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Application of Geogrids on the Geotechnical Properties of Subgrade Materials under Soaked Condition

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Abstract

Highway construction is one of the main engineering design and construction in civil engineering in many countries all over the world. Existing studies have shown that civil engineers engaging in highway construction have several challenges during road construction especially as it is related to the topography of the site ,inadequate subgrade soil and high water table, inspite of this challenges ,the application of geogrids as a geotechnical property is imperative to improve the subgrade of soils with soaked condition.

Soil samples were labeled (A, B& C) at random. These samples were taken to the Laboratory for experiments to identify and determine the Grain size analysis, atterberg, compaction and California bearing ratio by placing the geo-grids at varying depths and in single layer under soaked conditions (48hrs) to determine the strength of the soil samples. The geogrids were introduced in three independent single layers i.e. 2/5, 3/5 and 4/5 the distance from the base of the mould. Samples A, B&C (3%, 9% &6%) respectively, 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(15.1%,14% & 12.2%) than when placed at 2/5 (12.8%,11% & 8.8%) and 4/5(11%, 10% & 8.3%) distances from the base.

The differences in the behavior of the soil under soaked conditions improve on increasing the number of layers of geo-grids. As a subgrade stabilizer it has shown great effect of improvement. It can be used to improve poor lateritic materials due to its low maintenance, corrosion resistance and increment in the service life of road pavement. This application of geogrids is a means to improve the strength of basic engineering and geotechnical properties of poor subgrade soils under soaked condition. This will reduce land wastage, uneconomical design of road construction. Geo-grids should be employed as a modernized form of improving road construction on poor subgrade materials.

Keywords: geogrids, CBR, highway construction, soaked conditions, reinforcement, subgrade.

1. Introduction

Highway construction is one of the main engineering designs and construction in civil engineering in many countries all over the world, subgrade layer is one important factor during construction of highway. Subgrade is the lowermost layer of any type so road pavement—whether rigid or flexible. It serves as the foundation for the pavement which transfers every load to the soil beneath. Subgrade is very important in pavement design and construction in that the stronger it is the lesser the thickness of other layers (i.e. base, sub-base and surfacing) laid on it, the longer the useful life of the pavement and the lesser the cost and frequency of maintenance.. In the construction of pavements, Laterite is widely used as subgrade which serves as 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 values. 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 (Alexander and Cady, 1962; Gidigasu, 1972).

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 in locations with high rainfall. It contains iron oxide minerals which react with some other forms of stabilizers such as limestone etc. This adverse effect of increased moisture content on most important properties of subgrade soils i.e. its strength, is largely responsible for a lot of pavement defects, Subgrade supports the pavement to carry load and hence should have adequate strength regardless adverse conditions such has high rainfall, flooding etc. Weaker soil sub-grade increases the pavement thickness, thereby adding to cost. Natural soil is of limited strength in many locations around the globe,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 (Willway *et al*, 2008). It was also concluded by

Sahoo and Nayak (2009) that increased moisture content decreases the strength of subgrade soil by soaking soil samples in the laboratory and assessing the varying CBR values while Chauhan (2010) concluded that the decrease in the strength has the highest rate within the first 24 hours.

subgrade soil has its water content raised when the ground water level is high or when water finds its way through cracks on the pavement surface to the underlying soil layers and finally to the subgrade. The effect of this movement of water can however be kept low if the soil has good drainage property. Increase in the moisture content of subgrade allows movement of soil particles relative to one another when loads are applied. This is majorly responsible for rutting in road pavements (Willway *et al*, 2008; Erlingsson, 2009),but with the application of geogrids helps improve the strength of the subgrade soils and reduce the pavement thickness due to its anti-corroding and tensile properties.(Olaniyan and Akolade, 2014).

