PERFORMANCE EVALUATION OF STABILIZED CLAYEY SOIL WITH RICE HUSK AND FLY ASHES

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MEng/SIPET/2018/9246

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING IN CIVIL ENGINEERING (GEOTECHNICAL ENGINEERING)

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ABSTRACT

The study focused on Performance evaluation of clayey soil stabilized with rice husk and fly ashes. Expansive soil otherwise known as problematic clay are considered a potential natural threat which can cause extensive damage to a structure if not adequately treated. The improvements in terms of compaction and strength characteristic were examined. Rice husk and fly ashes were added to the clayey soil sample by dry weight with selected dosage as 0, 2:4, 4:6, 6:8, 8:10 and 10:12%. British standard heavy, British standard light and West African standard compactive effort were employed. Result for the soil identification and classification shows that the soil is classified as A-7-5 according to American Association of State Highway and Transportation Officials (AASHTO) and as Sandy Clay (SC) according to Unified Soil Classification System. the stabilized clayey soil shows 62-76% increment in terms of its compaction characteristic the maximum dry density (MDD) .and a decreased value for its corresponding optimum moisture content (OMC). The CBR and UCS of the clay were improved by 256% and 88% respectively with the optimal values obtained at 2:4% Rice husk and Fly ashes addition. This therefore indicates that the addition of rice husk and fly ashes to a class of clayey soil improves the soil stiffness and resistance to deformation and can be used as a construction material.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

GLOSSARY OF ABBREVIATIONS

BSH	British Standard Heavy
BSL	British Standard Light
CBR	California bearing ratio
FA	Fly Ash
RHA	Rice Husk Ash
WAS	West African Standard
UCS	Unconfined Compressive Strength
MDD	Maximum Dry density
OMC	Optimum moisture content
Gs	Specific gravity
LL	Liquid limit
PL	Plastic limit
γ_d	dry density

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Dcficient clayey soil lacks enough strength to withstand the load from a structure, therefore, the strength has to be increased to make the soil suitable (Arun *et al.*, 2019). Clayey soil are said to be soils which have large fraction of fine particles such as silts, clay soils having high moisture contents, peat foundation and loose sand deposits near or under the water table (Kamon and Bergado, 1992). Several methods such as prefabricated vertical drains, geotextile reinforcing, cement and lime stabilization have been successfully implemented to improve such soils which would increase the properties of these soft clays (Amir and Indra, 2007). Clayey soil are characterized with high compressibility, low bearing capacity, low strength and low permeability (Otoko, 2014).

Rice Husks (or rice hulls) are the hard protective outer shell of grains of rice. It shields the rice during growing season. Rice Husk Ash (RHA) is gotten from the burning of rice hulls and can be used in Portland cement production, as good thermal insulating materials, sealing fine cracks in structures and as fuel.

Fly ash is one of the by product from the combustion of coal in coal fired power plants. In industrial context, it is said to be the ash produced during the combustion of coal. The two types of fly ash are class C and Class F. Class F fly ash is produced by burning antharacite or bituminous coal which usually has less than 20% Calcium Oxide (CaO). It has pozzolanic properties only. Class C is produced from burning lignite. It has both pozzolanic and cementitious properties and contains more than 20% Calcium Oxide (CaO). Alkaline and Sulphate (SO_4) are usually higher in class C. The distinctive different between Class F and Class C fly ash is the amount of Calcium (Ca), Silicon (Si), Aluminium (Al), and Iron (Fe) content.

Soil stabilization is a process whereby soils are modified to improve its properties. Stabilization increases shear strength of the soil, It controls swelling and shrinkage properties of soil which improves the load bearing capacity of a subgrade. Soil stabilization is used in roadways construction, parking areas, site development projects, airports and many other construction conditions where subsoil are not suitable for construction. Wide range (ranging from expansive clays to granular materials) of subsoil are improved using stabilization. Lime, Portland cement, Bitumen, Lime-kiln dust, Cement kiln dust are used as additives to improve soils.

Geotechnical Engineers are faced with the problem of deficient soils such as clay, hence the need for soil improvement. Soil improvement can be achieved either by modification or stabilization or both. Modification is improvement of soil by addition of a modifier such as cement or lime to improve its index properties, while stabilization on the other hand is the treatment of soil to enable improvement of their strength and durability such that it is suitable for construction.

1.2 Statement of the Research Problem

The issue of expansive soils otherwise known as problematic clay is usually of concern to civil engineers. They are considered a potential natural threat, which can cause extensive damage to structures if not adequately treated. Such soils swell when given access to water and shrink when they dry out. Soil stabilization has been implemented for improving the properties of this type of soil (Arunav and Swapnaneel, 2016).

Most of the cities in Nigeria like Benin, Bayelsa and Uyo suffer the fate of weak soils and also clayey, silty clay and lateritic soils borrowed for construction works or other engineering purposes needs to be stabilized or modified to improve its properties (Onyelowe and Kennedy, 2012). Due to the rapid growth in population and vast development in infrastructures, the demand for land has increased significantly for the past few decades. This has led to the limited availability of land resources. Hence an engineer is forced to carry out the numerous construction activities even on problematic soil. There comes the impor;tance of ground improvement techniques.

1.3 Aim and Objectives of the Study

The aim of this research is to evaluate the stabilization of clayey soil with Rice Husk and Fly Ashes .

The objectives include;

i. determine the physio-chemical properties of rice husk ash and fly ash.

ii. examine the compaction characteristics of stabilized clayey soil with selected dosages of rice husk ash and fly ash.

iii. determine the strength characteristics of stabilized clayey soil with selected dosages of rice husk ash and fly ash.

1.4 Justification of the Study

Deficient clayey soil generally exhibits undesirable engineering properties they tend to have low shear strength to lose shear strength further upon wetting or other physical disturbances. Cohesive soil can creep over time under constant load, especially when the shear strength is approaching its shear strength, making them prone to sliding. They develop large lateral pressure and they tend to have low resilient modulus values. For this reasons deficient clay are generally poor materials for foundation. Stabilization of deficient clayey soil with rice husk and fly ashes will decrease the expansive and shrinkage nature of clayey soil, and can be used as a construction material.which also will reduce the cost of stabilization when compared to other types of stabilization.

1.5 Scope of the Study

This research work was limited to clayey soils obtained around Birgi and Lapai-Gwari villages within Minna, Niger State which was subjected to laboratory test that describe the physical and engineering properties of the soil in its natural form and also with varying percentages of Rice Husk and Fly Ashes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Review

Soil serves as bed for engineering structures such as bridges, highway, dam, tunnel and other civil engineering structures. The suitability of soil is major requirement before embarking on foundation works, basically to check for its properties and behaviour under loading (Surendra and Sanjeev, 2017). Clayey soils have the capacity to swelling immediately as they come in contact with moisture. During this state of moisture percolation, the clay minerals become charged with the negative ion on the surface and positive ions on the edge adsorbed moisture also dissociates to its dipole forming hydrogen (H^+) and hydroxyl (OH^-) ions and it shrinks after the absense of water (Buivan and Onyelowe, 2018). Due to the problematic properties of the clayey soil as a result of its erratic behavior, it is technically important that such problematic soils are improved upon either by stabilization or modification

Chayakrit *et al.* (2016) examined the viability of using Fly Ash (FA) and Calcium Carbide Residue (CCR) as a sustainable binder to improve strength of soft marine clay. The strength of the stabilized soil was found to be strongly dependent upon Fly Ash (FA) and Sodium Hydroxide (NaOH) concentration. The optimal ingredient providing the highest strength **was found to be dependent on water content. Zhen *et al.* (2016) studied the feasibility of** Fly Ash (FA) based geopolymer.The metastable structure of natural loess has resulted in construction delay and catastrophic failure. It was found out that Potassium Hydroxide renders a higher unconfined compressive strength than Sodium Hydroxide (NaOH) geopolymer. With an increasing Fly Ash/loess ratio, the compressive strength and Young modulus increases.

The micro-structural characterization unveils that a compact and stable microstructure has been developed in the stabilized loess. Harishma and Anjana (2017) studied the improvement of the geotechnical properties of soil by adding waste material (Fly Ash) and the study revealed that on addition of fly ash, liquid limit, plastic index and maximum dry density decreased while optimum moisture content increased. California Bearing Ratio and Unconfined Compressive Strength also increased but to an optimum value and then it decreases.

Akinleye *et al.* (2015) carried out a research on the use of Rice Husk Ash as a stabilizing agent on lateritic clay soils. The research concluded that on the addition of rice husk ash, the index properties of the soil increased which qualifies it as a good stabilizing agent for subgrade in road construction and back filling in retaining walls but the mix should not exceed 10% of Rice Husk Ash.

Alhassan and Alhaji (2017) concluded from a review research that the use of agricultural waste like Rice Husk Ash has great potentials in improving the geotechnical properties of deficient soil. This helps in providing stable and durable structures, reduces cost of soil improvement and environmental nuisance cost by this waste. It would also add to the economic value chain of the rice farmer producers (Zhen *et al.*, 2016).

2.2 Soil Stabilization

Generally, soil stabilization is referred to as any physical, chemical, mechanical, biological or combined method of improving a natural soil to meet an engineering purpose (Winterkorn and Pamukcu, 1991). Stabilization increases the shear strength of soil, controls shrink-swell properties of soil, and improves the load bearing capacity of a subgrade which supports pavements and foundations.

2.3 Purpose of Soil Stabilization

The purpose of soil stabilization is **:**

a) To improve soil strength.

b) It brings about economy in construction.

c) It improves the undesirable properties of soils..

d) It improves permeability characteristics.

e) In wet weather, it is used to provide a working platform for construction operations.

2.4 Types of Soil Stabilization

Soil stabilization can either be surface stabilization or subsurface (ground improvement) stabilization.

2.4.1 Surface stabilization

Surface stabilization involves a situation where by the influence zone is less than 1m (Ulmeyer *et al.*, 2002). Surface stabilization includes mechanical stabilization, physical stabilization and chemical stabilization.

2.4.1.1 Mechanical stabilization

This involves the use of mechanical energy to improve the soil properties without the use of additives or other binding agents. It is the simplest method of stabilization and it is used mostly in the construction of roads, embankment, and railways. Factors affecting mechanical soil stabilization are;

a. Aggregate mechanical strength: Mechanical stabilization is affected if the mixture is not properly designed or if compaction is insufficient.
b. Mineral composition: The composition of the mineral is linked with the mechanical stability of the mixed soil. The mineral present in the soil should resist weathering action.
c. Gradation: Pore spaces between the coarse aggregate have to be filled with fine aggregate to attain a high density in the mixed soil.
d. Compaction: For high density and stability mix, adequate compaction is necessary in the soil mix.
e. Soil properties: Plasticity index in the soil has to be under control since it reduces the soil stability. When a clayey soil is in a saturated condition, plasticity index of the soil is affected.

2 4.1.2 Physical stabilization

In this type of stabilization, two or more soils are blended together to improve the physical properties of the soils. (Chen, 2003) Additives are also used in this method. Physical stabilization includes

a) Cement stabilization: This involve the addition of cement to soil which has a binding effect and produces a weak form of concrete referred to as soil cement. The amount of cement added depends on the type soil. Where soil is very weak, cement stabilization is not advisable. Factors affection cement stabilization are;

i. Types of soil: Cement stabilization is applied preferably to granular soil but it can also be applied to fine grained soils.

ii. Mixing, compaction and curing: To achieve better stability, the mixing, compaction and curing has to be adequate.

iii. Admixtures: Cement has some important admixtures itself which helps in creating adequate bond. Admixtures play an important role in the reaction between cement and water.

b) Lime stabilization: This is a process of adding lime to the soil to improve its properties. Lime stabilization involves the exchange of ions between soil and lime. When soil is treated with lime, cation exchange takes place between them which increases plastic limit and reduces plasticity index and as a result, there is an increase in stability of soil. Lime acts as a binding material in a case where clay soil contains gravel(Haas and Ritter, 2019) . Lime stabilization is suitable for soils such as clay, silty clay, and clayey gravel. It is not suitable for sandy or granular soil. High Calcium (quicklime, CaO), hydrated high Calcium lime [$Ca(OH)_2$], Dolomite lime [$CaO+MgO$], Normal hydrated dolomite lime [$Ca(OH)_2+MgO$] and pressure hydrated dolomite lime [$Ca(OH)_2+Mg(OH)_2$] are basically the five (5) types of lime. Factors affecting lime stabilization are

i. Soil type: Soil should contain sufficient quantity of pozzolanic content in order to be able to react with lime. This reaction increases strength of the lime-soil mix.

ii. Lime type: Quicklime is more effective than hydraulic lime (slaked lime). Where quicklime is to be used, care should be taken by workers as skin burn may occur. Due to this, slake lime is mostly used either in its dry powder form or by mixing it with water.

iii. Lime content: Plastic limit increases resulting in a decrease in plasticity index when lime is added to soil in the presence of water. Fixation point is achieved when on further addition of lime, there is a decrease in plasticity limit.

iv. Compaction: The density of lime-soil mix should be greater to obtain a greater strength.

v. Curing: Proper curing must be provided for a particular mix particularly during the initial stage where rate of strength gained is rapid.

c) Bituminous stabilization: In this type of stabilization, a controlled amount bituminous material (such as bitumen, asphalt and tar) is mixed with weak or deficient soil. Bitumen increases cohesion and load-bearing capacity of the soil. Bituminous stabilization renders the soil mix resistant to water action. Bitumen is non-aqueous systems of hydrocarbon that are soluble in carbon di-sulphide. Tars are obtained from destructive distillation of organic material such as coal. Asphalts are materials in which the primary components are natural or refined petroleum bitumen (Kramer and Gleixner 2006). Factors affecting bituminous soil stabilization are

a. Nature of soil: It is very effective in stabilizing sandy soils having little or no fines. It can be used to stabilize cohesive soils having a plastic limit less than 20% and liquid limit less than 40%. Clays cannot be treated because of the mixing problems and it would require large amount of bitumen.

b. Amount of asphalt: The use of asphalt improves the water proofing nature of the soil resulting in better stabilization.
c. Mixing: Thorough mixing provides better quality of the soil-mix.
d. Compaction condition: The density of the mixture of soil and asphalt is governed by the volatile content and the amount of bitumen as well as the type of compaction. In order words, the lower the volatile content, the higher the strength.

2.4.1.3 *Chemical Stabilization*

Soils are improved by the addition of different chemicals. The principal advantage is that the setting and curing time can be controlled. The performance of the soil mix depends greatly on the ground water movement. Chemical stabilization is more expensive than other types of stabilization techniques. Chemicals used in chemical stabilization are Calcium Chloride, Sodium Silicate, Polymers, chrome lignin, other chemicals.

i. Calcium Chloride: When added to a soil it causes colloidal reaction resulting in an alteration of the soil characteristics. It is deliquescent and hygroscopic and reduces the loss of moisture (Fengyin and Fenghong, 2016) The freezing point of water is reduced which results in a reduction in the chances of frost heave. It causes a slight increase in maximum dry unit weight.
ii. Sodium Silicate: This is known as water glass. It is injected directly into the soil. It increases the soil strength and makes soil impervious. When soil that

is mixed with Sodium Silicate is exposed to air or groundwater, the soil may lose its strength.

iii. Polymers: Polymer may be natural (such as resins) and synthetic (such as Calcium acrylate). They are long-chained molecules formed by polymerizing of certain organic chemicals called monomers (James, 2011). Catalyst can also be added with the monomers to the soil.

iv. Chrome Lignin: Lignin is one of by product in paper production. Chrome lignin is formed from black liquor in sulphite paper production. Sodium or Potassium bicarbonate is added to sulphite liquor to form chrome lignin. When added to soil, it reacts slowly to cause an effect on the soil particles. Quantity of chrome lignin required varies from 5 to 20% by weight.

v. Other Chemicals: Chemicals such alkyl chlorosilanes, silonates amines and quaternary ammonium salts are used in soil as water proofing materials. Coagulating chemicals such as calcium chloride and ferric chloride have been used to increase the electrical attraction and to form flocculated structure in order to improve the permeability of soil. Phosphoric acids combined with a wetting agent are used in cohesive soils. It reacts with clay minerals to form an insoluble aluminum phosphate.

Chemical soil stabilization is affected by some chemical since the chemical plays a major role in the stabilization.

i. Coagulating chemicals: These are used basically to improve the permeability of the soils.

ii. Chemical quantity: The quantity required varies from 0.1 - 0.2% of the weight of the soil for an adequate soil mix.

2.4.2 Sub-surface stabilization (ground improvement)

Subsurface stabilization (or ground improvement) is referred to as geotechnical processes used in improving the engineering properties of the soil thus making it more stable and durable (Chen, 1981). Table 2.1 shows different types of soil improvements technique.

Table 2.1: Method of soil improvement

Ground Reinforcement	Ground Improvement	Ground Treatment
Stone columns	Deep dynamic compaction	Soil cement
Soil nail	Drainage/Surcharge	Lime admixtures
Micropiles (Minipiles)	Electro-osmosis	Fly ash
Jet grouting	Compaction grouting	Dewatering
Ground anchors	Blasting	Heating/freezing
Geosynthesis	Surface compaction	
Fibre reinforcement		
Lime Columns		
Vibro-concrete column		
Mechanically stabilized earth		
Biotechnical		

(**Source:** Chen, 2003)

i. Vibrocompaction (Vibroflotation): This is used for densifying loose sands to create stable foundation soils. It involves the rearrangement of soil particles into a denser configuration by the use of powerful depth vibrations. This method of soil improvement reduces foundation settlement and risk of liquefaction due to seismic activity.

ii. Vacuum consolidation: This method is used for improving saturated soils. It can be used in place of preloading techniques eliminating the risk of failure.

iii. Preloading (or precompression): This is a process which involves the placement of additional vertical stress on a compressible soil to remove pore water over time. Pore water dissipated reduces the total volume causing settlement. Preloading reduces secondary compression and improves bearing capacity.

iv. Heating (or vitrification): Soil particles are broken down to form crystalline or glass product. It involves the use of electrical current to heat the soil and modify the physical characteristics of soil. Temperature of heating range from 300–1000^{0}C. Vitrification of soil causes immobility of radioactive or contaminated soil.

v. Ground freezing: It can be used as a temporary underpinning. It prevents ground water from flowing into an excavated area. This involves the process of refrigerating which convert in- site pore water to ice and acts as a cement or glue, bonding together adjacent particles of soil or blocks of rock to increase their combine strength thus making them impervious.

vi. Mechanically stabilized earth structures: This involves the use of metallic (strip or bar mat) or geosynthetic (geogrid or geotextile) reinforcement which is connected to a precast concrete or prefabricated metal facing panel to create a reinforced soil mass.

vii. Soil nailing: This involves the process of reinforcing the ground by passive inclusions which are closely spaced, to create in-site soil and restrain its displacement. Soil nailing is used in railroad and highway cut slopes. It is also used in funnel portals in steep and unstable stratified slopes.;

viii. Micro-piles: These are small diameter piles (usually 300mm) which have the ability of sustaining high loads. Micro-piles are used for structural support, stability and foundation. It is also used to prevent movement as well as soil strengthening.

ix. Grouting: This is the injection of materials (grouts) into a soil or rock formation to improve the properties of the soil or rock. Grouting increases soil strength, rigidity and reduces ground movement. Permeation, compaction, fracture, jet grouting are examples of grouting method used in soil improvement.

2.5 Rice Husk Ash (RHA)

Rice husk is obtained by winnowing. Rice Husk Ash is produced by burning rice husk at a temperature between 600-700^{0}C for two (2) hours. The process is shown in Figure 2.1 Burning processes are open field burning, fluidized-bed furnace burning and industrial furnace burning (Cai, 2016). Open field burning which produces poor quality rice husk ash and has low reactivity. This is an uncontrolled burning method.

a) Fluidized-bed furnace burning is a controlled method and combustion heat can be used to generate electricity.

b) Industrial furnace is more environmental friendly and also economical. If burning is efficient, a silica content of 90-95 percent is achieved.

Some typical properties and elements in Rice Husk Ash are presented in Table 2.2 which includes; Silica (SiO_2), Carbon (C), Calcium Oxide (CaO), Magnesium Oxide (MgO), Potassium Oxide (K_2O), Haematite (Fe_2O_3), Sodium (Na), Titanium Oxide(TiO_2). (Cai,2016).

A. Rice grain field *B. the husk*

1C. ash after burning

Figure 2.1: Rice Husk Ash processes

(Source:www.slideshare.net)

Table 2.2: Typical Properties of Rice Husk.

