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Utilization Of Geotextile For Soil Stabilization

D.A. Ogundare[1.], A.O. Familusi[2.], A.B. Osunkunle[3.] AndJ.O. Olusami[4.]
[1, 2 ,4]*Department of Civil Engineering, Federal Polytechnic Ede, Osun State, Nigeria*
[3]*Department of Civil Engineering, University of Ilorin, Kwara State, Nigeria*
[*]*Corresponding Author: D.A. Ogundare*

ABSTRACT:*Soil stabilization is the process of improving the load bearing capacity and engineering properties of subgrade soil to support pavements and structures. This work examined the stabilization of two soil samples (lateritic and clay) using geotextile as reinforcement. Geotechnical test were carried out to determine Particle size analysis, Atterberg Limit test, moisture content, specific gravity, Compaction test and California Bearing Ratio test. The two soil samples according to American Association of State and Highway Transportation Officials (AASHTO) are classified as A-7-6 and A-7-5 which are adjudged as 'poor' subgrade materials. CBR test were conducted with and without non-woven geotextiles with the non-woven geotextiles placed at depths H/4 from the top and base surfaces of the soil in single layer under unsoaked conditions to determine the strength of the soil samples. The result showed that the strength of the soil samples increased by introducing non-woven geotextile in the soil as the one placed at depth H/4 from the base surface showed higher CBR values (15.1% and 19.6%) than when placed at depth H/4 (14.1% and 18.2%) from the top surface.The experimental results give a clear indication that the presence of geotextiles increases the CBR value of the soil thus, geotextile should be employed as a modernized form of improving road construction on poor soils and to reduce the layer thickness of pavements.*
KEYWORDS:*Geotechnical test, geotextile, pavement, reinforcement, stabilization.*

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I. INTRODUCTION

Roads should be constructed on strong native soil deposits and the behaviour of road surface depends on the strength of the fill material and the subgrade below it. 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 [1]. Stabilization is being used for a variety of engineering works, the most common application being in the construction of road and airfield pavements, where the main objective is to increase the stability or strength of soil and to reduce the construction cost [2]. Subgrade soil supports the pavement and serves as foundation to carry load and for this purpose, an appropriate value of CBR is required for subgrade soil in order to ensure adequate strength to support the imposed traffic load regardless adverse conditions such has high rainfall and flooding. However, not all subgrade soils are able to meet up with this criterion because some have a considerably low and thus inappropriate CBR values. Natural soil is of limited strength in many locations around the globe and 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 [3].

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 [4].Geotextiles are planar polymeric materials that have been extensively used in roads for separation and reinforcement in flexible pavement systems and for many years, the principal use of geotextiles has been as a separator during the construction of roadworks and in the area of stabilization [5]. 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 [6]. However, the geosynthetic must minimize the possibility of erosion of the drainage layer and resist clogging of the filter over the design life of the pavement. Geotextiles 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 [7]. 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. Thus, 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 [8].

The results obtained from the assessment of the geotechnical properties of the unreinforced and reinforced soil samples will be used to determine the usefulness of the soils in road construction by comparing it to the Federal Government of Nigeria specification for road construction [9] as this will guide engineers on the choice of suitable subgrade soils in order to deliver sustainable and cost-effective projects.

II. MATERIALS AND METHODS

Soil types; lateritic and clay collected from Ogbondoroko borrow pit in Asa Local Government Area (LGA) located on latitudes 8º00’ and 9º10’ North of the equator and longitudes 2º45’ and 4º15’ East of the Greenwich Meridian [10] in Ilorin, Kwara State labeled (A and B) were collected and used for experiment while the non-woven geotextile shown in Plate 1 below was gotten from Maccaferri Nigeria Limited, Port-Harcourt. The soil samples were gotten in polythene to prevent loss of moisture to the atmosphere.