Geo-grids provide interlocking of 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, The sheets are flexible and permeable and generally have the appearance of a fabric (Palmeira *et al*, 2008).,they are polymeric in nature with tensile strength varying from 100 to 220KN, they are either biaxial or uniaxial in strength i.e. they are biaxial when they have major strength in both X, Y directions 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.(Olaniyan and Akolade, 2014).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.(Olaniyan and Akolade, 2014).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

Soil samples A, B & C was collected at random from three different locations (Gbogan/Oshogbo road, Abere-ikirun/Oshogbo road and Ogbomosho/Oshogbo road) respectivelyin osun state, Nigeria.Samples A and C are determined as granular soils using grain size analysis and atterberg test while sample B is silty-clay in nature. California bearing ratio and compaction test were carried out on each of the samples at the geotechnical and structural laboratory Oshogbo, osun state Nigeria. 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 soaked 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 soaked conditions without reinforcement and then with reinforcement at different levels.The soaked CBR values were obtained in this study after the soil samples has been soaked for 48 hours (2 days).

3. Result and Discussion

The summary of the result of the laboratory test (grain size analysis, compaction and atterbergs limit) shown below. The engineering property test (California bearing ratio (CBR)) is 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 figures below. 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
2.00	**mm**	107.2	30.2	69.8
425	**micron**	236.9	66.8	33.2
75	**micron**	263.7	74.3	25.7
Dust	**-**	91.0	25.66	-

Source: Olaniyan and Akolade, (2014)

Table 2: Sieve Analysis of preliminary Results for Sample B

Test sieve (normal sizes)		wt. retained in gms	Percentage retained	Total %passing
2.00	**mm**	40.0	16.2	83.8
425	**micron**	119.0	48.1	51.9
75	**micron**	156.1	63.1	36.9
Dust	**-**	91.4	36.9	-

Source: Olaniyan and Akolade, (2014)

Table 3: Sieve Analysis of preliminary Results for Sample C

Test sieve (normal sizes)		Wt. retained in gms	Percentage retained	Total %passing
2.00	**mm**	38.5	13.1	86.9
425	**micron**	124.2	42.2	57.8
75	**micron**	193.9	65.8	34.2
Dust	**-**	100.7	34.2	-

Source: Olaniyan and Akolade, (2014)

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%

Source: Olaniyan and Akolade, (2014)

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%

Source: Olaniyan and Akolade, (2014)

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%	3%	0%

Source: Olaniyan and Akolade, (2014)

