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Influence of Cement, Bitumen and Lime on Some Lateritic Soil Samples as Pavement Material

To cite this article: Lucia O Agashua and Adebanji S Ogbiye 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **413** 012012

IOP Conf. Series: Materials Science and Engineering **413** (2018) 012012 doi:10.1088/1757-899X/413/1/012012

Influence of Cement, Bitumen and Lime on Some Lateritic Soil Samples as Pavement Material

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Abstract- This study was carried out in order to determine cement, lime and bitumen prerequisite of some lateritic soil specimens as sub base materials. Soil specimens A, B, C was collected from Dual carriageway road construction project at Estate Iwo road, Osogbo, Osun state and stabilized with 0, 3, 6, 9, and 12% of cement, lime and bitumen. Various laboratory test was conducted on the soil specimen such as California Bearing Ratio (C.B.R), Compaction, Atterberg's limit test and particle size distribution. The investigation revealed that beneficial effects were obtained by the addition of cement, Lime and Bitumen to improve the strength of weak or poor soils. The C.B.R values are 9.88%, 4.36% and 7.27% for sample A, B and C respectively at 0% additive content and at 12% additives, the samples gave C.B.R values of 55%, 50.0% and 50.00% by using cement. All the three samples have maximum C.B.R values of 45.0% with lime as additives. For using bitumen, result gave maximum C.B.R values of 41% for sample A and B and Sample C have 40.0%. Addition of additives improved the samples from a poor subbase material to an excellent subbase material with C.B.R values over 30%. Hence, soil improvement of laterite samples from the studied site can be carried out successfully by using Lime or bitumen judging from the result of the various tests on the different soil – additive mixtures.

1. Introduction

Country developments have stirred knowledge of economic resources management in the nation, hence people are being stimulated to be assiduous at resources earlier reprehend and provide way for such materials to be recycle (Akinje, 2015). Currently, sites such as abandoned sanitary landfills (Garbage dumps), swamps, bays, mashes, hillsides and other poor areas are being used for construction sites, this trend expected to both continue and accelerate when alternative sites are not available or environmental considerations, citizen opposition and zoning regulation severely limit the option available, therefore it becomes more necessary to modify or stabilize the available soil to obtain the needed properties (Amu et al., 2011). In cases such as earthdams, embankments or other fills, where selected materials in sufficient quantities may not be available, selective use of the available materials and understanding of both the function of the earth structure and the mechanics of the earth mass, can produce a satisfactory solution via use of zoned construction (Ali, 2012). Tropical regions lateritic soils fill about 23% land surface, choose for highway materials usage can be economically seen (Akinwumi et al., 2012). Ali (2012) attest that soil stabilization is the technique in improving soil engineering and physical properties so as to acquire predetermined goals. It may be any or a combination of one or more of the following; Mechanical densification with various types of mechanical equipment as rollers, falling weights explosives, static pressure, fabrics, freezing and so on; additives – Gravel to cohesive soils, clay to granular soils, Chemical additives such as Portland cement, Lime fly ash (by product from coal burning) often with lime or Portland cement, asphalt cement, sodium and calcium chlorides paper mill waste and others (Wright and Dixon, 2013; Osinubi and Amadi2010). To stabilize unpaved roads, addition of gravel layers to be partially worked into a clayey road surface is common, in fine grained soils, it involves excavating to a depth and blending the excavated soil with Portland cement, fly ash, lime with sufficient water. Addition of lime, fly ash and sometimes portland cement is made in clayey deposits particularly those subject to large volume changes to effect a ion exchange to reduce the activity of the clay minerals. It could be obtained by addition of aggregate, lime, salt, bitumen, resinous materials, cement and calcium chloride (Akinje, 2015) and (Kadyali and Lai, 2008). Engineers are facing most economical stabilization technique problem at a particular project depends on stabilizer material readily availabe for use and right choice at certain time couple with strength achievement for road design and construction work (Osinubi and Amadi, 2010); Stabilizer like lime, bitumen and cement increases parameters of soil strength, improve capability and reduces settlement of soil at lower cost especially in construction works that needs greater volume of soil improvement (Zhang and Yi, 2011) and (Latifi et al., 2013). Traditional stabilizer such as fly ash, lime, bituminous materials and cement; non traditional stabilizer involves acids enzymes, lignin derivatives, liquid polymers, silicates, resins and ions have lesser water content when soil grain is coarse (Akinwumi et al., 2012; Garber and Hoel,2010). Cement an hydraulic binder; finely grinded inorganic material made from materials which contain the proper proportions of lime, silica, alumina and iron with minor amounts of magnesia and sulphur trioxide, when reacted with water forms a paste that set as well hardens through hydration reactions means and processes, retains strength after hardening and stable under water, whereas bitumen a genetic names applied to various mixtures of hydrocarbons gaseous, liquid, semisolid or solid in nature and is completely soluble in carbon disulphide, most common materials within this family of bitumen are tars, pitches and asphalts. It has a number of properties which make them useful in the construction industry, it has tendency to adhere to a solid surface and this adhesiveness will depend on the surface and the state of the bitumen. Types are: Tar – used to saturate felt paper and to coat Kraft paper to render it waterproof; Pitch-coal tar – used in making pitch (after distillation of coal) and gravel built-up roofs; asphalt- results from the refining of naphtha base crude oils which produce aviation – grade gasoline feel soil, cold – test lubricating oils and asphalt (Wright and dixon, 2013; Latifi et al., 2013).

