COMPARISON BETWEEN TWO GRADES OF CEMENTS FOR THE STABILIZATION OF IKOLE-EKITI SOILS

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ABSTRACT

The performance of a pavement depends on the quality of its sub-base and subgrade layers. As the foundation for the pavement's upper layers, the subgrade layer plays a key role in mitigating the detrimental effects of static and dynamic stresses generated by traffic. Therefore, building a stable subgrade is vital for constructing an effective and long lasting pavement system. This project work, review the investigation carried out on the strength characteristic of laterite in its natural state and with addition of different grade of cement. The texts comprised of sieve analysis, compaction, atterberg limit, California bearing ratio test, natural moisture content and specific gravity test. The result of these tests showed that the lateritic soil under study improved its engineering characteristic substantially on the addition of cement. The effect of the two cement grades made a positive impact on the lateritic and the effect of the stabilizer on the soil, as evidenced by a marked reduction in plasticity index, the maximum dry density and an improvement in shrinkage and drainage characteristic, plastic and liquid limit and the optimum moisture content. It was discovered that the two cement grades used has a high CBR value at 6% and 8%, that make the material to be suitable for engineering works and high way construction. It could then be ascertained that the addition of cement to laterite soil is beneficial to strength improvement of the soil.

DEDICATION

This project is dedicated to GOD Almighty, who has been my source of knowledge and wisdom and also to my family who has been a support to me always

ACKNOWLEGMENT

Am so thankful to all that contributed to the success of this project.

I wish to particularly thank the following:

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The 5th year class of 2018

All the members of my family and friends for the relentless support and encouragement.

CERTIFICATION

This is to certify that this proposal was written by ABOLARIN ROWLAND (CVE/13/1049) under my supervision and is approved for its contribution to knowledge and literary presentation. All sources of information are specifically acknowledged by means of references, in partial requirements for the award of Bachelor of Engineering (B.Eng) degree in civil Engineering, Federal University Oye- Ekiti.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The performance of pavements depends upon the quality of subgrade and sub-base. A stable subgrade helps produce a long-lasting pavement while a sub-base function is to transmit the traffic load from the road to the subgrade. A high level of spatial uniformity of a subgrade in terms of key engineering parameters such as shear strength, stiffness, volumetric stability, and permeability is vital for the effective performance of the pavement system.

A number of environmental variables such as temperature and moisture affect these geotechnical characteristics, both in short and long term. The subgrade works as the foundation for the upper layers of the pavement system and is vital in resisting the detrimental effects of static and dynamic stresses that are generated by traffic.

The sub grade or embankment soil on which a pavement is built is a very important part of the pavement structure because:

(a.) It is the layer on which the remainder of the structure is supported and helps resist the destructive effects of traffic and weather.
(b.) It acts as a construction platform for building subsequent pavement layers.
(c.) The entire pavement section would have to be removed and replaced to correct embankment performance problems created by lack of strength or uniformity.

It is imperative that the sub grade be built as strong, durable, uniform and economical as possible. The most economical embankment is one that will perform well for many years.

Engineering properties of soils play a significant role in civil engineering construction works particularly in road constructions. This makes imperative, the testing of soil, on which a foundation or superstructure is to be laid. This would determine its geotechnical suitability as

construction material. In recent times, the alarming rate at which lives are being lost in Ikole due to road failures calls for a solution. The solution could be brought by critical geotechnical testing of the engineering soil.

Several authors have worked on the geotechnical properties of specific soils, especially lateritic soils or Red Soils. Among them are:

Report on successful use of lateritic soils as base and sub-base materials in road construction. (Jackson,1980)

Use of laterite soil in connection with construction of road,highways and airfields. (Vallerge et al, 1969)

The engineering problems associated with lateritic soil were evaluated by (Lyons et al, 1971).

Report on addition of lime to the soil to increase its optimum moisture content, liquid limit, California Bearing Ratio (CBR) etc. (Balogun, 1984)

A study of the engineering properties of some soil samples from Ilorin area, showed that they could be stabilized by compaction and that the samples could yield maximum strength if they are compacted on the dry side of their optimum moisture content (omc), (Alao,1983)

This paper examines the geotechnical properties of the soils around Ikole-Ekiti , Ekiti state in Nigeria, and their suitability as subgrade and Sub-base materials for road pavement construction in the country.

