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Research Paper

Effects of Glass Fines on the Geotechnical Properties of Lime-Stabilized Lateritic Soil

**[1]J.A. Ige, [2] A. B. Olayanju, [3] O.A. Ibikunle and [4]T.G. Fawole
[1]*Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso-Nigeria*
[2,3,4]*Department of Civil Engineering, Adeseun Ogundoyin Polytechnic, Eruwa -Nigeria*

ABSTRACT
Engineering properties of soil plays a significant role in Civil Engineering construction works particularly in road construction, foundations, embankments, slope stability, subgrade materials and dams, hence the need for stabilization of poor soil to fit for the purpose intended. The aim of this work is to study the effect of the addition of lime and powdered glass on the Geotechnical properties of poor lateritic soil.
In achieving this, laterite was collected from a construction site in Under G area Ogbomoso, Nigeria. The soil sample was air dried and pulverized. Glass fines up to 6% at intervals of 2% by mass of the soil sample were added to the lateritic soil stablilized with lime at 0, 2, 4 and 6% replacement by mass of the soil sample. Sieve analysis, Atterberg limit, British Standard (BS) Compaction, California Bearing ratio (CBR) and Unconfined Compressive Strength (UCS) tests were conducted on the stabilized soil specimens.
The result of the natural soil sample revealed that the percentage passing sieve No. 200 was 52%. The liquid limit, plastic limit and plasticity index are 48.5%, 25.1% and 23.4% respectively. The maximum dry density increased with the addition of glass fines from 0% to 4% and decreased beyond starting from 4% addition of lime content. 6% lime and 4% gave the optimum value of MDD for the stabilized soil. The CBR of the soil increased continuously from 0 to 6% glass contents. The UCS analysis shows an increment from 325kN/m^2 to 461kN/m^2. Addition of lime decreased the LL and PI while it increased the PL considerably
Hence it can be deduce that the stabilized soil can be used for the purpose of filling and subgrade material in Civil engineering construction

KEY WORDS:* *Glass fines, lime, soil

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I. INTRODUCTION

Engineering properties of soil plays a significant role in civil Engineering construction works particularly in road constructions, foundations, embankments, slope stability, subgrade materials and dams (Omotoso and Ojo 2012). In recent times the alarming rate at which lives are being lost due to collapsed buildings and road failures calls for a solution. The long term performance of any construction project depends on the engineering competence of the underlying soils. This made it imperative to critically and deliberately carry out geotechnical test of the engineering soil. This would determine its geotechnical stability as a construction material.

However, there is a need to improve the geotechnical properties of the soil to fit the purpose intended. One of the ways to do that is stabilizing the soil which is the alteration of soils to enhance their physical properties. It could increase the shear strength of a soil, control its shrink-swell properties, improve its load bearing capacity, durability under adverse moisture, high permeability, poor workability, dust nuisance, withstand both static and dynamic stresses, increase resistance to erosion, weathering and reduce undesirable properties such as swelling, shrinkage, high plasticity characteristics and difficulty in compaction. Stabilization of soils can also aid in dust control on roads and highways particularly unpaved roads, in water erosion control and in fixation and leaching control of waste and recycled materials. Soil stabilization deals with physical, physio-chemical methods to make the stabilized soil serve its purpose as construction material through the use of controlled compaction, proportioning and addition of suitable admixture. The basic principle of soil stabilization are evaluation of the properties of the soil, then deciding the method of supplementing the lacking property by the effective and economical method of stabilization and designing the stabilized soil mix for desired stability values which would be considered for construction. When selecting a stabilizing agent, the types of soil, purpose for which the stabilized layer will be used, the desired quality of the stabilized soil, required strength and durability of the stabilized layer, cost and environmental conditions are some key factors to consider.

Laterite is a soil and rock type rich in iron and aluminum and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty red coloration because of high iron oxide content. They are developed by intensive and prolonged weathering of the underlying parent rock. Laterite soil in its natural state generally have low bearing capacity and low strength due to high content of clay. When lateritic soil contains a large amount of clay materials, its stability and strength cannot be guaranteed under load in presence of moisture. Laterite soil consists of high plastic clay, the plasticity of the soil may result to cracks and damage on roadway pavements, building foundation or any civil Engineering construction projects. It is of a great importance to then stabilize the lateritic soil by altering its properties and making it suitable for construction works.(Nnochiri and Aderinlewo 2016).

Due to various factories and industries, large volumes of waste are produced daily. The disposal of the waste generated from industries has become serious issue as solid waste management is one of the major environmental concerns in the world. The recycling and reuse of the waste has become the best alternatives in solid waste. The reuse of such waste will reduce the environmental impact and is more economical because the energy required to reuse the recyclable material is less than that of virgin material. The utilization of these waste products in construction industry is best option due to large number of construction site all over the world.

According to the World commission on environment and development, Sustainability means meeting the needs of the present without compromising the ability of the future generations to meet their own needs (Afolayah 2017). Also the interest of the construction community in using waste or recycled materials in construction is increasing because of the emphasis placed on sustainable construction. The management of waste is a matter of national and international concern. The volume of waste does not actually constitute the problem but the ability or inability of governments, individuals and waste disposal firm to keep up with the task of managing waste and the environment. There is no doubt that a daily environment affects the standard of living, aesthetics sensibilities, health of people and thus the quality of lives. The corollary is that improper disposal or storage of this waste can constitute hazards to the society through the pollution of air, land and water.