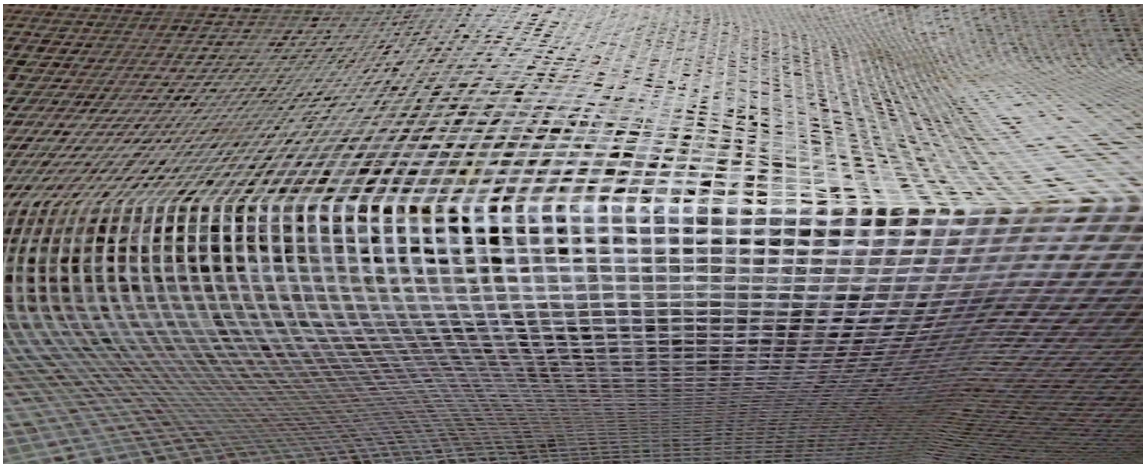

Plate 1: Sample of the non-woven geotextile material used

Conventional tests were carried out for evaluation of soil suitability for engineering purposes. Laboratory procedures were followed and thereafter, several of the required geotechnical analyses were carried out. These include particle size analysis, liquid limit, plastic limit, plasticity index, specific gravity, standard compaction test and the California Bearing Ratio (CBR) test. These test were performed according to [11] and [12]. The compaction tests were conducted using a rigid metal mould with internal diameter of 150 mm and height of 175 mm. The soil samples were compacted in three layers with each layer compacted with 25blows of a 2.5kg rammer dropping from a height of 310 mm.The CBR tests were carried out on the compacted soils in single layer under unsoaked conditions without reinforcement and with the reinforced non-woven geotextile as shown in Figure 1 placed at depths H/4 from the top and base surfaces of the soil in the CBR mould. 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.

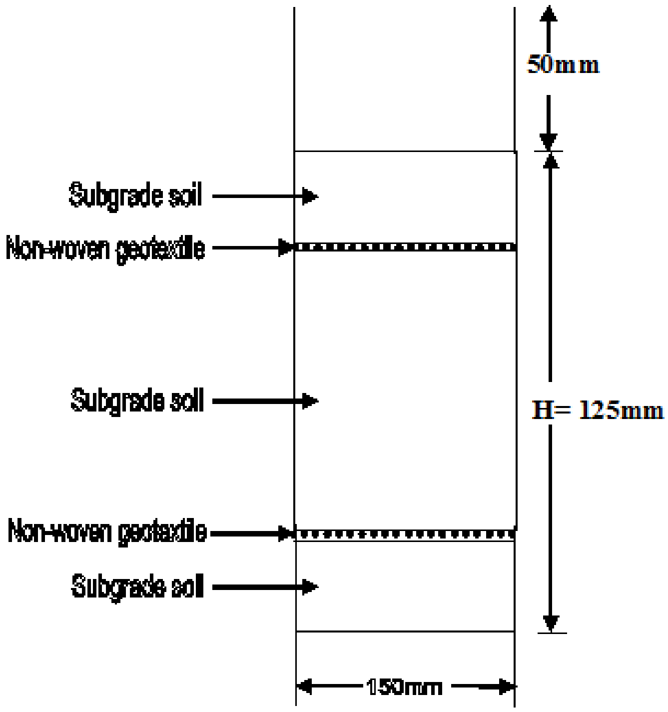

Figure 1: Cross-sectional diagram showing the subgrade soil and non-woven geotextile layers

2.1 Geosynthetic material

A non-woven geotextile produced from synthetic fibres, such as polypropylene, polyester and polyamide were interfaced between the soil at depths H/4 from the top and bottom surfaces in the CBR mould. The properties provided by the manufacturers are given in Table 1 below.