S/N	Property Range
1. Bulk density (kg/m^3)	96-160
2. Length of husk (mm)	2-5
3. Hardness (Mohr's scale)	5-6
4. Ash (%)	22-29
5. Carbon (%)	35
6. Hydrogen (%)	4-5
7. Oxygen (%)	0.23-0.32
8. Nitrogen (%)	0.23-0.32
9. Sulphur (%)	0.04-0.08
10. Moisture (%)	8-9
11. SiO_2	67.3
12. $Al2O_2$	4.9
13. $Fe2O_3$	0.95
14. CaO	1.36
15. MgO	1.81
16. Loss of Ignition (LOI)	17.78

(Source: Cai, 2016.)

2.6 Fly Ash (FA)

Fly Ash is a residue obtained from the incineration of coal. It is a fine powder produced from industrial plants using pulverized coal or lignite as fuel. Fly ash varies from light to dark grey in term of colouration which depends on its carbon content. Quality of fly ash varies from source to s;ource. The Chemical compounds in fly ash are Silicon dioxide (SiO_2), Aluminum Oxide (Al_2O_3), Iron (III) Oxide (Fe_2O_3), Calcium Oxide (CaO), Magnesium Oxide (MgO), Sulphurtrioxide (SO_3) and Sodium Oxide (Na_2O).

2.6.1 Types of fly ash

According to American Society for Testing and Material (ASTM C618), Fly Ash are of two classes which are Class C and Class F which has a requirement of loss ignition (LOI) less than 4 percent and 75 percent of ash must have a fineness of 45µm or less as shown in Table 2.3

Table 2.3: Types of fly ash

Class F Fly Ash	Class C Fly Ash
It has less than 20 percent lime	It has more than 20 percent lime
It requires cementing agents like quick lime, hydrated lime	It has self-cementing properties
It can be used in high sulphate condition	It is not to be used in high sulphate condition
It is used in high fly ash content concrete mixes	It is limited to low fly ash content concrete
It is used primarily for structural concrete	It is used primarily for residential construction

2.6.2 Environmental problem of fly ash

i. Groundwater contamination: Elements such as Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Thallium, Selenium, Molybdenum and Mercury which may be harmful are contained in coal. Fly Ash contained from combustion of coal contains enhanced concentration of these elements and its potential to cause ground water pollution is significant. In 2014, resident living near Buck steam station in Duke Ville, North Carolina were told that "coal ash pit near their homes could be leaching dangerous material into groundwater", (Fisher, 2014). Environmental Integrity Project (EIP, 2014) studied the unsafe levels of Arsenic, Cobalt, Lithium and other contaminants which were present in the groundwater near the ash dump sites. The report concluded that the fossil fuel industry in Texas has failed to comply with Federal regulation on coal ash processing and State Regulators have also failed to protect the groundwater.

ii. Ecology: Combusted coal creates an alkaline dust which has a high pH (ranging from 8 -12). This dust can be deposited on top soil thereby increasing the pH thus affecting plants and animals in the surroundings.

iii. Contaminants: Fly Ash contains trace concentration of heavy metals and other substance that are known to be detrimental to human health in sufficient quantities.

The fly ash process is shown in Figure 2.2 .the process begins with coal source and concludes with ponded ash for utilization.

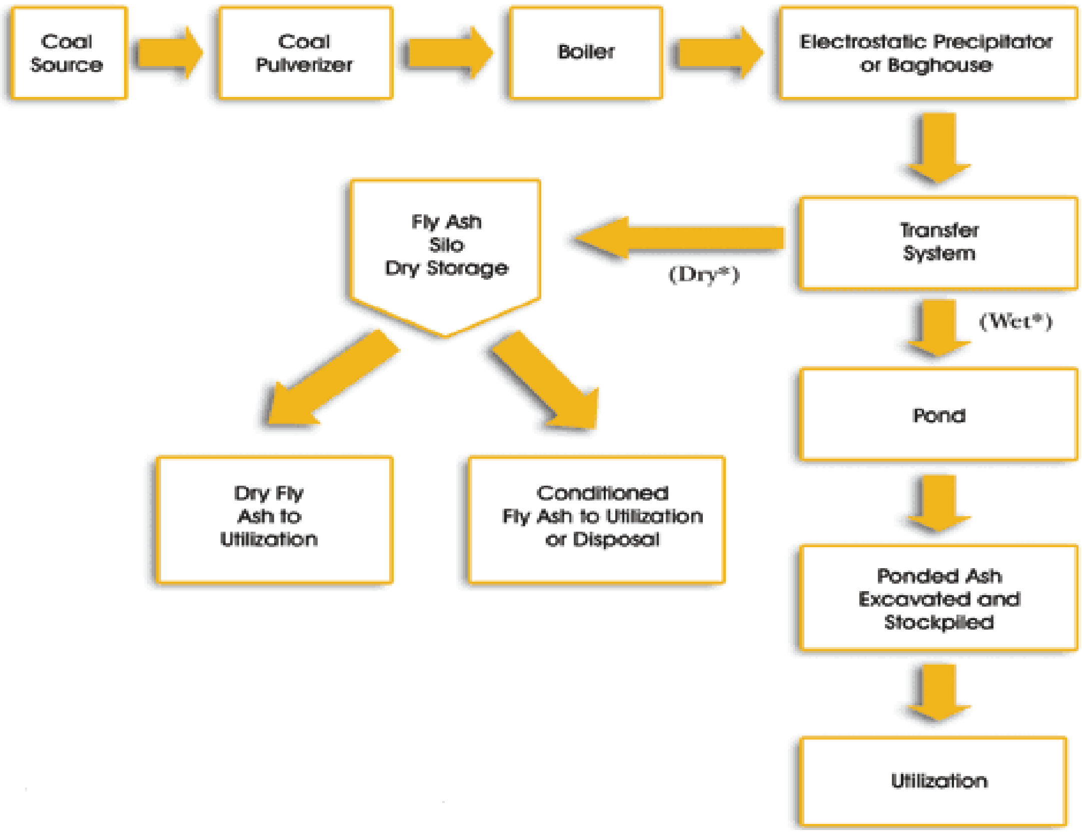

Figure 2.2: Fly ash production process

(Source: https://www.fhwa.dot.gov/pavement/recycling/fach01.cfm)

2.6.3 Fly ash utilization

The utilization of fly ash is of great essence. Some of applications are in

a) **Agriculture:** Alkaline fly ash (fly ash produced mostly in Indian) improves soil quality. Addition of fly ash to fertilizers increases the yield in terms of grains and silage.

b) **Metallurgy:** Fly ash contains about 20 – 25 percent Alumina. One tone of fly ash with about 400kg of additives such as lime and gypsum can produce 150kg of Alumina and 1250kg of pozzolanic cement which can be used as a raw material in quality bricks making.

c) **Construction material:** Fly ash as a pozzolanic material contains a good proportion of Silica. It has a tremendous potential to be used as an alternative material. In order to maintain the rate of technological development, materials such as fly ash, fibre glass, reinforced plastics and glass, reinforced gypsum are used as construction materials. Fly ash is also used in large quantities for road works.

d) **Flowable fill:** Fly ash generally supplements the Portland cement in greater volume. The fine nature of fly ash acts as a ball bearing allowing it to flow freely. Class C fly ash is used for flowable fill.as shown in Figure 2.3

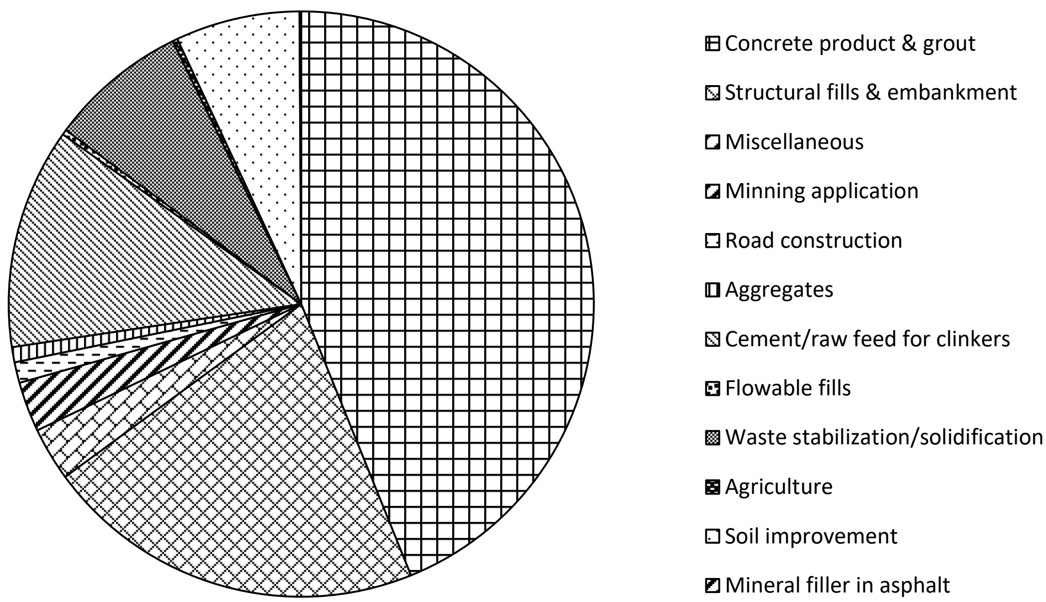

Figure 2.3: Chart showing vaious applications of fly ash

(Source:www.sciencedirect.com)

2.6.4 Disposal of fly ash

Fly Ash produced from a coal plant is either stored, recycled or disposed. More than 65 percent of fly ash produced in the world is disposed of in landfills or ash ponds. Modes of fly ash disposal are

i. Dry fly ash disposal: Fly ash is collected in Electrostatic Precipitator is transported to fly ash bunkers using pressurized air and then get transported through trucks or conveyors at the site and disposed by constructing a dry embankment.
ii. Wet fly ash disposal: Fly ash is collected in Electrostatic Precipitator is mixed with water to form slurry which is transported through pipe to the ash ponds or dumping areas near the plants.

2.6.5 Environmental considerations of fly ash disposal

Fly ash disposal in terms of environmental aspect aims at minimizing air and water pollution. Fly ash produced by thermal power plant can cause air, surface water and groundwater pollution.

a. Air pollution: This is caused by direct emission of toxic gases from the power plants and also wind-blown ash dust from ash mounds or ponds.
b. Surface water pollution: Wet system of disposal in most power plants causes discharge of particles of ash directly into the nearby surface water system.
c. Groundwater pollution: The long storage of ash in pond can cause leaching of toxic metal from ash which can contaminate the underlying soil and ultimately the groundwater system as shown in Figure 2.4

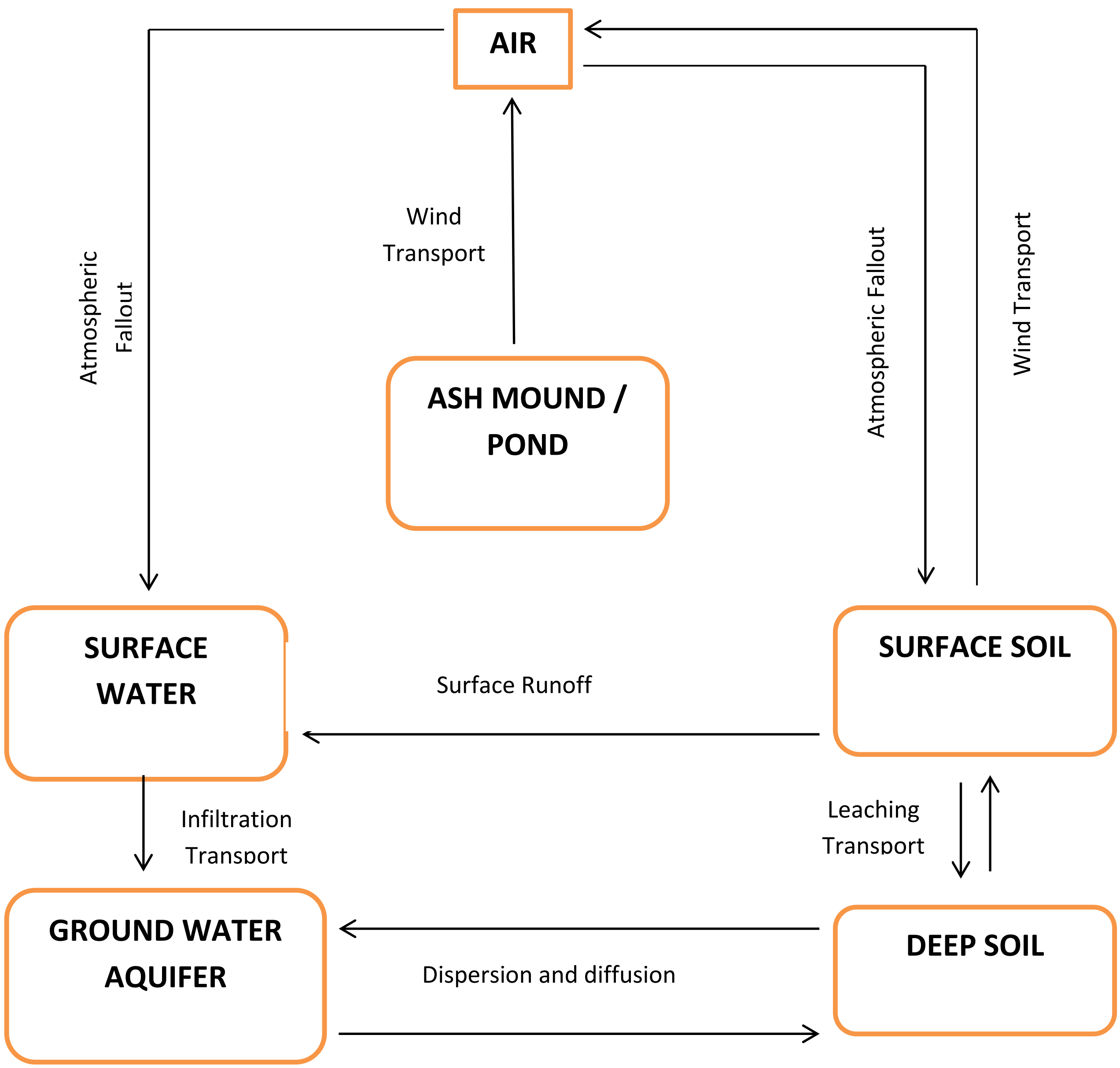

Figure 2.4: Schematically pathways of pollutant movement around fly ash disposal

(Source:www.researchgate.net)

2.7 Pozzolanas

ASTM C618-78 describes pozzolana as siliceous or siliceous and aluminous materials which in themselves possesses little or no cementitious value but, will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form cementitious compounds possessing cementitious properties.

A pozzolana is broadly defined as an amorphous or glassy silicon or aluminosilicate material that react with calcium hydroxide formed during the hydration of Portland cement in concrete to create additional cementitious material in the form of calcium silicate and calcium silicoaluminate hydrates.pozzolanas contain high percentages of silica. Other necessary oxides for a reactive pozzolanas are alumina and iron oxides. The in-situ is expected to be in amorphous state, which is more reactive than the crystalline silica. (Mohamedbhai and Baguant, 1990). The ASTM C618 – 78 specifications for pozzolanas is given in Table 2.4

An essential physical property of a cementing material that affects its affinity for water is its fitness. The activity of pozzolanas are increased by fine grinding ASTM C618-78 specification requires that the percentage passing sieve No. 200 ≥ 85%.

2.7.1 Use of pozzolanas in soil stabilization

To minimize the high cost of soil improvement when conventional additives are used, geotechnical engineers have focused on pozzolanas for use as substitute or partial replacement for the standard stabilizers. A larger amount of these materials is obtained from agricultural wastes. (Cokca, 2001)

When plant residues are burnt, organic materials which are the largest constituents are broken down and disappear as carbon dioxide, water vapour etc. The ash which remains contains mostly inorganic residue, notable silica in amorphous form which reacts with the oxides in the soil thus aiding the improvement of the soil properties. Recent research which focused on the use of rice husk ash-based promoter, a general improvement on the properties of the soil was reported. The ash has also been used as admixture along with lime and cement in stabilizing black clay soil (Osinubi *et al.*, 2009). This application will go a long way in reducing the total cost of stabilization and the potentials to use some quantities of the waste ash that have constituted an environmental problem

Table 2.4: Properties of Pozzolanas (ASTM C618-78)

Property	Class N	Class F	Class C
Chemical Properties			
$SiO_2 + Al_2O_3 + FeO_3$ (%)	70	70	50
SO_3 (Max. %)	4	5	5
MgO (Max %)	5	5	5
Loss of Ignition	10	2	6
Physical Properties			
Moisture Content (%)	3	3	3
Fineness (%) on sieve No20mm	85	85	85
Pozzolanic Activity Index with OPC at 28 days (%)	75	75	75
Pozzolanic Activity Index + lime At 7 days	5.5	5.5	5.5

(Source :ASTM C618-78)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The materials used in this research include; clayey soil, Rice husk, Fly ashes and water. Materials were carefully transported to the Civil engineering laboratory of Federal University of Technology Minna for analysis..

3.1.1 Clayey soil

The soil sample used in this research was obtained around Birgi and Lapai-Gwari villages within Minna, Niger State. The sample was collected at a depth of 1.00 - 2.00m using undisturbed sampling method. The soil sample was subjected to index properties tests before treatment with the additives.

3.1.2 Rice husk ash

The rice husk sample used in this research work was obtained from Bida, Niger State. The ash was produced by burning the husk in an enclose incinerator in an open field for two hours. The ash was then transported to the laboratory and sieved through sieve 75µm size and then stored in air-tight polythene bags.

3.1.3 Fly ash

The fly ash for this research was obtained in powdered form from a major supplier in Lokoja, Kogi State. It was a representative of typical fly ash available for construction purposes.

3.1.4 Water

The water for the study was obtained from borehole at the Federal University of Technology, Minna Civil Engineering laboratory. The water used is colourless, odourless and free from visible impurities in accordance with BS EN 1008:2002

3.2 Methods

The method adopted in this study is summerised in Figure 3.1

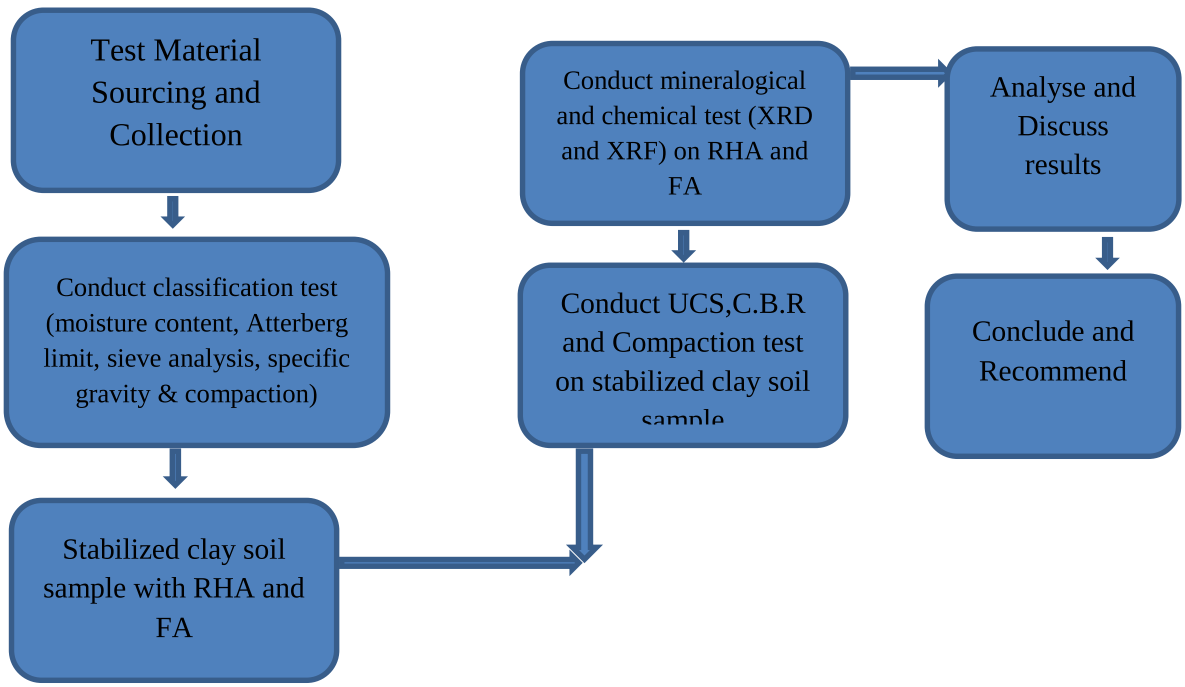

Figure 3.1: Flow Chart of the Research Method

1800g of the natural soft clay soil was weighed and added with the required mass of RHA and FA. The amount of water added was based on the value of optimum moisture content (OMC). The soil, RHA and FA in the required proportion was then mixed thoroughly and then placed in a split mould of height 80 mm and 38 mm diameter and compacted at three layers with two blows each using a 3.15 kg rammer falling freely at a height of 30cm. The sample was then removed from the mould, and the excess soil trimmed and stored in a properly labelled polythene bag. The sample for testing was prepared as per the requirement of the tests. The pulverized soil sample was first sieved through the required sieve for a particular test. The required quantum soil was weighed out for the test. The material to be added to the soil was also sieved through the required sieve, for the particular test and then the required quantum was weighed out on the weight basis as per the percentage to be added to the soil for test. The various proportions like 2:4, 4:6, 6:8, 8:10and 10:12% of rice husk ash and fly ash respectively. The soil and the material were then mixed together in dry conditions thoroughly before testing. The mixed sample was then used for performing the various tests. The laboratory analysis was carried out in accordance with British Standard methods of test for soil; While BS 1377(1990) was used for the natural soil sample, BS 1994(1990) was used for the stabilized soil samples.