2. Materials and Methodology

Study Area

The materials used for this research work are lateritic soil specimen, cement, lime, bitumen and water. Lateritic soil specimen used in this research was collected from three location at Okada estate Oke – fia bye pass road, NUJ, Moye petrol station, Dada Estate Osogbo, Osun State, Nigeria and was labelled A – C. Ungoing construction works exposed the soil strata and the specimen was taken at 2m depths using Trial Pit method. The samples were air dried to remove excess water, the additives used are cement, bitumen and lime. The cement and slaked lime used for these tests was Portland cement purchased from the Oja Oba market Osogbo and properly stored in the laboratory to prevent unnecessary hardening while S 125 bitumen used was gotten from Dekit Construction Company, Dada Estate Osogbo, Osun State Nigeria. Potable water that was treated in the laboratory were used throughout the test, Tests on the lateritic soil specimen was carried out in the Department of Civil Engineering Laboratory, Federal University of Technology Akure, Ondo state, Nigeria, collected samples were gently broken down for sieving and soaked for24 hours before carrying out the test. Atterberg samples were mixed to near plastic limit and allowed to equilibrate for 24 hours before testing while compaction and C.B.R were carried out using standard methods by American Association of State and Transportation Officials (AASHTO, 2007) for 0%, 3%, 6%,9% and 12% additive contents for strength comparison.

Sampling and Laboratory Analysis

Particle Size Distribution expresses the size of particle in a soil in terms of percentages by weight of boulders, cobbles, gravel, sand, silt and clay and results given in form of fractions by weight of different size grades. This expressed as percentage of the whole sample and summed to obtain a cumulative percentage, curves are then plotted on a semi-logarithmic paper to give a graphical representation of the particle size distribution, slope of the curve provides an indication of the degree of soiling also determine the percentage by weight of particle within the different size ranges. The weight of soil retained in each sieve is determined and the cumulative percentage by weight passing each sieve is calculated. The Atterberg are water contents which define the various stages of consistency for a given soil. Liquid limit