Table 1: Properties of non-woven geotextile

Particulars	Non-woven geotextile
Mass per unit area (g/m^2)	203
Grab Tensile strength (N)	710
Puncture Resistance (N)	1820

Source: [13].

III. RESULTS AND DISCUSSION

The results of the analysis of geotechnical parameters of the soil samples are presented and subsequently discussed and for ease of discussion, the results are presented as graphical plots and tables.

3.1. Soil classification and subgrade rating

The virgin soil samples A and B are classified using [11] and are considered as A – 7 – 6 and A – 7 – 5 soils with Group Index Value (G.I) of 7 and 8 respectively. Figure 2 shows the particle size distribution for the virgin soils and AASHTO subgrade rating for this type of soil is 'poor'.

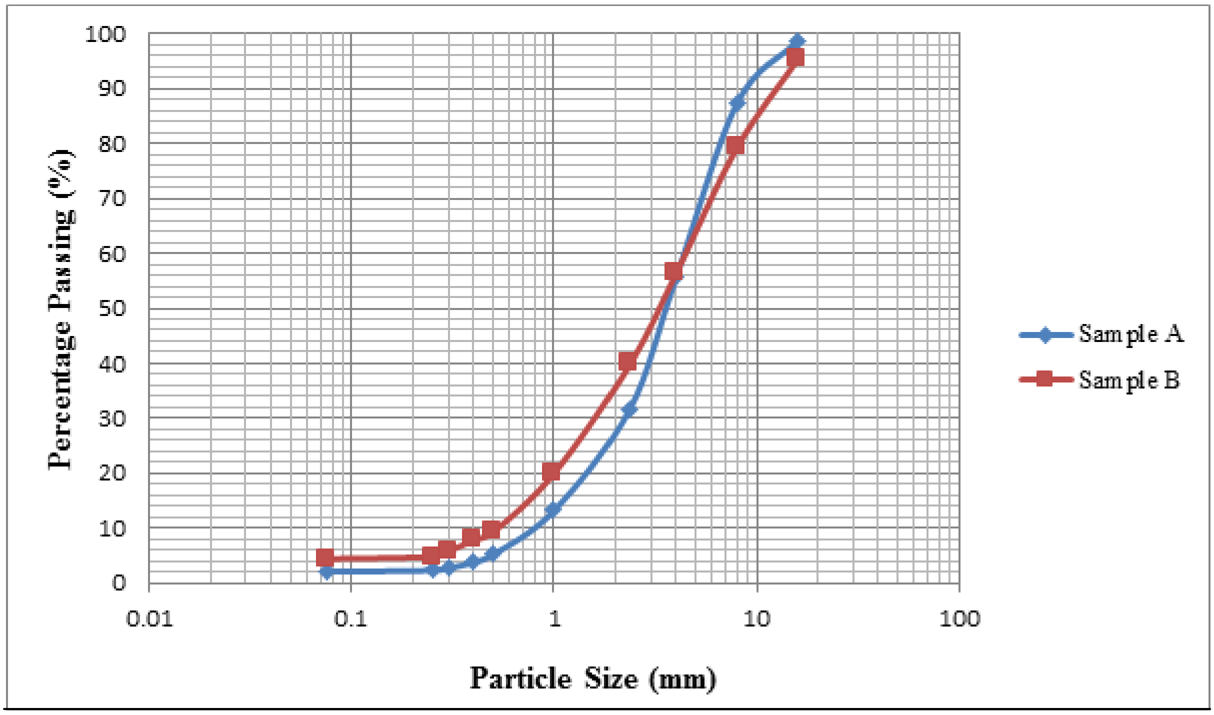

Figure 2: Particle size distribution for the two soil samples

3.2. Atterbergs Limit Test

The analyses in Table 2 show that soil samples A and B have liquid limits of 35.5% and 43.5% while the plastic limits are 20% and 29%. [14] had noted that liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity, between 70% and 90% very high plasticity and greater than 90% extremely high plasticity. This suggests that the two samples have intermediate plasticity while the plastic limit which are not in excess of 33% are considered to be within the regulatory standards of construction materials. However, the two soil samples with plasticity index of 15.3% and 14.1% are generally above 12% set by Nigerian Government Standard Specification of subgrade soils for roads and bridges which are considered not good.

3.3. Moisture Content

The moisture content of the soil samples A and B are 17.9% and 19.3% (Table 2) and from the recorded values, it can be inferred that the moisture content is high. The implication of a high moisture content is that the soil might exhibit a reduced strength [15].

Table 2: Summary of some geotechnical properties

Particulars	Sample A	Sample B
Liquid limit (%)	35.50	43.50
Plastic limit (%)	20.20	29.40
Plasticity index (%)	15.30	14.10
Moisture content (%)	17.90	19.30
Specific gravity (g)	2.70	2.63
Optimum Moisture Content (O.M.C) (%)	14.50	12.00
Maximum Dry Density (M.D.D) (g/cm^3)	1.35	1.39

3.4. Specific Gravity

The specific gravities for samples A and B are 2.70 and 2.63 (Table 2) which shows that these values fall within the range for lateritic soil (2.50 – 2.75) and clay soil (2.60 – 2.90) [16]. This is considered to be acceptably high because it is required that soils to be used for construction should have specific gravity that is not less than 2.25 and the mineral composition of the crystalline rock might have contributed to the relatively high specific gravity values [15].

3.5. Compaction Test

This test was performed to establish 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. These values are presented in Table 2 and the dry density values – moisture content relationship curves for the virgin soil is presented in Figure 3.

