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COMPARATIVE ANALYSIS OF SELECTED STABILIZATION AGENTS FOR SUBGRADE SOIL

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ABSTRACT

The lateritic soil which is the major material used in road construction sometimes may be unsuitable which leads to failure of the pavement profiles. This study therefore evaluated the use of hydrated lime, cement and bitumen in stabilizing lateritic soil.

Lateritic soil samples were collected from proximal four (4) different borrow pits namely Odookun-Igbeti (OI), Gbemi-Igbeti (GI), Isafa-Kisi (IK), Yoyin-Kisi (YK) along Igbeti-Kisi Road, Oyo State, Nigeria. The stabilized soil mixture was prepared by using 2, 4, 6 and 8% hydrated lime, cement and bitumen by weight of soil samples, while the unstabilized sample served as control. The unstabilized and stabilized samples were subjected to Specific Gravity (SG), Particle Size Analysis (PSA), Liquid Limit (LL), Plastic Limit (PL), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and unsoaked California Bearing Ratio (CBR), in accordance with British Standard BS 1377: 1990.

The SG and PSA values for the unstabilized samples obtained from OI, GI, IS and YK were 2.28, 2.41, 2.22, 2.47 and 35.14, 33.78, 41.10, 41.04%. LL and PL values were 33, 33, 19, 34% and 22, 17, 23, 14%, respectively. The corresponding MDD, OMC and unsoaked CBR were: 1.79, 1.90, 1.72, and 1.81 g/cm3, 15.0, 15.5, 18.9, 13.3%, and 18, 11, 4, 17%, respectively. The corresponding ranges of values for stabilized samples for the varying percentage of the stabilizing agents were: Lime: LL (33 - 36, 33 - 42, 39 - 43, 34 - 42%); PL (19 - 26, 17 - 27, 23 - 28, 14 -27%); MDD (1.67 - 1.95, 1.79 - 1.95, 1.64 - 1.76, 1.63 - 1.92 g/cm3); OMC (11.4 - 15.0, 11.0 -15.5, 11.5 - 18.9, 9.0 - 13.3 %); and CBR (48, 43, 17, 30%), respectively. For Cement: LL (33 -38, 33 - 38, 39 - 48, 34 - 48 %); PL (21 - 26, 17 - 26, 23 - 32, 14 - 30%); MDD (1.76 - 1.88, 1.76 - 1.90, 1.72 - 1.94, 1.73 - 1.82 g/cm3); OMC (10.9 - 15.0, 12.5 - 16.6, 12.6 - 18.9, 9.0 - 13.3 %); and CBR (45, 39, 29,31%), respectively. While for Bitumen: LL (30 - 34, 29 - 34, 38 - 41, 34 -38%); PL (17 - 24, 13 - 23, 17 - 24, 14 - 26%); MDD (1.67 - 1.95, 1.73 - 1.93, 1.72 - 1.93, 1.68 -1.92 g/cm3); OMC (11.4 - 15.0, 9.0 - 15.5, 13.0 - 18.9, 9.0 - 13.3%); and CBR (56, 41, 20, 25%), respectively.

The study has shown that lateritic soil samples obtained from the four sites required stabilization based on geotechnical properties, hence the stability of the laterite soil samples were enhanced with hydrated lime, cement and bitumen.

Keywords: Stabilization, lime, cement, bitumen and laterite

INTRODUCTION

The long term performance of any construction project depends on the stability of the underlying lateritic soils. Lateritic soils have been extensively used in roadways and embankment due to its excellent improvement after compaction. Engineers are often faced with the problem of constructing road bed on or with soils which do not possess sufficient strength to support wheel load imposed upon them either in construction or during the service life of the pavement. It is at time necessary to treat these soils to provide a stable sub grade or a working platform for the construction of the pavement. These treatments are generally classified into two processes; soil modification or soil stabilization.

The purpose of sub grade modification is to create a working platform for construction equipment. This modification in the pavement has no role in the design process; it only reduces the plasticity of unbound base and sub base materials. While the purpose of sub grade stabilization is to enhance the strength of the sub grade and this increased in strength is taken into account in the pavement design process.

Pavement designers have always been searching for technical and economical solutions for roadway application. Soil stabilization technique which is normally used for the improvement of local soils is considered economical. The properties of a lateritic soil may be improved by additions of binders; usually cement hydrated lime or bitumen.

Portland cement is produced by heating to high temperature a mixture of calcareous materials (such as limestone) [$CaCO_3$] and materials containing silicates and Aluminates (such as clay and shale) [SiO_3 and $A1_2$

O_3]. If water is added to Portland cement it forms hydrated calcium silicates and Aluminates which in time form a hard matrix in which the particles with which the cement has been mixed are embedded.

Most soil materials with the exception of organic soils and soils containing sulphates can be stabilized with cement. It is however difficult to mix cement intimately with clayey materials. Thus clayey materials and high plasticity soils are usually best treated with lime. It is desirable therefore, that materials to be stabilized with cement have plasticity index (PI) of less than 20 percent, and coefficient of uniformity of at least 5.

Hydrated lime reacts with clay materials surface in the high pH environment promoted by the lime water system. In the high pH environment, the surface mineralogy is altered as it reacts with the calcium ions (Ca^{++}) to form cementitious holding capacity (drying), swell reduction, improved stability and ability to construct a solid working platform (Little, 1999).

Stability occurs when the proper amount of lime is added to the reactive soils. This is different from modification because a signification level of long term strength gain is developed through a long term pozzolanic reaction, which is the formation of calcium silicates and calcium Aluminate hydrates as the calcium from the lime react with the silicates and Aluminates solubilized from the clay mineral surfaces.

Lime has many different manufacturing and environmental application, It's largest construction related use is for stabilization of foundation soils, material that underlie highway and airfield pavements, building structures, drainage canals and earth dams.

In 2003, more than 1.6million metric tonnes of lime were used for soil stabilization in U.S.A (Miller 2004). Beneficial effect of compacted soil lime and soil cement mixtures on geotechnical properties has been discussed in previous studies (Osinubi &Nwaiwu, 2006), (Felt & Abrams, 2004), while bitumen has being in use by man over 5000 years ago as water-proofing and bonding agent. The use of bitumen on roads in recent times picked up in the nineteenth century. Natural rock asphalt was usually used, but a petroleum distillation began to grow as an industry to fuel vehicles, the residue found equally increasing use in constructing better roads.

Bituminous stabilization is generally done with bitumen as binder. Bitumen are normally too viscous to be used directly, these are used as cut-back with some solvent, such as gasoline. These are also used as emulsions, but in this form they require a longer drying period. Any inorganic soil which can be mixed with bitumen is suitable for bituminous stabilization.

Lime is produced by burning of lime stone in kilns and the quality of lime obtained depends upon the parent material and the production process. Five majors types of lime are identified, namely; high calcium quick lime (CaO), hydrated lime [$Ca(OH)_2$], dolomitic lime (CaO + MgO), normal hydrated Dolomitic lime [$Ca(OH)_2$ + MgO] and pressure, hydrated Dolomitic lime [$Ca(OH)_2$ + MgO_2]

The term lime is used in this study to mean quick lime (calcium Oxide, CaO) and hydrated lime [calcium hydroxide, $Ca(OH)_2$], which according to (Bell, 1993) are commonly used for soil stabilization.

Cement is a material normally used for uniting or bonding other materials. It is initially plastic but hardens progressively over a period of time. The most important type of cement is Portland cement; so called because it produces a concrete that resembles the natural lime stone found at Portland in Dorset.