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(W_1) is the water content at which 25 blows of the liquid limit machines closes a standard groove cut in the soil for a distance of 12.7cm. LL were carried out on the samples from different locations, 200gm of the soil was weighed and pulverized by using 425mm sieve with the aid of the spatula. The soil passing through 0.425mm sieve were mixed with water to a stiff consistency until the paste is uniform and left for 24 hours. Plastic limit (Wp) is the water below which the soil no longer behaves as a plastic material. It is range of water contents between W_L and the plastic limit Wp that the soil behaves as a plastic material, this range is termed the plasticity (or plastic) index. Ip is also the water content at which thread of soil when rolled to a diameter of 3mm will just crumble. Compaction the process of increasing the density of a soil by packing the particle closer together with a reduction in the volume of air, there is no significant change in the volume of water in the soil. The curves which are obtaining by plotting moisture content versus dry density for each test are known as compaction curves. As the moisture in the soil is increased, the dry density increases at least up to a point where it reaches a maximum value. From the curve, optimum moisture content which is the moisture content at which the maximum dry density is obtained by determining the highest point on the compaction curve (Apex) and dropping vertical down to the horizontal moisture scale or line. Compaction test were carried out on the natural sample of soils collected from Dada Estate bye pass road after which 3, 6, 9 and 12 percentages of Portland cement, Lime and bitumen were added for soil-additive mixtures. The soil samples were first pulverized, 500gm of each sample was measured and about 4% of water added, thoroughly mixed for the first and divided into three equal parts, immediately compacted in the B.S mould in three layers. Each layer was compacted using 25 uniformly spaced blows of a 5.5Kg rammer dropping at a height of 12 inches (304.8). The compacted specimen and mould were then weighted and a representative sample taken for moisture content and dry density determination. The same process was repeated for all the additive but different is the mixture of the required percentage of Lime, cement and Bitumen. After compaction, the bulk density and water content of the soil were determined and dry density calculated. Dry density was plotted against water content with the formation of a curve. The maximum possible value of dry density is referred to as the "Zero air voids". The OMC determined is used to control the quantity of water to be added during the compaction of soil earthwork in road construction. For California Bearing Ratio (CBR) Test about 6kg of the soil sample passing through N0 4 sieve was mixed with the desired amount of optimum moisture content (OMC) previously obtained from compaction Test and compacted in the C.B.R mould. It involved compacting the soil in three layers given 15 blows with a 2.5kg rammer. The mould and compacted soil were placed under the California bearing ratio machine and tested with penetrations of 25, 50, 15, 100, 125 to 750 inches. The steps were repeated for the bottom surface for each sample. The C.B.R test is essentially a penetration test having the function of measuring the soil resistance to penetration prior to reading to estimate shearing value. This action is an exact duplicate of what vehicles exert on a flexible pavement structure. It can be defined as an indirect way of measuring the shear strength of soil for use as subgrade or base material in flexible pavement construction. The C.B.R is calculated as the ratio of the force required to push the plunge to a certain depth into the soil to that force required to push the same plunge to the depth into a standard sample of compacted crushed stone that is C.B.R % equal (Test load / standard load) x 100.

3. Results and Discussion

Laboratory test were performed on the three samples collected for the purpose of identification, classification and determination of the engineering characteristics of the material used. The samples were treated with 3%, 6%, 9% and 12% of Cement, Lime and Bitumen contents in the laboratory for properties evaluation all in accordance with AASHTO 2007 Pavement manual and Approximate equivalent classification from AASHTO 2007 Pavement manual;

Table 1: Basic and Engineering Properties of the selected laterite soil

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PROPERTIES	**SOIL SAMPLES**		
	A	**B**	**C**
Grain Size Distribution Coarse (%) Fine (%) Bulk density (KN/m^3)	 90.85 09.15 14.64–29.76	 93.45 06.55 12.23–22.24	 93.90 06.10 14.64–22.78
Consistency Limit (%) Liquid Limit Plastic Limit Plasticity Index	 43.00 19.09 23.91	 43.50 25.65 17.85	 21.50 16.33 5.17
Maximum Dry Density (KN/m^3)	18.65	16.62	14.80
Optimum Moisture Content (%)	9.15	9.90	9.15
California Bearing Ratio (%)	9.88	4.36	7.27
Soil Classification	A-2-7	A-2-7	A-2-4
Soil Type	Silty or clayed clayey gravel and sand		

Particle Size Distribution

The results of the particle size analysis are shown in Table 2, graphically represented in Figure 1 for the three samples collected from Okefia- Dada Estate Road, Osogbo, Osun State. The result shows that sample A higher in fine and bulk density than sample B as well higher tha sample C, while sample C greater in Coarse aggregate than Sample B and far greater than sample A.

Table 2 Particle Size Distribution of Control Sample A, B and C

Samples	**Material type**		**Bulk density range (KN/m^3)**
	Fine (%)	**Coarse (%)**	
A	09.15	90.85	14.64 – 29.76
B	06.55	93.45	12.23 – 22.24
C	06.10	93.9	14.64 – 22.78