Waste generated from construction, industrial, agricultural as well as commercial activities often include large quantities of broken tiles, asbestos, glasses, food wastes, paper, plastic and other discarded residual items which always constitute disposal problems in the environment. (Oluremi etal 2016). One of the most attractive ways of managing such wastes is to consider the possibility of waste minimization and reuse because the disposal of these wastes has become a great concern to the populace. These materials pose a great threat to the environment as they oftentimes result in pollution of the locality because they are majorly non-biodegradable (Oluremi etal 2016).

Glass is an amorphous material with high silica content ($Si0_2$) thus making it practically pozollanic when particle is less than 75μm. Glass is a unique inert material that could be recycled many times without changing its chemical properties (Abdallah 2011). It has widespread practical, technological and decorative use for example window panes, table wares, optics and optoelectrons. The most familiar and historically the oldest types of manufactured glass are silicate glasses based on the chemical compound silica the primary constituent of sand. Many applications of silicate glasses derive from their optical transparency, giving rise to their primary use as window planes. Glass will transmit, reflect and refract light; these qualities can be enhanced by cutting and polishing to make optical lenses, prisms, fine glassware and optical fibres for high speed transmission by light. Glass, although brittle is extremely durable and many examples of glass fragments exist from early glass making cultures. Because glass can be formed or molded into any shape, it has been traditionally used for vessels like bowls, vases, bottles, jars and drinking glasses.

Glass, one of the major non-biodegradable wastes produced in the world is often being used in building construction industries for various building components as well as in medicinal industries and in food and beverage industries to make millions of packaging bottles. As the usage of glass increases, so also the volume of waste glass generated increases. According to Topcu and Canbaz (2004), United Nations estimated the yearly volume of solid waste disposed to about 200million tons worldwide out of which 7% was made of glass. It was also reported by Ganiron (2014) that glass makes up of 7% (approximately 12million tons) of the total weight of the United States municipal solid waste disposal annually. Out of this, only 20% of this glass is being recycled while the remaining 80% becomes waste that adds to environmental pollution. This inherent problem therefore makes the reuse of the waste glass inevitable. Many highway agencies like New Jersey Department of Transportation and others routinely allow glass to be substituted up to 10% by unit weight for aggregate in asphaltic concrete pavement (Ganiron 2013). Extensive studies have been carried out on the partial replacement of cement, fine and coarse aggregate with waste glass in concrete which result in improvement on properties of concrete. The introduction of waste glass in cement will increase the alkali content in the cement. It also helps in bricks and ceramic manufacture and it preserves raw materials, decreases energy consumption and volume of waste sent to landfill. As useful recycled materials, glass and glass fines are mainly used in fields related to Civil Engineering for example in cement as pozzolana (supplementary cementitious materials) and coarse aggregate. Recently, glass and its powder have been used as a construction material to decrease environmental problems.

Rapid industrial development has increased the rate of depletion of natural resources and increased dump sites. Due to rapid urbanization, the volume of solid waste generation in Nigerian cities has increased and grown beyond what the capacity of the city authorities can handle. This has resulted in a poor solid-waste management system that signifies serious environmental crises in most Nigerian towns and cities (Oladele et al. 2012). As the usage of glass increases so also the volume of waste glass generated increases. This inherent problem therefore makes the reuse of the waste glass inevitable. Glass forms a major component of solid waste in many countries of the world, but only small proportions of this waste are recycled or reused while about 70-80% is being disposed to the landfill and thereby increasing the amount of environmental waste (Abdulwahab and Ajamu 2015).The use of local materials is of paramount importance to sustainable construction because of its availability, cost effectiveness and ability to protect the environment. Waste materials generated during construction and demolition of structures can cause serious problems due to costs associated with disposal and environmental pollution.

II. MATERIALS AND METHODS

2.1 Materials

Glass Fines : Waste broken bottles was collected from a bar shop located at Isale-Ejigbo, Oko, Oyo State Nigeria (Lat. $7^0$56'52''N and Long. 4^o20'20''E). The broken bottle was cleansed to remove the dirt materials and impurities. It was then sundried and crushed into powder and was sieved through 75µm aperture to increase its surface area for better reactivity. It was ensured that the glass fines were kept air tight before and after use to prevent contaminations through moisture and other materials in the atmosphere.

Lateritic Soils : The Lateritic soil that was used throughout the experimental study was a natural reddish brown laterite that was collected as a disturbed sample from a construction site at Under G area Ogbomoso, Oyo state Nigeria (Lat. $8^0$9'54''N and Long. $4^0$16'4''E). The soil sample was pulverized and air-dried.

Lime :The Lime that was used for the study was hydrated lime that was obtained at the market in Ogbomoso, Oyo state. Nigeria.

Water: The water that was used for the testing procedure was taken from the school premises and it was ensured that the water was clean and free from impurities or reactive agent.

2.2 Testing Methods

The lateritic soil sample was mixed with varying percentages of glass fines (0, 2, 4 and 6%) and lime (0, 2, 4 and 6%) by weight of soil sample. Particle size analysis, Atterberg limits, compaction, California bearing ratio and unconfined compressive strength tests were conducted on the stabilized soil specimens in accordance with BS 1377 (1990) in order to investigate the impact of glass fines and lime on the geotechnical properties of the lateritic soil. The tests that were carried out are as follows:

2.2.1 Natural Moisture content

The natural moisture content of the natural sample was determined by crumbled 20g of the soil and placed it loosely in a clean can. The weight of the can was measured to the nearest 0.1g and recorded as M_1. The can and its content was weighed and recorded as M_2 and then placed in the oven to dry for 24 hours. After the drying, the can with its content was removed from the oven and allowed to cool down. The can with its content was weighed and recorded as M_3. The moisture content of the soil sample was determined and expressed as percentage of the dry sample. The moisture content (w) is derived using equation 1 and 2

$$w = \frac{\text{Weight of water}}{\text{Weight of drysoil}} X\ 100\% \quad (1)$$

$$w = \frac{\text{M2}-\text{M3}}{\text{M3}-\text{M3}} X\ 100\% \quad (2)$$

Where:

M_1 = weight of empty can

M_2 = weight of wet soil + can and M_3 = weight of dry soil + can.