Compaction characteristics of the natural soil, rice husk ash and fly ash stabilized samples were also obtained using three energy levels that is; BSL, BSH and WAS, following procedures outlined in BS 1924-2:(1990) and NGS (1997). Also, Unconfined Compressive Strength (UCS) of the natural soil ,RHA and FA samples were obtained according to procedure outlined in BS 1377 (1990) Part 7, using three energy levels that is; BSL, BSH and WAS. California Bearing Ratio (CBR) was also determined for unsoaked samples following procedures outlined in ASTM (1883) and AASHTO T193-81(1981).

The laboratory test performed on the natural soil to determine its engineering properties were in accordance with BS 1377 (1990) and BS 1924 (1990). The following tests were performed:

3.2.1 Mineralogical and chemical characterisation (Physio-chemical properties)

3.2.1.1 X-ray diffraction (xrd)

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material. X-ray is based on a constructive interference of x-rays and a crystalline sample. Analysis of X-ray power diffraction was performed at the Electron Microscope Unit, Department of Physics, Faculty of Natural Sciences, Ahmadu Bello University, Zaria. To determine the oxide and metallic composition of the rice husk ash and fly ash used..

The X-ray power diffraction patterns were obtained using a Scintag Theta-Theta X-ray Diffractometer which is used to analyse powders, bulk samples, polymers, polycrystalline thin films. Additional information that can be obtained through X-ray diffraction includes crystalline size, percentage crystallinity, quantification of phases in a sample and lattice parameter determination. The machine has an automated interface with a computer. The samples were automatically run after which the diffractogram with the corresponding date of intensity versus 2ϴ was displaced on the computer monitor. Minerals present were identified by comparison with established pattern and data available in the Mineral Power Diffraction File Data Book, (ICDD, 2001).

3.2.1.2 X-ray fluorescence (xrf)

X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by being bombarded with high-energy X-rays or gamma-rays. The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry, forensic science, archaeology and art objects. the XRF was carried out at the Electron Microscope Unit, Department of Physics, Faculty of Natural Sciences, Ahmadu Bello University, Zaria. To determine the oxide and metallic composition of the rice husk and fly ashes..

3.2.2 Soil identification test

The following test were carried out to identify the class of clayey soil sample used which includes:Particle size distribution, natural moisture contents, specific gravity,Atterberg limit,liquid limit,Plastic limit and plasticity index.

3.2.2.1 Particle size distribution

This test was carried out to determine the particle size distribution of the soil sample in accordance with BS 1377-2:1990. A representative sample of mass 300g was used for this test. This test was carried out using set of sieves. The sieves were cleaned and arranged orderly from sieve 5mm at the top and sieve 0.075mm at the bottom just before the collection pan. Dry weight of the sample was recorded before pouring it into the sieve assemblage. The mechanical shaker was turned on for 10 minutes. Thereafter, weight retained in each sieve and the collection pan was obtained.

Apparatus: apparatus used in particle size distribution are Set of test sieves, weighting Balance, mechanical sieve shaker and oven.

Procedure:

A representative sample of 300g that was air-dried was taken and sieve washed, the sample was placed in the oven to dry. Set of test sieves were prepared and arranged in order, with size 5mm the top, and sieve 0.075mm at the bottom. A receiver pan was placed under all of the sieves to collect samples, the weight of all the sieves and the pan were measured separately. The prepared sample was poured into top of the set of sieves. The stack in the mechanical shaker were properly fixed, the timer was set between 10 and 15 minutes before switching on the shaker. As the shaker stopped, masses of each sieve and retained soil/material was taken.

Mass of soil retained = (Weight of sieve + sample) – Weight of sieve

% retained = Mass of soil retained ÷ Total mass of soil x 100

% finer = 100 – Cumulative % retained

Finally, the percentage passing was plotted against B.S. sieve sizes using logarithmic graph.

See the result of the particle size distribution analysis is presented in Appendix A.

3.2.2.2 Determination of specific gravity test

The determination of specific gravity was carried out according to BS 1377 (1990) test (B) for fine–grained soils. It is the ratio between the unit masses of soil particles and water. Determination of the volume of a mass of dry soil particles is obtained by pacing the soil particles in a glass density bottle filled completely with the desired distilled water. The density bottle and the stopper were weighed to the nearest 0.001g (m_1). The air-dried soil was transferred into the density bottle, and the bottle, content and the cover were weighed as m_2. Water was then added just enough to cover the soil; the solution is gently stirred to remove any air bubble. The bottle was then filled up and covered. The covered bottle was then wiped dry and the whole weighed to the nearest 0.001g (as m_3). The bottle was subsequently emptied and filled completely with water, wiped dry and weighed to the nearest 0.001g (m4). The specific gravity is calculated using the equation below:

$$Gs = \frac{M_2 - M_1}{[M_4 - M_1] - (M_3 - M_1)} \tag{3.1}$$

Where,

Gs = Specific gravity

M_1 = Weight of density bottle (g)

M_2 = Weight of density bottle plus dry soil (g)

M_3 = Weight of bottle, soil and water (g)

M_4= weight of bottle and water (g)

The results of specific gravity is presented in Appendix B

3.2.2.3 Atterberg limit

The test includes the determination of the liquid limits, plastic limits and the plasticity index for the natural soil. The tests were conducted in accordance with Test 1(A) BS 1377 (1990) Part 2 for the natural soil and the results presented in Appendix C.

3.2.2.4 Liquid limit

Test 1(A) B.S 1377 (1990) describes the procedure for the determination of liquid limit test of a soil which was used for this work. The liquid limit is the water content at which the soil changes from the liquid state to the plastic state. It is expressed in terms of water content as a percentage. It is essentially a measure of a constant value of a lower strength limit of viscous shearing resistance as the soil approaches the liquid state. At the liquid limit, the clay is practically like a liquid but possess a small shearing strength. The method used for the liquid limit will be cone penetrometer.

About 200g of the soil sample passing through sieve 425μm was air-dried, placed on a smooth mixing disc and then mixed with water to form a uniform paste. The wet soil paste was then transferred to the cylindrical cup of the cone penetrometer apparatus, ensuring that no air is trapped in the process. The wet soil was then leveled up to the top of the cup, striking over excess soil with the side of the spatula to give a smooth surface and then placed on the base of the cone penetrometer apparatus. The penetrometer was adjusted that the cone point just touches the surface of the soil paste in the cup and the pointer adjusted to zero. The vertical clamp was then released allowing the cone to penetrate the soil paste under its own weight for about 5 seconds and the penetration of the cone taken to the nearest millimeter. The test was repeated to have four sets of values of penetration.

3.2.2.5 Plastic limit

The plastic limit of a soil is the water content of the soil below when it ceases to be plastic. It is the upper strength limit of consistency. The soil begins to crumble when rolled into threads of 3mm diameter. The proportion of the soil passing sieve 425μm which was for the determination of the liquid limit was also used for the determination of the plastic limit. About 300g of the soil was air-dried, placed on a smooth mixing disc and then mixed with water to make it plastic enough to shape into a small ball. The plastic soil was then allowed to mature for sometimes; a small portion (about 8g) was later collected and rolled with fingers on a glass plate. A thread of 3mm was then formed by rolling at a rate of about 80 to 90 strokes per minute counting one stroke when the hand moves forward and backward to the starting point. The rolling was then continued until the soil begins to crack. The pieces of the cracked soil thread were then collected into a moisture content container. The procedure was repeated twice with a fresh sample of plastic soil each time.

3.2.2.6 *Plasticity index (PI)*

The plasticity index of the soil is the difference between the liquid limits of the natural/various mixes of the soil and their corresponding plastic limits. It is the range of water content where the soil is plastic. Many engineering properties have been found to empirically correlate with the PI and it is also a useful engineering classification of fine-grained soil. Plasticity index of the samples was calculated as:

$$PI = LL - PL \tag{3.2}$$

Where,

LL=Liquid limit and

PL=Plastic limit

3.2.3 Strength test

3.2.3.1 Compaction

Compaction is the densification of soil by direct application of mechanical load with the sole aim of reducing the air voids between the soil particles. Upon compaction, compacted soil sample experiences reduction in volume. To achieve the maximum dry density (MDD), water must be applied at optimum quantity that is; Optimum Moisture Content (OMC). The soil sample was air dried and thoroughly pulverized so that it passes through BS sieve No. 4 (4.75mm). Test specimens were obtained by mixing reasonable quantity of dry soil with 2:4%, 4:6%, 6:8%, 8:10% and 10:12% RHA and FA (by dry weight of soil). Compaction characteristics of the natural soil and stabilized samples were also obtained using three energy levels that is; British Standard Light (BSL), West Africa Standard (WAS) and British Standard Heavy (BSH), following procedures outlined in BS 1377-4(1990), BS 1924-2(1990) and NGS (1997).

British standard light (BSL)

Apparatus: the apparatus used in carrying out the british standard light are 100mm diameter cylindrical compaction mould, Proctor rammer weighing 2.5 kg, No.4 Sieve, Steel straightedge, Moisture containers, Graduated cylinder, Mixer, Controlled oven, Metallic tray and a scoop.

Procedure:3000g of soil sample that passes through sieve No. 4 was used, the weight of the mould is denoted as W_1**.** Sample soil was gradually mixed with water to achieve desired moisture content (w). The thoroughly mix soil was placed in the mould in three (3) layers. 25 blows of 2.5kg rammer was applied on each layer with a free fall of 300mm. thereafter, mould collar was carefully removed and trimmed so that the soil levelled with the mould, then the weight of mould with the soil sample was taken as (W_2). Soil was extruded from the mould using a metallic extruder to determine the moisture content at the top and bottom of the sample. The soil was placed again in the mixer, water was added to achieve higher moisture content. This process was repeated for 6 times. Therefore, the dry density γ_d is obtained as;

$$\gamma_d = \frac{100\,\gamma}{100 + w} \qquad (3.3)$$

Where;

γ = weight of the compacted moist soil / volume

w = compaction moisture content

British standard heavy (BSH)

In this sphere of compaction, the mould and amount of soil used are the similar as with British Standard Light compaction except that a heavier rammer of 4.5kg falling from a height of 300mm to the soil surface was used. Also, the compacted layers for British

Standard Heavy increased to 5 while the number of blows per layer remains the same. Procedure for Calculating dry density is the same as with BSL.

West Africa standard (WAS)

West Africa Standard (WAS) was conducted following the procedure used in British Stand Light and British Standard Heavy compaction. While 25 blows were applied per layer in BSL and BSH compactions, 10 blows were used for WAS compaction. 4.5kg rammer was also used for this compaction effort, falling through a height of 300mm. Procedure for Calculating dry density is similar as with BSL and BSH

3.2.3.2 California bearing ratio (CBR)

The California Bearing Ratio (CBR) is strength test used to compare the bearing capacity of a given material with that of well graded crushed stone. CBR measures the resistance of a material to penetration of standard plunger under moisture and density conditions. CBR is primarily used for, but not limited to evaluating the strength of cohesive materials possessing 19 mm particle sizes or less, such as in subgrade and base course materials for flexible pavement. The CBR test involves application of load to a small penetration piston at a rate of 1.3mm/minutes and recording the load at 0.64mm – 7.62mm penetration. This test was done in accordance with procedures outlined in AASHTO T193-81.

Apparatus for CBR test

Loading machine-any compression machine can operate at constant rate of 1.25mm per minute can be used. Cylindrical moulds. moulds of 150mm diameter and 175mm height provided with a collar of about 50mm length and detachable perforated base. Compaction rammer, surcharge weight-annular weights each of 2.5kg and 147mm diameter. IS sieve 20mm, coarse filter paper, weighing balance.

Procedure for CBR test

Sieve the sample through 20mm IS sieve. Take 6 kg of the sample of soil specimen. Add water to the soil in the quantity such that optimum moisture content or field moisture content is reached.

Then soil and water are mixed thoroughly. Spacer disc is placed over the base plate at the bottom of mould and a coarse filter paper is placed over the spacer disc.The prepared soil water mix is divided into five. The mould is cleaned and oil is applied. Then fill one fifth of the mould with the prepared soil. That layer is compacted by giving 62 evenly distributed blows using a hammer of weight 4.5kg.

The top layer of the compacted soil is scratched. Again second layer is filled and process is repeated. After 3rd layer, collar is also attached to the mould and process is continued.After fifth layer collar is removed and excess soil is struck off. Remove base plate and invert the mould. Then it is; clamped to baseplate.

Surcharge weights of 2.5kg is placed on top surface of soil. Mould containing specimen is placed in position on the testing machine.

The penetration plunger is brought in contact with the soil and a load of 4kg (seating load) is applied so that contact between soil and plunger is established. Then dial readings are adjusted to zero. Load is applied such that penetration rate is 1.25mm per minute.

Observations during CBR test

Weight of soil taken

Weight of surcharge

Area of plunger, A

Proving Ring Calibration Factor

Result of California Bearing Ratio Test

1. California Bearing Ratio at 2.5mm penetration
2. California Bearing Ratio at 5.0mm penetration
3. California Bearing Ratio of subgrade soil

3.2.3.3 Unconfined compressive strength (UCS) `

Roy (2014) observed that unconfined compressive strength is the most common and adaptable method of evaluating the strength of stabilized soils. It is also the main test recommended for the determination of the required quantity of additive to be used in soil stabilization (Singh and Singh, 1991). Unconfined compressive strength is defined as the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test (Keshav *et. al*., 2018). Since there is no confined pressure, it is called unconfined compression test. The unconfined compressive strength (UCS) tests were performed on the stabilized soil sample according to BS 1377(1990) Part 7 using the three energy levels and the results are presented in Appendix E.

The stabilized soil was filled into a properly oiled split mould and collar of height 80mm and diameter 38mm. The samples were given 2 blows using a 3.15 kg rammer falling through height 30cm for the first layer. More samples were added into the mould and given another 2 blows for the second layer with another 2 blows for the final level after addition more sample into the mould. The mould was then untied and excess sample trimmed with a knife. The caste sample was then trimmed to a height of 76 mm before carrying moisture content test on the excess soil sample. The mass of the wet sample was also determined to calculate the bulk density of the sample. The UCS testing machine was then geared up and both the proving ring and deformation dial gauges adjusted to zero. At the elapsed day of curing, the specimen was then placed centrally on the lower platen of the UCS testing machine and a compressive force applied to the specimen. The UCS machine was then switched on and the load reading taken from the proving ring dial gauge at deformation intervals of 0.05, 0.1, 0.2, 0.3, 0.4, continuously until the sample deforms. The machine was the unloaded and the sample removed. The procedure was repeated for each varying percentage of RHA and FA. UCS of the samples were calculated using the following equation:

$$Unconfined\ Compressive\ Strength = \frac{failure\ load}{Surface\ Area\ of\ Specimen} \tag{3.4}$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Preambles

This chapter presents and discusses all the results obtained from the laboratory tests carried out in the stabilization of clayey soil using rice husk and fly ashes.

4.2 Soil Identification Test Result

Result of tests conducted on specimen of clayey soil with rice husk ash and fly ash blend stabilized samples at Federal University of Technology civil engineering laboratory are presented and discussed herein. The results of test conducted to determine the index properties of natural clayey soil for this research is presented in Table 4.1.

Result of particle size distribution and summary of index properties of the natural soil are presented in Appendix A. The natural soil has 60.0% of silt – clay material passing through sieve No. 200. It has a Liquid Limit (LL) of 42% Plastic Limit (PL) of 26.10% and Plasticity index of 15.9% therefore, this soil is classified as A-7-5 according to AASHTO classification system and as Sandy Clay (SC) according to (USCS) Unified Soil Classification System. Based on the class of this soil according AASHTO classification system, the natural soil is unsuitable for most civil and geotechnical engineering works because the plasticity index and liquid limit are above the maximum 12 and 30% values respectively recommended for subgrade according to NGS (1997). The result of the Consistency Limits is presented in Appendix C which indicates that the soil has high tendency of retaining water, resulting in high compressibility and loss of shear strength (Arora, 2011). The value of the specific gravity test result is presented in Appendix B. Results shows that the soil has a specific gravity of 2.65. According to results obtained defining the index properties of the natural soil tested is therefore, classified under A-7-5 according to AASHTO soil classification system and as Sandy Clay (SC) according to Unified Soil Classification System (USCS). This therefore implies that the natural soil is not suitable for use as construction material except stabilization is considered for this soil.

Table 4.1: Index Properties of Natural clayey Soil

Property	**Value**
% Passing BS sieve +No. 200	60.0%
Specific Gravity	2.65
Liquid Limit	42%
Plastic Limit	26.10%
Plasticity Index	15.90%
AASHTO Classification	A-7-5
USCS classification	SC
Colour	Brownish

4.3 Mineralogical and Chemical Characterisation (physio-chemical properties)

4.3.1 X-ray diffraction (xrd) for RHA and FA

The X-ray power diffraction patterns were obtained using a Scintag Theta-Theta X-ray Diffractometer which is used to analyse powders, bulk samples, polymers, polycrystalline thin films. Additional information that can be obtained through X-ray diffraction includes crystalline size, percentage crystallinity, quantification of phases in a sample and lattice parameter determination. The machine has an automated interface with a computer. The samples were automatically run after which the diffractogram with the corresponding date of intensity versus 2ϴ was displaced on the computer monitor. Minerals present were identified by comparison with established pattern and data available in the Mineral Power Diffraction File Data Book, (ICDD, 2001).