MATERIALS AND METHODS

Materials Sourcing

Laterite-Lateritic soil samples used were collected randomly from four (4) different borrow pits namely Odookun-Igbeti (OI), Gbemi-Igbeti (GI), Isafa-Kisi (IS), Yoyin-Kisi (YK) along Ogbomoso-Igbeti-Kisi Road Oyo State, Nigeria at the depth of two (2) metres. It was collected in bags and quickly transferred to the laboratory in accordance with B.S 5930

Hydrated Lime {Ca $(OH)_2$}-The hydrated lime {Ca $(OH)_2$} used was purchased from a Local market.

Cement-Some quantity of Portland cement was procured from a store and was quickly transferred to the laboratory.

Material Preparation

The specimen of soil samples used for the different Laboratory test were prepared by treating laterite with hydrated lime, cement and bitumen in proportions of 0, 2, 4 and 8% by dry weight of laterite. Specimen with 0% of these stabilizers served as the control.

Classification Test

This process was used to ascertain the soil potential for reactivity with either lime or cement. Grading was done to determine the suitability of the soil sample for lime stabilization or cement stabilization, or bitumen stabilization. If the soil has at least 25% passing the 0.075mm sieve size and has a plasticity index (PI) of a least

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10, then the soil is suitable for lime stabilization. Otherwise, cement stabilization is preferable. To classify the soil, grain size analysis was done by weighing some quantity of the soil sample and passed it through a series of sieves with the mesh size reducing progressively. This was done by shaking the sieves using a manual sieves shaker. Different sieve sizes was used, with the finest size been 75micron (0.075mm) sieve. The weight of the soil retained on each sieve was measured. After the particle size distribution process four (4) different grain size ranges were extracted from the sample corresponding to the quantities retained between sieve openings (in mm) of 0.075-0.150, 0.150-0.212, 0.212-0.425 and 0.425-2.360; this was prepared in cube mould and subsequently tested to determine the strength characteristics under different temperatures. Materials passing sieve No 8 (aperture 2.360mm) but retained on sieve No 70 (aperture 0.212mm) was collected for subsequent use as fine aggregate. This was tested for strength characteristics and water absorption capacity under different temperatures.

Compaction Test

This test was performed to determine Maximum Dry Density (MDD) Optimum and corresponding Moisture Contents (OMC) in accordance with BS 1377 procedure and liquid limit (LL) and plastic limit (PL) were determined along with.

Determination of Appropriate lime Demand

BS 1377 provides the procedure which is known as Eades and Grim pH test. In this test the lowest percentage of lime in the soil sample that produces a laboratory pH 12.40 (pH for saturated lime water) is the minimum lime percentage required to stabilize the soil.

The dry soil sample was serene through No 40 sieve and divided into ten (10) parts. These were mixed with 0%, 2%, 4%, 6%, 8%, 10%, 12%, and 14%, hydrated lime by weight of the dry soil sample in accordance with BS 1377, care was taken to avoid a temperature of above 25°C, as pH of lime-soil-water mixture is temperature dependent. The soil samples were then poured in plastic containers each contains about three (3) parts of water of the lime-soil volume and mixed thoroughly.

Determination of Appropriate Cement Content

Cement content necessary for effective stabilization varies with the type of soil. The strength of soil-cement mix for a particular soil type varies with the cement content expressed as a percentage by weight of the dry soil between 2 and 10 was adopted. For preliminary estimation purposes a value of 10 percent seems reasonable. The criterion in the past was a 7day unconfined compressive strength of 1.7.MN/m^2 with moist-cured cylindrical specimens having a height to diameter ratio of 2:1. Recent practice is to adopt strength of 2.8MN/m^2. Table 1 gives the range of cement requirements as per American practice.

Determination of Appropriate Bitumen Content

The amount of bitumen required for stabilization generally varies between 4 to 7% by weight. The actual amount is determined by trial. From the table, the quantity of cement needed for stabilization of gravelly soil is lesser than that required for stabilization of silty or clayey soils. It is observed that for the range of cement contents normally employed in stabilization work, the strength of the mixture increases with increase in cement content.

California Bearing Ratio Test

After 24hours soaking, the sample was brought out and left for 15 minutes at room temperature before it was subject to the CBR test.

Unconfined Compressive Strength Test

The Unconfined compressive strength of concrete is the most common measure for judging the quality of layer, the characteristics strength of laterite-cement and laterite-lime layer was based on the 28 days cube strength i.e. the crushing strength of standard 100mm cubes at an age 28days after mixing. The characteristics strength of the concrete cubes were determined.

Water Absorption Capacity Test

Water absorption capacity was determined by measuring the decrease in mass of a saturated sample after oven drying to a constant mass. The ratio of the decrease in mass of the mass of the dry sample, expressed as a percentage was termed water absorption capacity.

$$Wa = (Ws - Wd)/Wd \times 100 \qquad equ1$$

Where:

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Wa = Percentage moisture absorption
Wd = Weight of dry sample
Ws = Weight of soaked sample.

RESULTS AND DISCUSSION

Index Properties of Natural Lateritic Soil

The index properties of the soil samples collected from the four borrow pits were presented in Table1. The Liquid limit, plastic limit and plasticity index values for the natural soil samples are 33, 22 and 11% for sample from OI, 33, 17 and 16% for sample from GI, 39, 23 and 16% for sample from IS and 34, 14 and 20% for sample from YK respectively. According Whitlow (1995), liquid limit less than 35% indicates low plasticity, between 35 and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and greater than 90% extremely high plasticity. This shows that soil samples from OI, GI and YK has low plasticity while the sample from IS had intermediate plasticity.

The corresponding classification of the soil is in accordance with American Association for state Highway and Transportation Officers (AASHTO) (1986). Soil samples from OI and GI are classified as A-2-6 whiles the soil samples from IS and YK are classified as CL according to the Unified Soil Classification System (USCS) (ASTM, 1992).

The maximum dry density (MDD) and the optimum moisture content (OMC) for the natural soil samples are 1.79, 1.90, 1.72 ,1.81 g/cm^3 and 15.0, 15.5, 18.9 and 13.3 for sample from OI,GI, IS and YK respectively.

Particle size distribution of soil samples

The results particle size distribution for soil samples from OI, GI, IS and YK were presented in Figure 1, 2, 3 and 4 respectively. The particles size analysis of four samples used for the stabilization process, sample at OI contained 35% of silty clay, 19% sand and 46% gravel (from to medium gravel present), sample from GI contained 34% clayed silty, 17% sand and 49% clayed silty, 26% sand and 33% fine to medium gravel, sample from IS contained 41% clayed silty, 26% sand and 33% fine to medium gravel and sample from YK contained 41% clayed silty, 14% sand and 55% from to medium gravel. It could be observed from Figure 1 that the percentage passing No. 200 BS sieve is 34.14, 33.78, 41.10 and 41.04% for OI, GI, IS and YK respectively. This results indicate that soil samples from OI and GI satisfied the limit of 35% or less for road according to Road and Bridges specification Revised Edition of Federal Ministry of Works Nigeria (1997) while soil samples from IS and YK failed to satisfied this requirements.

Specific Gravity

The average specific gravity of the soil samples from the different locations were presented in Figure 5. The average specific gravity were 2.28, 2.41, 2.22 and 2.47 respectively for the soil samples from OI, GI, IS and YK. This specific gravity values are in agreement with the findings of Bello *et al*. (2014).

Natural Moisture Content

The natural moisture content results for all locations were presented in Figure 6. The summary results for the moisture contents for each location were determined. The values obtained for the natural moisture content were 5.05, 4.00, 3.74 and 4.12 respectively % for the soil samples from OI, GI, IS and YK. These values were lower than the value obtained by Amu *et al.*, (2005). Figure 6 shows that soil sample from OI had the highest specific gravity followed by samples from YK and GI and sample from IS had the lowest moisture content value. The low moisture content obtained for soil sample from IS was justified by the result obtained for the specific gravity of the same soil sample and this was due to the presence of some heavy minerals in the soil sample. General observation of the soil showed that the soil is prone to change in moisture content and could become a little soft or slippery during wet season though hard and gritty during dry season.