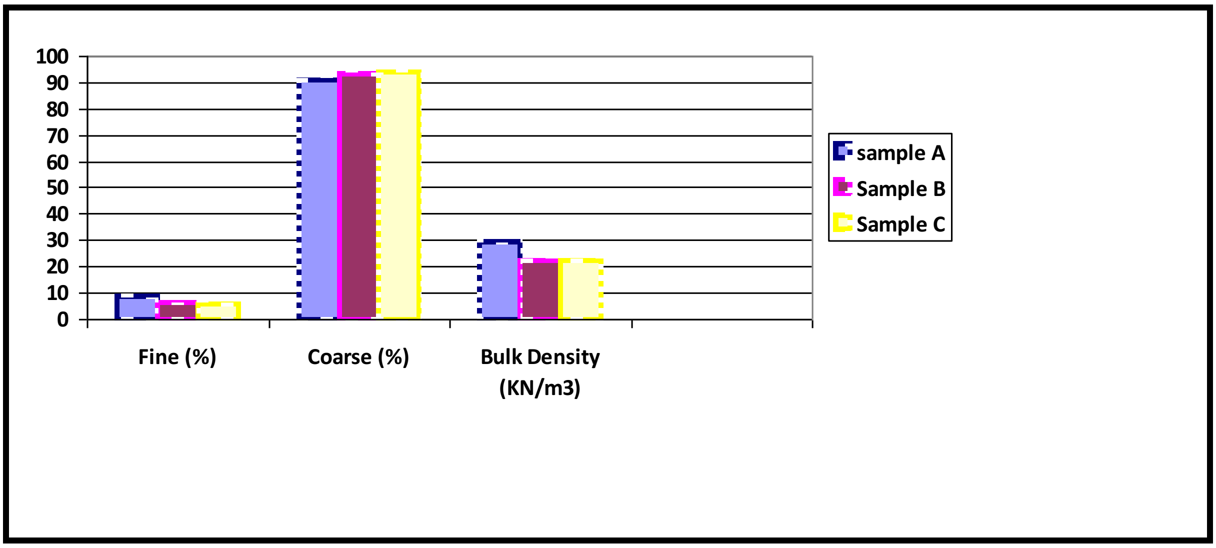

Figure 1: Graph for particle size distribution for samples

Atterberg Limits

The test results are analyse in Table 3 and 4 and graphically illustrated in Figures 2and 3 reveal that the average Lime additive (3%) Liquid limit and plastic limit value is higher than cement additive which is also higher than bitumen additive, while Bitumen additive (3%) average plasticity index greater than lime additive which also greater than cement additive. Also Lime additive (12%) Liquid limit and plastic limit value is higher than bitumen additive which is also higher than cement additive, while Bitumen additive (12%) average plasticity index greater than lime additive which also greater than cement additive.

Table 3 Atterberg Limit test Control, Cement treated, Lime treated and bitumen treated sample at 12%

Samples		**Liquid Limit (LL)%**	**Plastic Limit (PL)%**	**Plasticity index (PI) %**
Control (0%)	A	43.00	19.09	23.91
	B	34.50	25.65	17.85
	C	21.50	16.33	05.17
	Average	**33.00**	**20.36**	**15.64**
Cement treated (12%)	A	35.30	31.00	4.30
	B	34.50	28.50	6.00
	C	33.50	29.50	4.00
	Average	**34.43**	**26.12**	**4.77**
Lime treated (12%)	A	36.42	30.85	5.57
	B	37.24	31.19	6.05
	C	33.50	29.50	4.00
	Average	**35.72**	**30.51**	**5.21**
Bitumen treated (12%)	A	36.49	30.50	5.99
	B	33.00	27.00	6.00
	C	33.40	29.40	4.00
	Average	**34.30**	**29.00**	**5.33**

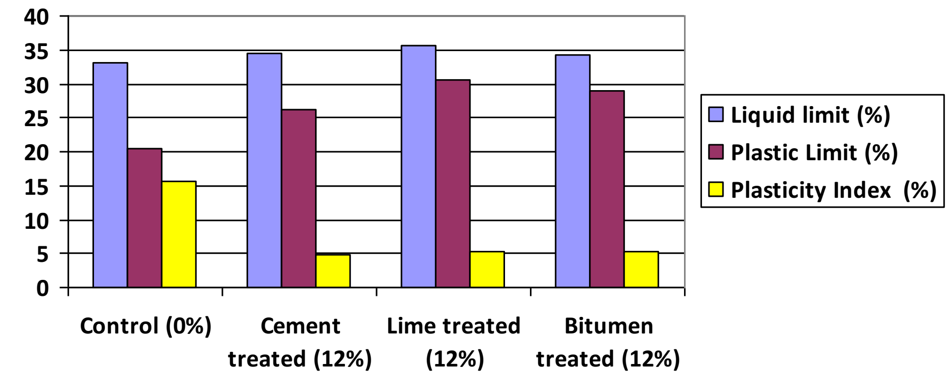

Figure 2: Chart for Atterberg Limit test (0% and 12%)

