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Reinforcement of Subgrade Soils with the Use of Geogrids

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Abstract: ***This paper examined the basic engineering and geotechnical properties of poor subgrade soils using geosynthetics like geo-grids to improve its strength. This is considered to be of great importance in civil engineering works. Subgrade soils, its properties like permeability and strength are essential to the design of pavement structures. Experiments were carried out to investigate the application of geo-grids on subgrade soils under unsoaked conditions. Geotechnical test were carried out to determine Grain size analysis, atterberg, compaction and California bearing ratio test. CBR test were carried out by placing the geo-grids at varying depths and in single layer under unsoaked conditions to determine the strength of the soil. The result shows that the strength of subgrade is considerably increased by introducing geo-grids reinforcement in the soil. It is found that geo-grids placed at 3/5 the distance from the base showed higher CBR value than when placed at 2/5 and 4/5 distances from the base. The differences in the behavior of the soil under unsoaked conditions improve on increasing the number of layers of geo-grids. As a subgrade stabilizer it has shown great effect of improvement. It has low maintenance, corrosion resistance and increases the service life of road pavement. Geo-grids should be employed as a modernized form of improving road construction on poor subgrade materials.***

Keywords: Reinforcement, Geogrids, Aggregate, Subgrade interface.

1. Introduction

Laterite is not uniquely identified with any particular parent rock, geologic age, single method of formation, climate per se, or geographic location. It is a rock product that is a response to a set of physiochemical conditions, which include an iron-containing parent rock, a well-drained terrain, and abundant moisture for hydrolysis during weathering, relatively high oxidation potential, and persistence of these conditions over thousands of years. (Perkins 2007).

Laterite, 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 (Ismeik, 1997). Typical laterite is porous and claylike which have negative effect in civil engineering works especially in road construction. It containsiron oxide minerals which react with some other forms of stabilizers such as limestone etc., but with the application of geogrids helps improve the strength of the soil due to its anti-corroding and tensile properties.

Geo-grids provide interlockingof aggregate at the subgrade interface, provided that the aggregate locksinto the grid structure that are of sufficient rigidity and geometry. The interlocking of the base aggregate and geo-grid is a function of the gradation and angularity of the aggregate and the geometry of the geo-grid. Weaker soils are generally clayey and expansive in nature which is having lesser strength characteristics. (Al-Qadi *et. al* 2007, Barksdale *et. al.* 1989). Geogrids are made from high molecular weight, high tenacity polyester multifilament yarns. The yarns are woven on tension in machine direction and finished with a polymeric coating,geogids are polymeric in nature with tensile strength varying from 100 to 220KN, they are either biaxial or uniaxial in strengthi.e. they are biaxial when theyhave major strength in both X, Ydirections and uniaxial when they have major strength along the Y-direction and minor strength along the X-direction, the biaxial geogrids was employed in this research to ascertain an excellent result.

Technique of improving the soil with geo-grid increase the stiffness and load carrying capacity of the soil through fractional interaction between the soil and geo-grid material improving laterite soil. The load coming on the road crust is transferred to the underlying soil. If the soil supporting the road crust is weaker, the crust thickness of road increases, which leads to the more cost of construction and most likely road pavement failures in the nearest future, but with the application of geogrids, 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. Geo-grids used within a pavement system perform two functions which are separation and reinforcements. The primary function of geo-grids is used as pavements reinforcement, in which the geo-grid mechanically improves the engineering properties of the pavement system.

2. Materials and Methods

In this research work, laboratory analyses were used to achieve the objectives. The soils samples were collected from three different locations in osun state Oshogbo, samples A and C are granular soils while sample B is silty-clay in nature. The following test: Grain size analysis, atterberg test, California bearing ratio and compaction test were carried out on each of the samples at the geotechnical and structural laboratory Oshogbo, osun state Nigeria. Grain size analysis was used for the test after washing and oven drying the samples, atterberg test was done to determine the plastic limit, liquid limit and plastic index of the soil samples. the compaction tests were conducted according to the West African Standard (WAS) using a rigid metal mould with internal diameter of 152 mm and height of 178 mm. the soil samples were compacted in five layers with each layer compacted with 27 blows of a 4.5kg rammer dropping from a height of 457 mm, The samples were tested under unsoaked conditions with the geo-grid introduced at different depths within the sample height in the mould, in single layers. The California Bearing Ratio Test (CBR Test) is a penetration test developed by *California State Highway Department (U.S.A.)* for evaluating the bearing capacity of subgrade soil for design of flexible pavement. This is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min.The CBR Tests were carried out on the compacted soils in unsoaked conditions without reinforcement and then with reinforcement at different levels.