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Table 1 Index Properties of Natural Lateritic Soil

Properties	Quantities			
	OI	GI	IS	YK
Liquid limit (%)	33	33	39	34
Plastic limit (%)	22	17	23	14
Plasticity index (%)	11	16	16	20
Percentage passing BS No. 200 sieve (%)	35.14	33.78	41.10	41.04
Group index	0	1	3	4
AASHTO classification	A-2-6	A-2-6	A-6	A-6
USCS classification	CL	CL	CL	CL
Maximum dry density (g/cm^{-3}) at BSL compaction	1.79	1.90	1.72	1.81
Optimum moisture content (%) at BSL compaction	15.0	15.5	18.9	13.3
C.B.R (%) (unsoaked)	18	11	4	17
Specific gravity	2.28	2.41	2.22	2.47
Natural moisture content (%)	5.05	4.00	3.74	4.12

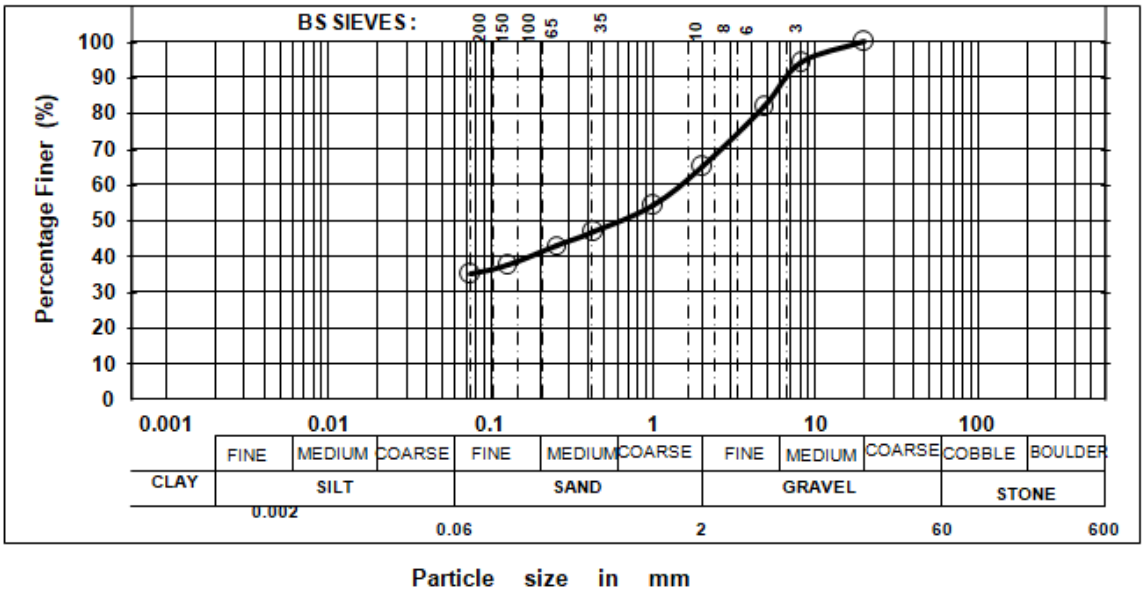

Figure 1 Particle size distribution curve of soil samples from OI

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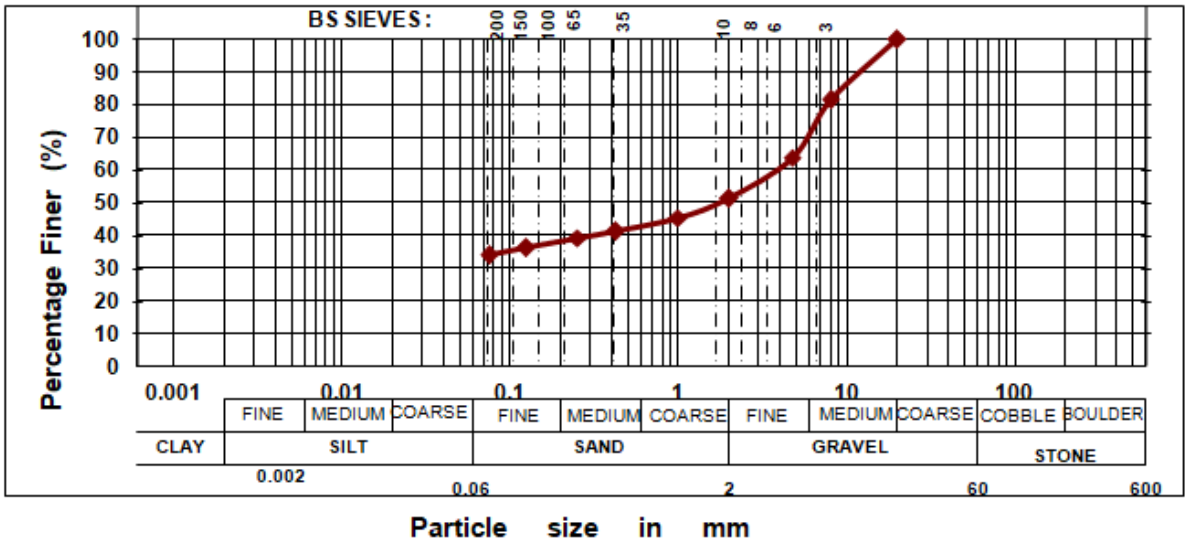