2.2.2 Specific Gravity

In determining the specific gravity of the soil sample, 100g of dried of dried soil sample that passed though 425µm opening were used for this test. A density bottle of 1 litre capacity with a rubber cork was cleaned, dried, weighed and recorded as W_1. The cork was removed and 100g of the sample was poured into the bottle, the cork was replaced weighed and recorded as W_2. Distilled water was poured into the bottle until it was half-filled with the water and topped by the cork. The bottle was shaken vigorously to remove all air-bubbles in the soil mass and finally the bottle was filled to the brim with the water, the density bottle with the rubber cork was then wiped dry, weighed and recorded as W_3.

The density bottle content was emptied and rinsed with distilled water, it was then filled with distilled water only and rubber cork replaced, wiped dry, weighed and recorded as W_4 and the specific gravity was computed using equation 5.

$$Specific\ gravity\ of\ soil = \frac{\text{Density of water}}{\text{Weight of water of equal volume}} \quad (3)$$

$$= \frac{W2-W1}{(W4-W1)-(W3-W2)} \quad (4)$$

$$= \frac{W2-W1}{(W2-W1)-(W3-W4)} \quad (5)$$

Where: W_1 = weight of the empty density bottle

W_2 = weight of dry soil + density bottle

W_3 = weight of soil + water + density

W_4 = weight of water + density

2.2.3 Particle size analysis

The sieves of sieve shaker were cleansed using cleaning brush to remove any particles struck in the openings. The weight of each sieve was recorded along with the receiving pan. Thereafter, the specimen was dried in the oven and it was weighed and the weight was recorded. The sieves were arranged in order as the small opening sieve to the last and larger opening sieve to the top. The weighed and recorded specimen was poured on the top sieve, the lid on; the stack of sieves inserted on the sieve shaker and the clamps was fixed. The shaker was allowed to work between 10 – 15 minutes so as to work accurately and the sieve stack was removed from the shaker then the weight of each sieve and receiving pan was weighed. The percentage by mass of material retained in each sieve was calculated and the cumulative percentage by mass of the total sample passing each sieve was calculated.

2.2.4 Liquid Limit

The weight of moisture can was measured and recorded then an amount of soil in a porcelain dish which passed the no.40 sieve pan was taken, water was added and it was mixed well until a smooth paste is derived. The mixture was leveled in the porcelain dish as to get a depth of 1cm and the soil was divided symmetrically using the grooving tool. After that, the handle of the liquid limit device was rotated so as to get two revolutions per second. While rotating the groove, the number of blows was counted until the separated sample came in contact to a length of 13mm. An amount of soil was taken to the moisture can from the soil sample where the groove disappeared. The wet soil sample was taken into the moisture can and both were measured. The soil sample was kept in the oven and allowed to dry well then the dry soil sample with the moisture can was measured. The porcelain dish was emptied and the same procedure was repeated to at least three times by adding water to the same sample. The liquid limit was obtained by plotting graph to number of blows against moisture content.

2.2.5 Plastic Limit

A soil sample was prepared and placed on the glass mixing plate. The soil was allowed to dry partially on the plate until it becomes plastic enough to be shaped into a ball. The ball was moulded between the fingers and rolled between the palms of the hands until the heat of the hands has dried the soil sufficiently for slight cracks to appear on its surface. The soil was moulded in the fingers to equalize the distribution of moisture and then the soil was formed into a thread about 6mm diameter between the first finger and thumb of each hand. The thread was rolled between the fingers, from the finger-tip to the second joint of one hand and the surface of the glass rolling plate. By applying enough pressure, the diameter of the thread was reduced to about 3mm in five to ten complete forward and back movements of the hand. It was ensured that a uniform rolling pressure was maintained. The soil was rolled continuously till the thread shears both longitudinally and transversely. The portions of the crumbled soil thread was gathered and transferred to a suitable container to calculate the moisture content. The moisture content is the plastic limit of the sample

2.2.6 Compaction

A quantity of dry soil sample that passed the 20mm sieve diameter was prepared. The mould with the baseplate attached was weighed and the internal dimension i.e. the height and the diameter was measured. The extension to the mould was attached and the mould assembly was placed on a solid base. The soil sample was mixed with a known percentage of water and was placed in the mould such that when compacted, it occupied a little over one-fifth of the height of the mould body. The rammer was then used to apply 27 blows dropped from a height of 250mm above the soil, the blows was distributed uniformly over the surface and it was ensured that the rammer always falls freely and not obstructed. More soil sample was added to the mould in three layers and compacted by the rammer so that the amount of soil used is sufficient to fill the mould body with the surface not more than 6mm proud of the upper edge of the mould body. The extension was removed; the excess soil was wiped off and the surface of the compacted soil was leveled with the use of the straight edge. The soil and mould with baseplate was weighed. The compacted soil from the mould was removed and placed on a large metal tray; a representative sample of the soil was taken for the determination of its moisture content. The remainder of the soil was broken and rubbed through the 20mm sieve and mixed with the remainder of the prepared test sample. A suitable increment of water was then added and mixed thoroughly into the soil. The compaction process was repeated to give a total of at least five determinations. The moisture content shall be such that the optimum moisture at which the maximum dry density occurs.