Previous research mostly worked on amorphous RHA since the ash in amorphous form has higher pozzolanic reactivity. But to obtain RHA in amorphous form, the rice husk need to thermally treated in controlled combustion in temperature ranging from 500º to 700ºC for the best pozzolanic reactivity (Ramezanianpour *et al*., 2009), which consequently will increase the production cost. In this research an attempt was made to use the original rice husk obtained from Bida, Niger State. Rice Husk Ash was produced by burning rice husk in an enclose incinerator in an open field for two hours. The ash was then transported to the laboratory and sieved through sieve 75µm size and then stored in air-tight polythene bags. while the fly ash was processed in powdered form from a major supplier in Lokoja, Kogi State. It is a representative of typical geopolymer available for construction purposes. Figure 4.1 shows the diffraction graph for RHA and its chemical properties presented in Plate I

From the diffraction graph crystalline phase was detected by the sharp peaks that occurred in the 28 and 21º of 2 theta scale, another low peaks also detected at 36, 40, 42 , 44.5, 47 , 57.5, 67º of 2 theta scale. While that of Figure 4.2 and Plate II crystalline phase was detected by the sharp peaks that occurred in the 28, 24 and 21º of 2 theta scale , with the low peaks at 36, 42, 46 , 50, 58 , 61 and 69º

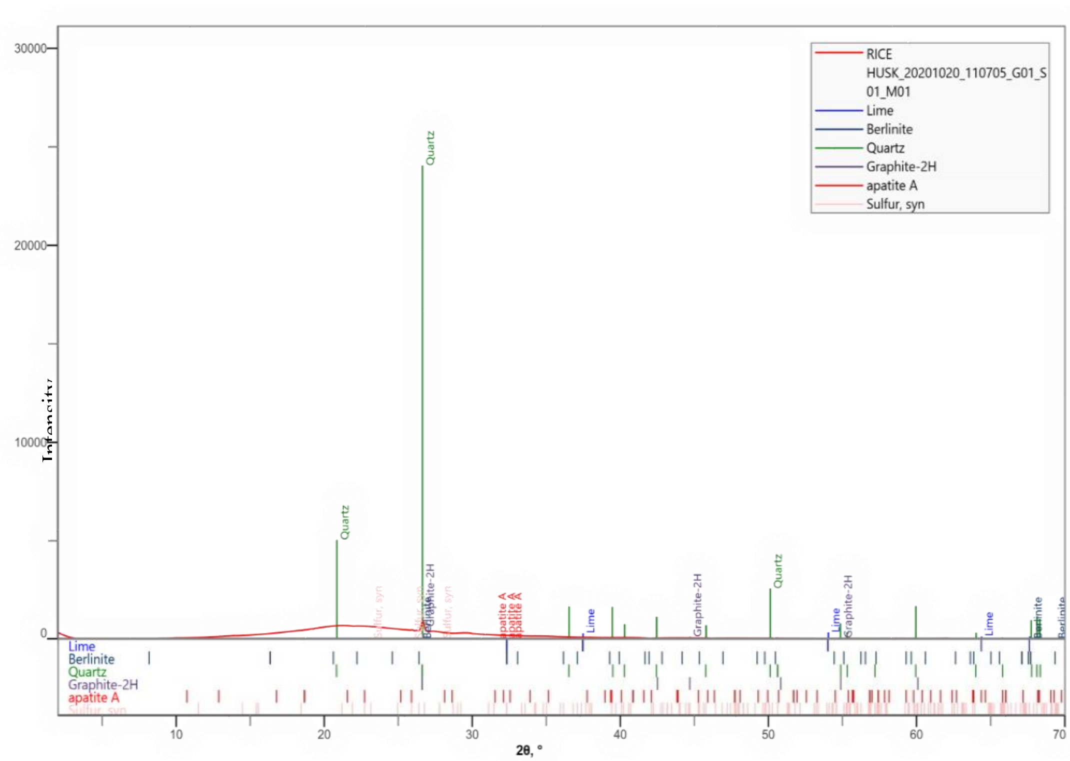

Figure 4.1: XRD image of RHA

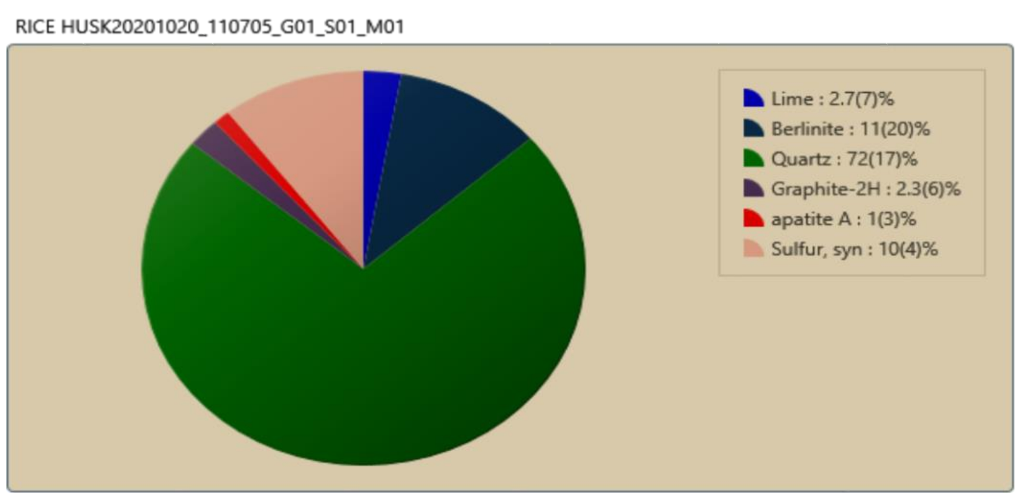

Plate I: XRD image of RHA

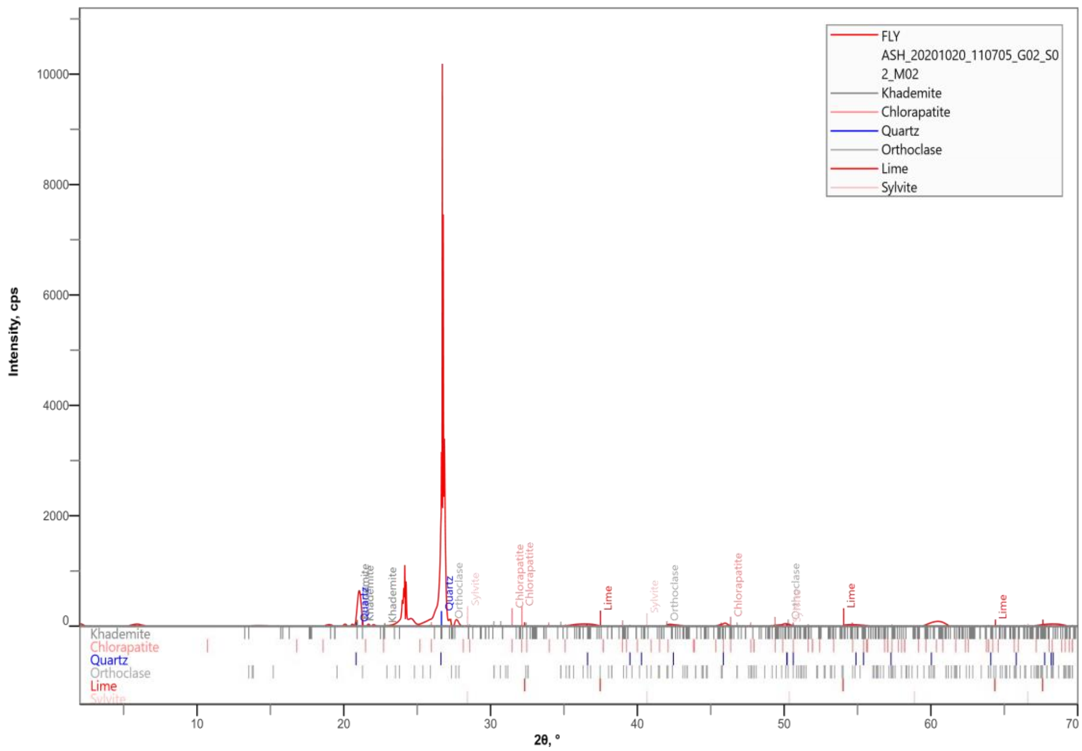

Figure 4.2: XRD image of FA

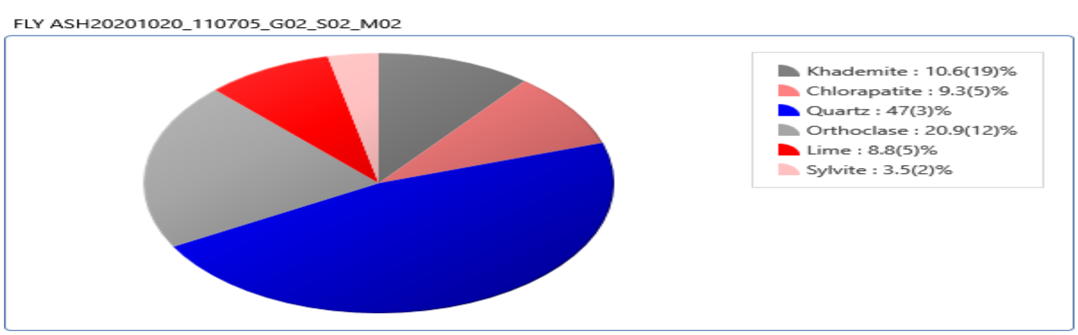

Plate II: XRD image of FA

4.3.2 X-ray fluorescence analysis (xrf)

XRF is an analytical technique employed to determined various chemical oxides composition of RHA and FA where the material re-emitted the x-ray in lower energy after itself been bombarded with higher energy X-ray. Figure 4.3 and 4.4 reveals the X-ray fluorescence oxide composition of the RHA and FA that was used in this research work.

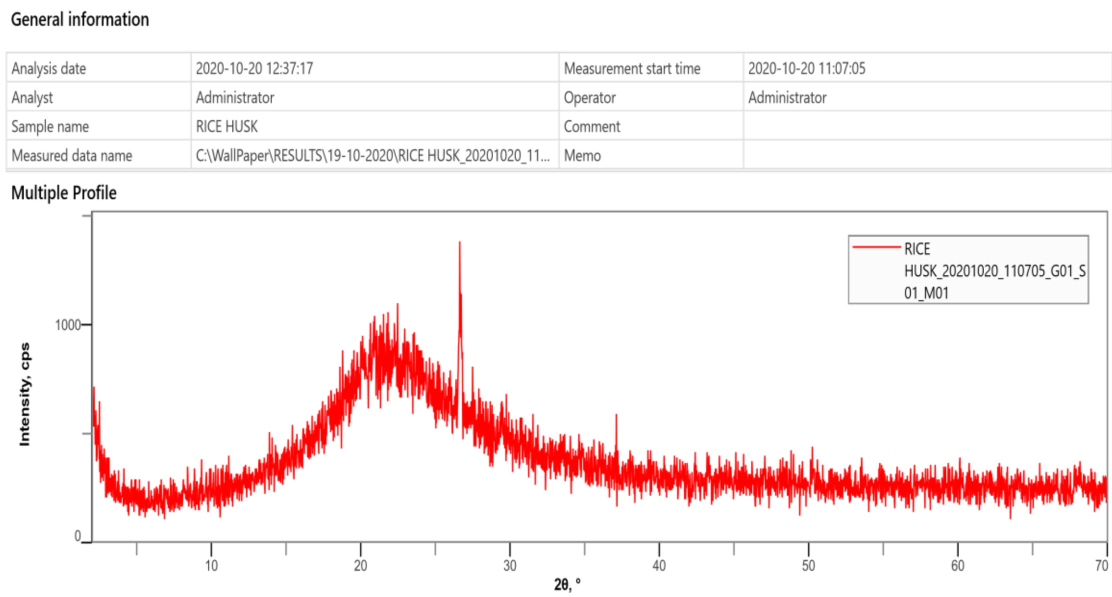

Figure 4.3: XRF image on RHA

General information

Analysis date	2020-10-20 13:21:33	Measurement start time	2020-10-20 11:14:20
Analyst	Administrator	Operator	Administrator
Sample name	FLY ASH	Comment	
Measured data name	C:\WallPaper\RESULTS\19-10-2020\FLY ASH_20201020_1107...	Memo	

Multiple Profile

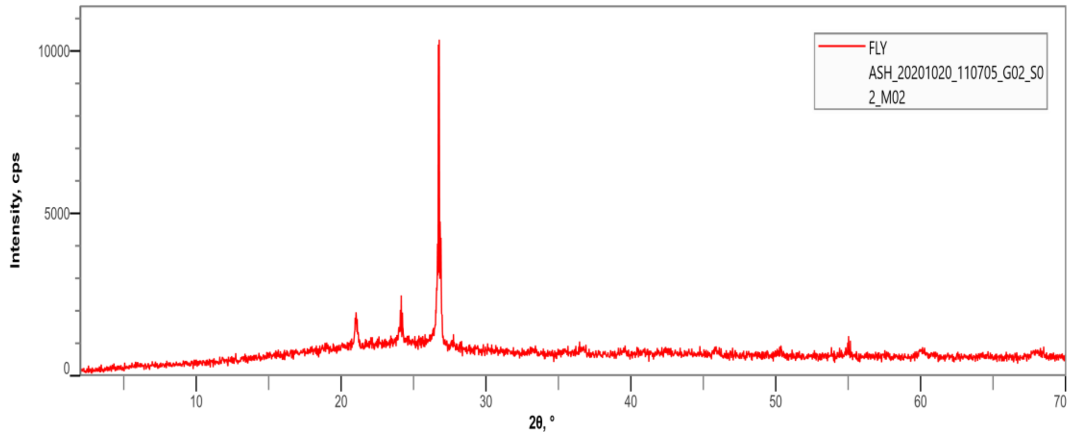

Figure 4.4: XRF image on Fly ash

According to ASTM C 618, pozzolan is siliceous and aluminous material which in them possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (Mehta, 1979). this RHA can be categorized as pozzolanic material based on the XRF result and classification of ASTM C 618-92a (Awal, *et al*., 1997). the fly ash used in this research work can be classified as type F according to ASTM.C 618-78.

4.4 Strength Test Result

4.4.1 Compaction

The Compaction test result is presented in Appendix D. compaction test on the natural soil was carried out using British Standard Light, West Africa Standard and British Standard Heavy. the maximum dry density changes with the addition of rice husk ash and fly ash for British light, British Heavy and West Africa Standard compaction. It can be observed that the MDD value for British Light compaction reduced from 1.900 for the natural soil to 1.850 g/cm³, then decreased to 1.740 and 1.49 g/cm³ before the value increased to 2.02 and 1.83 g/cm³ for proportion of (8:10) and (10:12) % of rice husk ash and fly ash content respectively. British Heavy compaction and West African Standard Compaction shows an initial decline of the MDD value at (4:6) % addition of rice husk ash and fly ash. The MDD then progressively increased from 1.850 - 2.010 g/cm³ at (2:4) % of rice husk ash and fly ash respectively. Unlike British Light, the MDD increased slightly from 1.900 - 2.020 g/cm³ at (8:10) %. These results indicate that the values of MDD increases with increasing energy level. British standard heavy gave the best performance of 2.010 g/cm³ at (2:4) % addition of rice husk ash and fly ash.

According to O'Flaherty (1988), the maximum dry density anticipated for silty clay soil using proctor test ranges between 1.60 and 1.845g/cm³ and Optimum moisture content between 15 – 25%. He estimated the maximum dry density of sandy clay soils between 1.75 and 2.165g/cm³, having OMC values between 5 and 18%. Result of particle size distribution of the natural soil is presented in Appendix A. The result shows that 60.0% of the test specimen passes through BS sieve No. 200, slightly higher than 35% as recommended in NGS (1997).

4.4.1.1 Effect of R.H.A and F.A.on compaction

Figure 4.5 shows the maximum dry density changes with the addition of rice husk ash and fly ash for British light, British Heavy and West Africa Standard compaction. It can be observed that the MDD value for British Light compaction reduced from 1.900 for the natural soil to 1.850 g/cm³, then decreased to 1.740 and 1.49 g/cm³ before the value increased to 2.02 and 1.83 g/cm³ for proportion of (8:10) and (10:12) % of rice husk ash and fly ash content respectively. British Heavy compaction and West African Standard Compaction shows an initial decline of the MDD value at (4:6) % addition of rice husk ash and fly ash. The MDD then progressively increased from 1.850 - 2.010 g/cm³ at (2:4) % of rice husk ash and fly ash respectively. Unlike British Light, the MDD increased slightly from 1.900 - 2.020 g/cm³ at (8:10) %. These results indicate that the values of MDD increases with increasing energy level. British standard heavy gave the best performance of 2.010 g/cm³ at (2:4) % addition of rice husk ash and fly ash.

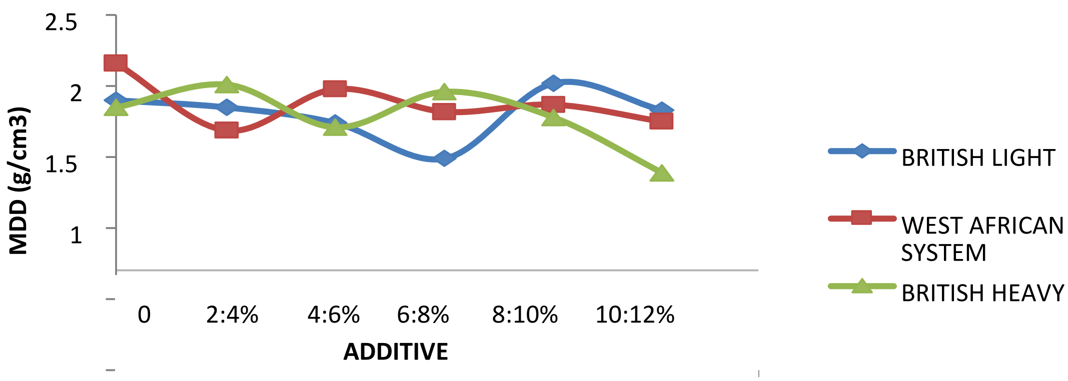

Figure 4.5: MDD variation with %RHA and %FA

4.4.1.2 Optimum moisture Content

The optimum water content (OMC) of natural soil and specimens containing various percentages of rice husk ash and fly ash are presented in Figure 4.6 The result shows that upon addition of rice husk ash and fly ash for British Standard Heavy and West African System energy level, the OMC value initially increased from 15.20 and 10.20% for natural soil to 18.10 and 15.4% respectively. Thereafter, the values reduce to a minimum of 13.5% and 13.1% at 4:6% of rice husk ash and fly ash. British Standard Light effort experienced reduction in OMC of the natural soil which is 17.20 to a minimum value of 20.90% at 8:10% of rice husk ash and fly ash. This result indicates that a MDD of 2.010 g/cm³ can easily be attained at 13.50% OMC for pavement subgrade.

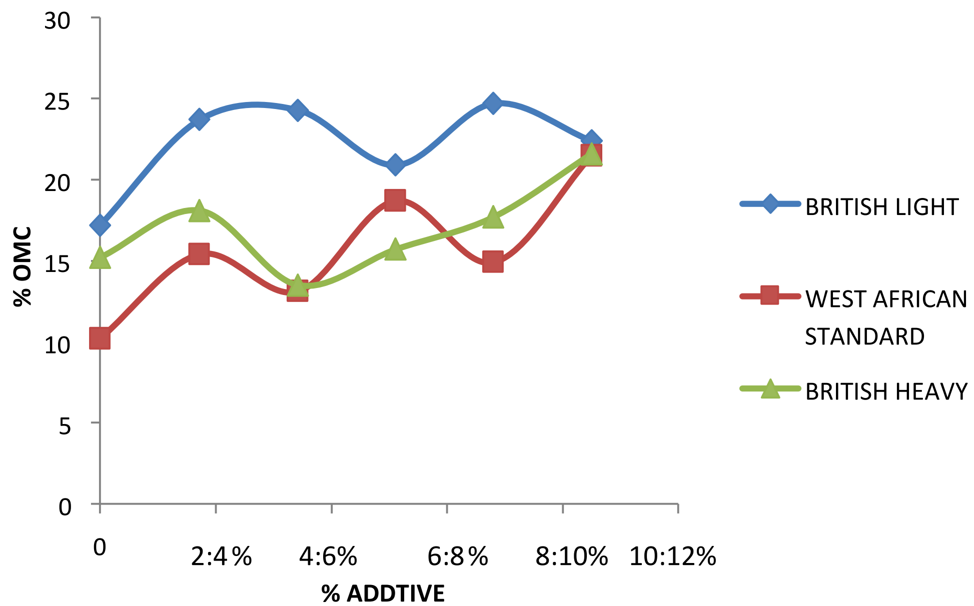

Figure 4.6: Variation of OMC with % rice husk ash and fly ash addition

4.4.2 California bearing ratio

The C.B.R values from the test result as shown in Appendix F and Figure 4.7 depicts that for the three compactive efforts like the British Heavy standard, British Light standard and West African standard the C.B.R values increased with the percentage addition of RHA and FA.. The California bearing ratio of the soil specimen was optimally increased by 256% (from 33 to 117.6 kN) at 2:4% mix proportion. This gives an optimal value as 117.6 kN when the British Heavy Standard compaction method was used at 2:4% addition of Rice husk ash and Fly ash.

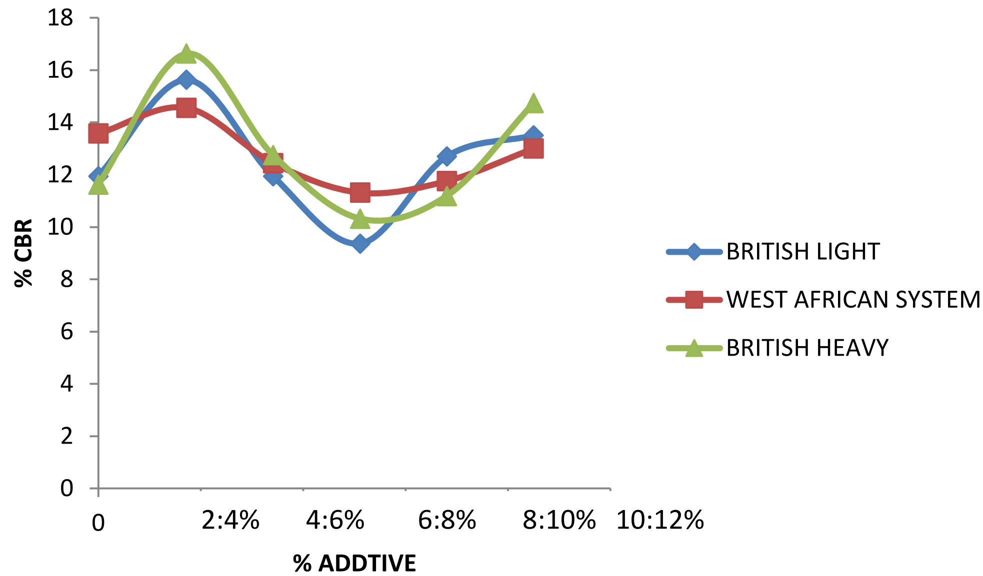

Figure 4.7: C.B.R value with %RHA and %FA

4.4.3 Unconfined compressive strength result

The unconfined compressive strength results of the natural clayey soil and specimens containing various percentages of rice husk and fly ashes are presented in Appendix E and Figure 4.8 to Figure 4.10. The result indicates that upon the addition of rice husk ash and fly ash for British Standard Heavy energy level, the UCS value initially increased from 297.14 to 632.84 kN/m^2 which is the optimal value at (2:4) %. Thereafter, the value decreased to 424.82 kN/m^2 at (4:6) % replacement of rice husk ash and fly ash. Other energy level such as the British Standard Light and West African Standard increase appreciably within (2:4 to 6:8)% addition of rice husk ash and fly ash .while a decrease value was observed within (8:10 and 10:12)% dosage of rice husk ash and fly ash.