Figure 1: Penetration piston machine used at the Geotechnical and structural Centre, Oshogbo osun state

3. Result and Discussion

Three soil samples were gotten from three different locations in Oshogbo ,osun state Nigeria in which the summary of the result of the laboratory test (grain size analysis, compaction and atterbergs limit) as well as the engineering property test (compaction,carlifonia bearing ratio(CBR)) are presented in the tables and figures below.

3.1 Grain size analysis

Grain size analysis or gradation test was a procedure used in the experiment to assess the particle size distribution of preliminary sample A, B and C of a granular material. These were shown in the tables and figuresbelow. The percentage passing through No. 200(75 micron) sieve from the three samples ranges between 25.7% and 36.9% showing that samples A and C are coarse materials while samples B is silty-clay according to the Unified soil classification system (USCS)(Holtz *et. al.*1986).Sample A and B are suitable for subgrade construction because it has high quality of soil strength as their percentage weight passing through sieve No. 200 is lesser than 35%, while sample C has percentage weight greater than 35%.

Table 1: Sieve analysis of preliminary result of sample A

Test sieve (normal sizes)	Wt. retained in gms	Percentage retained	Total % passing
10.0 mm	19.4	5.5	94.5
5.0 mm	44.7	12.6	87.4
2.00 mm	107.2	30.2	69.8
1.00 mm	146.8	41.4	58.6
600 micron	225.4	63.5	36.5
425 micron	236.9	66.8	33.2
300 micron	245.5	69.2	30.8
150 micron	256.6	72.3	27.7
75 micron	263.7	74.3	25.7
Dust -	91.0	25.66	-

Table 2: Sieve Analysis of preliminary Results for Sample B

Test sieve (normal sizes)	wt. retained in gms	Percentage retained	Total %passing
20.0 mm	-	-	100
10.0 mm	-	-	100
5.00 mm	11.9	4.80	95.2
2.00 mm	40.0	16.2	83.8
1.00 mm	60.0	24.2	75.80
600 micron	107.0	43.2	56.80
425 micron	119.0	48.1	51.9
300 micron	130.9	52.9	47.1
150 micron	147.2	59.5	40.5
75 micron	156.1	63.1	36.9
Dust -	91.4	36.9	-

Table 3: Sieve Analysis of preliminary Results for Sample C

Test sieve (normal sizes)	Wt. retained in gms	Percentage retained	Total %passing
20.0 mm	-	-	100
10.0 mm	2.4	0.8	99.2
5.00 mm	10.8	3.7	96.3
2.00 mm	38.5	13.1	86.9
1.00 micron	67.3	22.8	77.2
600 micron	109.0	37.3	62.7
425 micron	124.2	42.2	57.8
300 micron	143.5	48.7	51.3
150 micron	179.1	60.8	39.2
75 micron	193.9	65.8	34.2
Dust -	100.7	34.2	-

Table 4: Percentage of materials from the sieve analysis of sample A

Silt Clay	*Sand*			*Gravel*		
	Fine	medium	coarse	Fine	medium	coarse
26%	2%	10%	33%	20%	10%	0%