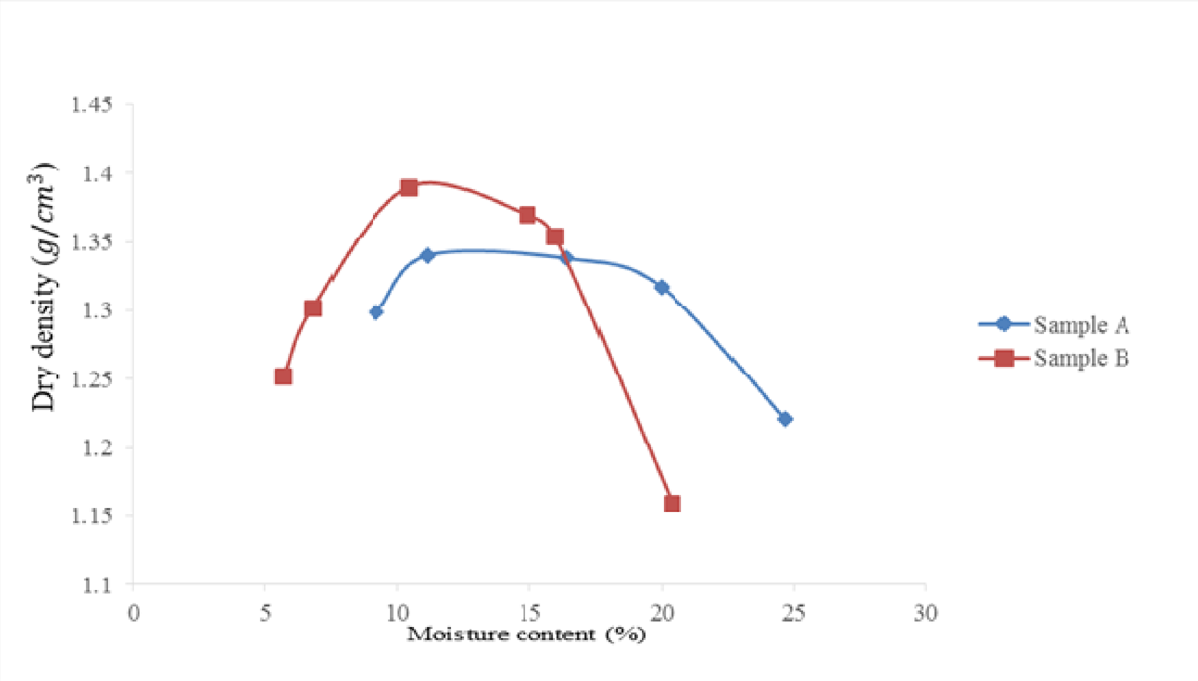

Figure 3: Dry density – Moisture content relationship of the soil samples

3.6. California Bearing Ratio (CBR) Test

The CBR is a semi empirical test that is often employed in the estimation of the bearing capacity of subgrade soils for design of pavement [17]. It measures the resistance a soil mass offers to the penetration of a plunger under specified density and moisture conditions. The more difficult it is to penetrate the soil, the higher the CBR rating. The results of unsoaked CBR with and without the reinforcement are presented in Table 3, Figures 4 and 5. 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 5 that due to the placement of non-woven geotextile, the CBR values increases irrespective of the placement depth. It is also 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 depth H/4 in the top and base regions for sample B but performs best at depth H/4 from the base 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.Table 4 shows a comparison between the geotechnical properties of the soil samples with and without non-woven geotextile with the Nigerian Government standard specification of subgrade soils for roads and bridges [9]. [9] recommends that soil to be used in road construction must have at least 10% CBR value which reveals that soil samples A and B when reinforced with non-woven geotextile satisfied the strength set for subgrade soils.

Table 3: Summary of the CBR values (Unsoaked 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	3.6	4.0	4.0	14.3	14.9	15.0
Sample B	6.0	6.6	7.0	20.5	17.4	21.0