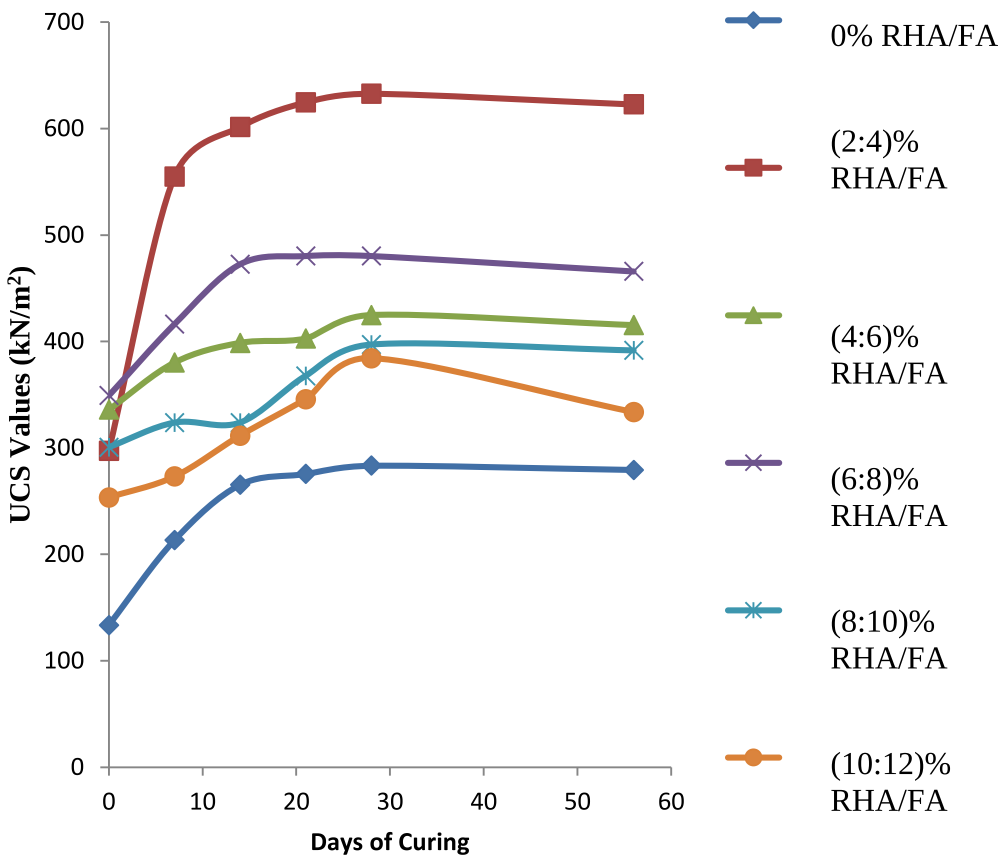

Figure 4.8: Variations of UCS values with curing days and % mix of RHA-FA composite using BSH compactive effort

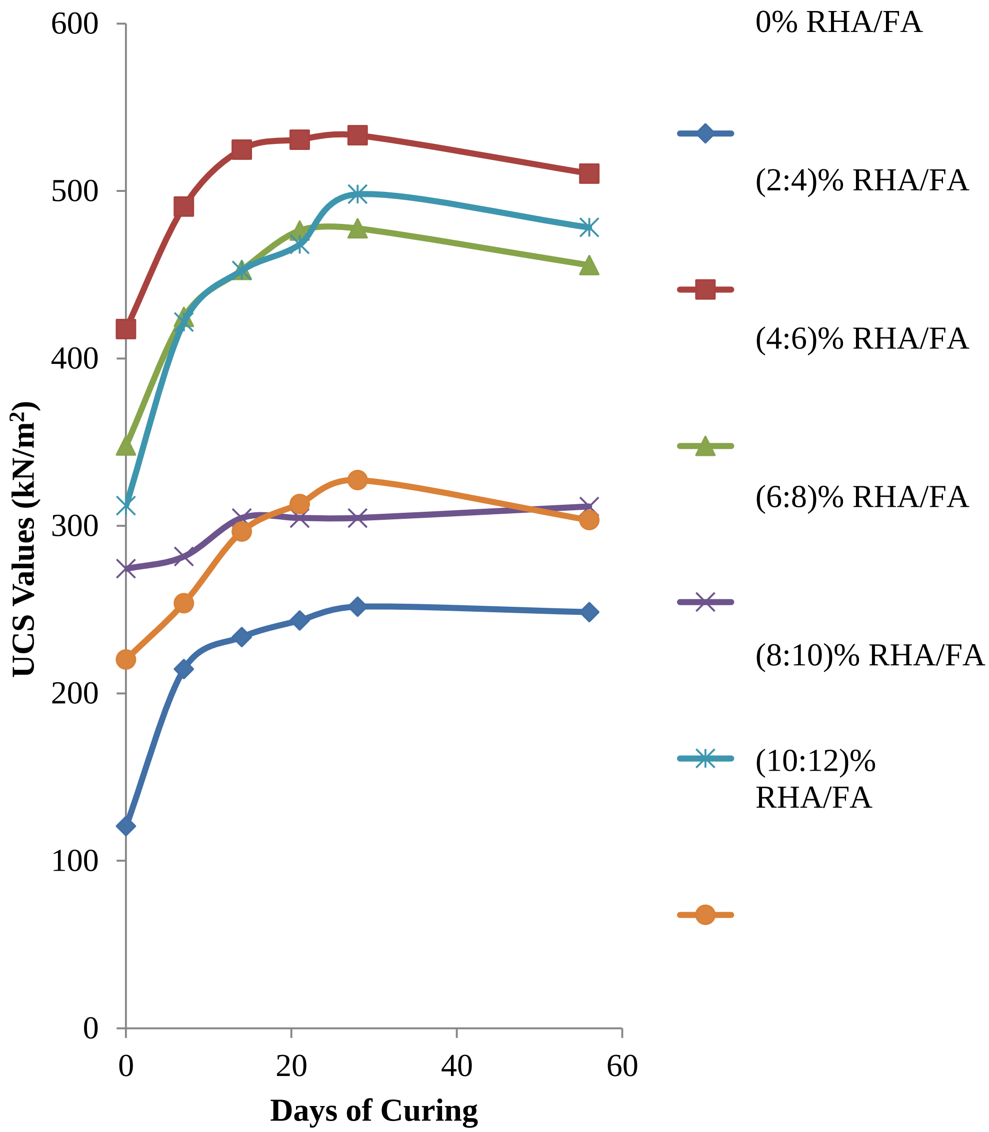

Figure 4.9: Variations of UCS values with curing days and % mix of RHA-FA composite using WAS compactive effort

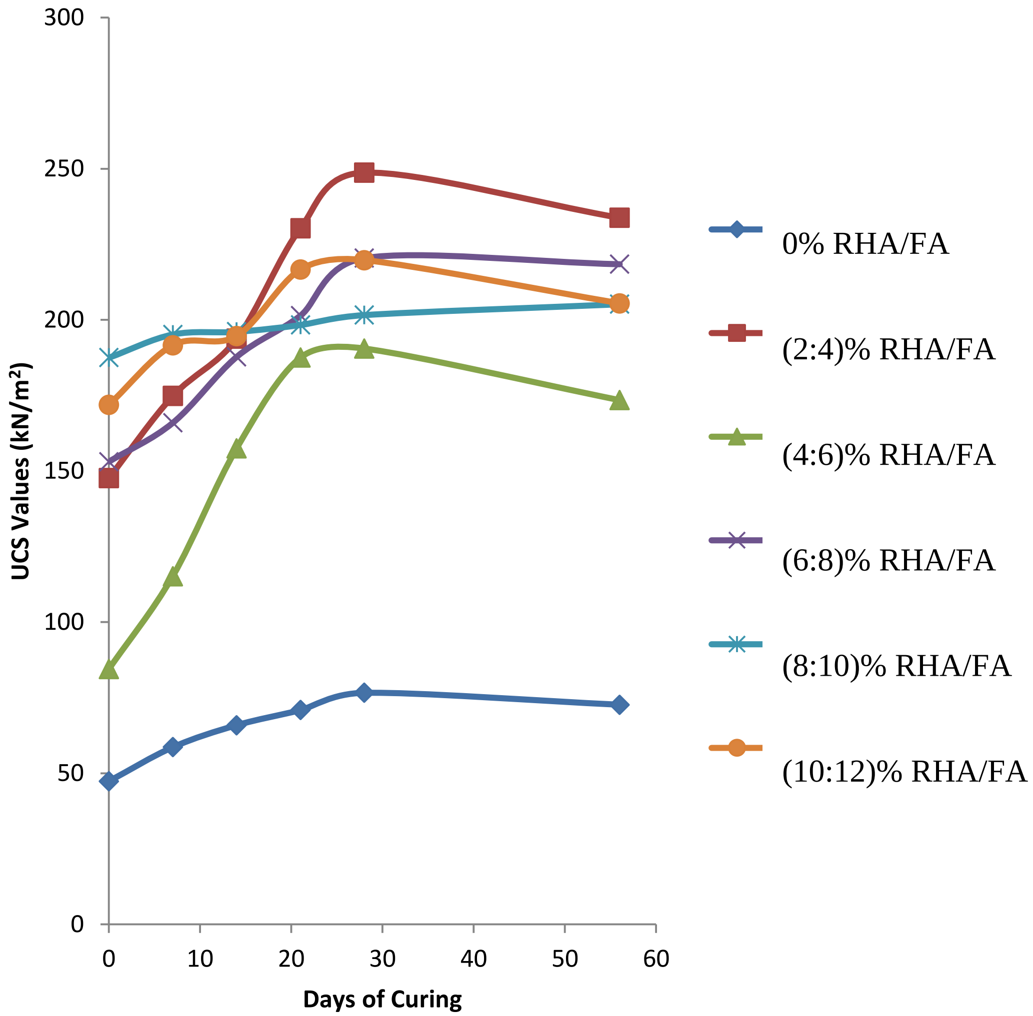

Figure 4.10: Variation of UCS values with curing days and % mix of RHA-FA composite using BSL compactive effort

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study examines the stabilization of soft clay soil with rice husk ash and fly ash blend adding up to (10:12) % respectively on the shear strength and compaction characteristics of the soil sample. Soil mixtures for compaction tests were compacted using British Standard Light (BSL), West Africa Standard (WAS) and British Standard Heavy (BSH) compactive efforts. The following conclusions were drawn from the study;

The physical and chemical properties of rice husk ash and fly ash were determined and classified as a pozzalanic material according to ASTM C618-92 (1992). The test soil is classified as A-7-5 and SC according to AASHTO and Unified Soil Classification System respectively. The Liquid Limit and Plasticity Index reduces with increasing percentage of rice husk ash and fly ash while the Plasticity Limit slightly increased with increment in rice husk ash and fly ash at 6:8, 8:10 and 10:12% respectively.

The compaction characteristics of stabilized soil with regards to the maximum dry density (MDD) with increasing energy levels increase from 1.520g/cm^3 to 1.710g/cm^3 at 2:4 additions of RHA and FA ash for the British Standard heavy compactive effort. The optimum moisture content (OMC) was reduced from 15.20% for the natural soil to 13.5% when stabilized at 4:6% for the British Standard heavy compactive effort. The results of the MDD (1.710g/cm^3) and OMC (13.5%) indicate that the optimum performance of rice husk ash and fly ash blend with A-7-5 soil at 2:4% is suitable for subgrade pavement construction using the British standard heavy compactive effort.

The strength characteristics with regards to the unconfined compressive strength (UCS) result of the soil was improved by 88% upon at 2:4% addition of rice husk ash and fly ash for British standard heavy compactive effort.The California bearing ratio of the soil specimen was optimally increased by 258% (from 33 kN to 117.6kN) at 2:4% mix proportion..

5.2 Recommendations

1. A-7-5 soil stabilized with rice husk ash and fly ash content above (10:12) % can be investigated to determine if the mixture meets the requirements for subgrade material as specified in local codes.
2. Combination of lateritic clayey soil, rice husk ash, fly ash and cementitious stabilizer can be investigated to examine if such combinations will improve the strength characteristic of the soil.

5.3 Contributiom to Knowledge

The study has established the potential of using rice husk and fly ashes to stabilize a class of clayey soil for construction purposes .with optimal values. the maximum dry density(MDD) and the optimum moisture content (OMC) ranging from 1.850 to 2.010 g/cm^3 and 15.2 to 13.5% .it also established that The strength characteristics with regards to the unconfined compressive strength (UCS) result of the soil was improved by 88% (297 to 632.kN/m^2) at 2:4% addition of rice husk ash and fly ash for British standard heavy compactive effort. The California bearing ratio of the soil specimen was optimally increased by 258% (from 33 to 118 kN which translates to loads) at 2:4% mix proportion.

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APPENDICES

Appendix A: Particle Size Analysis of Test Soil

Table A1: Particle Size Distribution Results

Sieve Designation	Percent by Weight		
	Mass. Retained	**% Retained**	**% PASSING**
5.00	10.80	3.60	96.40
3.35	11.10	3.70	92.70
2.36	12.00	4.00	88.70
2.00	7.30	2.43	86.27
1.180	22.80	7.60	78.67
0.850	8.80	2.93	75.73
0.600	15.80	5.27	70.47
0.425	10.40	3.47	67.00
0.300	8.90	2.97	64.03
0.150	10.80	3.60	60.43
0.075	1.30	0.43	60.00

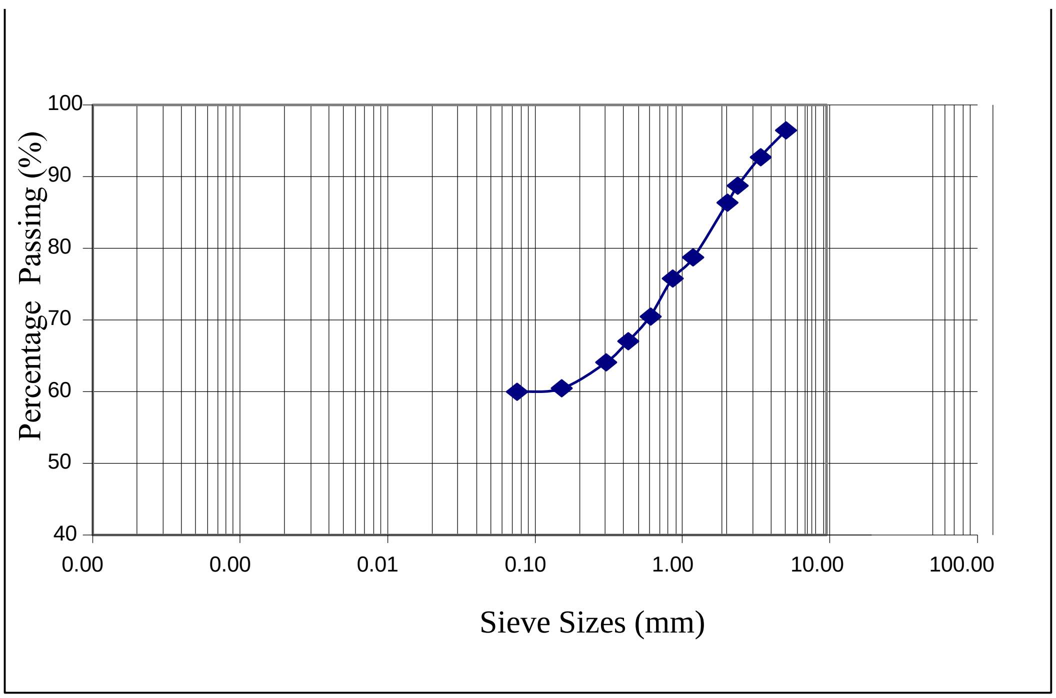

Figure A1: Particle size distribution curve of Natural Lateritic Soil

Appendix B: Specific Gravity of Test Soil

Table B1: Specific Gravity Test Results

Bottle Number	B1	B2	B3
Mass of bottle (g)	126.5	69	97.4
Mass of bottle + wet soil (g)	419.3	187.3	388.7
Mass of bottle + dry soil (g)	198.77	100.05	166.95
Mass of bottle + water (g)	374.3	168	345.3
Specific Gravity, Gs	2.65	2.64	2.66
Average Specific Gravity, Gs		2.65	

Appendix C: Consistency Limits of Natural soil

Table C1: Consistency Limit Results

LIQUID LIMIT DETERMINATION							
	LIQUID LIMIT					**PLASTIC LIMIT**	
Trial Number	1	2	3	4	5	1	2
Penetration (mm)	4.50	8.80	11.00	15.00	20.30		
Wt. of wet soil + can	29.60	30.00	31.40	30.20	36.50	26.60	26.30
Wt. of dry soil + can	28.70	28.90	29.90	28.60	33.00	26.30	25.90
Wt. of can	24.70	24.90	24.60	24.50	24.80	24.90	24.60
Wt. of dry soil	4.00	4.00	5.30	4.10	8.20	1.40	1.30
Wt. of water	0.90	1.10	1.50	1.60	3.50	0.30	0.40

Water content %	22.50	27.50	28.30	39.02	42.68	21.43	30.77
Liquid limit %	42.00		Average Plastic Limit			26.10	