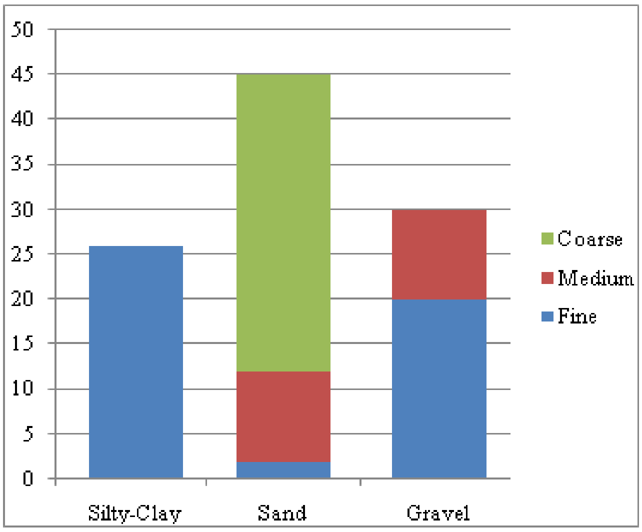

Figure 2: Bar chart showing various percentages of material in sample A

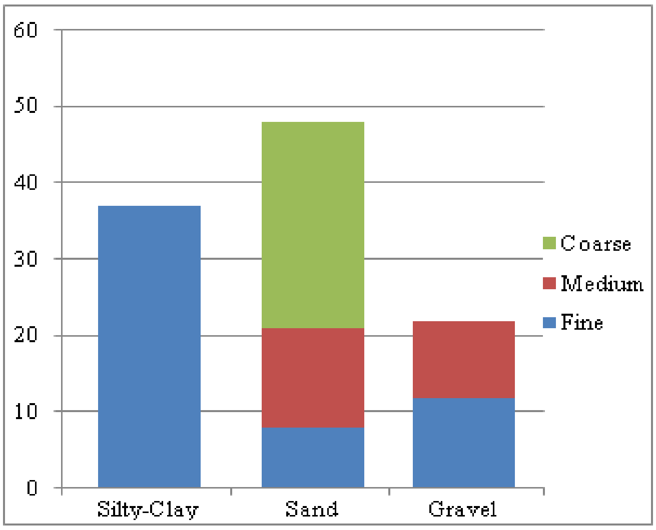

Figure 3: Bar chart showing various percentages of material in sample B

Table 5: Percentage of Materials from the Sieve Analysis of Sample B

SILT CLAY	**SAND**			**GRAVEL**		
	Fine	medium	coarse	Fine	medium	coarse
37%	8%	13%	27%	12%	4%	0%

Table 6: Percentage of material from the sieve analysis of sample C

Silt Clay	*Sand*			*Gravel*		
	Fine	medium	coarse	Fine	medium	coarse
34%	9%	17%	25%	10%	34%	0%

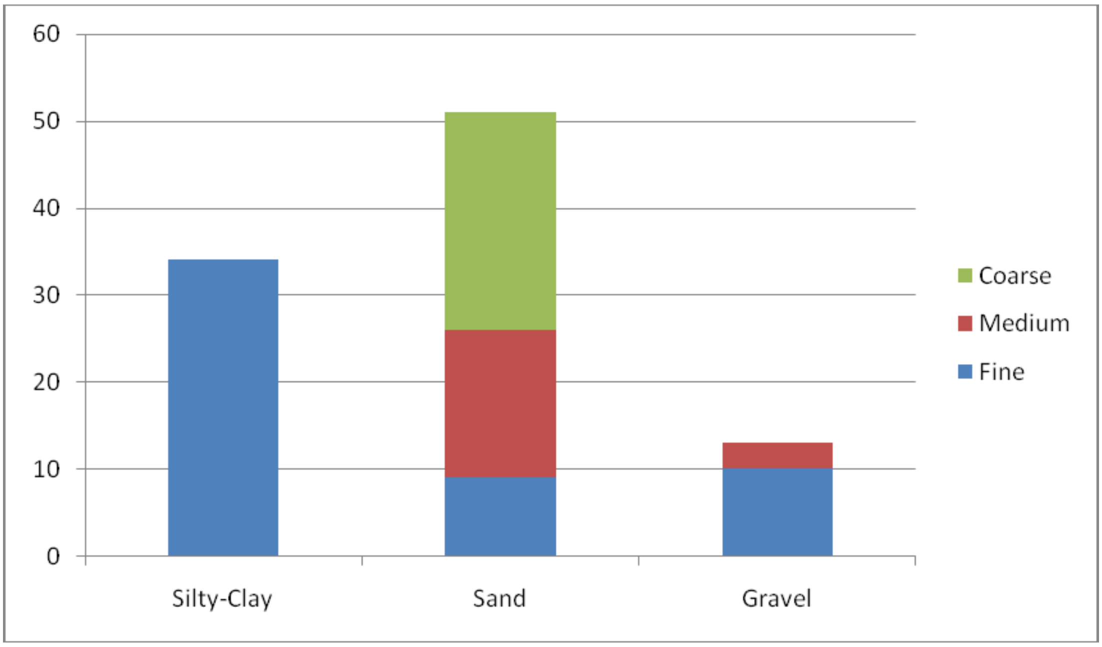

Figure 4: Bar chart showing various percentages of material in sample C

3.2 Atterberg limits test

Table 7 below shows the summary results of the preliminary analysis of soil samples. The natural moisture content of samples A, B and C were 0.72, 3.81 and 1.05% respectively. Sample A had the lowest natural moisture content while sample B had the highest. This is a function of the voids ratios and the specific gravities of the soil sample. According to whitlow (1995), liquid limit less 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 7: Summary of Atterberg Limit