Table 4 Atterberg Limit test Control, Cement treated, Lime treated and bitumen treated sample at 3%

Samples		**Liquid Limit (LL)%**	**Plastic Limit (PL)%**	**Plasticity index (PI) %**
Control (0%)	A B C	43.00 34.50 21.50	19.09 25.65 16.33	23.91 17.85 05.17
	Average	**33.00**	**20.36**	**15.64**
Cement treated (3%)	A B C	45.19 45.19 42.00	28.81 26.10 24.50	16.38 19.09 17.50
	Average	**44.13**	**26.47**	**17.66**
Lime treated (3%)	A B C	44.40 45.50 42.00	22.49 26.50 24.75	21.91 19.00 17.25
	Average	**43.97**	**24.58**	**19.39**

Bitumen treated (3%)	A B C	42.00 47.00 40.00	18.09 21.58 24.00	23.91 25.42 16.00
	Average	**43.00**	**21.22**	**21.78**

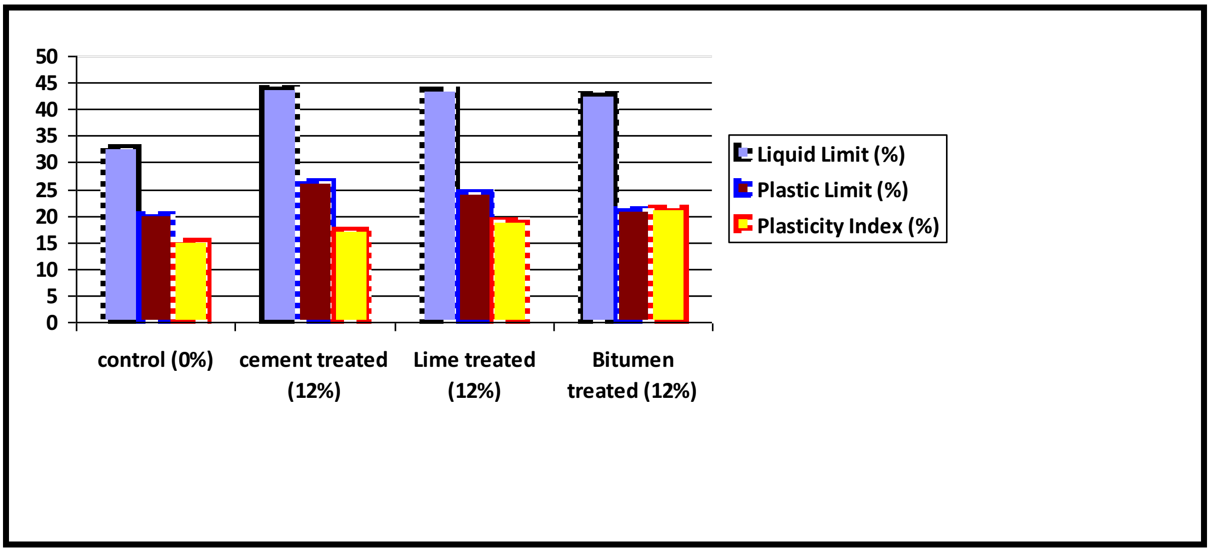

Figure 3: Graph for Atterberg for all samples (0% and 3%)

Compaction Test

The test results are analyzed in Table 5 and 6 and graphically illustrated in Figures 4 and 5 shows three samples show low dry densities which will lead to low strength of the samples if used for construction materials in its natural state. The average Lime additive (3%) Maximum Dry density value is higher than cement additive which is also higher than bitumen additive, while Bitumen additive (3%) average Optimum dry density values greater than lime additive which also greater than cement additive. Also Bitumen additive (12%) Maximum Dry density value is higher than Lime additive which is also higher than cement additive, while cement additive (12%) average Optimum dry density values greater than bitumen additive which also greater than lime additive.