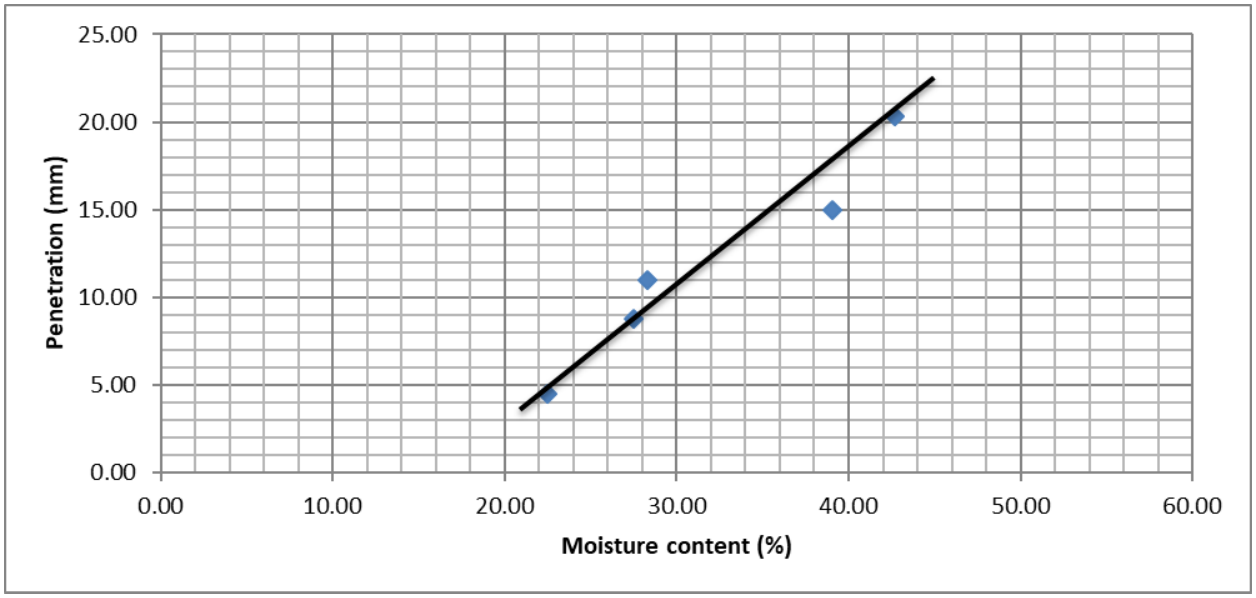

Figure C1: Liquid Limit Determination Curve

Appendix D: Compaction Test of Soil

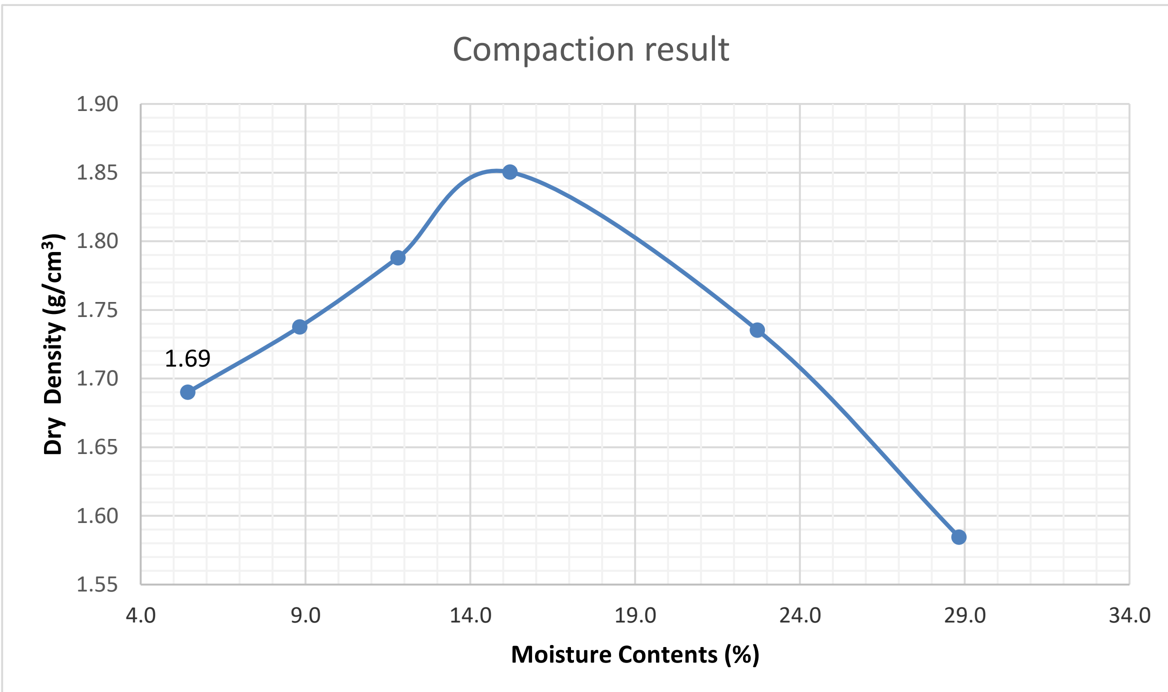

Figure D1: British Standard Heavy (BSH) for natural soil

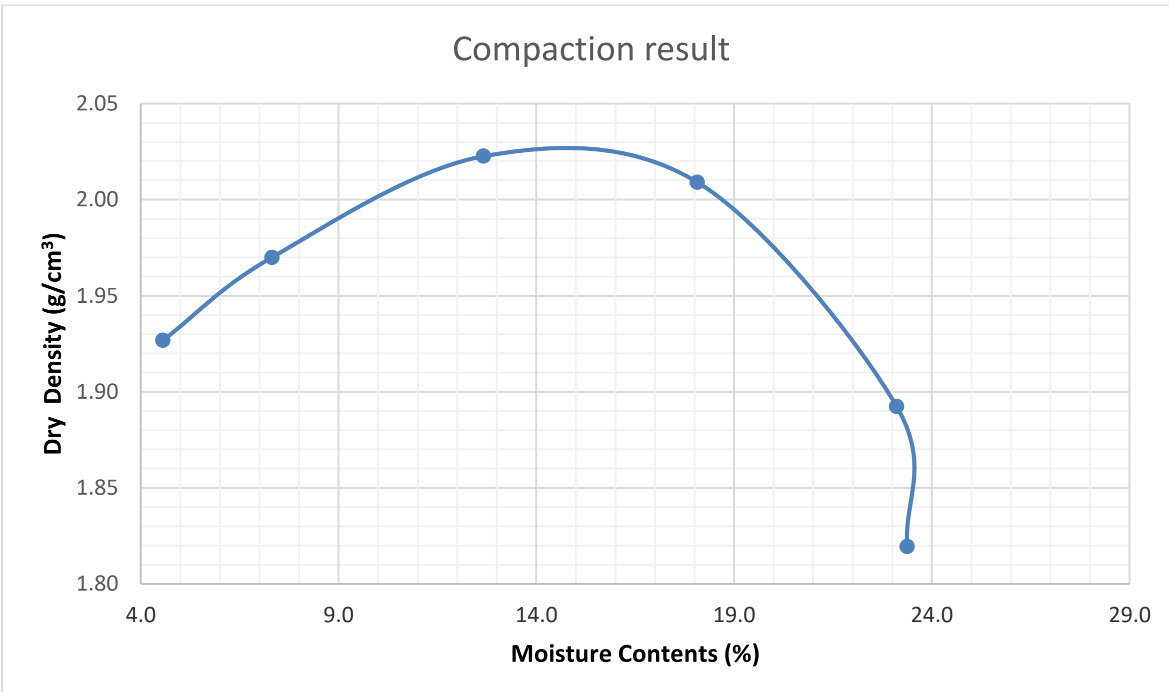

Figure D2: British Standard Heavy (BSH) at 0% RHA and FA

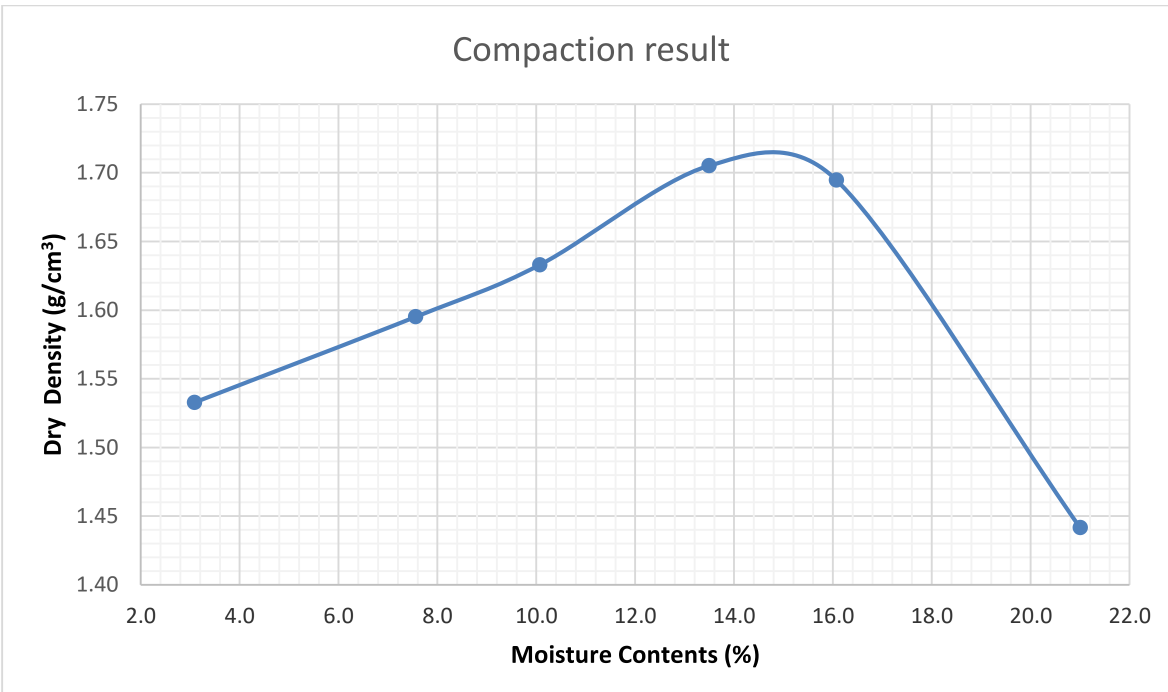

Figure D3: British Standard Heavy (BSH) at (2:4) % RHA and FA

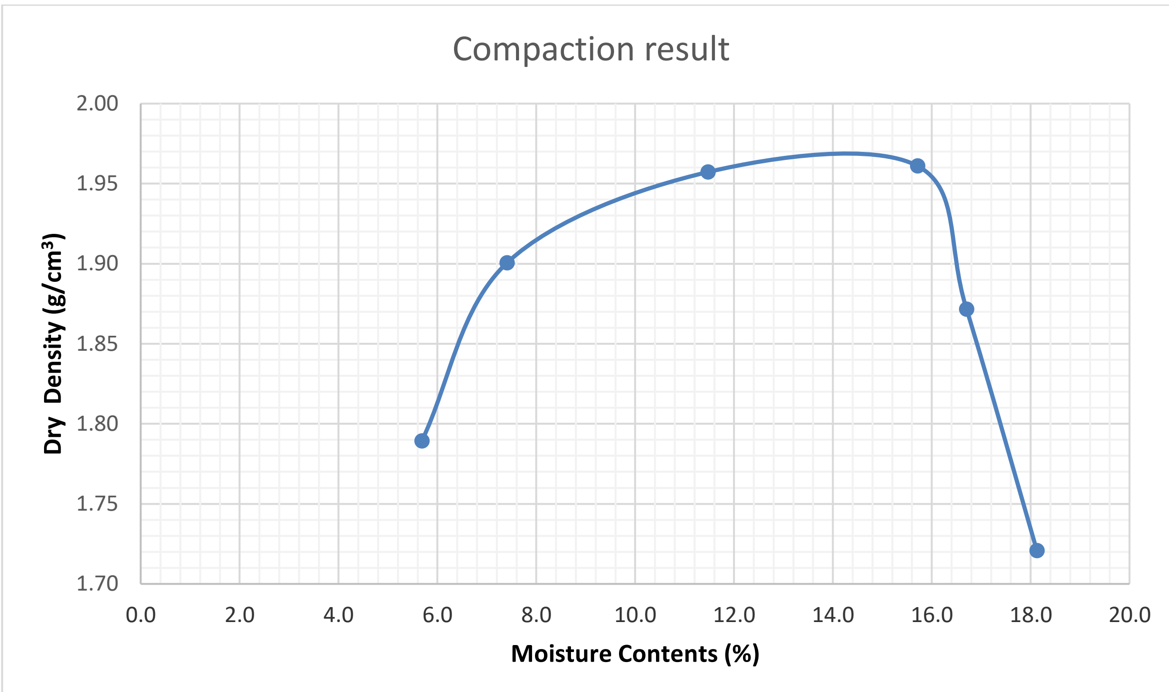

Figure D4: British Standard Heavy (BSH) at (4:6) % RHA and FA

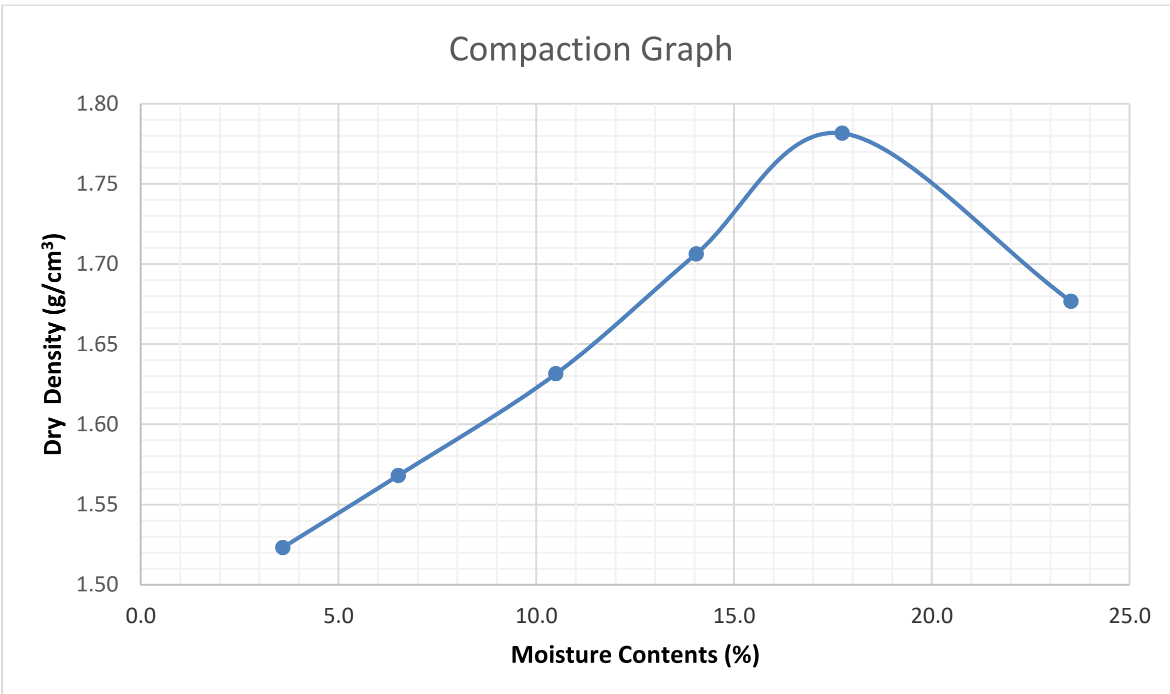

Figure D5: British Standard Heavy (BSH) at (6:8) % RHA and FA

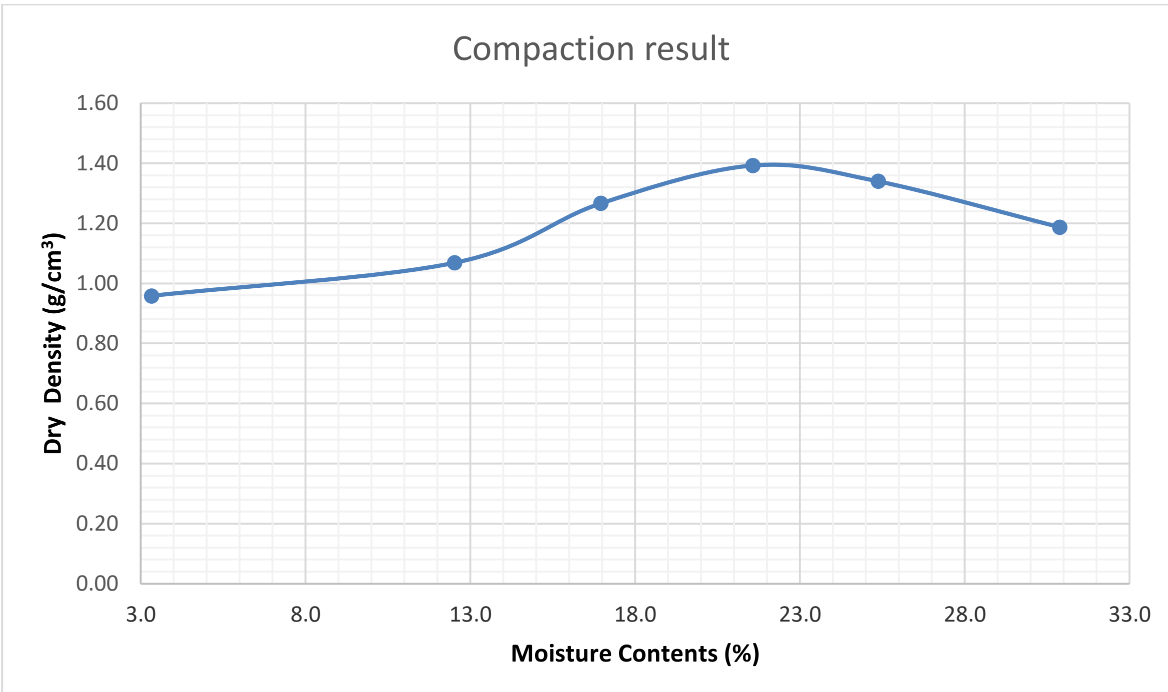

Figure D6: British Standard Heavy (BSH) at (8:10) % RHA and FA

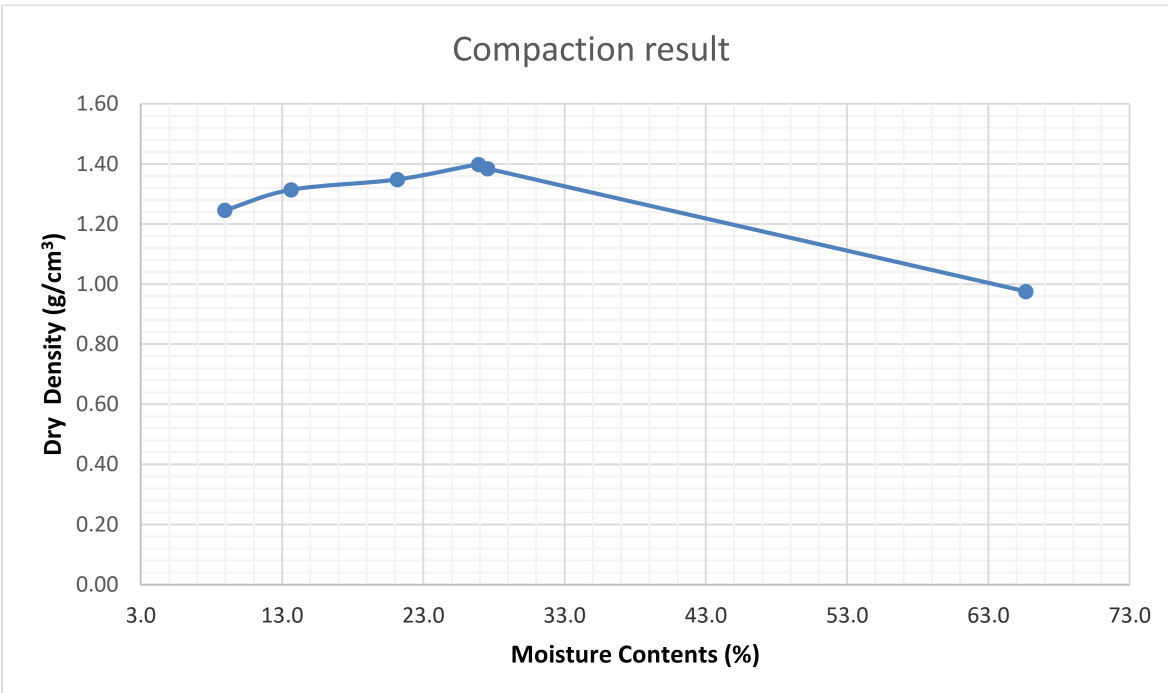

Figure D7: British Standard Heavy (BSH) at (10:12) % RHA and FA.

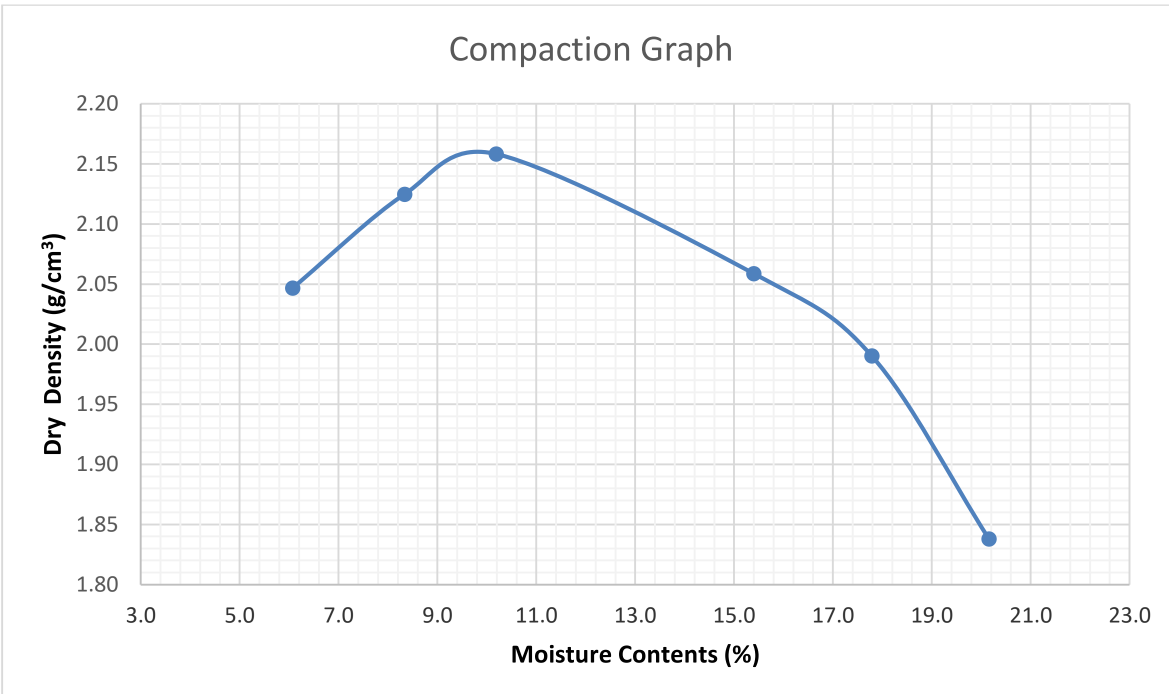

Figure D8: West African Standard (WAS) at (0)% RHA and FA.