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

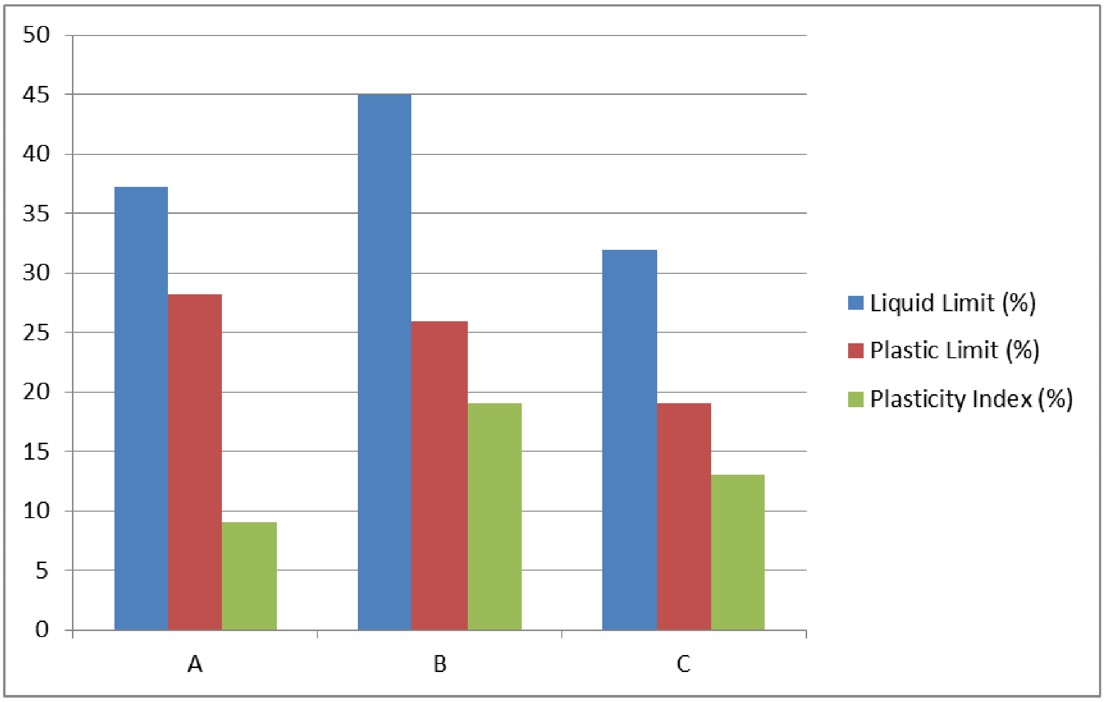

Fig 1: Histogram representation of Atterberg limit of soil samples

Source: Olaniyan and Akolade, (2014)

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

Source: Olaniyan and Akolade, (2014)

3.4 California Bearing Ratio (CBR)

The results of soaked CBR with and without the reinforcement at different depths and number of layers are presented in table 9, figures 2, 3 and 4 below. There was a considerable increase in the CBR values under soaked condition after the inclusion of the geogrids at 2/5(12.8%, 11%, 8.8%), 3/5(15.1%, 14%, 12.2%) and 4/5(11%, 10%, 8.3%) the height of the mold of samples A, B&C respectively as when compared with the initial CBR value of the soaked samples before the inclusion of the geogrids.

Table 9: Summary of CBR values with and without Geogrids (soaked 48hours)

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

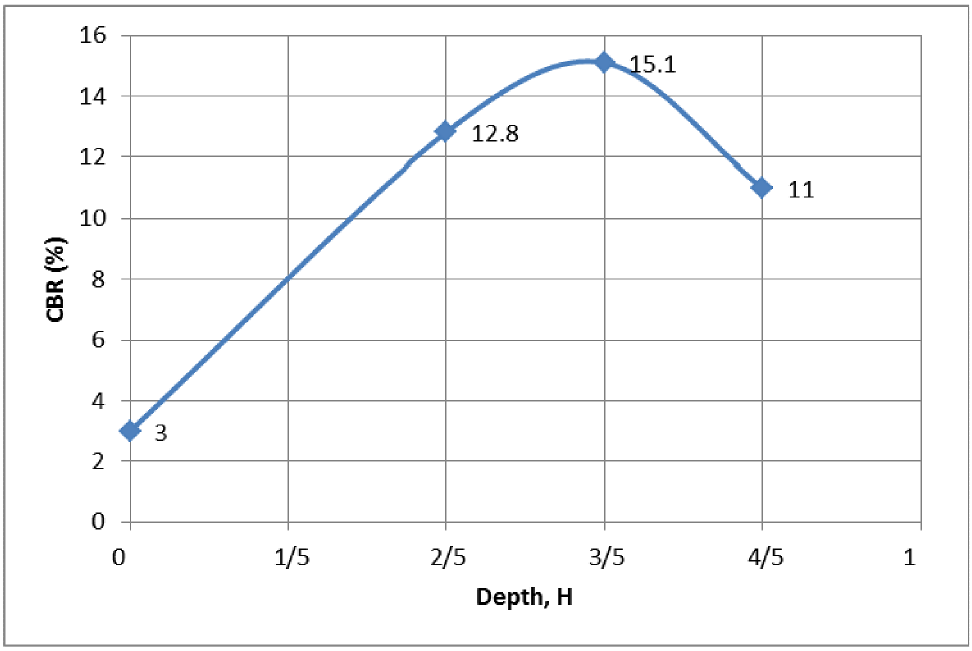

Fig. 2: Graph of CBR against depth of soaked sample A before and after introducing the geogrids