1.2 Problem Statement

The Civil Engineer is faced with the practical problems raised by use of soil as a foundation and construction material. A consideration of careful experimental investigation and the need for simplicity in the means employed has to be attained.

In Nigeria, the non-availability of generalized relevant data in this area, particularly for initial preliminary engineering planning and designs, has been the major cause of failure of most of highway construction projects, such that, failure occurs almost immediately after the project is commissioned or even before.

The construction material, which is used for engineering highway projects, is as important, as other engineering design factors. In road pavement design, the soil materials used in the pavement construction transmit the axle-load to the sub-soil or sub grade. Hence, the durability of a highway pavement is a function of the ease and rigidity of the pavement soil to transmit the stresses induced in it to the sub-soil such that unnecessary deformation is avoided.

1.3 Aim and Objectives of the Study

1.3.1 Aim of the study

This study is aimed at stabilizing Ikole-ekiti soils with cement to improve its suitability as sub-base and subgrade materials for road pavement.

1.3.2 Objectives of the study

1. Take soil samples and test the samples
2. After classification of the soil, check the suitability as sub-base and subgrade materials
3. Stabilization with cement of the soil samples that did not meet with the requirement as sub-base and subgrade material for road pavement.

1.3.3 Scope of the study

From the test results, the study will conclude with appropriate judgment on the suitability of the Ikole-ekiti soil as grade material with reference to standards on various manuals. And those that failed will be stabilize with cement to meet the requirement for road pavement