Table 5 **Compaction test Control, Cement treated, Lime treated and bitumen treated sample at 12%**

Samples		**Maximum Dry density (MDD) KN/m^3)**	**Optimum moisture content (OMC) %**
Control (0%)	A B C	18.65 16.62 14.80	09.50 09.90 09.15
	Average	**16.69**	**09.52**

Cement treated (12%)	A B C	13.05 14.70 9.15	30.00 10.00 19.00
	Average	**12.30**	**20.00**
Lime treated (12%)	A B C	17.00 15.30 19.00	17.25 11.00 9.30
	Average	**17.10**	**12.52**
Bitumen treated (12%)	A B C	20.00 13.60 19.00	10.00 22.00 7.00
	Average	**17.53**	**13.00**

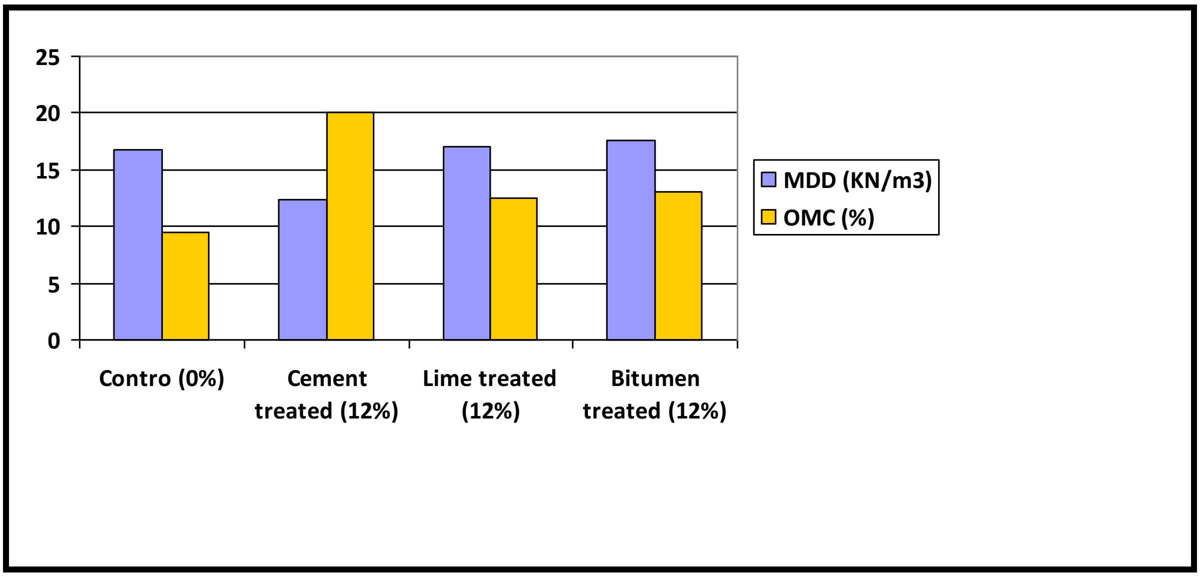

Figure 4: Compaction Chart for samples (0% and 12%)

Table 6 Compaction test Control, Cement treated, Lime treated and bitumen treated sample at 3%

Samples		**Maximum Dry density (MDD) KN/m^3)**	**Optimum moisture content (OMC) %**
Control (0%)	A B C	18.65 16.62 14.80	09.50 09.90 09.15
	Average	**16.69**	**09.52**

Cement treated (3%)	A B C	16.80 19.80 19.60	16.50 11.50 14.80
	Average	**18.73**	**14.27**
Lime treated (3%)	A B C	17.90 18.80 20.20	21.60 13.40 14.00
	Average	**18.97**	**16.33**
Bitumen treated (3%)	A B C	17.25 15.80 19.95	11.40 8.60 10.00
	Average	**17.67**	**10.00**