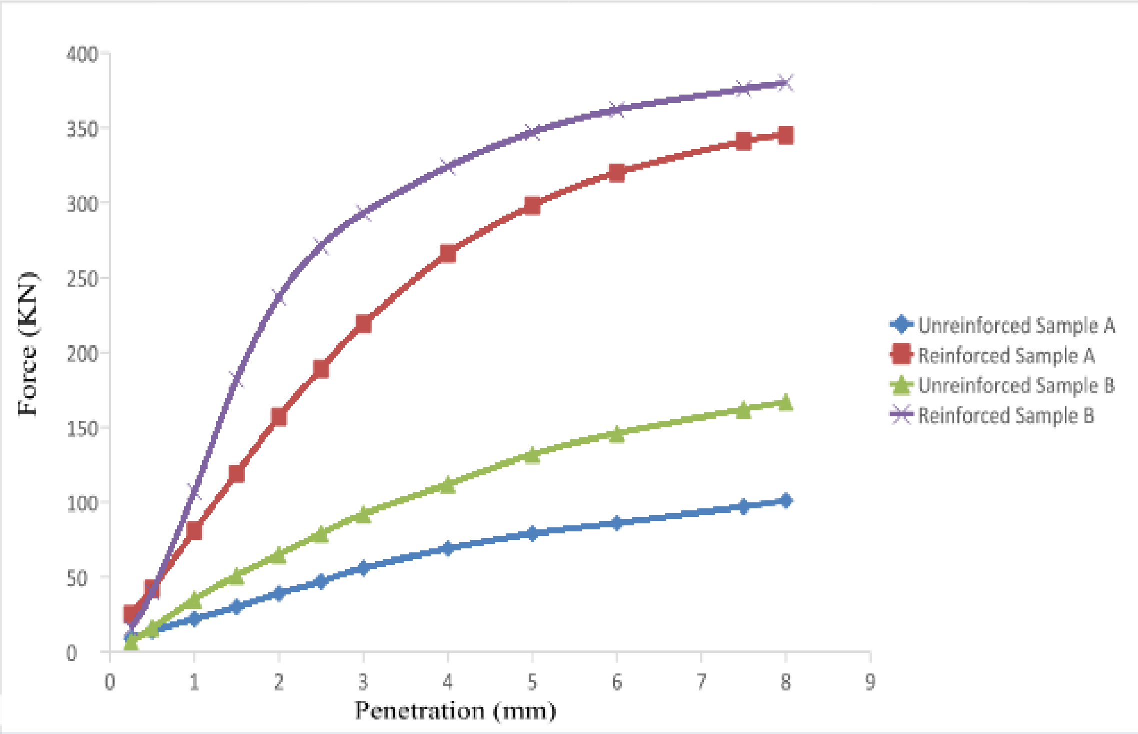

Figure 4: CBR values for reinforced and unreinforced soil sample

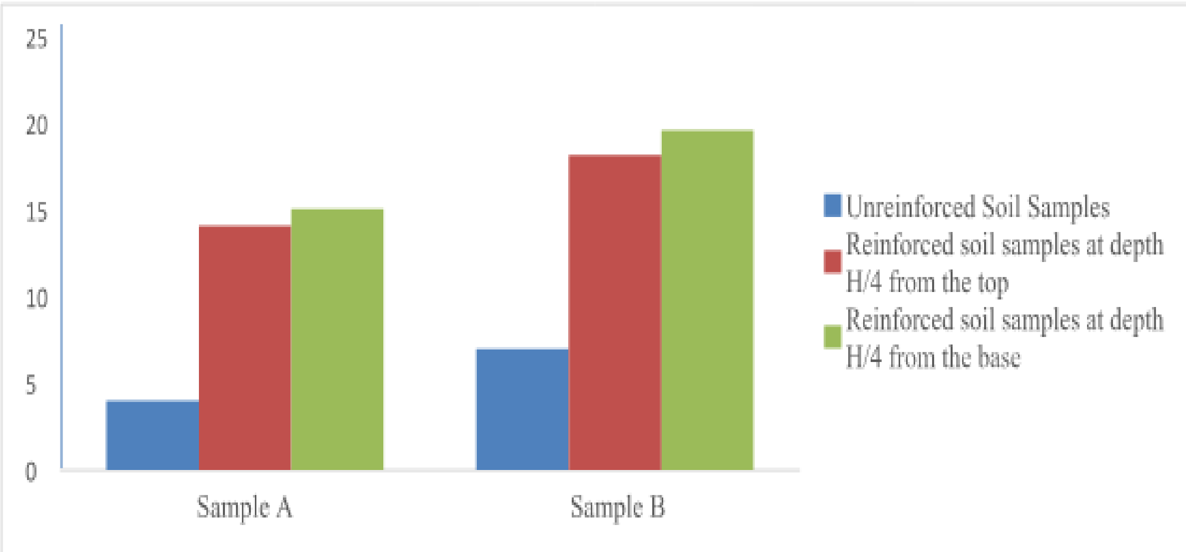

Figure 5: Effect of unreinforced and reinforced soil samples at depths H/4 from top and base surfaces in the CBRmould

Table 4: Evaluation of the soil properties

GEOTECHNICAL PROPERTIES	SOIL SAMPLES				FEDERAL MINISTRY OF WORKS GENERAL SPECIFICATION (1997) REVISED	REMARKS
	Sample A	Sample B	Sample A	Sample B	Subgrade	
Liquid Limit (%)	35.5	43.5	35.5	43.5	≤ 35%	All the samples are not ok
Plasticity Index (%)	15.3	14.1	15.3	14.1	≤ 12%	All the samples are not ok
	Without non-woven geotextile		With non-woven geotextile			
Unsoaked CBR (%)	4.0	7.0	15.0	21.0	≥ 10%	Samples A and B with non-woven geotextile are good for subgrade soil

3.7. Design for flexible pavement

The structural capacity of flexible pavements is attained by combined action of the different layers of the pavement where 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 21% when reinforced with non-woven geotextile and 7% when unreinforced with non-woven geotextile in its unsoaked condition has pavement thicknesses of 9cm and 17.5cm respectively which indicates that increase in the CBR values leads to decrease in the pavement layer thicknesses thereby reducing the cost of road construction.