1.4 Map of Study area

Below is the map of the study area

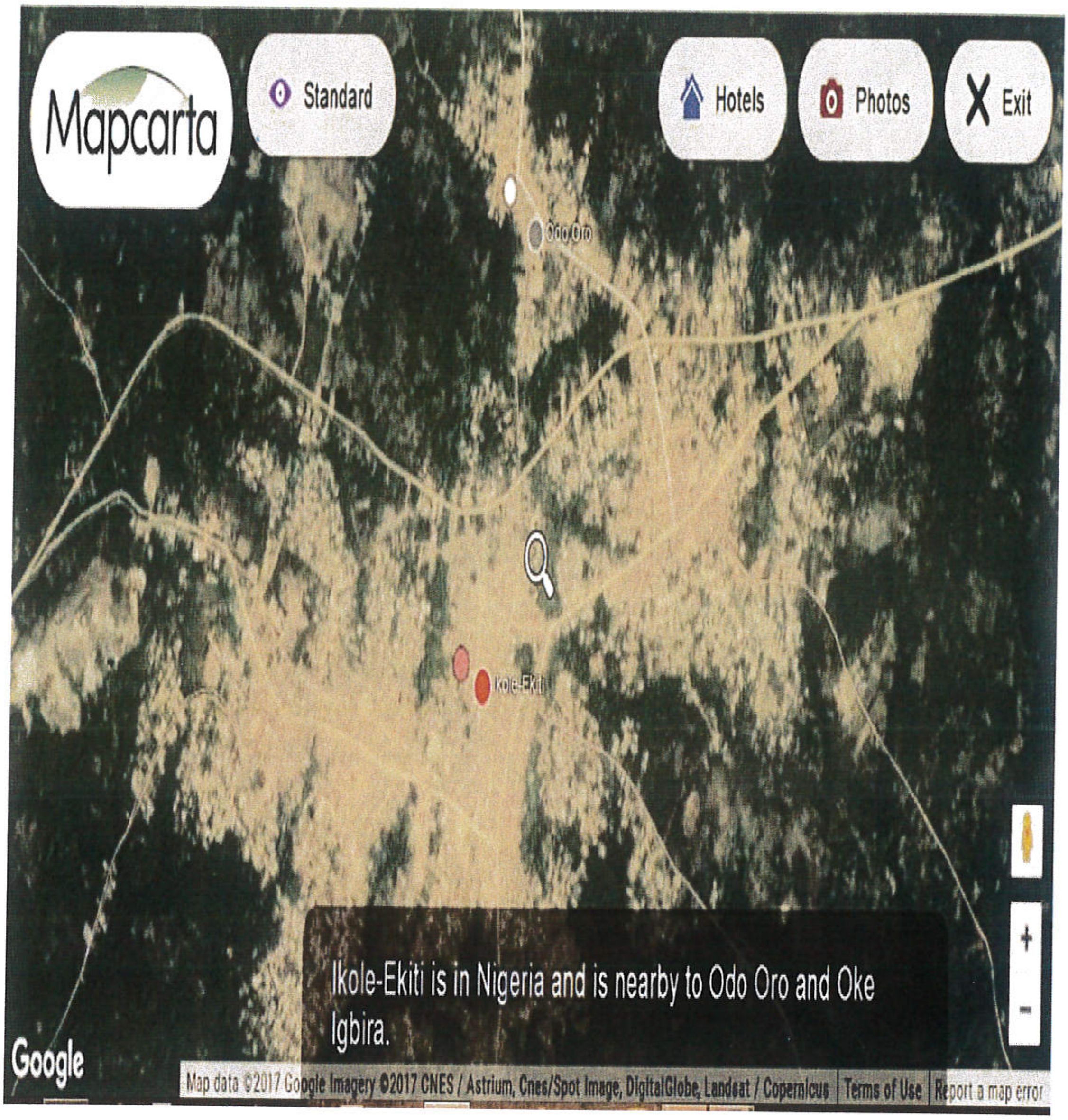


Figure1.1: The map of Ikole -Ekiti

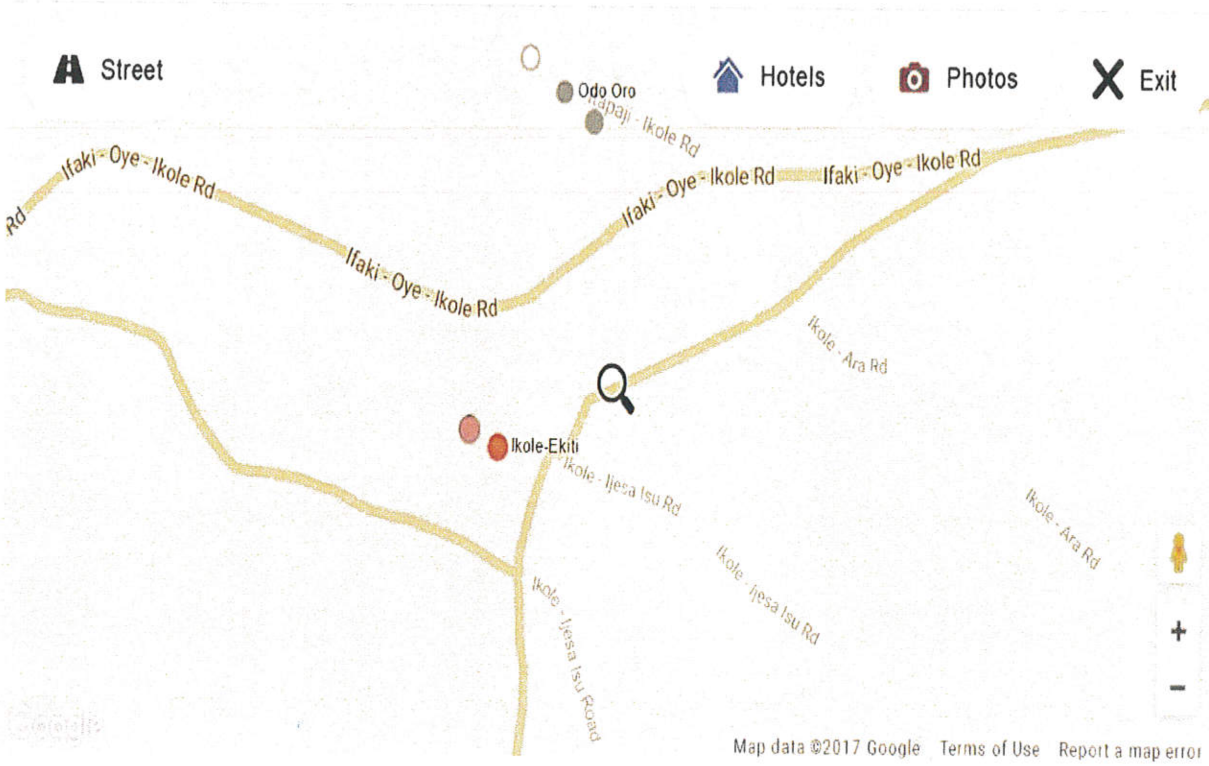


Figure 1.2: Street Satellite View of Ikole Area

Ikole is a Local Government Area of Ekiti State, Nigeria. Its headquarters are in the town of Ikole. It has an area of 321 km² and a population of 168,436 at the 2006 census, it can be

found on coordinates 7°47′0″N 5°31′0″E

Today, Ikole-Ekiti, is the Headquarters of the old Ikole District Council, the defunct Ekiti North Division and the Headquarters of defunct Ekiti North Local Government and now Headquarters of Ikole Local Government. Ikole is about 65 kilometres from Ado, the capital of Ekiti State of Nigeria. The town is situated on a very plain and well-drained land on the northern part of the State – about 40 kilometres from the boundary of Kwara State. The town is gifted with good fertile farmlands which ensure future expansion of agriculture and allied industries as well as a high swell in its population growth.