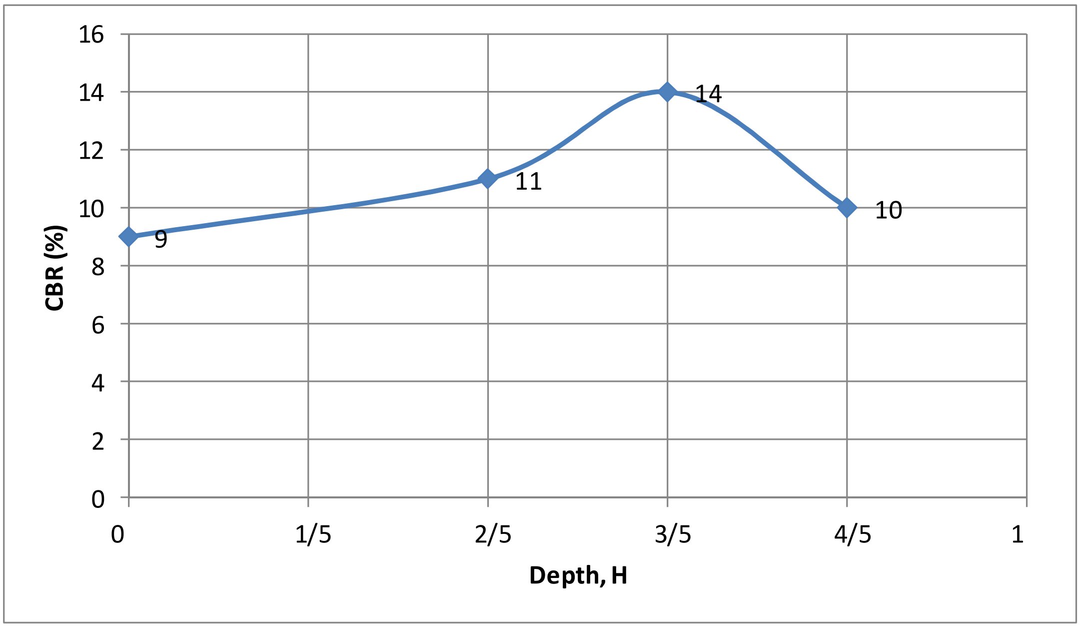

Fig.3: Graph of CBR against depth of soaked sample B before and after introducing the Geogrids

