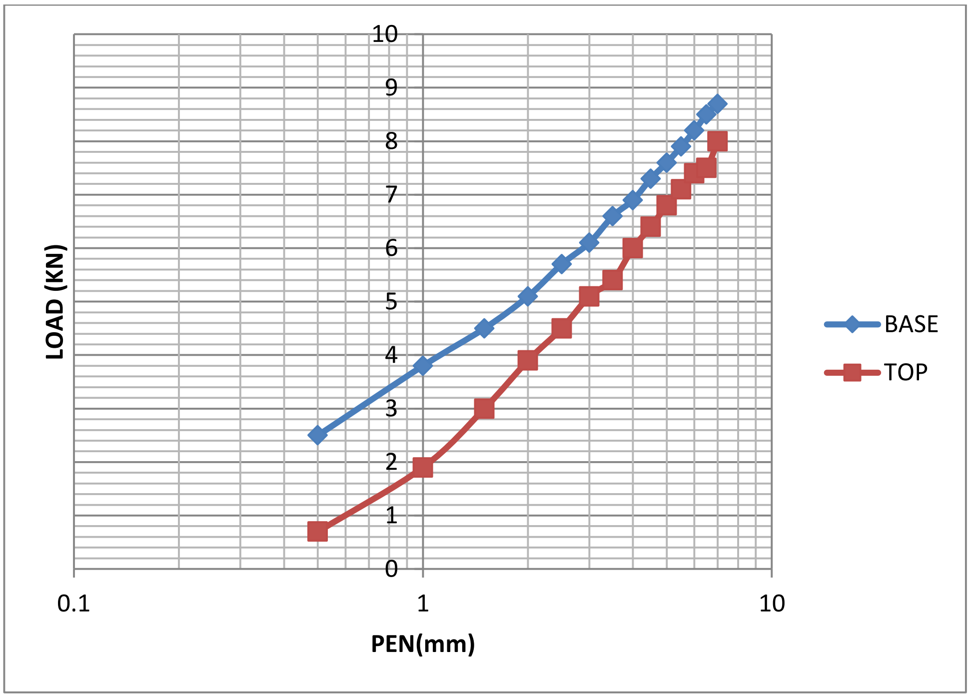

Figure 4 Shows the 1st and 3rd of Geotextile in Sample A

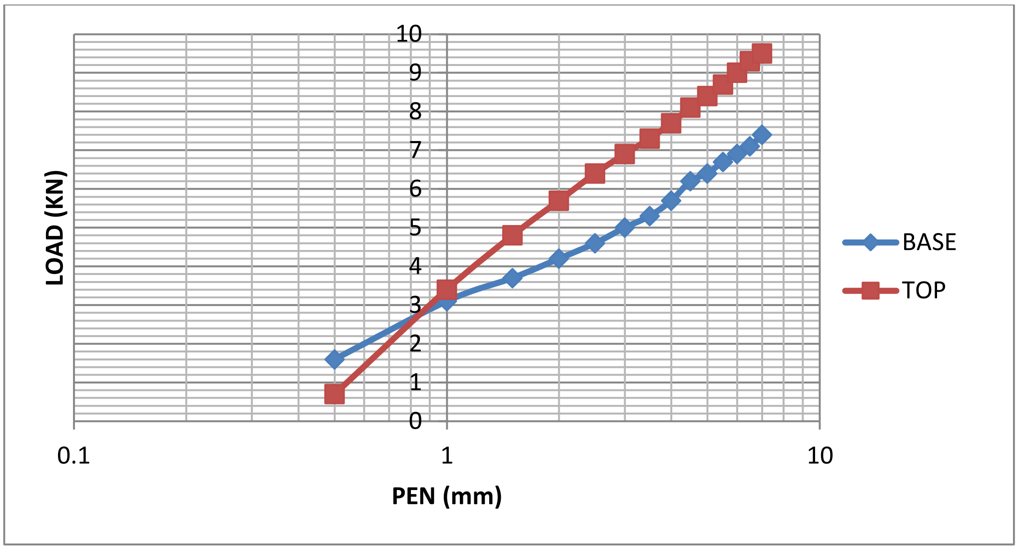

Figure 5 Shows the Zero (0) layer of Geotextile in Sample B

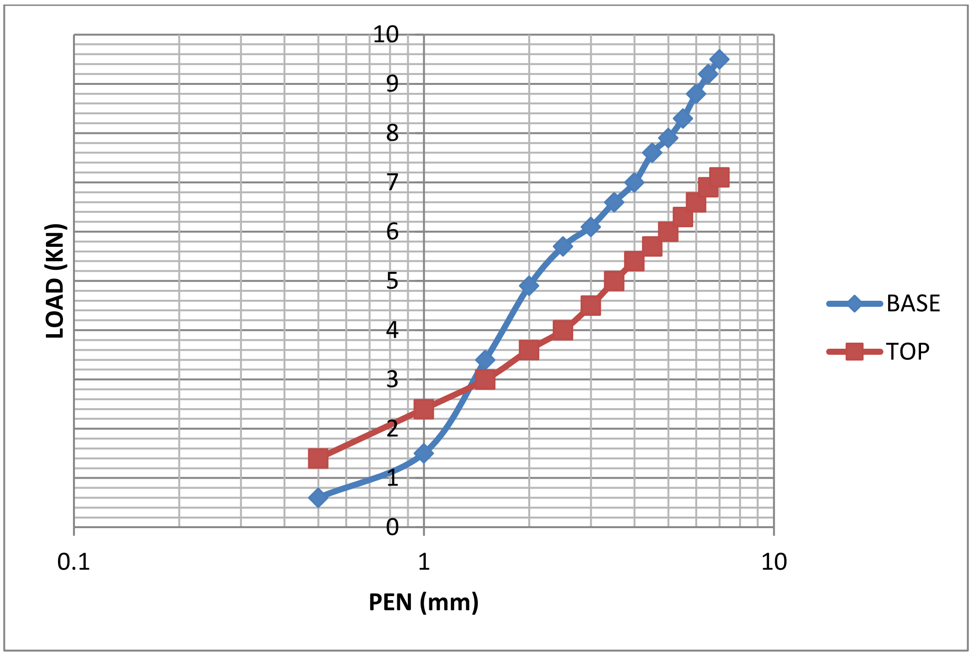

Figure 6 Shows the 1st layer of Geotextile in Sample B

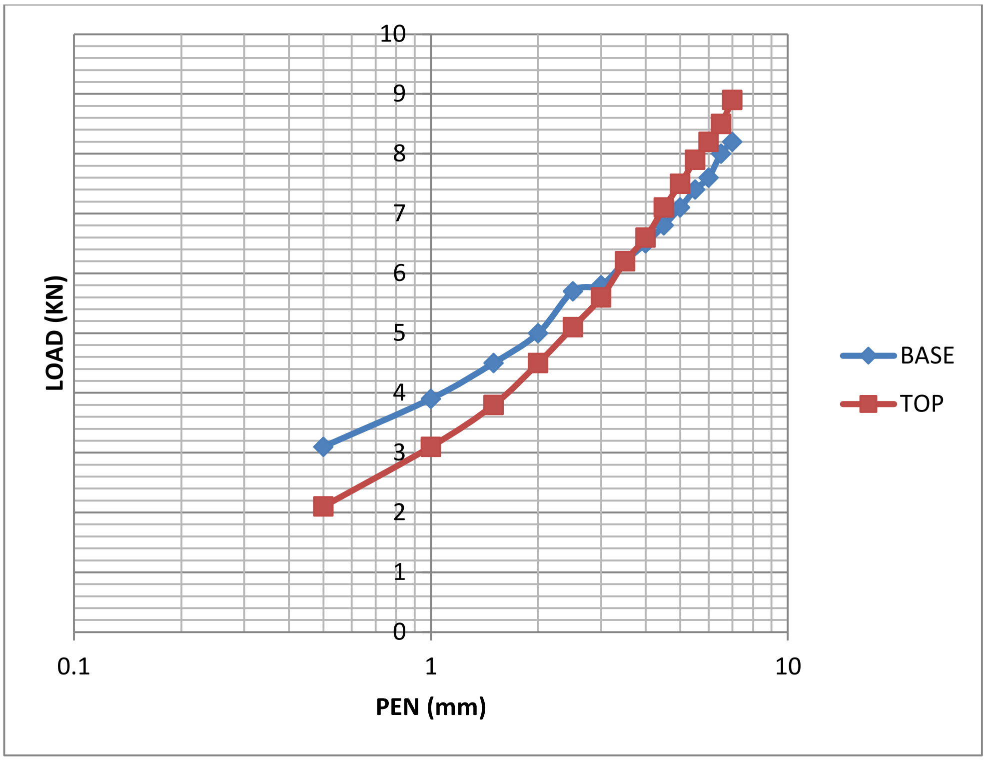

Figure 7 Shows the 3rd of Geotextile in Sample B

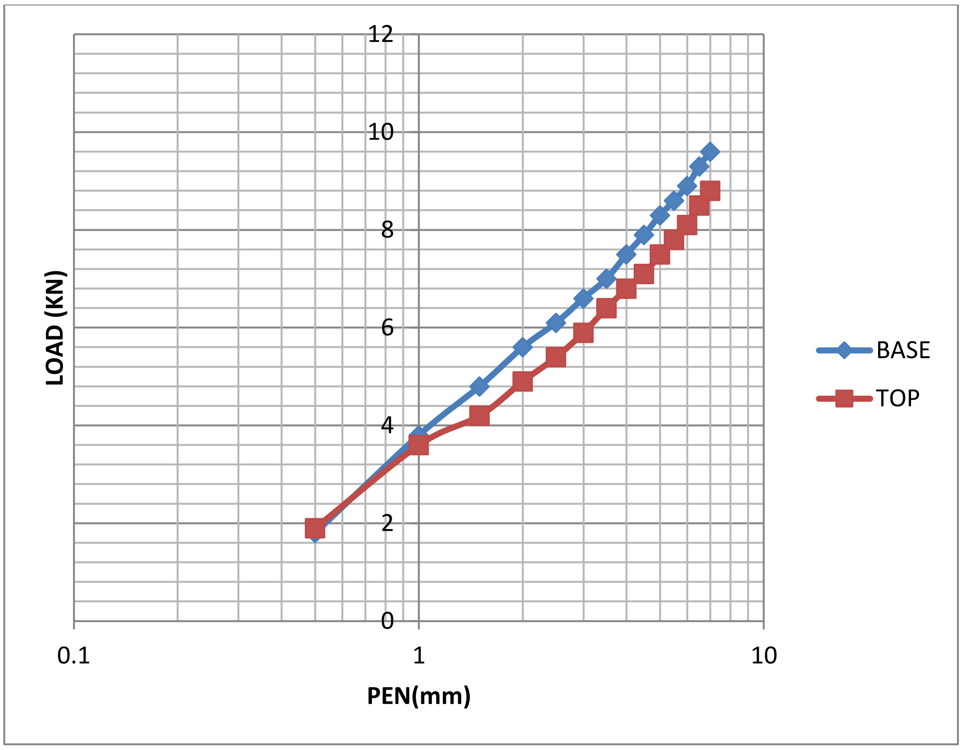

Figure 8 Shows the 1st and 3rd layer of Geotextile in Sample B