Ikole is situated in the deciduous forest area of the State. Rainfall is about 70 inches per annum. Rain starts in March and peters out in November. The good drainage of the land makes it very suitable for agricultural pursuits. It is a common feature that trees shed their leaves every year during the dry season which begins in November and ends in February. The two seasons – Dry Season (November – February) and Rainy Season (early March – midNovember) are quite distinct and they are very important to the agricultural pursuits of the people.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Flexible pavement is composed of a bituminous material surface course and underlying base and sub-base courses. The bituminous material is more often asphalt whose viscous nature allows significant plastic deformation. Most asphalt surfaces are built on a gravel base, although some 'full depth' asphalt surfaces are built directly on the subgrade. Depending on the temperature at which it is applied, asphalt is categorized as hot mix asphalt, warm mix asphalt, or cold mix asphalt. Flexible Pavement is so named as the pavement surface reflects the total deflection of all subsequent layers due to the traffic load acting upon it. The flexible pavement design is based on the load distributing characteristics of a layered system (aboutcivil.org, 2014).

It transmits load to the subgrade through a combination of layers. Flexible pavement distributes load over a relatively smaller area of the subgrade beneath. The initial installation cost of a flexible pavement is quite low which is why this type of pavement is more commonly seen universally. However, the flexible pavement requires maintenance and routine repairs every few years. In addition flexible pavement deteriorates rapidly; cracks and potholes are likely to appear due to poor drainage and heavy vehicular traffic (aboutcivil.org, 2014).

Flexible pavement consist of different layers such as,

Sub-grade

Sub-base course

Road base course and

Surface course

Sub – grade: This bears the load of pavement and traffic load in other to reduce the effective thickness.

Sub – base course: This is introduced due to poor bearing capacity of the sub grade soil or high traffic density. It is made to improve earths its function is to transmit the traffic load from the road and spreading as jet over a large area of the sub grade formation level.

Road base course: The function of the base is bearing the late load from the traffic and long heed from the over wearing surface and spreading it uniformly over a large area of the sub grade or sub-base.

Surface course: The wearing course is to spread the wheel load to the road base against surface water. The presence of bitumen improves the water proofing property. It also provide skid resistance (grossarchive.com).

Highways construction should be carried out in such a manner as to ensure serviceability and durability. Determination of project feasibility depends largely on consideration of soil aspects and properties. Application of design principles concerning soils, influence the planning and construction of highway infrastructure.

Sub grade soil is the integral part of the road pavement structure, which provides support to the pavement. The sub grade and its different properties are very much important in the road pavements structure. The major function of the sub grade is to provide the support to the pavement against traffic loading and for this; the sub grade should possess sufficient stability under adverse climate and heavy loading conditions.

When soil is used in the embankment construction, along with stability incompressibility is also an important factor as differential settlement may cause failures. Compacted and stabilized soil is often used as sub-base or base course. The soil or sub grade is therefore considered as one of principal highway material.

The various characteristics of soil include Soil Composition, Soil Colour, Soil Texture, Soil structure, Soil Water, just to mention a few. To ascertain the suitability of a given soil, from its multiple characteristics, intensive geotechnical tests should be carried out on a sample.(aboutcivil.org,2014)

Moreover, since performance of pavements depends upon the quality of sub grade, a stable sub grade helps produce a long-lasting pavement. A high level of spatial uniformity of a sub grade in terms of key engineering parameters such as shear strength, stiffness, volumetric stability, and permeability is vital for the effective performance of the pavement system. A number of environmental variables such as temperature and moisture affect these geotechnical characteristics, both in short and long term. The sub grade work as the foundation for the upper layers of the pavement system is vital in resisting the detrimental effects of climate, as well as static and dynamic stresses that are generated by traffic. (Nyamewa, 2015)