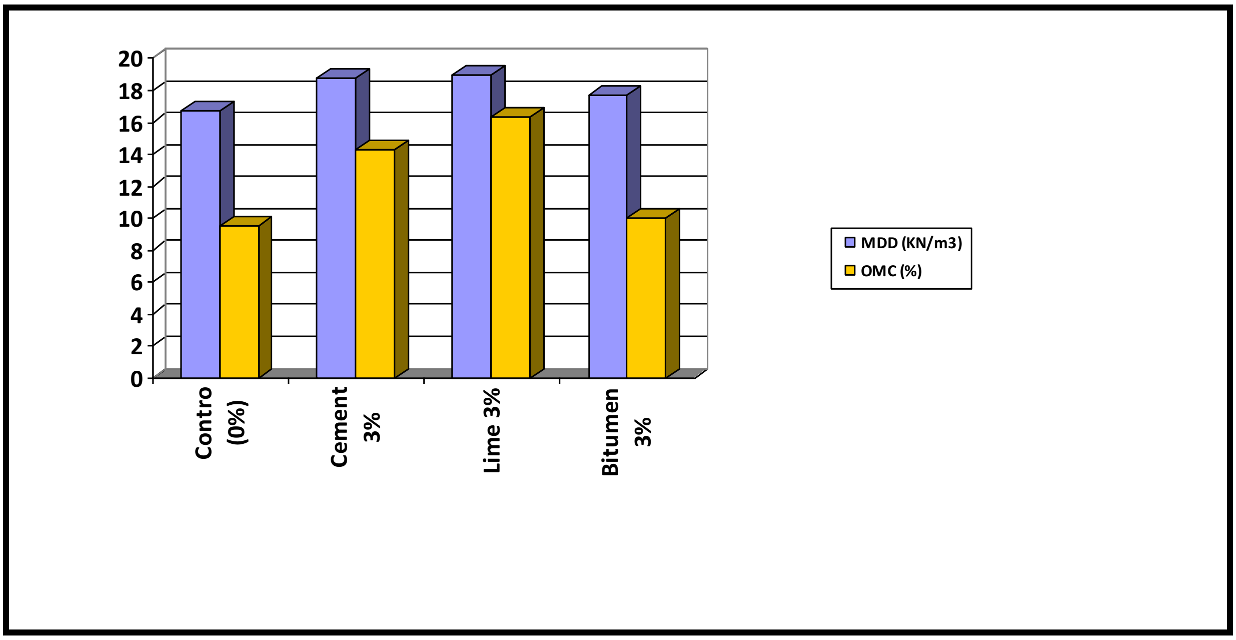

Figure 5: Compaction Chart for samples (0% and 3%)

California Bearing Ratio (C.B.R) Test

The test results are analyse in Table 7 and 8 and graphically illustrated in Figures 6 and7. The three samples categorized as poor sub base materials based on AASHTO 2007 reveal three samples show low dry densities which will lead to low strength of the samples if used for construction materials in its natural state. The average Lime additive (3%) California bearing ratio value is higher than cement additive which is also higher than bitumen additive while average cement additive (12%) California bearing ratio is higher than Lime additive which is also higher than bitumen additive.

Table 7 California bearing ratio Control, Cement treated, Lime treated and bitumen treated sample at 12%

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Samples		**California Bearing ratio (C.B.R) %**
Control (0%)	A B C	9.88 4.36 7.27
	Average	**7.17**
Cement treated (12%)	A B C	55.0 50.0 50.0
	Average	**51.67**
Lime treated (12%)	A B C	45.0 45.0 45.0
	Average	**45.0**
Bitumen treated (12%)	A B C	41.0 40.0 40.0
	Average	**40.33**

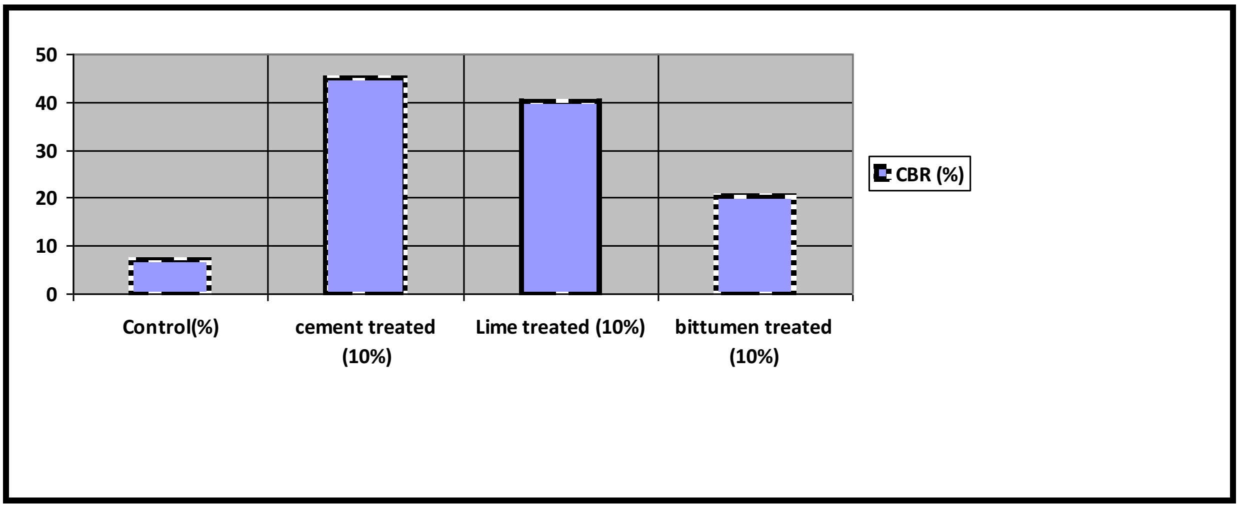

Figure 6: Graph of California bearing ratio for samples (0% and 3%)