2.2.7 California bearing ratio (CBR)

A quantity of dry soil sample that passed the 20mm sieve diameter was prepared and mixed with the equivalent water content as determined from it OMC. The mould was weighed with the baseplate attached and then the internal dimensions of the mould were measured. The extension collar was attached to the mould and the baseplate was covered with a filter paper. The mould assembly was made to rest on a solid base and the soil sample was compacted in three layers with each layer compacted with 63 blows of 2.5kg rammer until the final level is just above the top of the mould. The collar was removed and the soil at the top was flushed with the scraper. The mould, soil and the baseplate was weighed. The mould with the baseplate containing the sample was placed centrally on the lower platen of the machine with the top face of the sample exposed. The appropriate annular surcharge disc was placed on top of the sample. The cylindrical plunger and the force-measuring device assembly were fitted into place with the face of the plunger resting on the surface of the sample. The force-measuring device and the penetration dial gauge was reset to zero. The machine was put on and the test started so that the plunger penetrates the sample at a nominal rate of 1mm/min and at the same instant, the timer was employed. The readings of the force gauge at intervals of penetration of 0.5mm to a total of 7.0mm was recorded. The plunger was raised and the surface of the sample was leveled by filling in the depression from the plunger. The baseplate was removed from the lower end of the mould, fitted securely on the top end and the mould was inverted. The penetration test was repeated for the top end also. The known mass of the soil sample was kept in a moisture can to determine the moisture content. The force applied to the plunger from each reading of the force-measuring device observed during the test was calculated. The graph of each value of force against the corresponding penetration was plotted. From the curve the forces corresponding to 2.5mm and 5mm penetration was read and it was expressed as a percentage of the standard forces at these penetrations. The higher percentage was taken as the CBR value.

2.2.8 Unconfined Compressive Strength (UCS)

A quantity of dry soil sample that passed the 20mm sieve diameter was prepared and mixed with the equivalent water content as determined from it OMC. The mould was weighed with the baseplate attached and then the internal dimensions of the mould were measured. The extension collar was attached to the mould and the baseplate was covered with a filter paper. The mould assembly was made to rest on a solid base and the soil sample was compacted in three layers with each layer compacted with 27 blows of 2.5kg rammer until the final level is just above the top of the mould. The collar was removed and the soil at the top was flushed with the scraper. The compacted specimen was cored and extruded using a locally fabricated corer and a jack. The mass of the specimen was determined, its length and diameter will also be measured. The specimen was placed centrally on the pedestal of the compression machine between the upper and lower platens. The machine was adjusted so that contact is just made between the specimen, upper plated and the force measuring device. The axial deformation gauge was adjusted to read zero. The initial readings of the force and the compression gauges was recorded. A suitable rate of axial deformation was selected such that the rate of axial strain does not exceed 2%/min. Compression was applied to the specimen at the selected rate and the simultaneous readings of the force-measuring device and the axial deformation gauges at regular intervals of compression was recorded. The test was continued until the maximum value of the axial stress has been passed or the axial strain reaches 20%. The load was removed from the specimen and the whole specimen was removed from the apparatus. A representative sample was selected to determine the moisture content. The axial strain of the specimen for each set of readings was calculated. The force applied to the specimen for each set of readings was calculated. The axial compressive stress in the specimen for each set of readings was calculated on the assumption that the specimen deforms as a right cylinder. The graph of compressive stress against the corresponding values of strain was plotted. A point was ascertained on the graph representing the failure condition which is the point at which the maximum compressive stress sustained by the specimen occurs or the point corresponding to a strain of 20%.the compressive stress of the specimen was determined from the point, this is the unconfined compressive strength. The axial strain of the specimen at failure was determined.

III. RESULTS AND DISCUSSION

3.1 Presentation of Result

The results of characteristics and the properties of the soil in its natural state before the addition of the additives were shown in Table 1

Table1: Properties of soil before addition of additives

Properties (Test)	Result
Natural Moisture Content (%)	16.82
Specific gravity	2.2
Percentage passing sieve 75μm (No. 200)	52
Liquid Limit (%)	48.5
Plastic Limit (%)	25.1
Plasticity Index (%)	23.4
AASHTO Classification	A-7-6(Poor soil)
USCS Classification	CL (Clayey soil with low plasticity)
OMC at BSL Compaction (%)	18.92
MDD at BSL Compaction (g/cm^3)	1.83
California Bearing Ratio (%)	17
Unconfined Compressive Strength (kN/m^2)	325

3.2 Sieve Analysis and Particle Size Distribution

Figure 1 shows the grain size distribution analysis for the lateritic soil sample. The percentage passing sieve No. 200 is 52% and this result did not satisfy the specification limits of 35% or less for road by Road and Bridges Specification Revised Edition of Federal Ministry of Works, Nigeria. It can be deducted that the soil sample is poor for sub-grade and sub-base course. Hence is the need for stabilization of the soil. The particle distribution curve shows that the soil has high percentage of silt and clay which has expansive properties on addition of water and contract when water is removed.