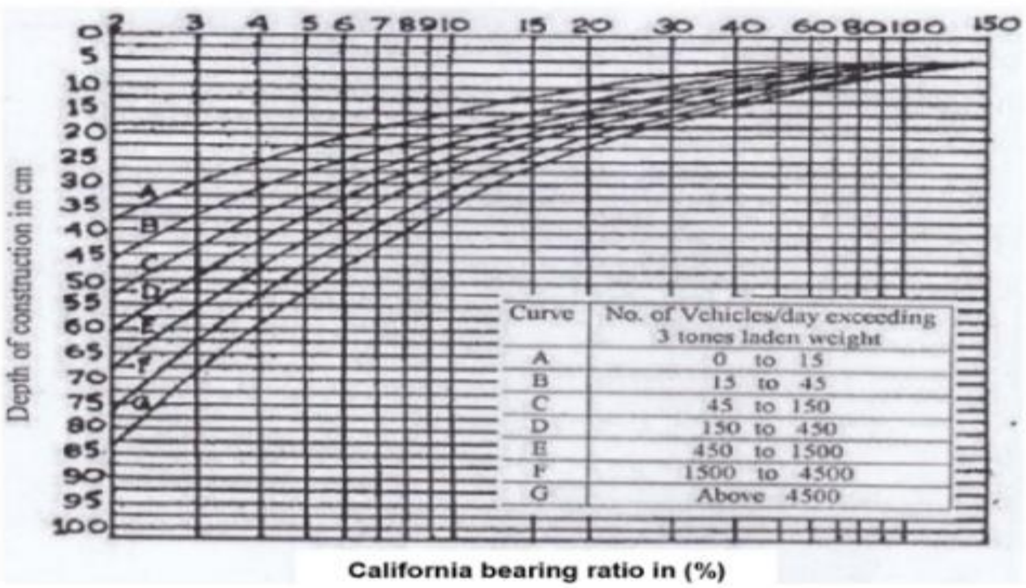

Figure 6: CBR – Depth relationship [18].

IV. CONCLUSION

The study investigated the application of non-woven geotextile to subgrade material as a form of reinforcement to road construction. The two soil samples were evaluated for suitability of subgrade in terms of their geotechnical properties. Results showed that the virgin soil samples A and B which belongs to A – 7 – 5 and A – 7 – 6 according to American Association of State and Highway Transportation Officials (AASHTO) are considered as poor subgrade materials. According to California Bearing Ratio (CBR) Test, it was observed that when the two soil samples were reinforced with non-woven geotextile, there was an increase in their CBR values in unsoaked condition (15% and 21%) than when compared with their CBR values (4% and 7%) without reinforcement which indicate that the soil samples reinforced with non-woven geotextile are suitable for subgrade as set by the Federal Ministry of Works General Specification (1997) criteria for subgrade soils.

Also, the application of non-woven geotextile at different depths generally increases the strength of the subgrade soil as measured by the California Bearing Ratio (CBR) regardless the level at which the non-woven geotextile is placed within the thickness of the subgrade. However, the depth at which the non-woven geotextile is placed dictates its effectiveness as reinforcement as it performs best at depth H/4 from the base surface as this gives the best increase in strength of the soil samples which will therefore aid in reducing the cost of the pavement thicknesses.

Geotextile reinforced soils present better performance than traditional soil under dynamic loadings. It is non-biodegradable, durable and also increases the ultimate service life of the pavement. It should, therefore be used to enhance the performance of a subgrade material in a pavement system.

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