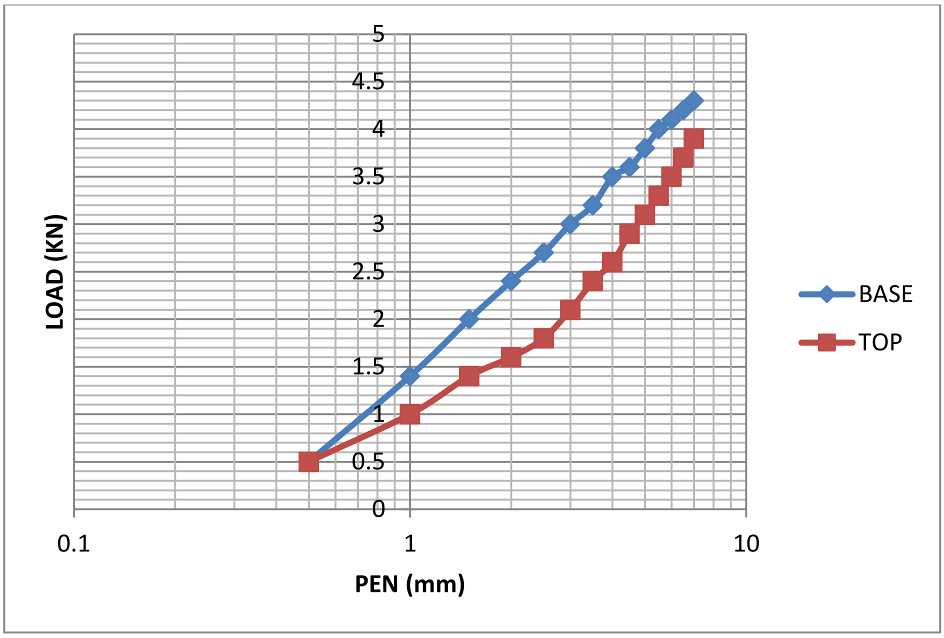

Figure 9 Shows the Zero (0) layer of Geotextile in Sample C

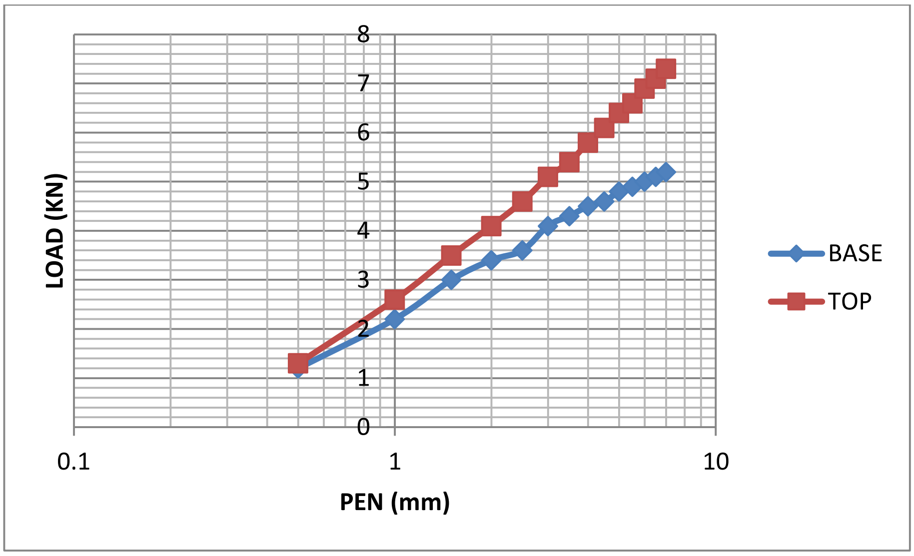

Figure 10 Shows the 1st layer of Geotextile in Sample C

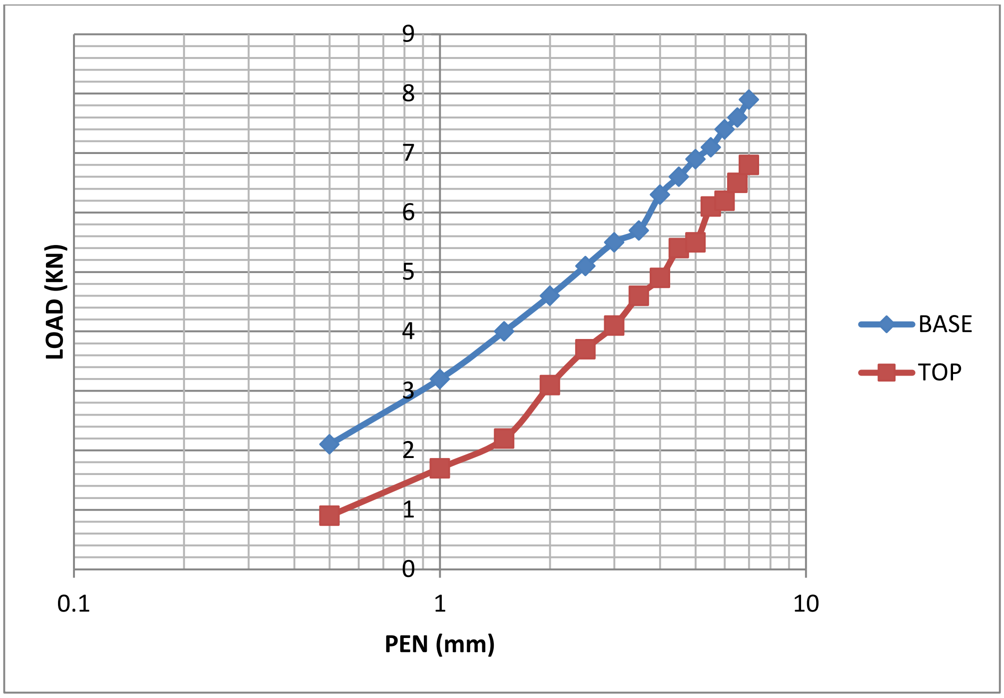

Figure 11 Shows the 3rd of Geotextile in Sample C

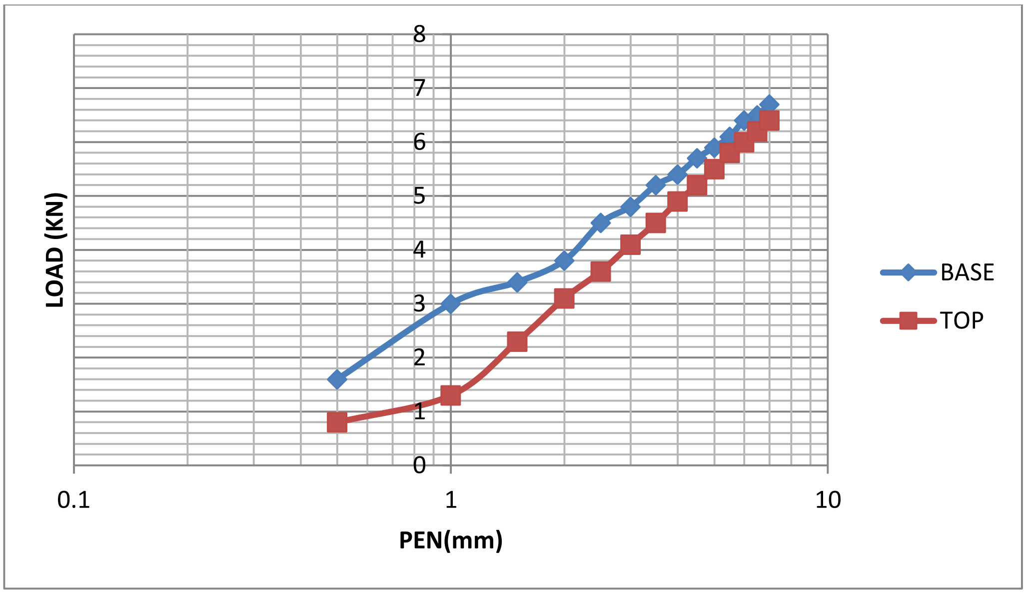

Figure 12 Shows the 1st and 3rd layer of Geotextile in Sample C

Discussion

The CBR values for the three soil samples when soaked (3%, 9% and 6% for sample A, B and C respectively) shows a great decline in the strength of the soil samples when compared with the CBR values obtained by Akolade (2013) when the same soil samples were unsoaked(8%, 20% and 20% for samples A, B and C respectively). This shows the great adverse effect of moisture in a soil even when it is compacted. Ennio *et al* (2007) also concluded that CBR decreases with increased number of days of soaking. The ongoing therefore supports the procedure for determining the design CBR for a road pavement which says that design CBR should be found when soil samples are soaked. This allows the CBR value of the compacted soil to be fond when the soil is saturated; this is actually the case for many subgrade having high water table (or ground water level).

The result of the CBR test for the soaked soil samples with the inclusion of geotextiles shows that geotextiles can be an antidote for the effect of moisture on the compacted subgrade. As moisture tends to bring the strength of the soil down, geotextiles raised it. The CBR for soaked sample A without geotextile is 3%, but with the inclusion of geotextile at 2/5 level of the thickness from the base, it is raised to 12.8%; 15.1% for 3/5 level and 11.0 for 4/5 level. The CBR results show that the effectiveness of the geotextile increased as the position of the geotextile is raised from top to bottom until it reached a point between 3/5 and 4/5 when the curve changed direction according to Figures 13,14 and 15

Table 2 Summary of CBR values with and without Geotextile.