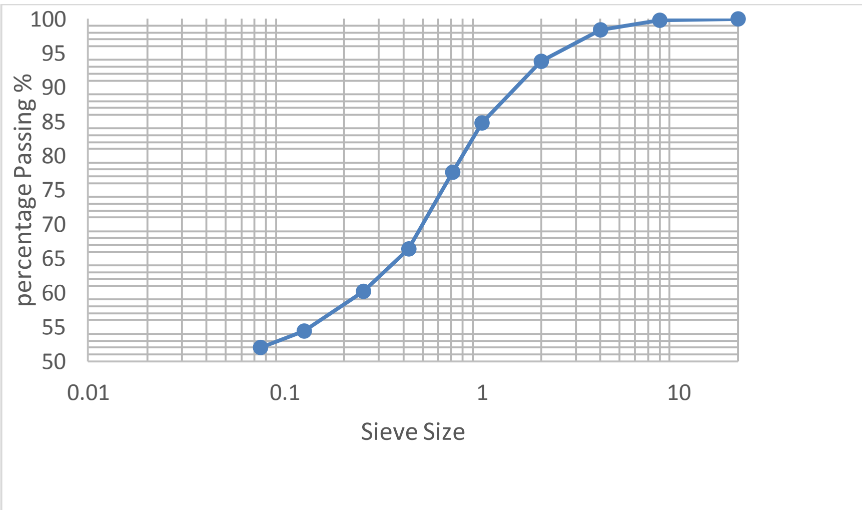

Figure 1: Sieve analysis gradation curve

3.3 Atterberg Limits

The Atterberg limit results include the liquid limits, plastic limit and the plasticity index of the soil sample with different variation of the additives as speculated in the methodology of this project work

3.3.1 Liquid Limits

From the result obtained from the analysis of data that was gotten from the laboratory test Figure 2 shows that there is a gradual decrease in the liquid limit of the soil sample from 48.5% to 43.5% as percentage of lime increases from 0% to 6%. Also the result shows that there is a gradual decrease in the liquid limit of the soil sample from 48.5% to 43.5% as percentage of powdered glass increases from 0% to 6%. For 2% lime content, the liquid limit decreased from 46.5% to 42.2% for 0 to 6% glass fines respectively. For 4% lime content, the liquid limit decreased from 45.5% to 42.0% for 0 to 6% glass fines respectively. Finally for 6% lime content, the liquid limit decreased from 43.5% to 41.7% for 0 to 6% glass fines respectively. This result indicates that liquid limit decreased with increasing lime content and increasing glass fines.

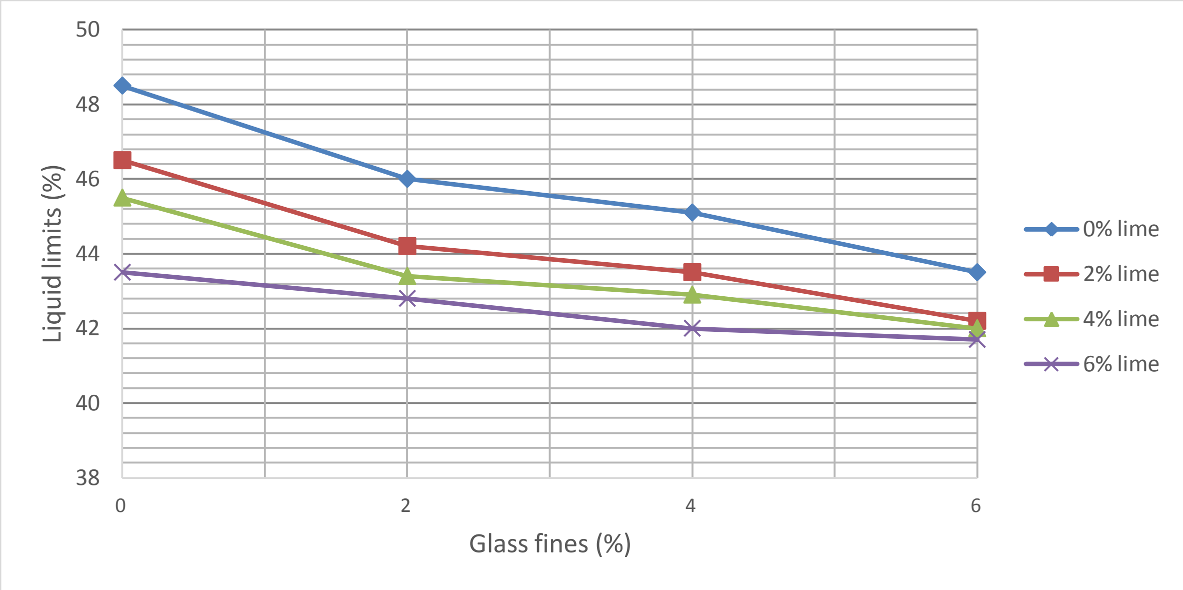

Figure 2: Liquid limits at based lime percentages and varying glass fines

3.3.2 Plastic Limits

From the result obtained from the analysis of data that was gotten from the laboratory test Figure3 shows that there is a gradual increase in the plastic limit of the soil sample from 25.1% to 32.4% as percentage of lime increases from 0% to 6%. Also the result shows that there is a gradual decrease in the plastic limit of the soil sample from 25.1% to 21.32% as percentage of powdered glass increases from 0% to 6%. For 2% lime content, the plastic limit decreased from 30.68% to 25% for 0 to 6% glass fines respectively. For 4% lime content, the plastic limit decreased from 31.3% to 25.3% for 0 to 6% glass fines respectively. Finally for 6% lime content, the plastic limit decreased from 32.4% to 27.5% for 0 to 6% glass fines respectively. This result indicates that plastic limit increased with increasing lime content and decreased with increasing glass fines.