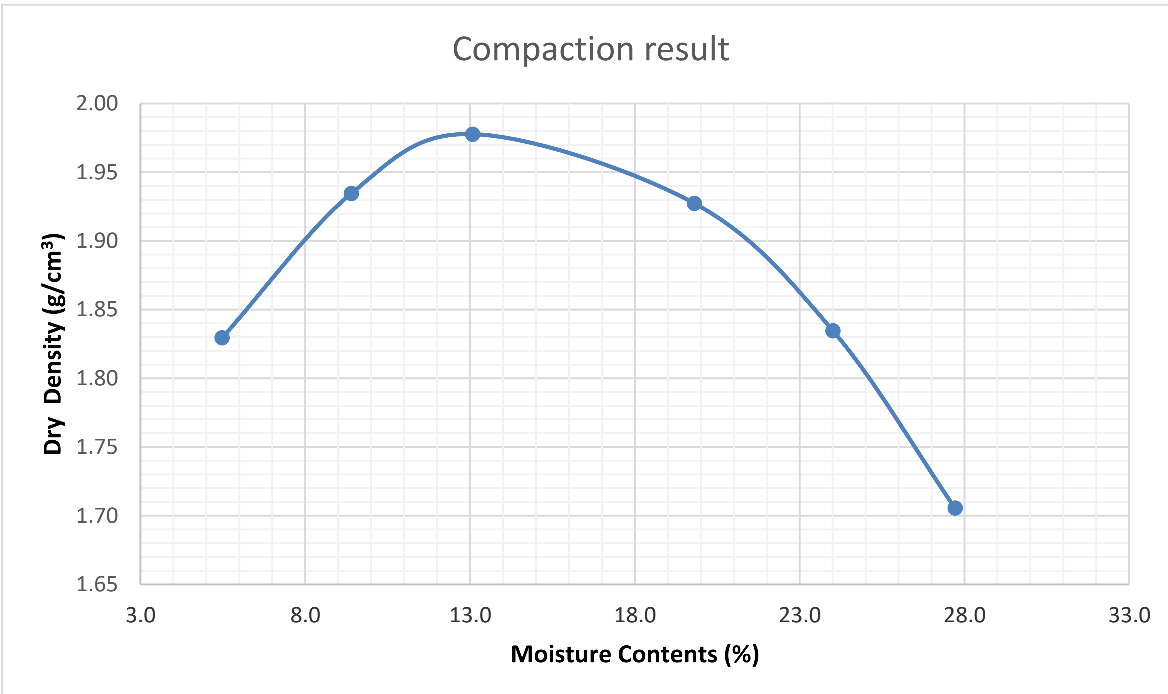

Figure D9: West African Standard (WAS) at (2:4)% RHA and FA

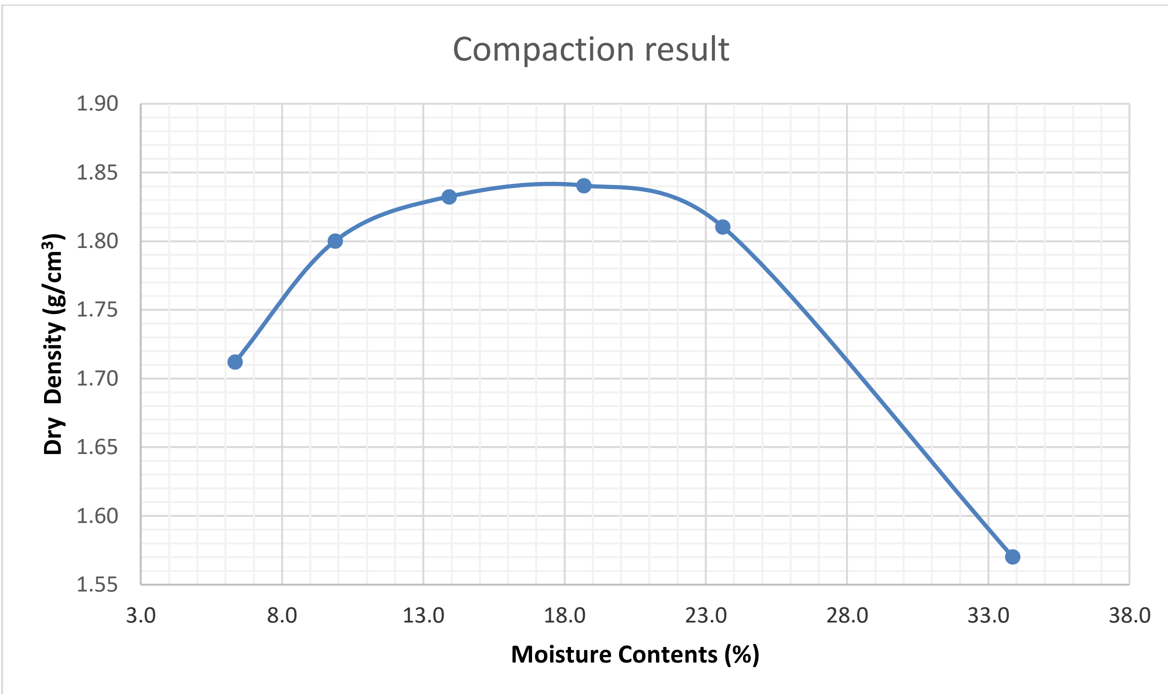

Figure D10: West African Standard (WAS) at (4:6)% RHA and FA

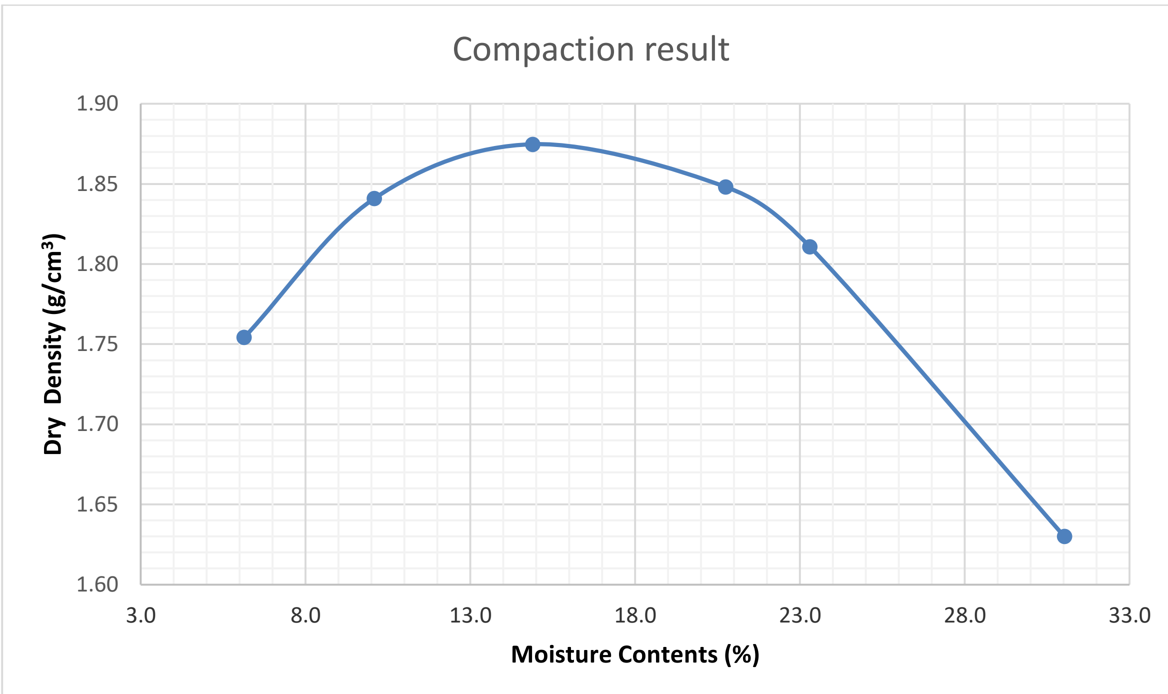

Figure D11: West African Standard (WAS) at (6:8)% RHA and FA

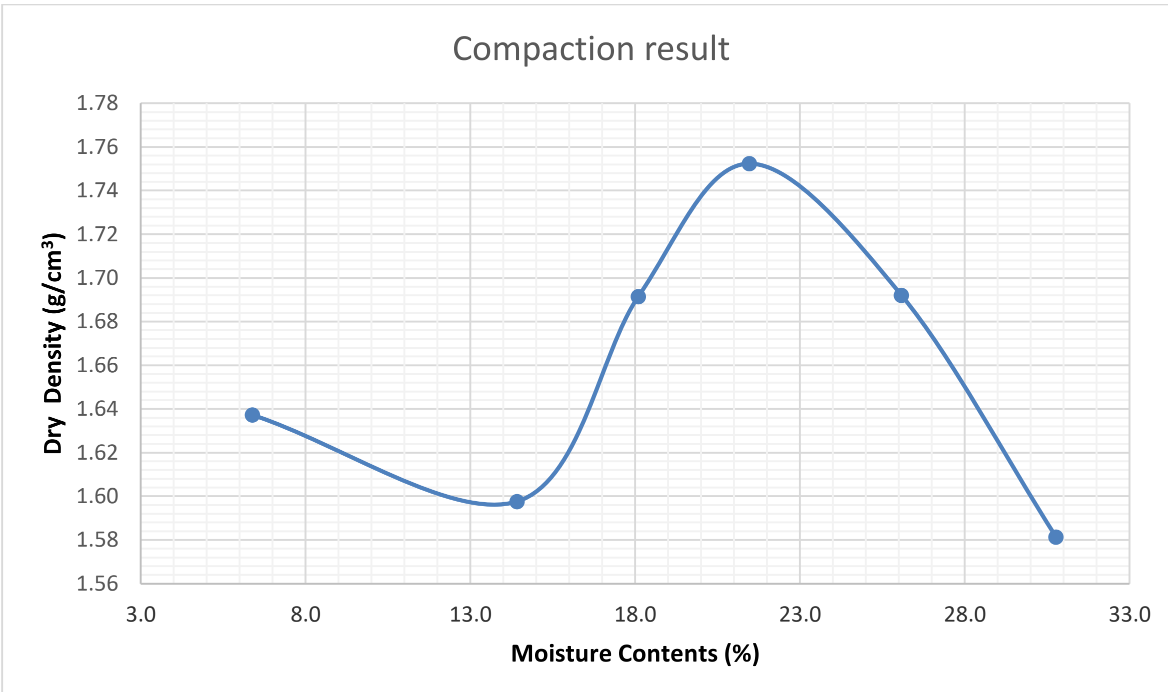

Figure D12: West African Standard (WAS) at (8:10)% RHA and FA

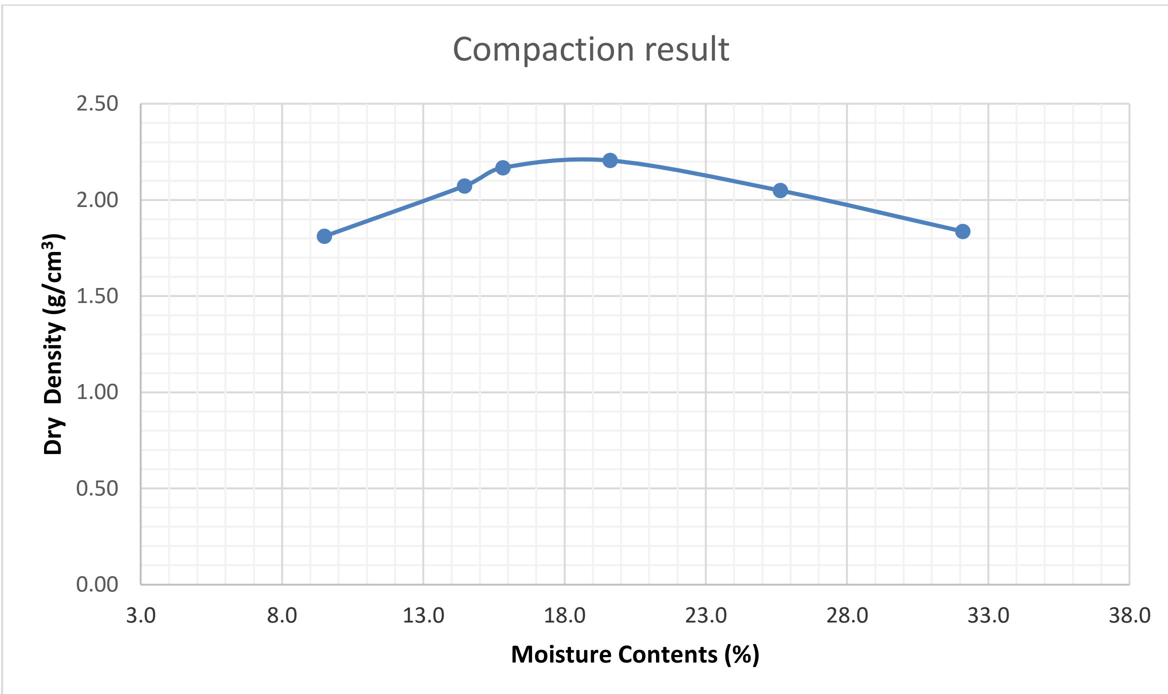

Figure D13: West African Standard (WAS) at (10:12) % RHA and FA

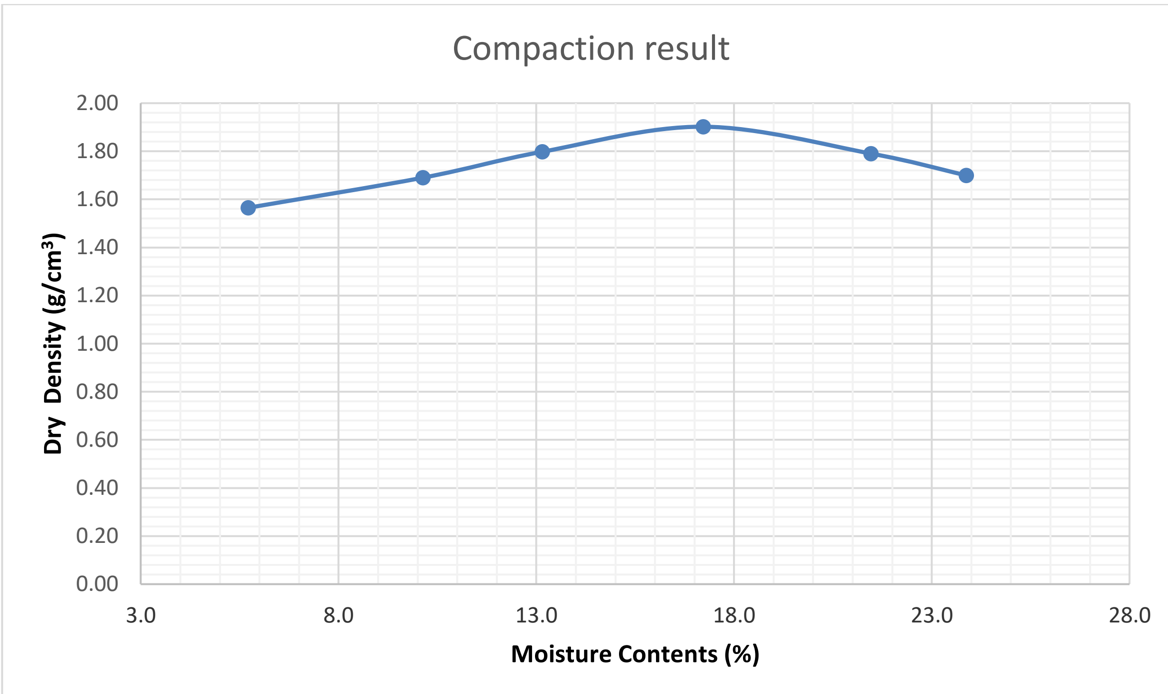

Figure D14: British Standard Light (BSL) at (0) % RHA and FA

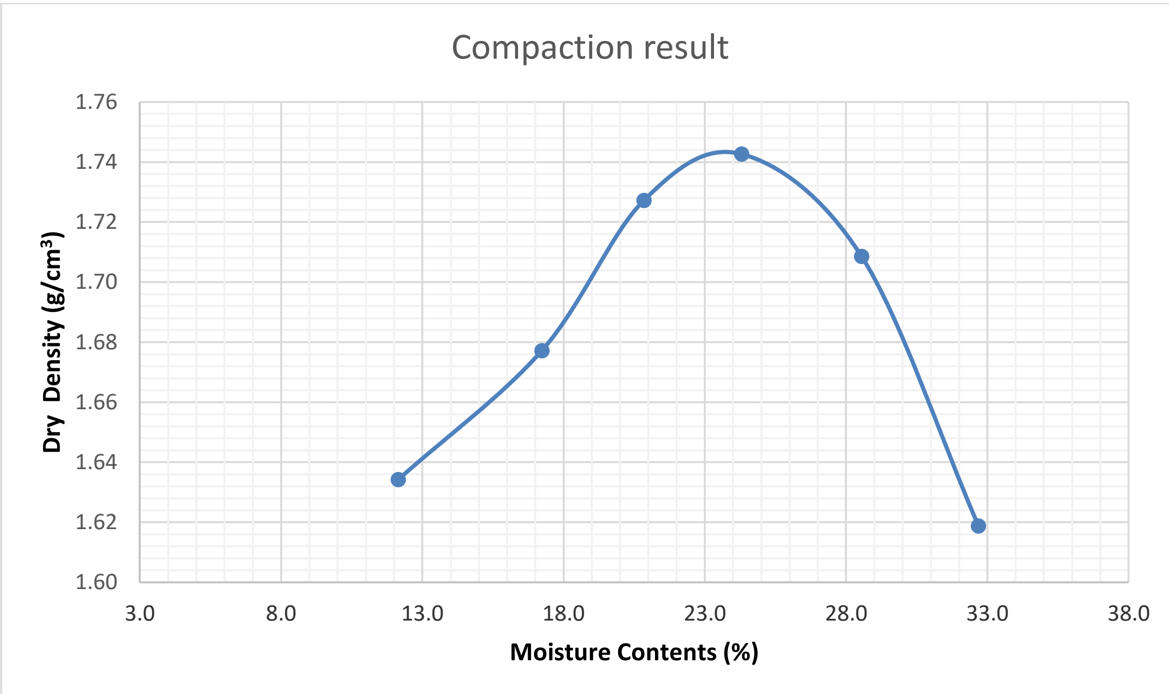

Figure D15: British Standard Light (BSL) at (2:4) % RHA and FA

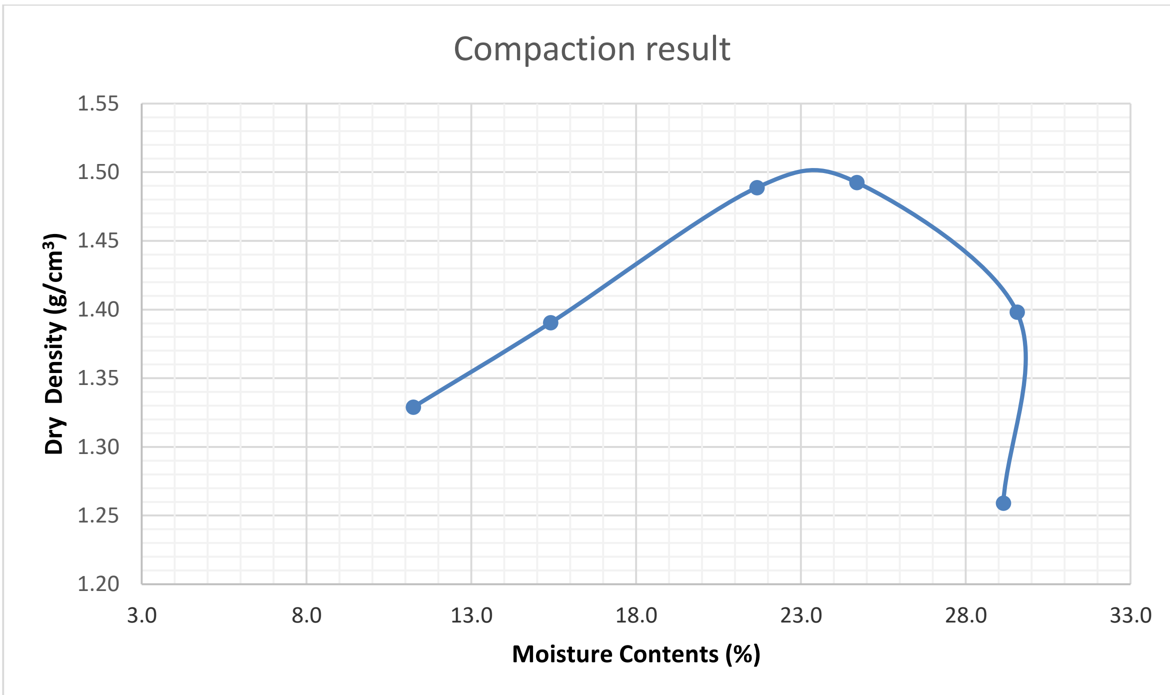

Figure D16: British Standard Light (BSL) at (4:6) % RHA and FA

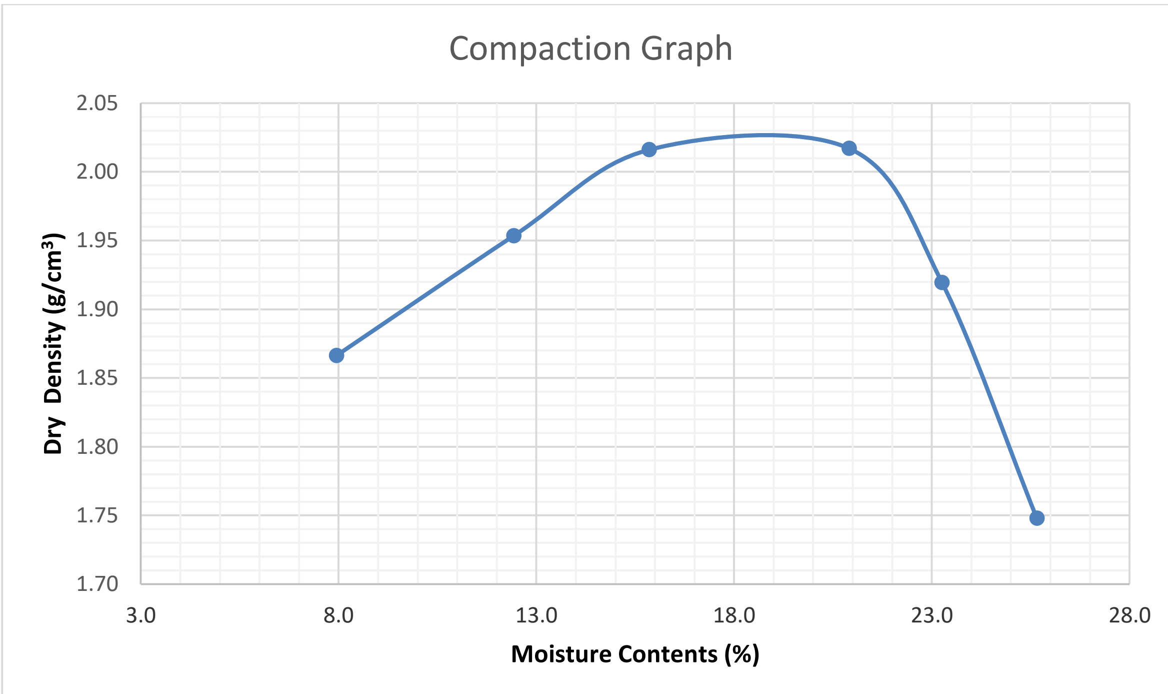

Figure D17: British Standard Light (BSL) at (6:8) % RHA and FA

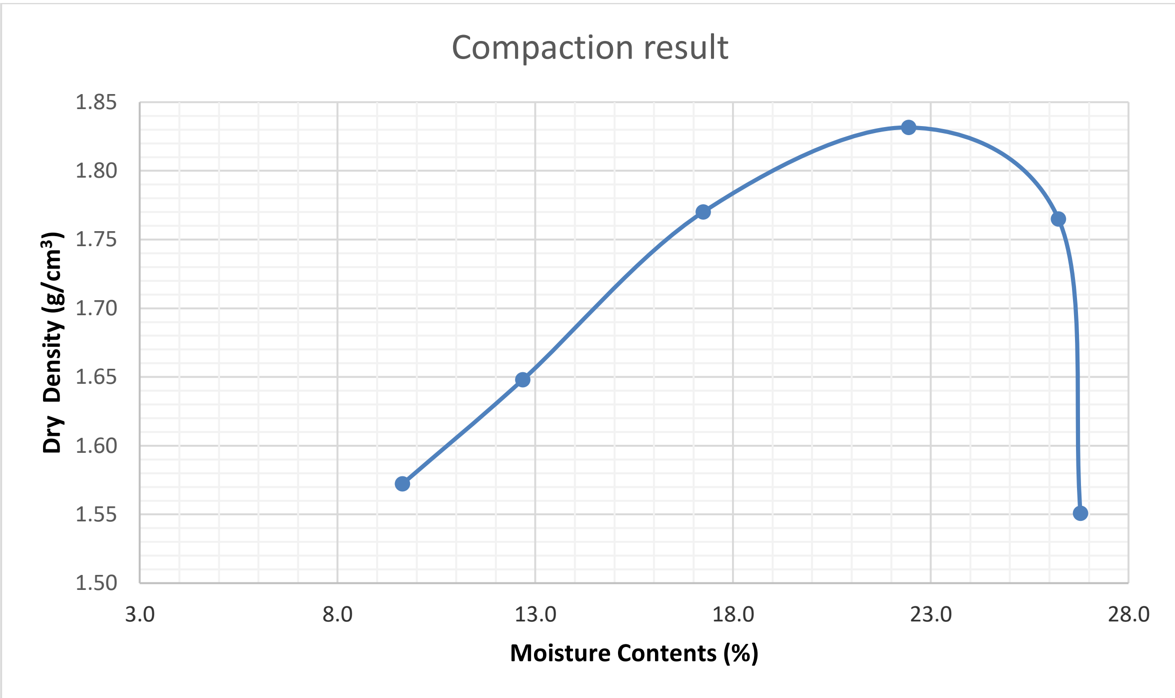

Figure D18: British Standard Light (BSL) at (8:10) % RHA and FA

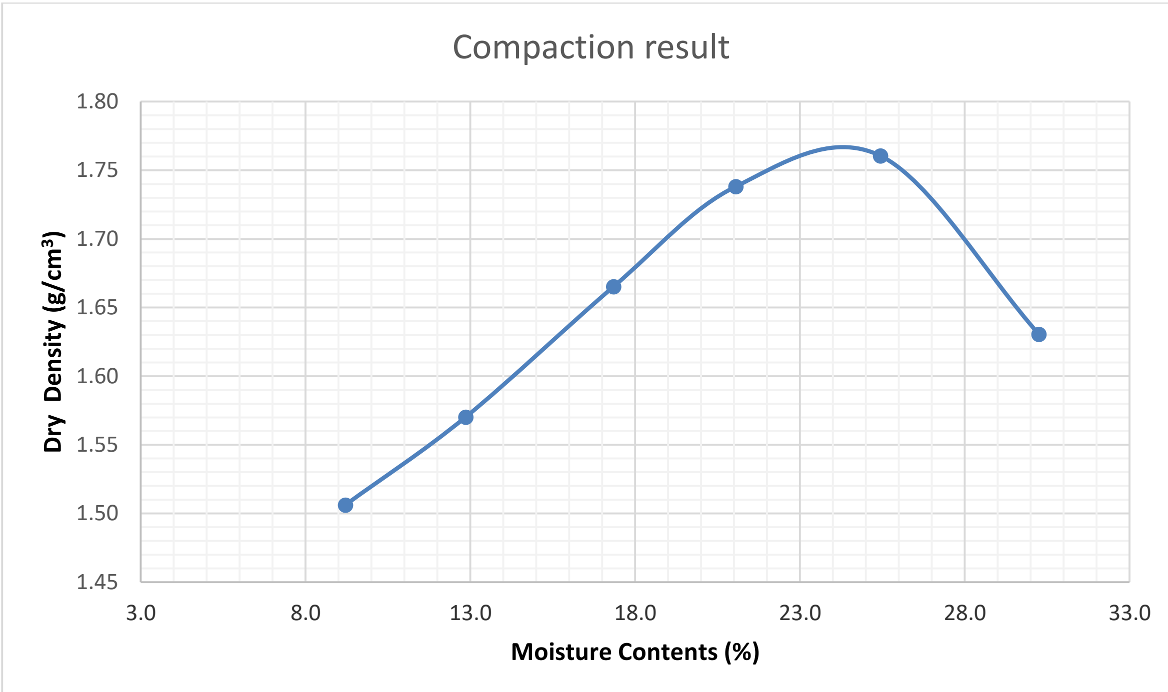

Figure D19: British Standard Light (BSL) at (10:12) % RHA and FA

Appendix E: Unconfined Compressive Strength on Soil Specimen

Table E1: Unconfined Compressive Strength for BSH, WAS and BSL

BSH	0	2:4	4:6	6:8	8:10	10:12