However, the interplay of geotechnical parameters and stabilization/treatment techniques is complex. This has resulted in a gap between the understanding of geotechnical properties of sub grades based on the design and construction practices for these elements. The purpose of this project is to synthesize findings from laboratory tests and national standards into a practical geotechnical design guide for sub grades. This project will help improve the design, construction, and testing of pavement foundations, which will in turn extend pavement life.
Good understandings of the basement soil on which highways and other transportation facilities are constructed are very important. The performance of a highway pavement is influenced to a very considerable extent by the subgrade material. (Salter,1988)

2.2 Geotechnical Properties of Soil

Geotechnical properties of geologic earth materials which parameters obtained from laboratory tests before any civil engineering construction takes place. Geotechnical analysis is required because it provides useful information on foundation soil. Engineering geologist, geotechnical engineers, geomorphologist among other professionals play an integral role in modern engineering project design this is because geotechnical analysis makes them aware of problem- soils which can cause structural failure, defects or collapse of civil engineering projects. (Kekere *et al., 2012*).

The general requirement that will be necessary are; Natural material and soil, soil types, classification of Ikole soil, lateritic soil definition, also the major properties required will be classes of subgrade bearing strength, classification of most Ikole subgrade material, moisture contents, shrinkage and swelling,the ease of compaction, subgrade compaction,subgrade requirement for pavement design, material suitable for pavement design

The geotechnical properties of a soil-such as the grain-size distribution, plasticity, compressibility, size limits, relative density, Atterbergs Limit, Hydraulic Conductivity, consolidation and shear strength are assessed by proper laboratory testing and, recently, emphasis has been placed on in situ determination of strength and deformation properties of soil, because this process avoids the sample disturbances that occur during field exploration (NPTEL).

2.3 Effect of Geotechnical Properties on Soil

(Adeyemi, 2000) worked on geotechnical basis for failure of some sections along the Lagos-Ibadan expressway of southwestern Nigeria. They made comparison between the geotechnical properties of soil below the stable and unstable sections of the road before such parameters can serve as basis for predicting the stability of flexible expressway pavement in the tropics.

(Jegede, 1994) worked on the pavement failure at a section along Ikere-Igbara –odo road in Ekiti states of Nigeria. He found out that the California Bearing Ratio of the soil ranges around 50% which showed poor soil physical properties lack of drainage facilities combines with the excess fine soi grade ranging between20%40% was responsible for failure along the area.

(Jedede, 1998) investigated failure over Talc-Tremolites-schist terrain of Ife-Ilesha expressway in Osun states and concluded that since the subgrade and the burrowed materials are schist derived, they contain talc and hydromica which makes it impossible for field compaction.

The engineering geological properties of sub-grade soil the proposed Ilawe-Ekiti high way southernwestern Nigeria was carried out by (Jegede, 1998), the result obtained showed that the natural moisture content range from 2.0% to 2.8%. The liquid limit range from 36.0% to 43.0% linear shrinkage range from 2.1% to 2.6% specific gravity range from 2.66 to 2.74. The compaction of the soil indicates dry density from 1910kg/m^3 to2,050kg/m^3 at optimum moisture content of 15% to 18.2%.These data obtained shows that soi is good for road construction work as subgrade and subbase material.

(Cyril C. Okpoli and Adesola A. Bamidele, 2016) were able to conclude based on a study performed on the "Geotechnical Investigation and 2D Electrical Resistivity Survey of a Pavement Failure in Ogbagi Road, Southwestern Nigeria" that the possible causes of the highway pavement failure in a typical basement complex area result from Clayey topsoil/subgrade soils tendency of absorbing water which makes them swell and collapse under imposed wheel load stress which subsequently lead to road failure (July 2016).

(Kekere *et al,2012)* mentioned conclusively in a research conducted on "Relationship between Geotechnical Properties and Road Failures along Ilorin – Ajase Ipo Road Kwara State, Nigeria" that geotechnical properties of the foundation of the road have significantly affected the rate of road failure along Ilorin- Ajase-Ipo road. Results have indicated that geotechnical properties were not properly analyzed before construction started to identify areas with problem soils which are threatening the road today with various forms of failures. It is also evidently clear from the findings that, the presence of clayey soil and sandy soil which were poorly graded have caused cracks, bulges which result in series of potholes and depression on the road. However, poor engineering construction also contribute to the rate of failure, it has been observed that the bituminous pavement of the road falls between 45-50mm which is far below engineering specification of 150-200mm a British standard for flexible pavement (cited in O'Flaherty 2001). Absence of drainage facility to discharge concentration of run-off especially during wet season and where drainage facilities are present, it is completely covered with sediments, the concentration of run off on the road also affects density rate of the road foundation hence weaken the stability of the foundation of the road (2012).