Soil sample	*Natural Moisture content (%)*	*L.L*	*P.L*	*P.I*	*AASHTO symbol*
A	0.72	37.2	28.2	9.0	A-2-4
B	3.81	45.0	25.95	19.05	A-7-6
C	1.05	32.0	19.0	13	A-2-6

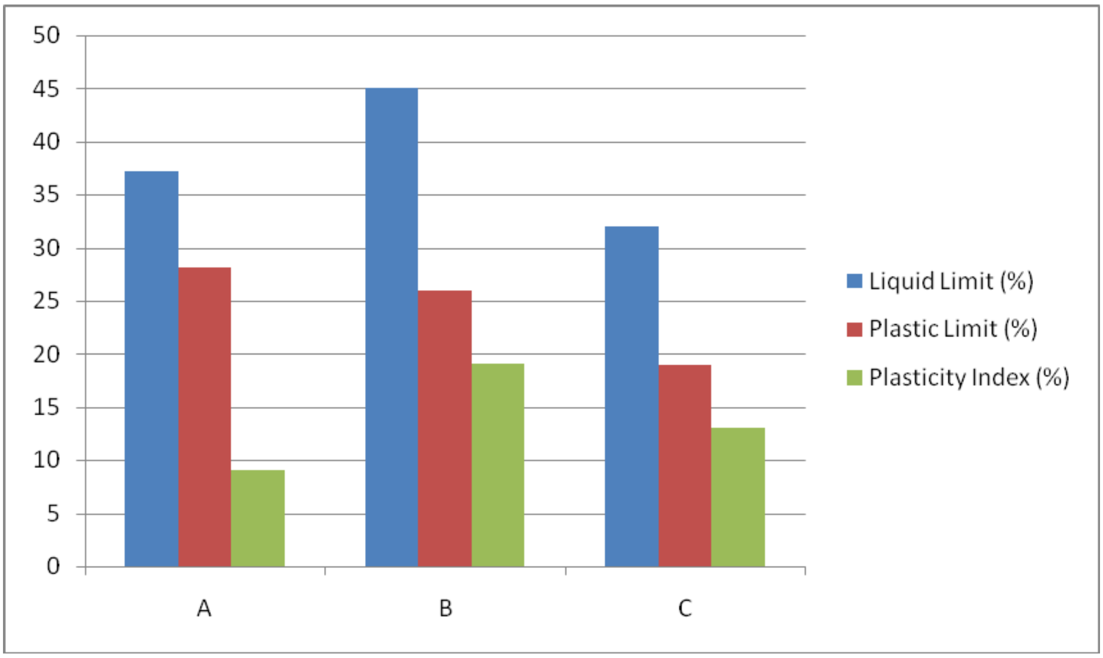

Figure 5: Histogram representation of Atterberg limit of soil samples

3.3 Compaction Test

This brought about an increase in soil density or unit weight, accompanied by a decrease in air volume. West African compaction test standard was employed with high energy compaction.

Table 8: Result of maximum dry density and the optimum moisture content of the preliminary samples.

Samples	Maximum Dry Density(MDD) (mg/m3)	Optimum Moisture content (%)
A	2.04	8.0
B	2.07	8.6
C	2.11	9.0

Table 9: Result of maximum dry density and the optimum moisture content of the samples introducing the geo synthetic materials

Samples	Maximum Dry Density(MDD) (mg/m3)	Optimum Moisture content (%)
A	2.08	7.43
B	2.07	6.50
C	1.95	9.03

3.4 California Bearing Ratio (CBR)

The results of unsoaked CBR with and without the reinforcement at different depths and number of layers are presented in table 10, figures 6, 7 and 8 below. There was a considerable increase in the CBR values under unsoaked condition after the inclusion of the geogrids at 2/5, 3/5 and 4/5 the height of the mould.

Table 10: CBR values for with and without Geo-grids (unsoaked sample)

Sample Unsoaked (%)	Soil without Geo-grid	(2/5)H	(3/5)H	(4/5)H
A	8	30	35	26
B	20	35	50	45
C	20	34	44	25