C	422.56	688.77	435.33	483.77	391.56	333.54
WAS	0	2:4	4:6	6:8	8:10	10:12
C	401.44	537.45	455.77	311.56	478.33	303.45
BSL	0	2:4	4:6	6:8	8:10	10:12
C	78.67	305.77	139.44	218.45	255.22	260.45

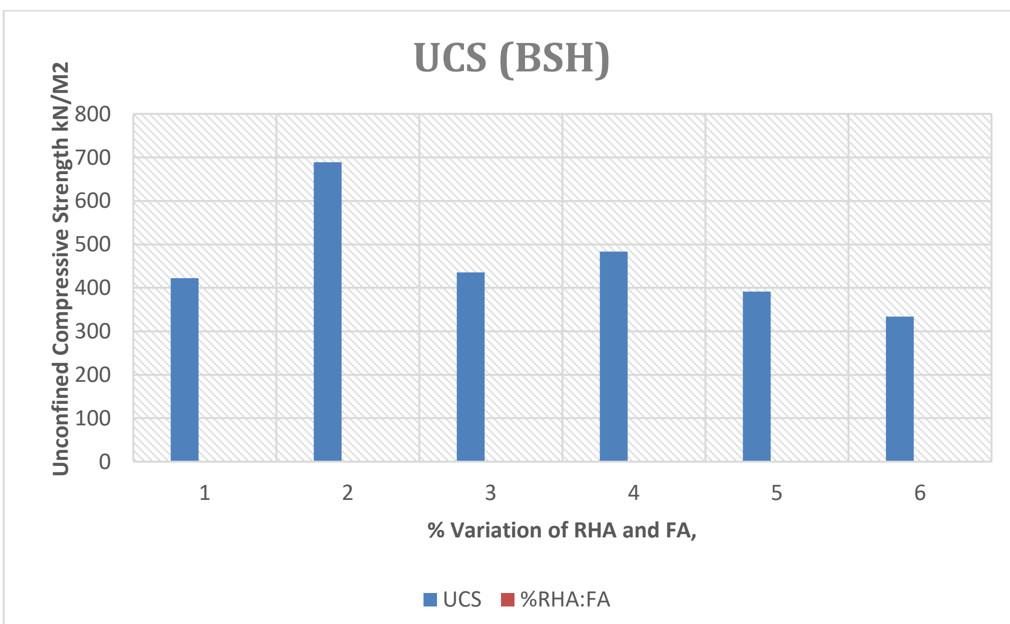

Figure E1: Unconfined Compressive Strength for BSH as RHAFA increases form 0 – 10:12%

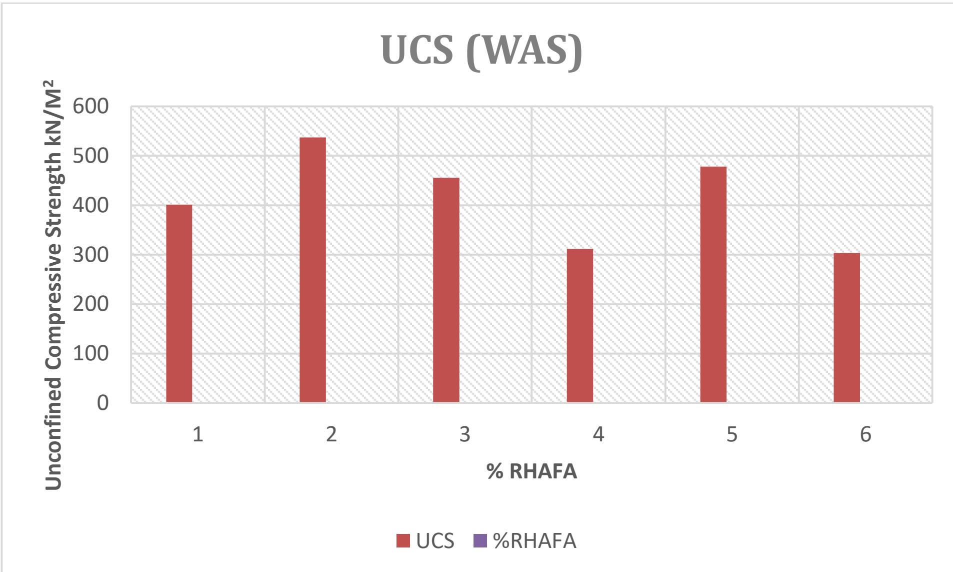

Figure E2: Unconfined Compressive Strength for WAS as RHAFA increases form 0 – 10:12%

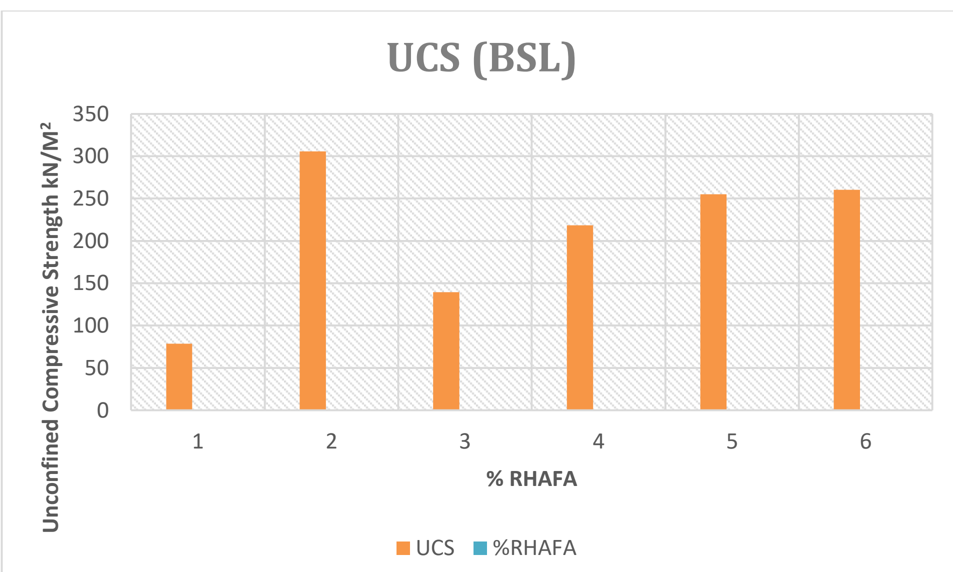

Figure E3: Unconfined Compressive Strength for BSL as RHAFA increases form 0 – 10:12%

Appendix F: Unsoaked CBR on Test Specimens

Table F1: CBR values for BSH, WAS and BSL compaction

British Standard Heavy	0	2:4	4:6	6:8	8:10	10:12
Unsoaked C.B.R	11.65	16.63	12.74	10.32	11.18	14.73
West African Standard	0	2:4	4:6	6:8	8:10	10:12
Unsoaked C.B.R	13.57	14.56	12.44	11.31	11.75	12.99
British Standard Light	0	2:4	4:6	6:8	8:10	10:12
Unsoaked C.B.R	11.94	15.63	11.93	9.36	12.69	13.50

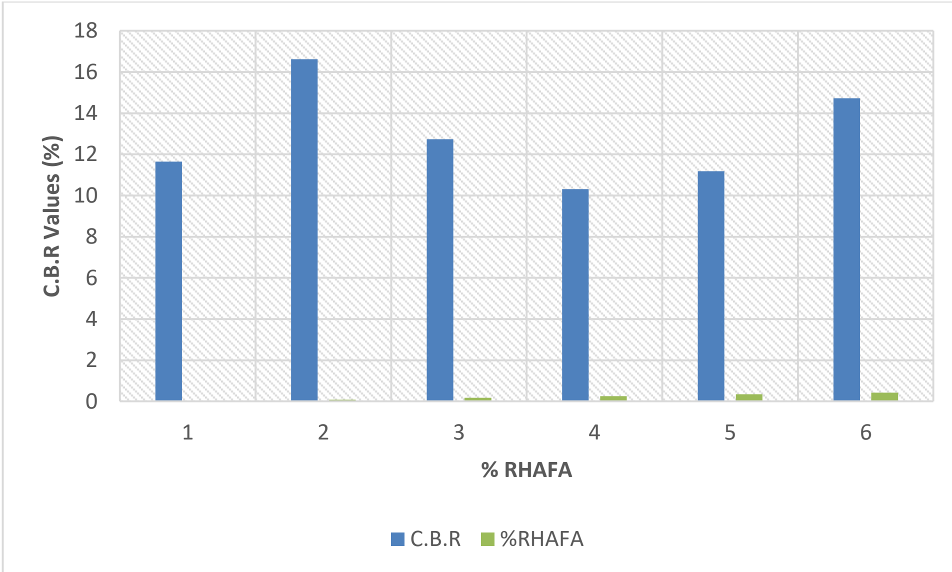

Figure F2: Unsoaked CBR values for BSH as RHAFA increases from 0 – (10:12) %.

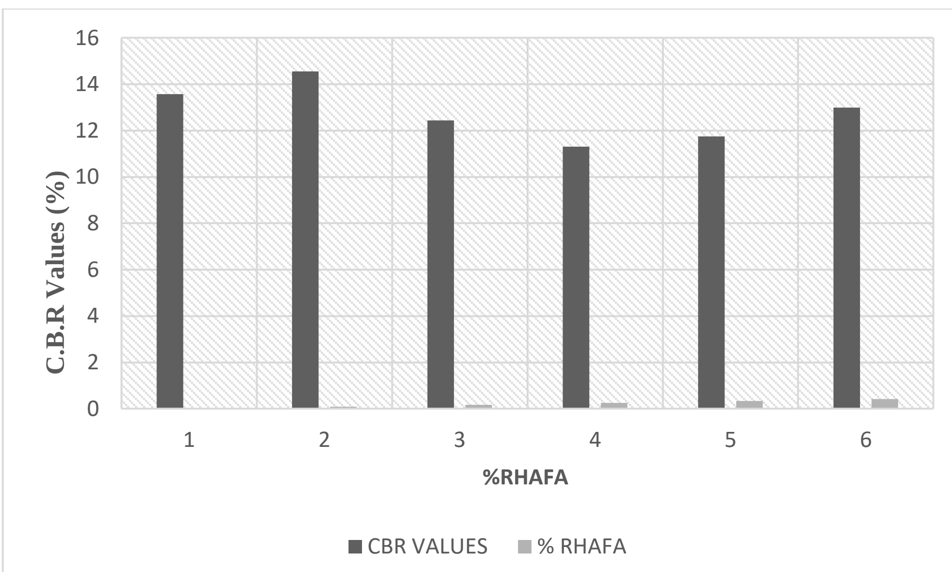

Figure F3: Unsoaked CBR values for WAS as RHAFA increases from 0 – (10:12) %.

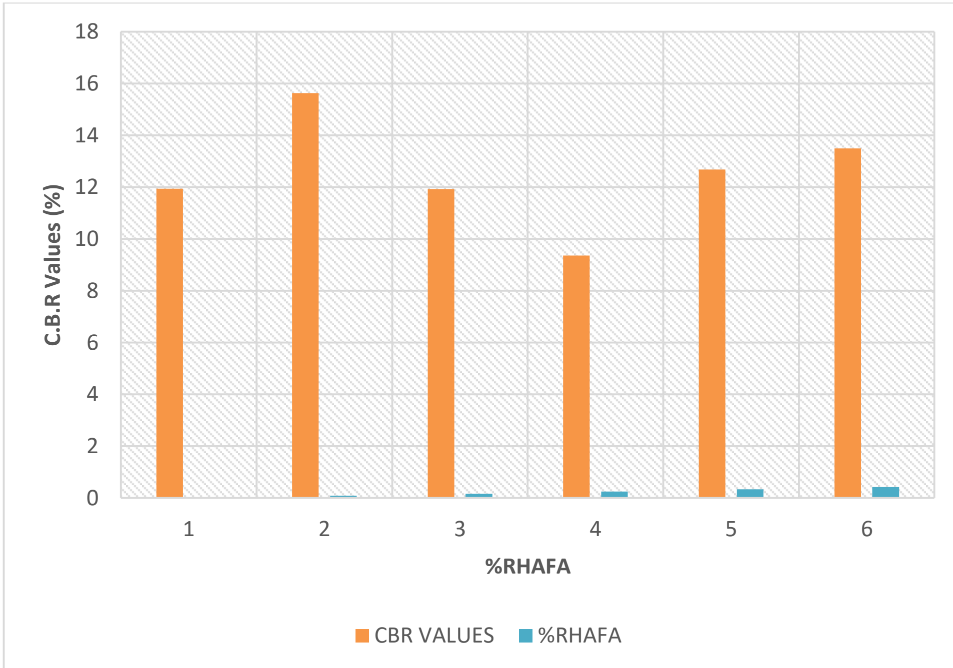

Figure F4: Unsoaked CBR values for BSL as RHAFA increases from 0 – (10:12)%