Sample Soaked (%)	Soil without Geotextile	(2/5H)	(3/5H)	(4/5H)
A	3	12.8	15.1	11
B	9	11	14	10
C	6	8.8	12.2	8.3

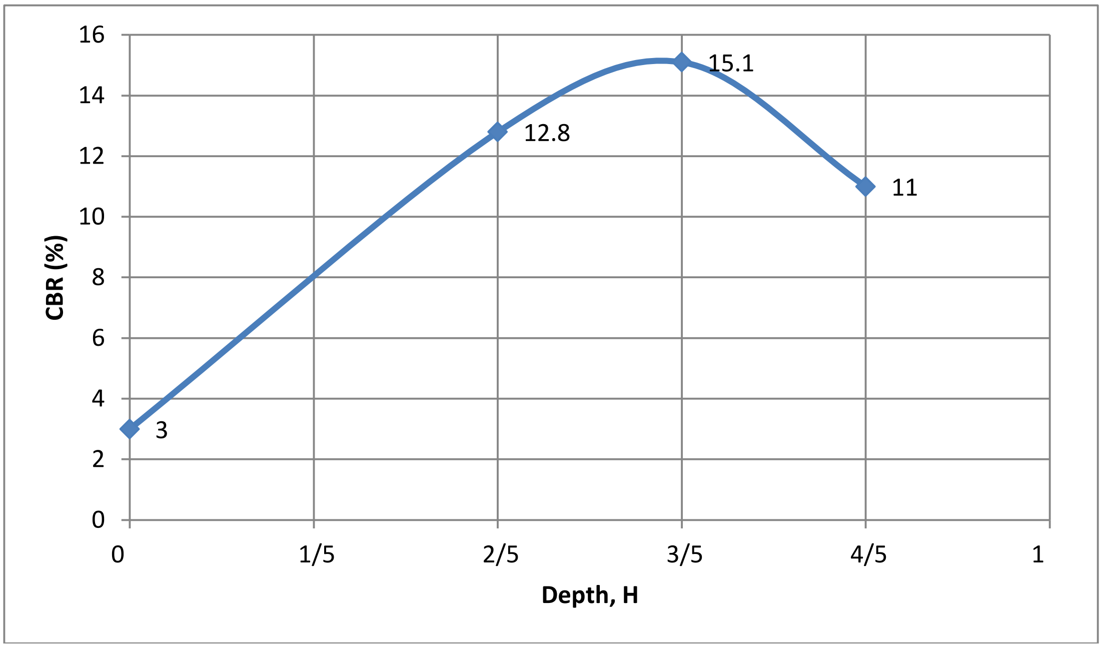

Figure 13 Graph of CBR against depth of soaked sample A before and after introducing the geotextile