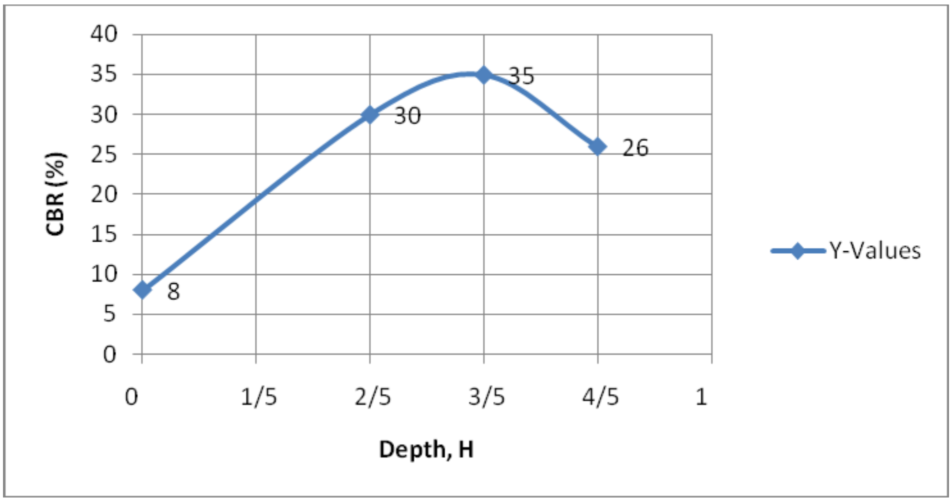

Figure 6: Graph of CBR (%) against depth (H) of Sample A before and after introducing the geo-grid

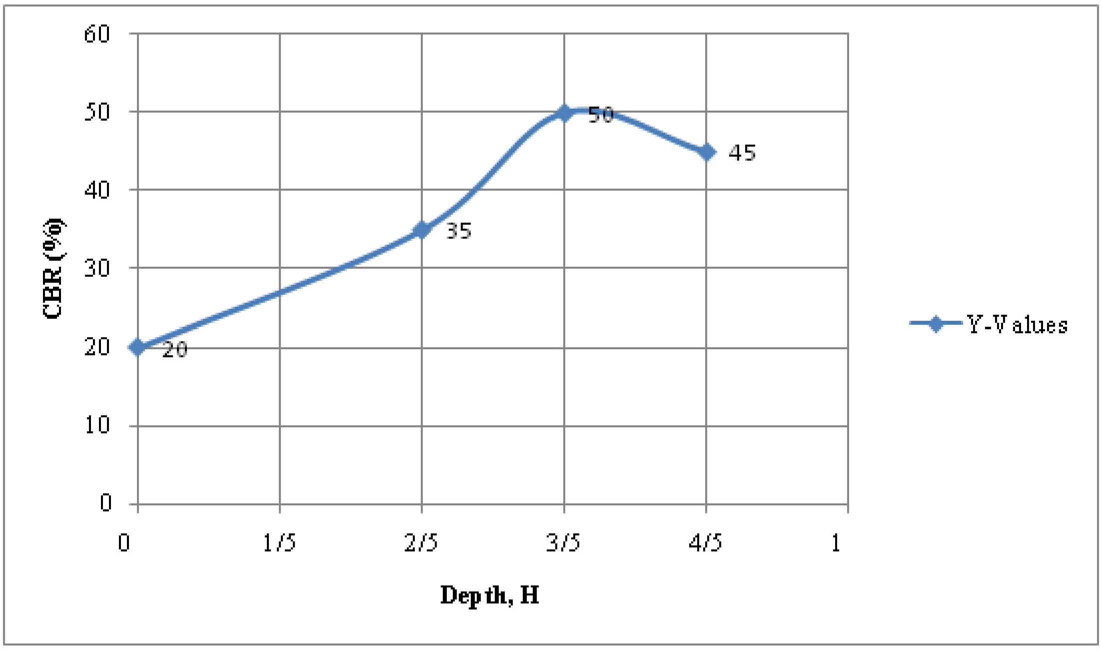

Figure 7: Graph of CBR (%) against depth (H) of Sample B before and after introducing the geo-grid

Figure 8: Graph of CBR against depth of Sample C before and after introducing the geo-grid

4. Conclusions and Recommendations

The study investigated the application of geogrids to subgrade material as a form of reinforcement to road construction. Theinclusion of the geo-grid considerably increases the strength of poor soils, which is reflected in the higher CBR values. The study shows that the strength of the subgrade is significantly altered positively by the positioning of the geo-grid at varying depth. It was observed that the highest subgrade strength is achieved when it is placed at 3/5H for a single layer although has satisfactory result at 2/5H and 4/5H respectively. On reinforcing the soil, there is considerable increase in performance of the subgrade in the unsoaked condition. The use of geogrids as reinforcement to poor soils improves its strength. It is non-bio degradable and therefore durable; it also increases the ultimate service life of the pavement. The use of Geogrids should therefore be encouraged as an effective and modern form of improving road construction on poor sub-grade materials. Further research should be analyzed in ascertaining the effect of geogrids on subgrade soils under under unsoaked condition.

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