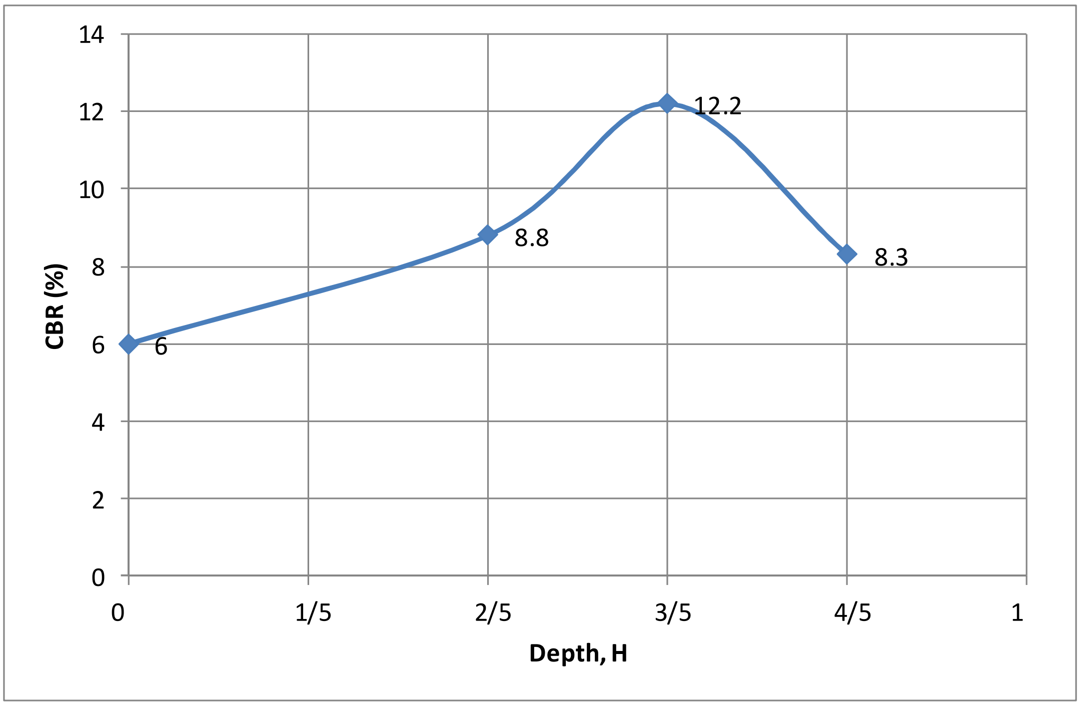

Fig.4: Graph of CBR against depth of soaked sample C before and after introducing the geogrids

4. Conclusion and Recommendation

The study investigated the application of geogrids to subgrade material under soaked conditions as a form of reinforcement to road construction. The initial CBR values of the soil samples show a 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. The application of geogrids 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 geogrids is placed within the thickness of the subgrade.However the depth at which the geogrids is placed dictates its effectiveness asreinforcement. It can be concluded that geotextiles performs 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 soaked. It can also be concluded from the experiments that geogrids is suitable as a means of reinforcement for adverse effects on soil strength posed by increased moisture content.

The use of geogrids as an aid or reinforcement to poor subgrade improves in the strength of poor subgrade soils. 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; also when used, it is advised that it is used at around 3/5 level of the depth from the base of the subgrade.

REFERENCES

Abhijit, P. and Jalindar, P. (2011). Effects of Bad Drainage on Roads. *International Institute for Science, Technology and Education, 1(1),* 1-7. Retrieved May 18, 2014 from http://www.iiste.org/Journals/index.php/CER/article/viewFile/725/626

Al-Qadi, I.L.et al. (2007), *Accelerated full-scale testing of geogrid-reinforced flexible pavements*, TRB 2007 Annual meeting (CD-ROM), Washington, DC: Transportation Research Board, National Research council.

Al-Qadi, I.L., Brandon, T.L., and Bhutta, A. (1997).Geosynthetic Stabilized Flexible Pavements. *Proceedings of Geosynthetics* '97, IFAI, Vol. 2, Long Beach, California, pp. 647-662.

Ampadu, S.I.K., (2007). A Laboratory Investigation into the Effect of Water Content on the CBR of a Subgrade Soil.Softbank E-Book Centre Tehran. Retrieved May 19, 2014 from http://ebooks.narotama.ac.id/files/Experimental%20Unsaturated%20Soil%20Mechanics/3.2%20%20A%20Laboratory%20Investigation%20into%20the%20Effect%20of%20Water%20Content%20on%20the%20CBR%20of%20a%20Subgrade%20soil.pdf

Appea, A.K. (1997). In-Situ Behavior of Geosynthetically Stabilized Flexible Pavement. *Unpublished M.Sc. Thesis, Virginia Polytechnic Institute and State University, Virginia.*Retrieved May 19, 2014 from :http://scholar.lib.vt.edu/theses/available/etd-111297-153911/unrestricted/alex.pdf

Chauhan, R. (2010). A Laboratory Study on Effect of Test Conditions on Subgrade Strength.*Unpublished B. Tech thesis, National Institute of Technology, Rourkela*. Retrieved May 18, 2014, from www.google.com/url?q=http://ethesis.nitrkl.ac.in/1935/2/Final-_2.pdf&sa=U&ei=7yh5U-fPBo_zoASWyICgDQ&ved=0CBEQFjAC&usg=AFQjCNFATxtSlzODoIfF41jp_LGkE4c-GA

Das, B.M. (2008). *Advanced soil mechanics (3rd edition*). New York: Taylor & Francis.

Day, R.W. (2006). *Foundation Engineering Handbook*. New York : The McGraw-Hill Companies, Inc.