Table 8: California bearing ratio Control, Cement treated, Lime treated and bitumen treated sample at 3%

Samples		**California Bearing ratio (C.B.R) %**
Control (0%)	A B C	9.88 4.36 7.27
	Average	**7.17**
Cement treated (3%)	A B	22.01 20.00

	C	23.00
	Average	**21.67**
Lime treated (3%)	A B C	24.00 35.00 18.00
	Average	**25.67**
Bitumen treated (3%)	A B C	18.00 16.00 12.00
	Average	**15.33**

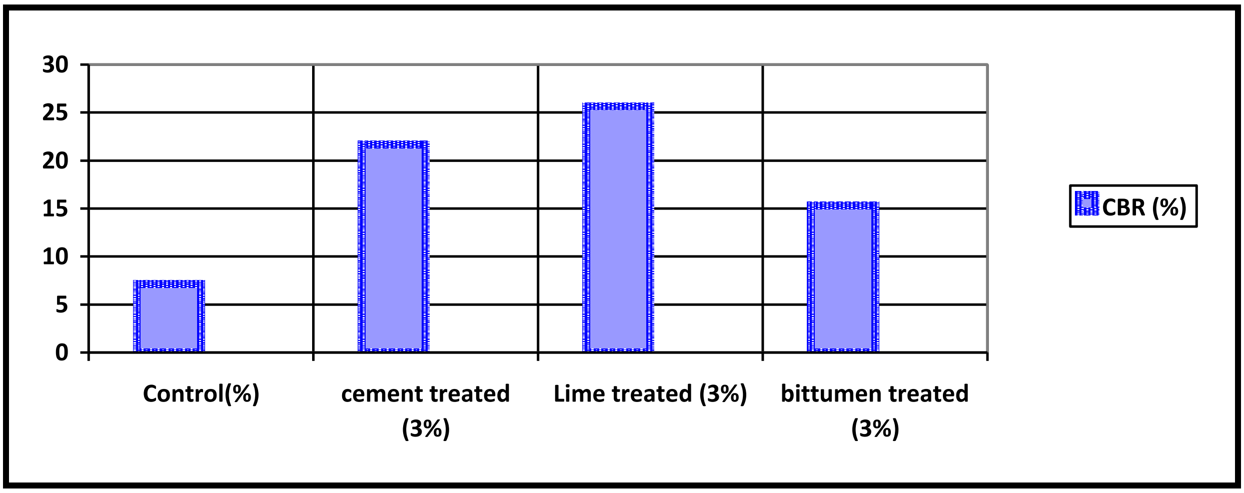

Figure 7: Graph of California bearing ratio for samples (0% and 3%)

4. Conclusion

The study of laterite soil sample from a construction site located at Dada Estate road, Osogbo Osun State shown that beneficial effects are obtained by the addition of cement, lime and bitumen to improve the strength of weak or poor soil. Lateritics soil sample A and B belong to A-2-7 while sample C is categorized as A-2-4 which is silty or clayed gravel sand. The Atterberg Limits of the samples ranges from 29.00% to 47% for Liquid Limit with plasticity index between 3 and 26. Atterberg at 3% and 12% lime additive LL and PL is greater and Bitumen additive higher in PI. For Compaction at 3%; lime additive MDD higher and Bitumen additive higher in OMC while 12%; bitumen additive MDD greater while cement additive higher in OMC. Lime additive at CBR 3% is highest while at 12% is cement additive. Increase in percentage of Lime additive also increase LL and Pl and increase in bitumen content as additive gave rise to PI values. Lower percentage of lime and bitumen additive gave highest values of MDD and OMC respectively; greater percentage of Bitumen and cement additive result to higher values of MDD and OMC respectively. With little amount of Lime additive and moderate quantities for Bitumen there will be great soil strength improvement but cement require large quantities before soil strength can be improve. From comparison with (Olugbenga Oludolapo Amu, Oluwole Fakunle Bamisaye and Iyiola Akanmu Komolafe, 2011) soil improvement of lateritic samples from the studied site at Osogbo, Osun state capital Nigeria can be carried out successfully by using Lime or bitumen additives.

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