Figure 2 Particle size distribution curve of soil samples from GI

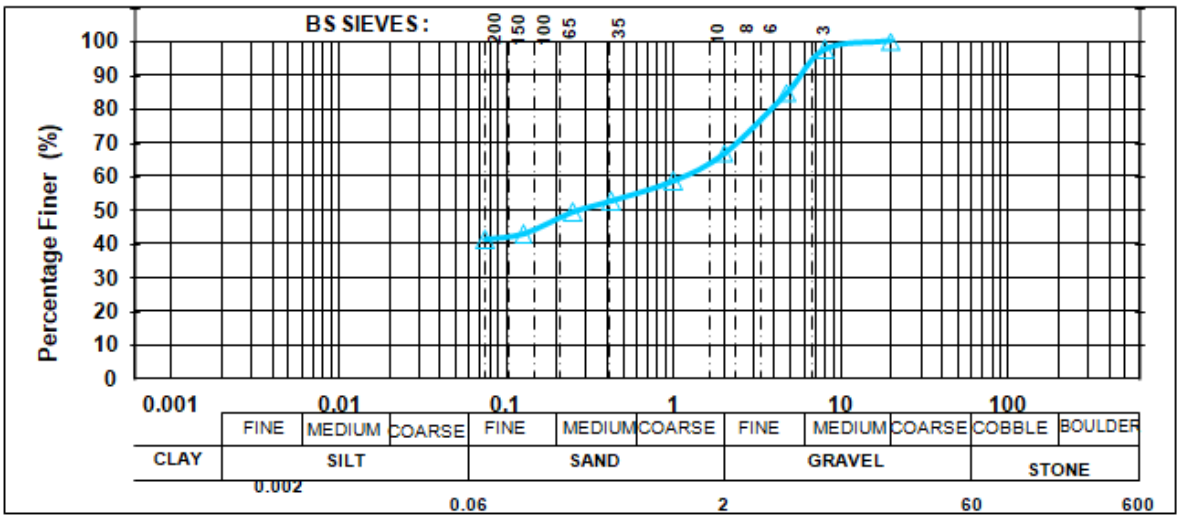

Figure 3 Particle size distribution curve of soil samples from IS

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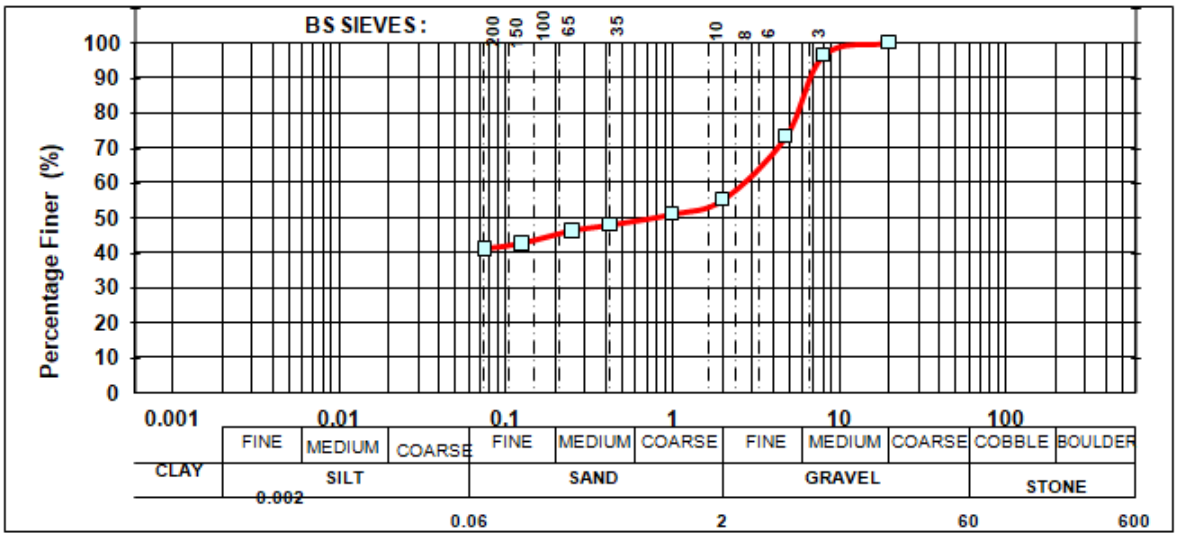

Figure 4 Particle size distribution curve of soil samples from YK

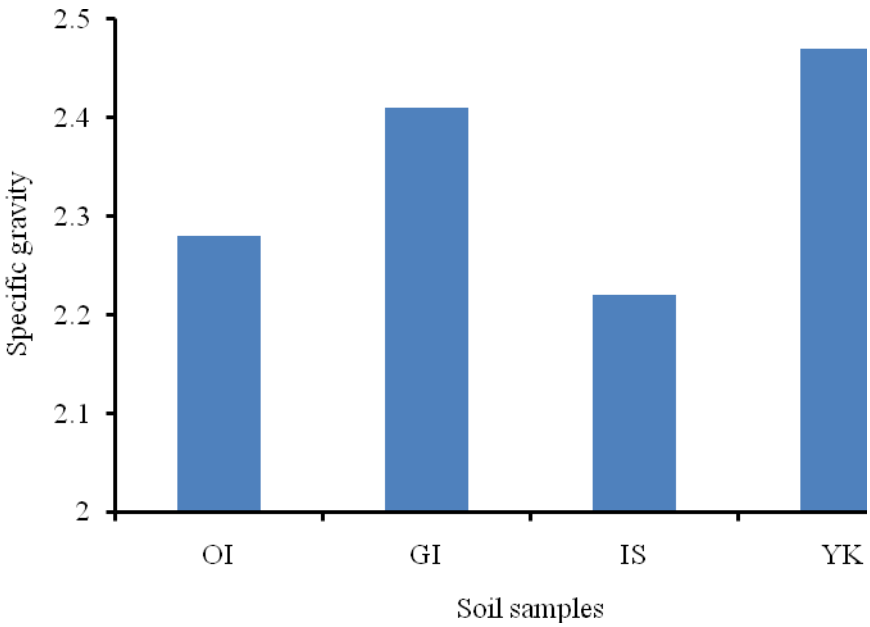

Figure 5 Variation of specific gravity with soil samples from different locations

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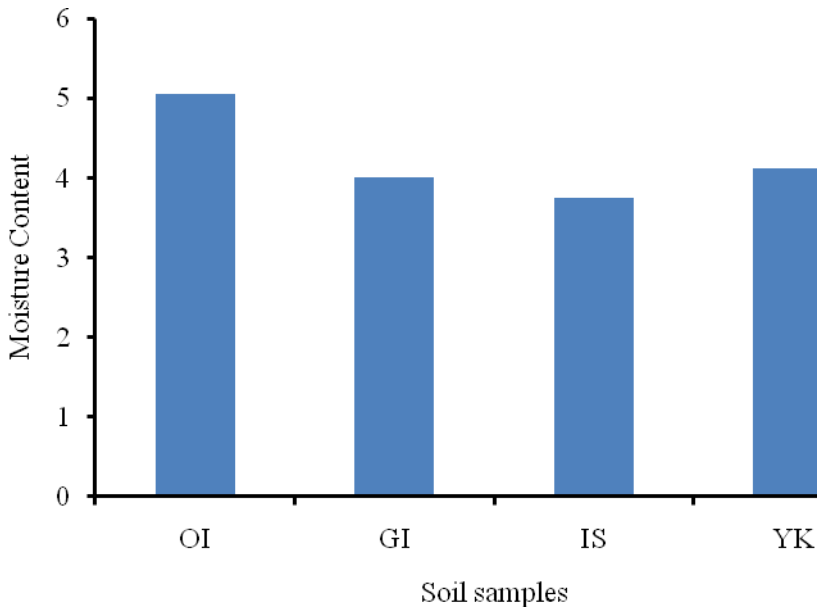


Figure 6 Variation of natural moisture with soil samples from different locations

Atterberg's Limit Test Result

From Figures 7-10 the addition of 2 to 8% of lime shows a decrease in the values plasticity index of the samples from OI. For the stabilized soil sample from GI the plasticity index decreases with the percentage increase of lime except for 6 and 8% lime content where there is a fall in the plasticity index value. Similar trend was observed for the stabilized soil sample from IS except that the PI value falls for 4 and 8% lime contents. Reverse was the case of the stabilized soil sample from YK where the plasticity index first decreased from with the addition of 2% lime content before it increases with the percentage increase in lime contents from 2 and 8%.

The results of liquid, plastic and plasticity index of lime stabilized lateritic soil samples ranges from 19 to 26% and 11 and 16% sample from OI, 33 to 43%, 17 to 27% and 11 to 16% for GI, 39 to 43%, 23 to 28% and 14 and 18% sample from IS and 34 to 42%, 14 to 27% and 13 and 20% sample from YK respectively.

The addition of 2% cement contents shows a decrease in the values plasticity index of the natural soil samples from OI while further addition of 4% cement contents show an increase in the PI value before it decreases further additions of cement.

The results of liquid, plastic and plasticity index of the bitumen stabilized lateritic soil samples ranges from 19 to 26% and 11 and 16% sample from OI, 33 to 43%, 17 to 27% and 11 to 16% for GI, 39 to 43%, 23 to 28% and 14 and 18% sample from IS and 34 to 42%, 14 to 27% and 13 and 20% sample from YK respectively. The addition of bitumen to soil sample from OI shows a decrease in the values of PI except for 4 and % bitumen content where there is a rise in the PI value.

Similar trend of PI values was observed for the soil samples from GI and IS. Reverse was the case of the stabilized soil sample from YK where the plasticity index first decreased from with the addition of 2 to 4% lime content before it increases with the percentage increase in lime contents from 6 and 8%.