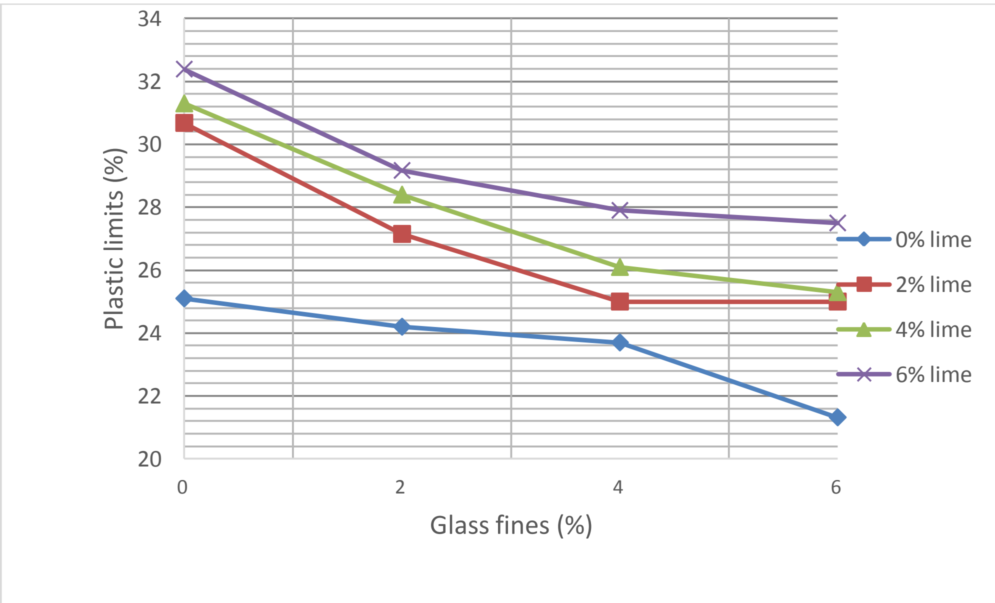

Figure 3 Behavior of plastic limit under various glass fines and lime contents

3.3.3 Plasticity Index

From the result obtained from the analysis of data that was gotten from the laboratory test Figure 4 shows that there is a gradual decrease in the plasticity index of the soil sample from 23.4% to 11.1% as percentage of lime increases from 0% to 6%. Also the result shows that there is a gradual decrease in the plasticity index of the soil sample from 23.4% to 21.4% as percentage of powdered glass increases from 0% to 4% then increases with 6% glass. For 2% lime content, the plasticity index increased from 15.82% to 18.5% for

0 to 4% glass fines and decreased with 6% glass. For 4% lime content, the plasticity index increased from 14.2% to 16.8% for 0 to 6% glass fines respectively. Finally for 6% lime content, the plasticity index increased from 11.1% to 14.2% for 0 to 6% glass fines respectively. This result indicates that lime and glass fines have significant effect on the plasticity index of the lateritic soil.

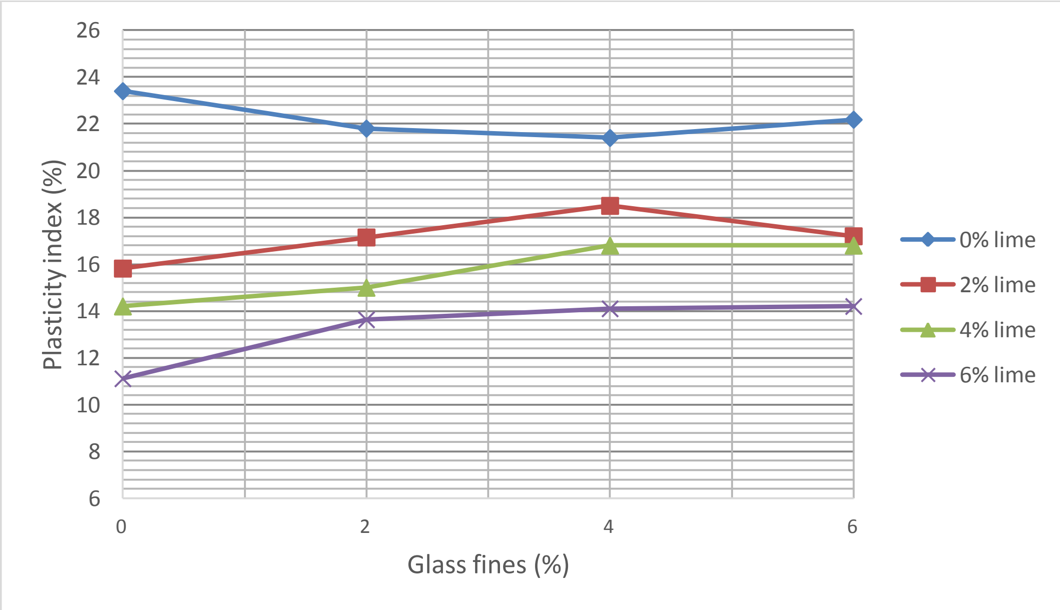

Figure 4: Behaviour of plasticity index under various glass fines and lime contents

3.3.4 Compaction

The optimum moisture content and the maximum dry density of the soil in its natural state and when additives has been added are obtained from the graph of dry density against moisture content. Figures 4.5 and 4.6 shows the behavior of the Maximum Dry Density (MDD) and Optimum Moisture content (OMC) under different percentages of glass fines and lime contents. The density ranged from 1.7 to 1.83g/cm^3 and the optimum moisture content ranged from 17.85 to 21.9%. The result shows that there is a decrease in the MDD from 1.83 to 1.67g/cm^3 as lime content increases from 0% to 6%. The MDD decreases with the increase in glass fines content up to 4% and increases further. For 2% lime content, the MDD decreases from 1.81 to 1.74 up to 4% glass fines content and increases further. For 4% lime content, the MDD increases up to 4% glass fines content then decreases further. Finally with 6% lime content, the MDD increases up to 4% glass fines content and decreases further.