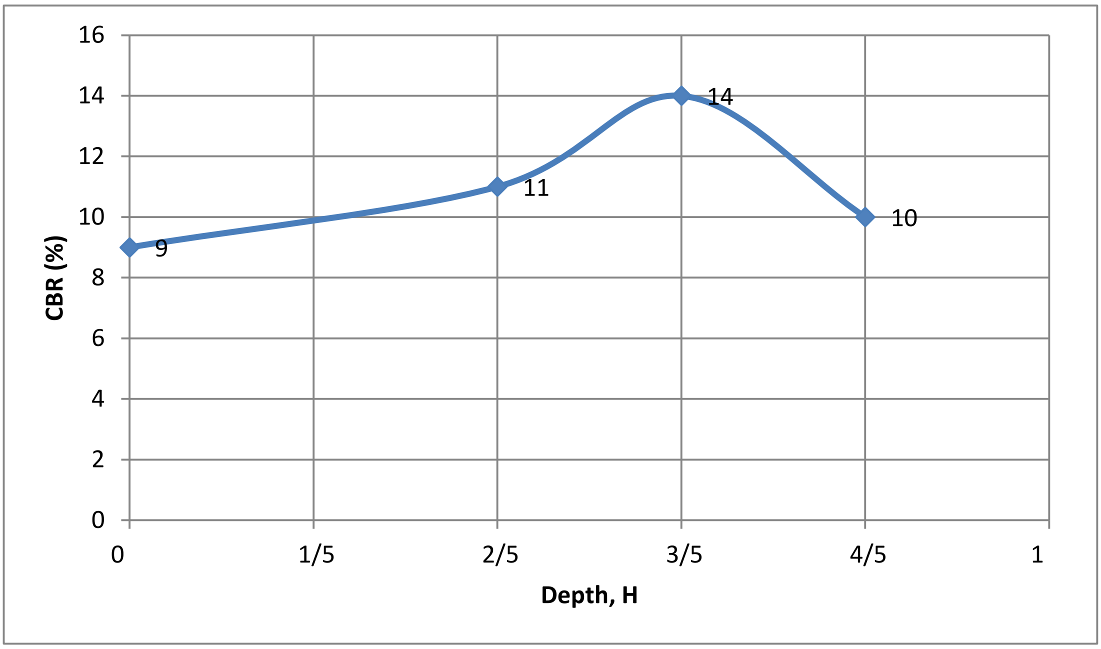

Figure 14 Graph of CBR against depth of soaked sample B before and after introducing the geotextile

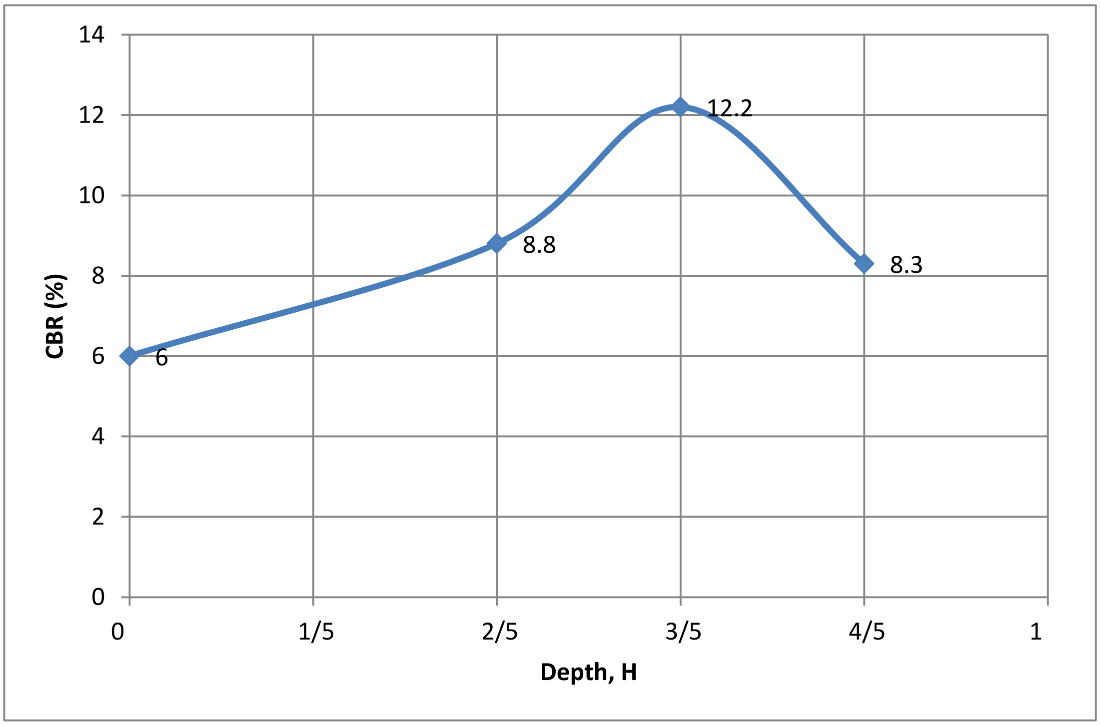

Figure 15 Graph of CBR against depth of soaked sample C before and after introducing the geotextile

CONCLUSIONS

i. The CBR values of the soil samples show a drastic reduction in the strength of the soil after being soaked for only 48 hours. This shows that subgrade soil, regardless of the initial strength suffers a reduction in their strength when they are soaked or saturated.
ii. It is found that the application of geotextile at different depths generally substantially increases the strength of the subgrade soil as measured by the California Bearing Ratio (CBR) regardless of the level at which the geotextile is placed within the thickness of the subgrade
iii. It was however found out that the depth at which the geotextile is placed dictates how effective the reinforcement action will be. And from the results of the experiments carried out in this study it can be concluded that geotextiles perform best at 3/5 level of the depth from the base as this gives the best increase in strength of the same soil samples when soaked and also when unsoaked.
iv. It can also be concluded from the experiments that geotextiles are suitable as a means of reinforcement for adverse effects on soil strength posed by increased moisture content.

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