Compaction Characteristics of the Soil

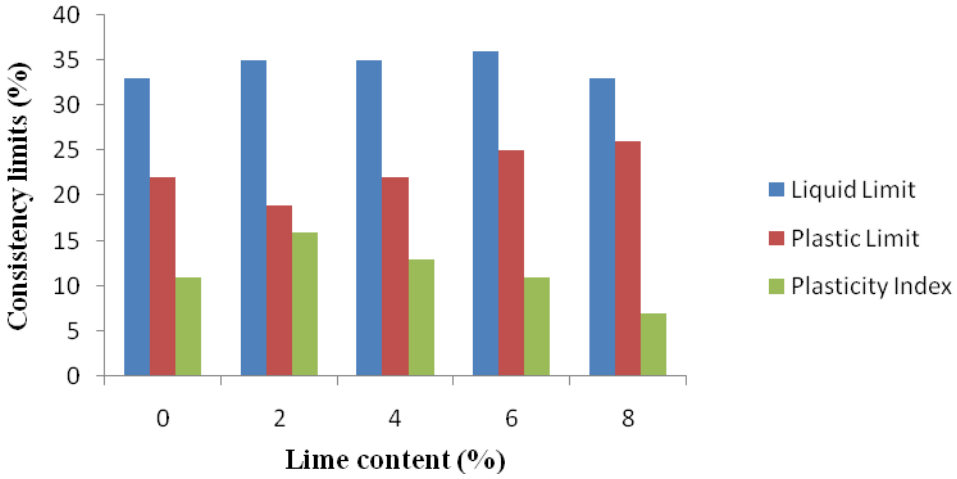
The results for maximum dry density (MDD) and optimum moisture content (OMC) of soil samples from each location stabilized with lime, cement and bitumen were presented in Figures 11-14. It was observed that MDD and OMC are 1.79, 1.90, 1.72, 1.81g/cm^3 and 15, 15.5, 18.9, 13.3% respectively for the unstabilized lateritic soil samples from OI, GI, IS and YK. The addition of lime in 2, 4, 6 and 8% by weight soil samples from OI, GI, IS and YK generally increased MDD and decreased OMC of the soil samples. The MDD increased from 1.79 to 1.95g/cm^3, 1.90 to 1.95g/cm^3, 1.72 to 1.84g/cm^3 and 1.81 to 1.92g/cm^3 respectively for the lime

stabilized lateritic soil samples from OI, GI, IS and YK. The OMC decreased from 15 to 11.4%, 15.5 to 11.0%, 18.9 to 11.5%, 13.3 to 9.0% respectively for the lime stabilized lateritic soil samples from OI, GI, IS and YK.

California Bearing Ratio (CBR)

The result of the California Bearing Ratio (unsoaked) test for soil samples from each location stabilized with lime, cement and bitumen were is summarized in Figure 7 to 9 respectively. The value for the CBR shown in Figure 7 to10 are 18, 11, 4 and 17% respectively for the unstabilized lateritic soil samples from OI, GI, IS and YK. The addition of lime in 2, 4, 6 and 8% by weight soil samples from OI, GI, IS and YK generally increased CBR values of the soil samples. The CBR increased from 18 to 48%, 11 to 43%, 4 to 17%, 17 to 30% respectively for the lime stabilized lateritic soil samples from OI, GI, IS and YK. It could be shown from Figure 4.7 that the optimum CBR values was obtained corresponding to 4, 6, 8 and 8% lime content for lateritic soil samples from OI, GI, IS and YK. This gives indication that lime can be effectively used to improve the CBR of soil.

The addition of cement in 2, 4, 6 and 8% by weight of soil samples from OI, GI, IS and YK as shown in Figure 8 followed similar with the addition of lime. The CBR increased from 18 to 45%, 11 to 39%, 4 to 29%, 17 to 31% respectively for the cement stabilized lateritic soil



Variation of consistency limits of soil sample from OI with different percentage of lime

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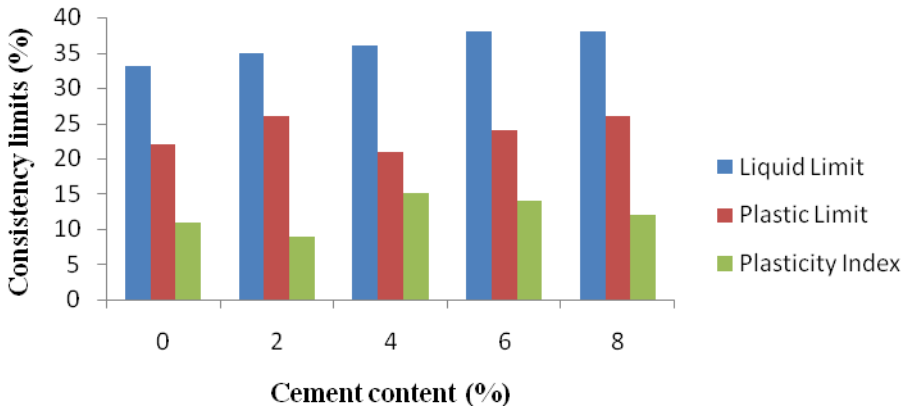
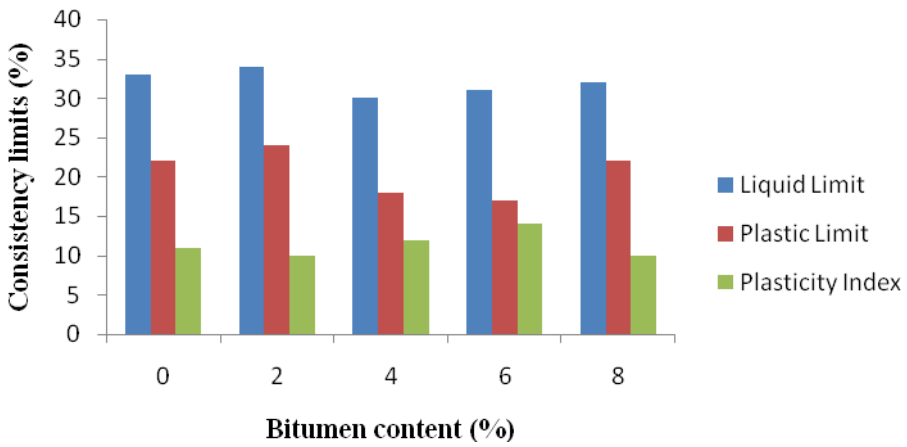


Variation of consistency limits of soil sample from OI with different percentage of cement



Variation of consistency limit of soil sample from OI with different percentage of bitumen
Figure 7 Variation of consistency limit of soil samples from OI with different percentage of lime, cement and bitumen

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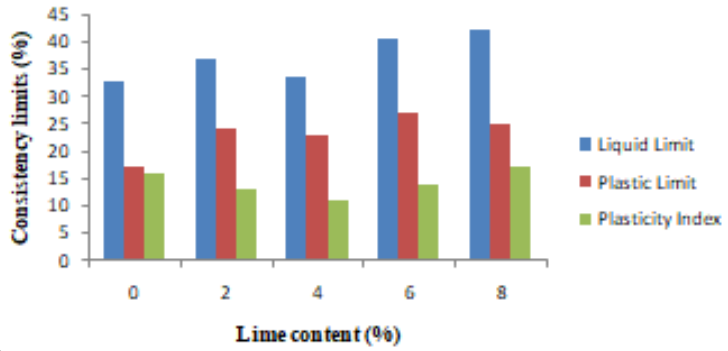
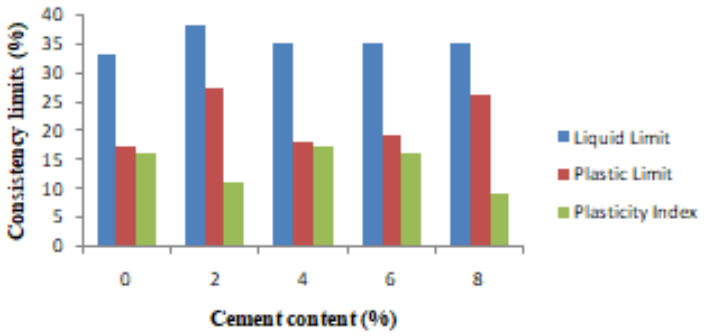
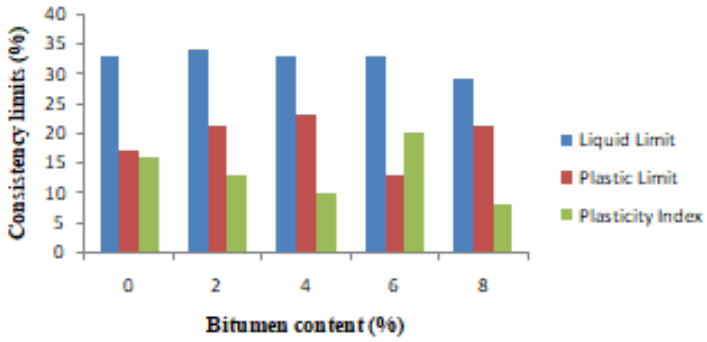