For the Optimum moisture content, the result shows that there is an increase in OMC up to 4% lime content the increases further. Also there is an increase in OMC up to 4% glass fines content. For 2% lime content, the OMC increases up to 4% glass fines content then increases further. For 4% lime content, the OMC decreases up to 4% lime content then increases further. Finally with 6% lime content, the OMC decreases from 0% glass content to 6% lime content.

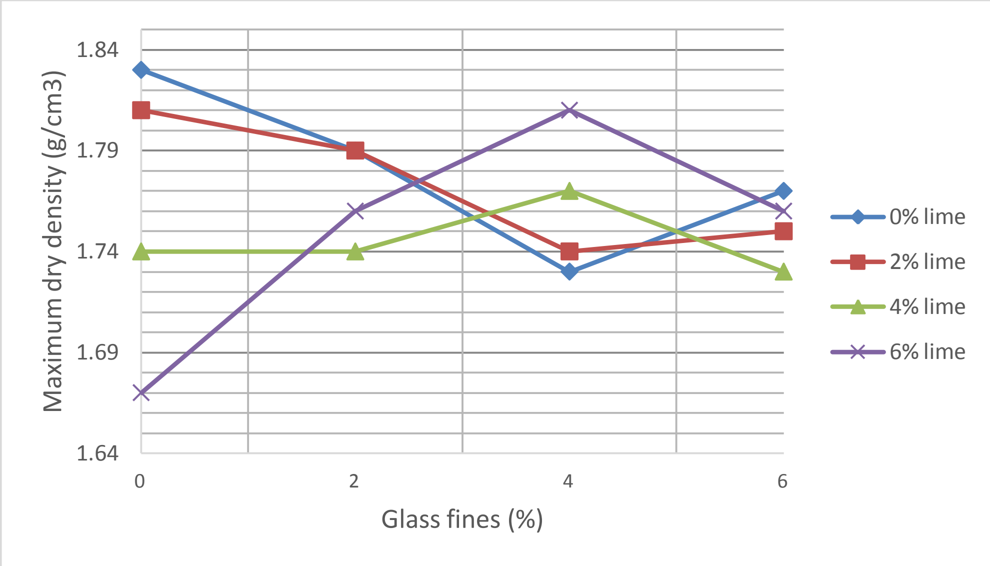

Figure 5: Behaviour of maximum dry density under various glass fines and lime content

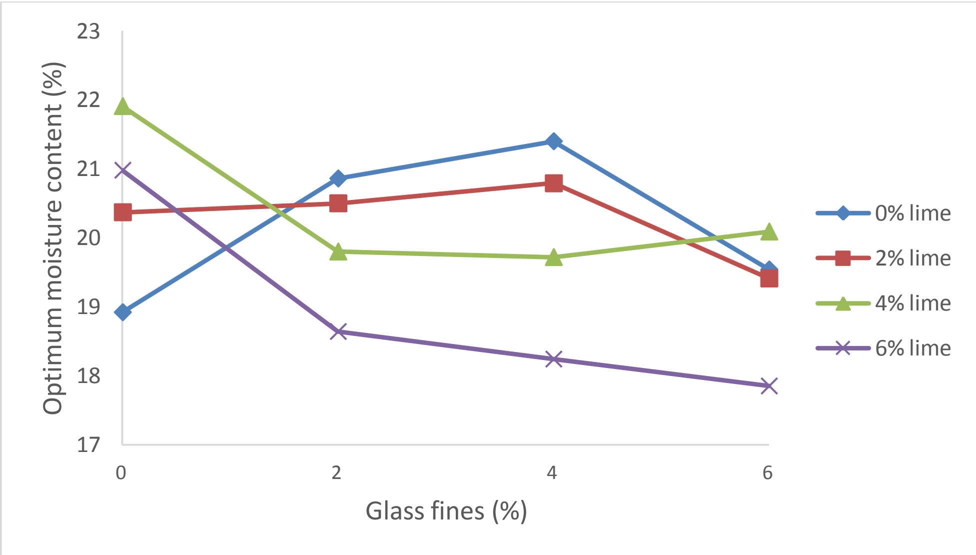

Figure 6: Behaviour of optimum moisture content under various glass fines and lime content

3.3.5 Unconfined Compressive Strength (UCS)

The effect of the glass fines and lime contents on the unconfined compressive strength of the lateritic soil at 14 days curing period is presented in Figure 7. The value of UCS increased as lime content increases from 0 to 6%. For 0% lime, the UCS value increased from 325 (0% glass) to 364kN/m^2 (6% glass). For 2% lime, the UCS value increased from 340kN/m^2 (0% glass) to 361kN/m^2 (6% glass). For 4% lime, the UCS value increased from 384kN/m^2 (0% glass) to 424kN/m^2 (6% glass). Finally for 6% lime, the UCS value increases from 0% to 4% and decreased further. The peak value of UCS 461kN/m^2 is gotten with the addition 6% lime and 4% glass fines content. The result shows that glass fines together with lime can serve as potential stabilizers for increasing the strength of soil.