EncyclopaediaBtitannica (2014).Laterite. Retrieved May 16, 2014, from http://www.britannica.com/EBchecked/topic/331578/laterite

Guler, E and Ocbe, C. (2003). Geotechnical Engineering, Bogazici University, 80815 *(Emirates Journal for Engineering Research, 8 (1),* 15-23

Holtz R. D., Kovacs W.D. An introduction to Geotechnical Engineering, prentice-hall, Inc., Englewoods, Cliff, New Jersey, 1981, 733 pp.

Hufenus, R. et al., *Full-scale field tests on Geosynthetics reinforced unpaved roads on soft subgrade*. Geotextiles and Geo-membranes, 24(1) 2006.

Lawson, C.R., 1995, Subgrade Stabilization with Geotextiles [Electronic version]. *Geosynthetics International, 2(4),* 741-763. Retrieved May 19, 2014 from: http://www.geosyntheticssociety.org/resources/archive/gi/src/v2i4/gi-v2-n4-paper6.pdf

Maxwell, S., Kim, W., Edil, T.B., Benson, C.H. (2005).Effectiveness of Geosynthetics in Stabilizing Soft Subgrades.*Wisconsin Highway Research Program #0092-45-15.*Retrieved May 19, 2014 from wisdotresearchtest.engr.wisc.edu/wp-content/uploads/45-15geosyn1.pdf

Olaniyan O.S and Akolade, A.S. (2014). Reinforcement of Subgrade soils with the use of Geogrids. *International journal of science and research, vol 3 issue 6, June 2014.*

Palmeira, E.M., Tatsuoka, F., Bathurst, R.J., Stevenson, P.E. and Zornberg, J.G. (2008).Advances in Geosynthetics Materials and Applications for Soil Reinforcement and Environmental Protection Works.*Electronic Journal of Geotechnical Engineering .Bouquet 08*. 1-38

Perkins, S.W. (1999) Geosynthetic reinforcement of flexible pavements: Laboratory based pavement test sections. Report No. FHWA/MT-99-001/8138., US Department of Transportation, Federal highway Administration, Washington, DC. Retrieved May 16, 2014, from http://mdt.mt.gov/other/research/external/docs/research_proj/geo-reinforce.pdf

Perkins, S.W. (1999). Mechanical Response of Geosynthetic-Reinforced Flexible Pavements. *Geosynthetics International, 6(5).*347-382.Retrieved May 16, 2014 from http://geosyntheticsociety.org/Resourses/Archive/GI/src/V615/GI-V6-N5-Paper2.pdf

RamanaathaAyyar T.S, Krishnaswamy N.R and Vishwamodhan B.V.S. (1989) "Geosynthetics for foundations on swelling clay", geotextile proceedings of the international Workshop on geotextile Banglore, Vol. CI and PRI New Delhi.

Ramasubbarao, G.V. and Siva Sankar, G. (2013).Predicting Soaked CBR Value of Fine Grained Soils Using Index and Compaction Characteristics [Electronic version].*Jordan Journal of Civil Engineering, 7*(3), 354-360.

Razouki, S.S. and Al-Azawi, M.S. (2003). Long – Term Soaking Effect On Strength And Deformation Characteristics Of A Gypsiferous Subgrade Soil. *Engineering Journal of the University of Qatar,16*, 49-60. Retrieved May 18, 2014 from http://qspace.qu.edu.qa/bitstream/handle/10576/7970/060316-06-fulltext.pdf?sequence=3

R. D. Barksdale, S. F. Brown, and F. Chan, *Potential benefits of geosyntethetics in flexible pavement systems.* National Cooperative Highway Research Program (NCHRP) Report No.315.Washington, DC: Transportation Research Board, National Research Council, 1989.

Sahoo, B. and Nayak, D. (2009). Study of Subgrade Strength related to Moisture. *Unpublished B. Tech thesis, National Institute of Technology, Rourkela*. Retrieved May 16, 2014, from http//ethesis.nitrkl.ac.in/1317/1/project_report.pdf

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