Variation of consistency limits of soil sample from GI with different percentage of lime



Variation of consistency limits of soil sample from GI with different percentage of cement



Variation of consistency limit of soil sample from GI with different percentage of bitumen

Figure 8 Variation of consistency limit of soil samples from GI with different percentage of lime, cement and bitumen

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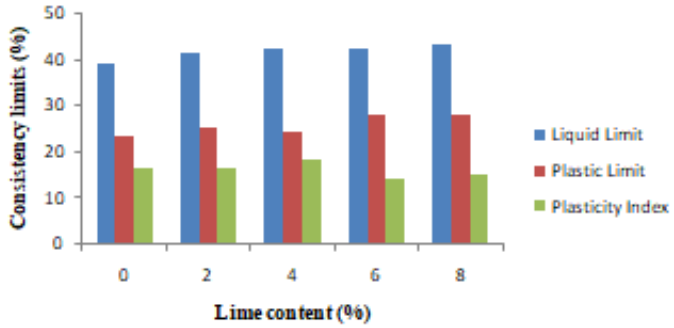

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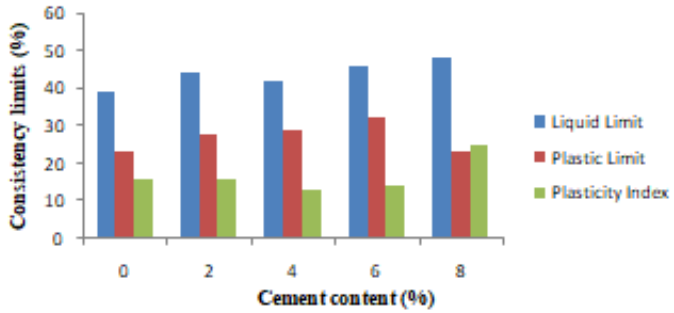
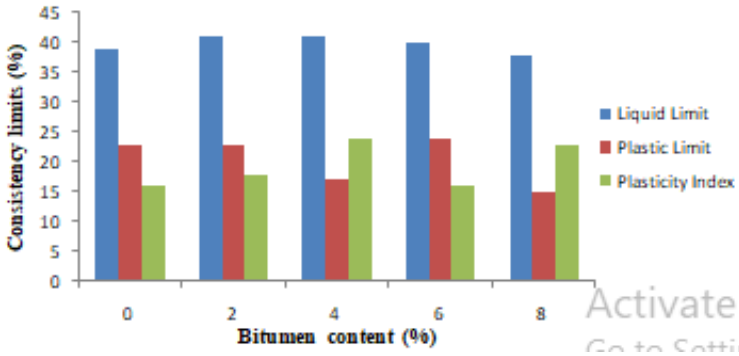


riation of consistency limits of soil sample from IS with different percentage of cement



Variation of consistency limit of soil sample from IS with different percentage of bitumen
Figure 9 Variation of consistency limit of soil samples from IS with different percentage of lime, cement and bitumen

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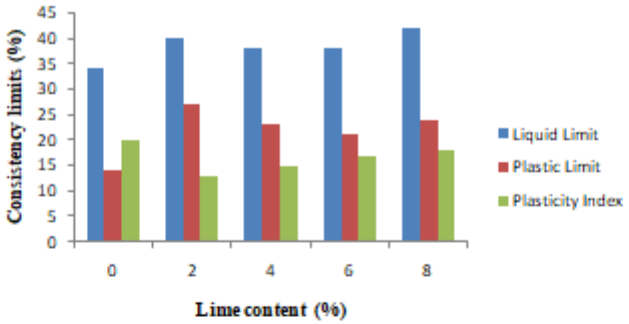
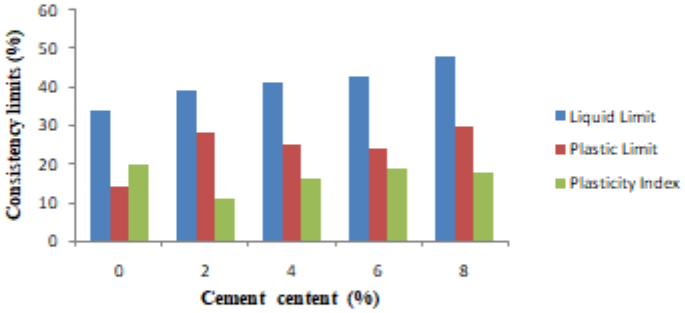
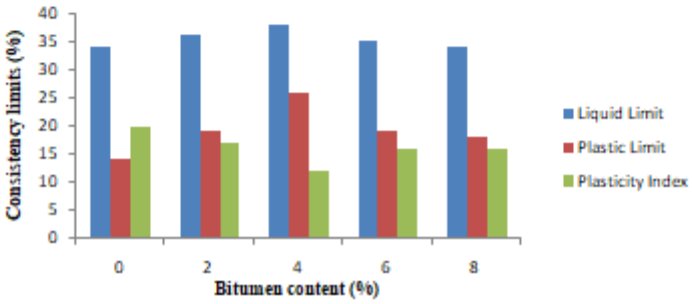


Variation of consistency limits of soil sample from YK with different percentage of lime



Variation of consistency limits of soil sample from YK with different percentage of cement



Variation of consistency limit of soil sample from YK with different percentage of bitumen

Figure 10 Variation of consistency limit of soil samples from YK with different percentage of lime, cement and bitumen