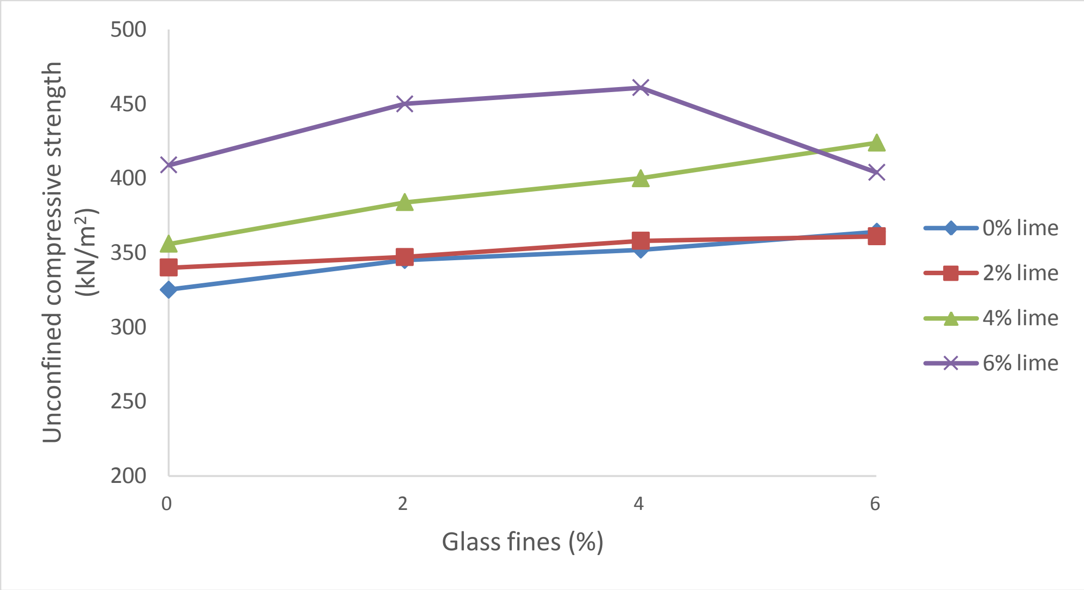

Figure 7: Effect of glass fines and lime on the UCS of lateritic soil

3.3.6 California Bearing Ratio (CBR)

Figure 8 shows the behavior of CBR (unsoaked) under different percentages of glass fines and lime. The value of CBR increased as lime content increases from 0 to 6% also it increases as glass fines content increases from 0 to 6%. For 0% lime content, the CBR value increased continuously from 17% (0% glass) to 24% (6% glass). For 2% lime, the CBR value increased from 19.6% (0% glass) to 28.5% (6% glass). For 4% lime, the CBR value increases from 26% (0% glass) to 33% (6% glass). Finally for 6% lime, the CBR value increases from 32% (0% glass) to 45% (6% glass). The result shows that glass fines together with lime can serve as potential stabilizers for increasing the CBR of soil. This gives an indication that lime and glass fines can be effectively used to improve CBR value of lateritic soil. At 6% glass and 6% lime contents, the lateritic soil can be utilized as subgrade material.

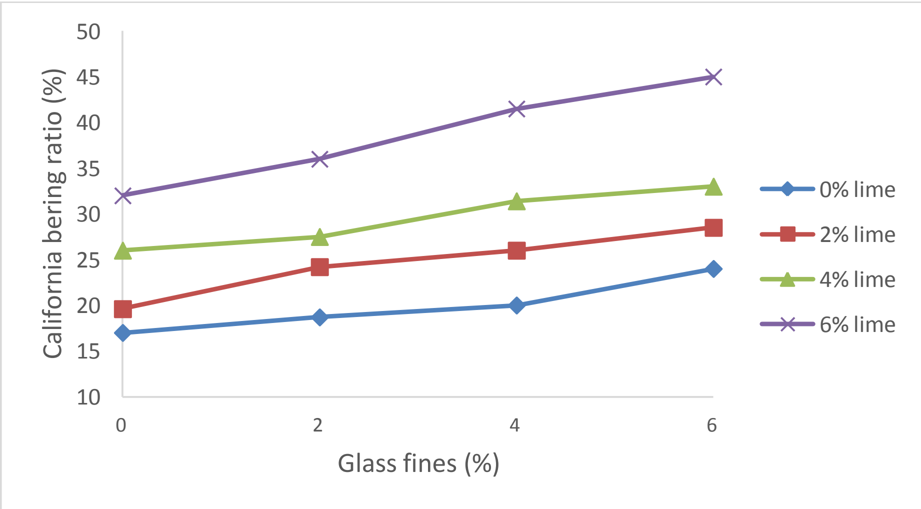

Figure 8: Effect of glass fines and lime on California bearing ratio

IV. CONCLUSION

The conclusion of the experimental results on lime and powdered glass improvement of the index properties of stabilized lateritic soil are presented as follows

- Particle size distribution revealed that the natural samples were predominantly fine grain with trace of coarse grain. The soil sample is classified as poor sample according to AASHTO classification
- Samples exhibited high LL value of 48.5% and when admixed with lime and powdered glass combination at varying percentages, there were improvement indicated by the reduction of liquid limit values.

The plastic index also reduces considerably in that the unstabilized sample was realized to be 23.4 and there was a considerable decrease up to 11.11%.

- The Maximum Dry Density (MDD) of the lateritic soil increased with the addition of glass fines from 0% to 4% and decreased beyond starting from 4% addition of lime content. 6% lime and 4% glass gave the optimum value of MDD for the stabilized soil.
- The UCS value obtained for stabilized soil samples are high compared to the value of the untreated sample. The peak value was obtained to be 461kN/m^2 at 6% of lime and 4% of glass fines content.
- The California Bearing Ratio (CBR) of the soil increased continuously with increasing glass and lime contents. Based on the results of this study, 6% addition of glass fines yielded the best results in terms of strength increment and this is therefore recommended for improving the strength characteristics of the lateritic soil.
- It can also be concluded that the glass fines is a good complement for lime stabilization in lateritic soil.

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