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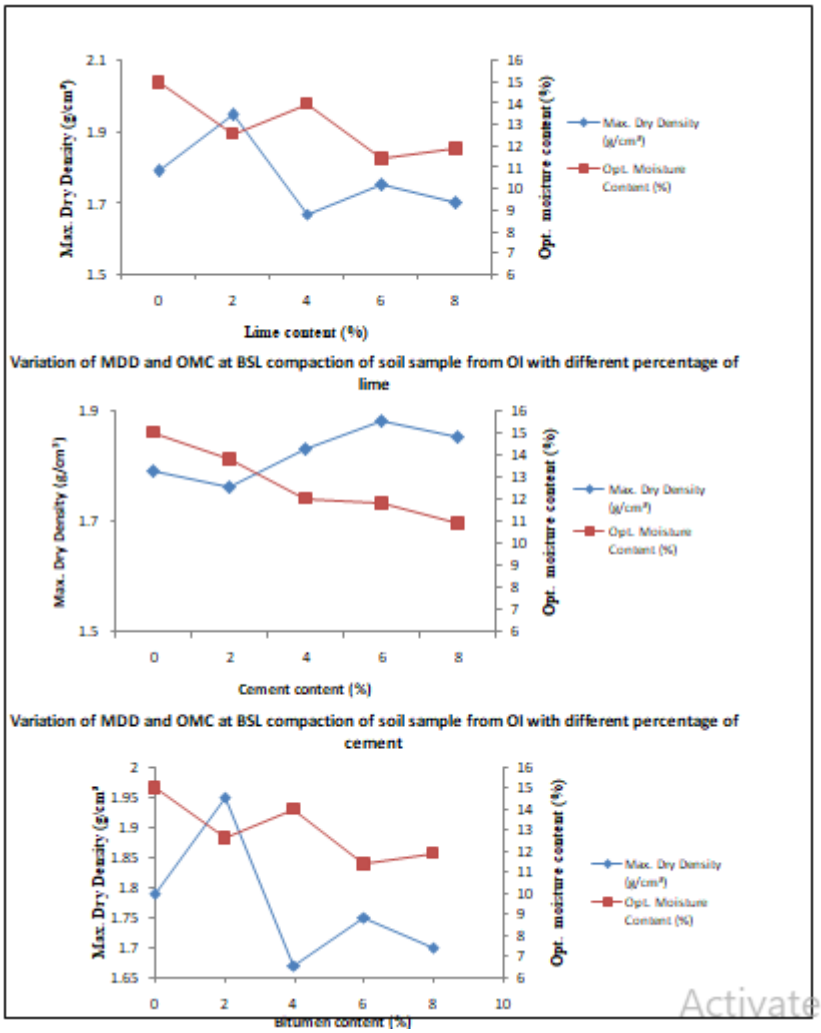

Variation of MDD and OMC at BSL compaction of soil sample from OI with different percentage of bitumen
Figure 11 Variation of MDD and OMC at BSL compaction of soil samples from OI with different percentage of lime, cement and bitumen

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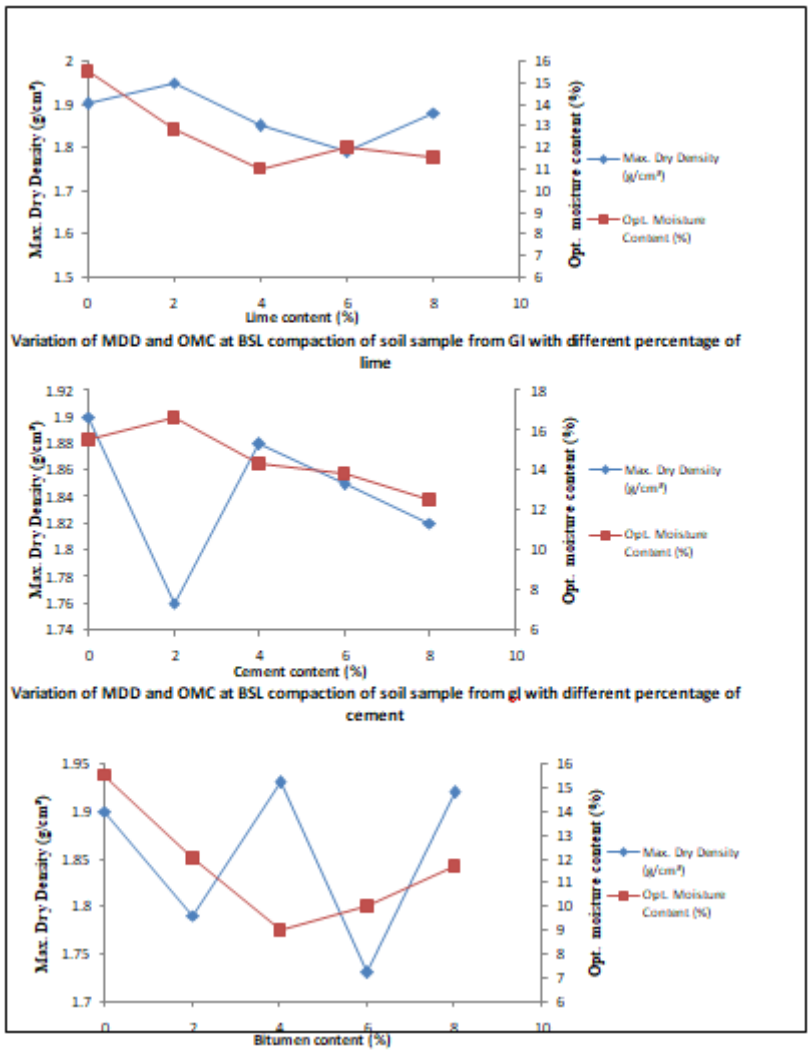

Variation of MDD and OMC at BSL compaction of soil sample from GI with different percentage of bitumen

Figure 12 Variation of MDD and OMC at BSL compaction of soil samples from GI with different percentage of lime, cement and bitumen

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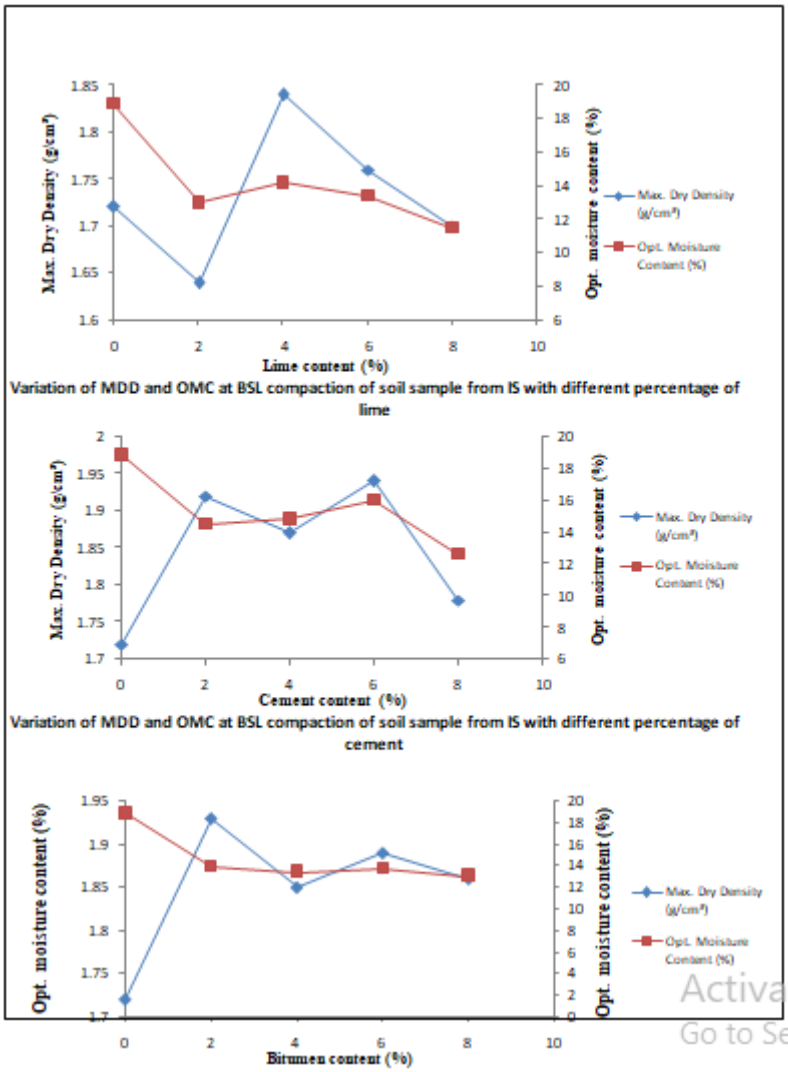

Variation of MDD and OMC at BSL compaction of soil sample from IS with different percentage of bitumen

Figure 13 Variation of MDD and OMC at BSL compaction of soil samples from IS with different percentage of lime, cement and bitumen

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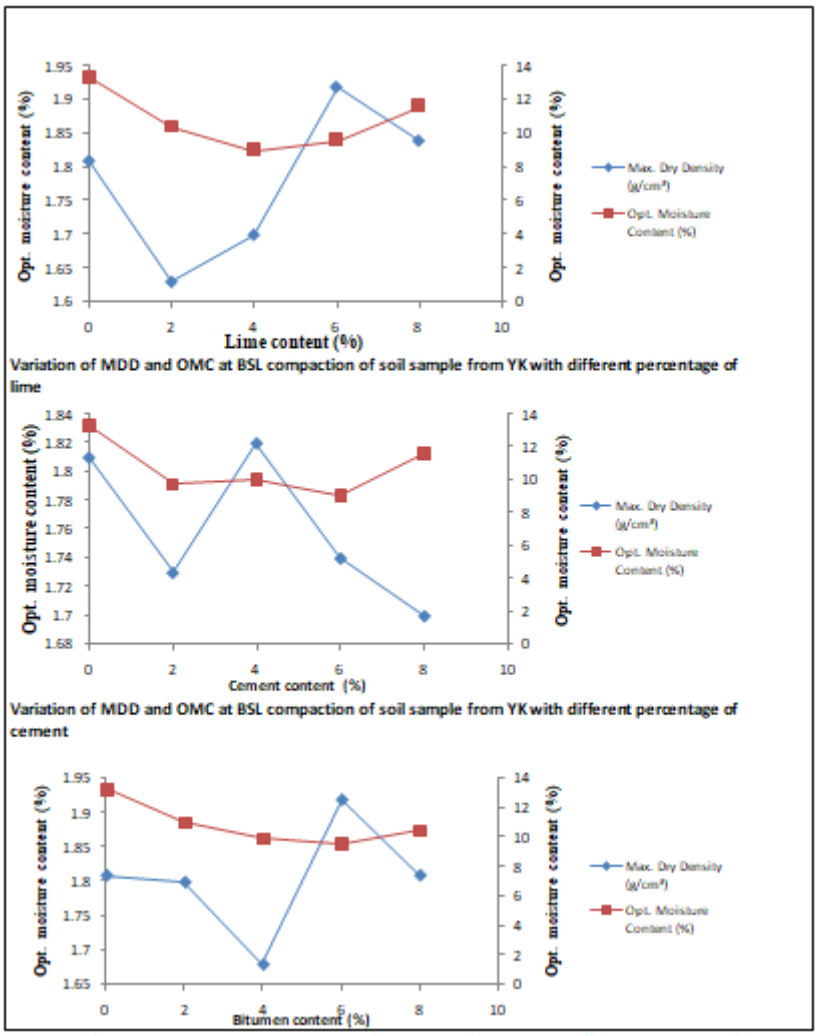

Variation of MDD and OMC at BSL compaction of soil sample from YK with different percentage of bitumen

Figure 14 Variation of MDD and OMC at BSL compaction of soil samples from YK with different percentage of lime, cement and bitumen

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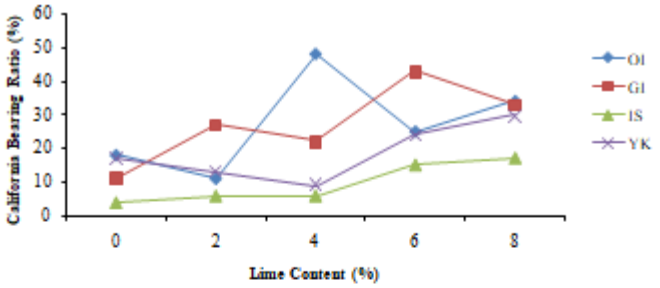

Figure 15 Variation of Unsoaked CBR of soil samples from with the application of Lime

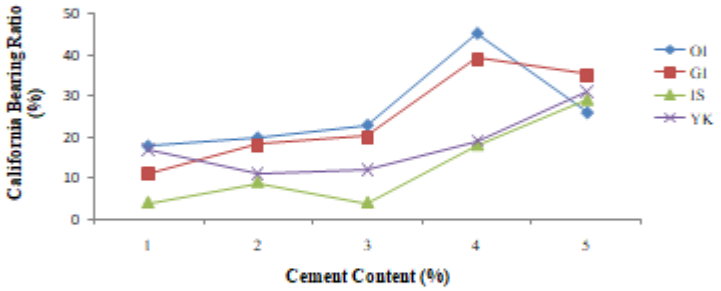

Figure 16 Variation of Unsoaked CBR of soil samples from with the application of cement

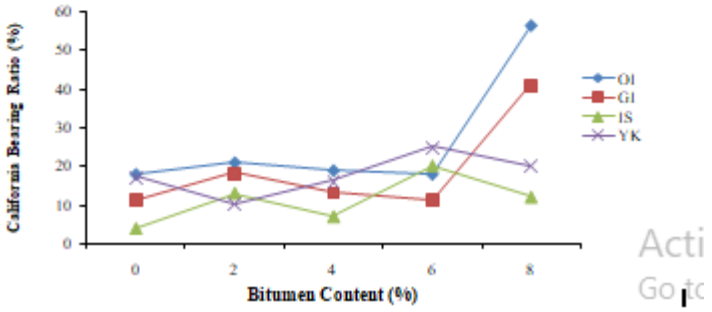

Figure 17 Variation of Unsoaked CBR of soil samples from with the application of bitumen

Samples from OI, GI, IS and YK. It could be observed from Figure 15-17 that the optimum CBR values was obtained corresponding to 6, 6, 8 and 8% cement content for lateritic soil samples from OI, GI, IS and YK. This gives indication that cement can be effectively used to improve the CBR of soil.

The CBR increased from 18 to 56%, 11 to 41%, 4 to 20%, 17 to 25% respectively for the lime stabilized lateritic soil samples from OI, GI, IS and YK. It could be observed from Figure 15-17 that the optimum CBR values was obtained corresponding to 8, 8, 6 and 6% bitumen content for lateritic soil samples from OI, GI, IS and YK. This gives indication that bitumen can be effectively used to improve the CBR of soil

This results indicate that the use of lime for the treatment lateritic soil from OI, GI, IS and YK was more effective than the use of cement which is in turn more effective than the use of bitumen since the optimum CBR values were achieved with low content of lime when compared with the content of cement and bitumen at which the optimum values of the CBR was achieved for the different soil samples.

CONCLUSION

Based on the results from the findings, the following conclusions were made:

[1] The properties of the natural soil shows that soil samples from OI and GI are suitable while soil samples from IS and YK are unsuitable for use as sub-grade and fill materials.

[2] The preliminary investigation shows that the soil samples from the 4 borrow pit considered are reddish brown in colour and classified as CL based on the Unified Soil Classification System (USCS).

However, soil samples from OI and GI are classified as A-2-6 while soil sample from IS and YK are classified as A-6 according to American Association for State Highway and Transportation Officers (AASHTO) (1986).

[3] There is increase in liquid limit, plastic limit and plasticity index values as the percentage of lime, cement and bitumen increases for the soil samples from the four (4) borrow pits considered. The use of lime is more effective in the reduction of plasticity index as more cement and bitumen content will be required to reduce the plasticity index value of soil samples from OI and GI compared to the content of lime used to achieve the same purpose.

[4] The maximum dry density increases as the optimum moisture content decreases as the lime, cement and bitumen contents increases. These results indicated that the use of cement in the treatment of lateritic soil is more effective in increasing the maximum dry density and decreasing the optimum moisture content when compared with the use of lime and bitumen.

[5] The use of lime has a greater influence on the CBR of the soil sample from OI compared to the use of cement and bitumen for the soil treatment as only 4% lime content was used to achieve maximum CBR value while 6 and 8% of cement and bitumen were used to attain the optimum CBR value for the same soil sample. Similar trends was observed when considering soil sample from GI, IS and YK.

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