(Kekere A.A. and Ifabiyi I.B, 2013) also revealed in their findings on a research on "Geotechnical Investigation of Road Failure along Ilorin-Ajase – Ipo Road Kwara

State, Nigeria" that the effort to maintain the road along Ilorin-Ajase Ipo road by government agency have not yielded any result because the maintenance carried out was approached wrongly. It is evidently clear from the findings that poor foundation materials like the subgrade and sub-base constitute the foundation of the road for instance, the presence of clayey soil and sandy soil have contributed to road failure witnessed on the road. It was recommended that areas badly affected should be scooped out and replaced with stabilized lateritic soils to ensure stability of foundation. In addition surface drainage should be provided to enable discharge of runoff because concentration of runoff during precipitation affects compaction level of the foundation where drainage facility is provided. Debris and sediments should be cleared regularly to avoid blockage of culvert and drainage channels to enable free flow of water from the surface of foundation because concentration of run-off affects stability of foundations (2013).

Field observation and laboratory experiment carried out by (Adegoke et al., 1980) (Mesida,1981) and (Ajayi, 1987) showed that road failures are not primarily caused by usage or design construction problems alone, but can equally arise from inadequate knowledge of the characteristics and behavior of the subgrade on which the roads are built and non-recognition of the influence of geology and geomorphology during the design and construction phases. Thus the design of the road way should be able to accommodate these factors mainly climate and geology as they determine the actual behavior of the roadway.

(Salcon, 1997) argue that, the strength of the road is depended on the road bearing capacity of the underlying soil which transmits the load to the parent rock.

Several authors have worked on the geotechnical properties of specific soils, especially lateritic soils or Red Soils. Among them are:
Report on successful use of lateritic soils as base and sub-base materials in road construction. (Jackson, 1980)

Use of laterite soil in connection with construction of road,highways and airfields. (Vallerge et al., 1969)

The engineering problems associated with lateritic soil were evaluated by (Lyons et al, 1971).

Report on addition of lime to the soil to increase its optimum moisture content, liquid limit, California Bearing Ratio (CBR) etc. (Balogun, 1984)

In the work of (Bolarinwa et al., 2017), from the soil exploration and laboratory analysis of ikole ekiti, it was inferred that the soil, encountered from the superficial to about 12m depth are mostly lateritic soils because they possess both cohesive and cohensionless soil properties.

Red soils obtained from earlier sampling and fieldwork, The aim is to attain geotechnical information, which is the composition and properties of the soil, which is essential to proper design and execution of engineering works, without which most of engineering construction will easily damage (Capper, 1963).

Study of the engineering properties of some soil samples from Ilorin area. Discovery that they could be stabilized by compaction and that the samples could yield maximum strength if they are compacted on the dry side of their optimum moisture content (omc). (Alao,1983)

(Nyamweya, 2015) said that laboratory tests should be carried out on borrow pit materials to be used for construction of roads so as to know their suitability for the intending purposes which would or could reduce cost of maintaining such roads in the long run if proper materials are selected or used, that could make roads stand a test of time.

2.4 Soil Stabilization

According to (Oyediran and kalejaye, 2011), Stabilization was defined as a means by which soil properties are improved and made more suitable for construction purpose, which can be mechanical, chemical and sometimes biological. (Ogunribido, 2011) affirmed that local materials identified for use in stabilization can be classified as either agricultural or industrial wastes. The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential.

Pavement design is based on the premise that minimum specified structural quality will be achieved for each layer of material in the pavement system. Each layer must resist shearing, avoid excessive permanent deformation through densification. As the quality of a soil layer is increased, the ability of that layer to distribute the load over a greater area is generally increased so that a reduction in the required thickness of the soil and surface layers may be permitted. The most common improvements achieved through stabilization include better soil gradation, reduction of plasticity index or swelling potential and increases in durability and strength. In wet weather, stabilization may also be used to provide a working platform for construction operations. These types of soil quality improvement are referred to as soil modification (Joint Departments of the army and air forces,1994). Portland cement can be used either to modify and improve the quality of soil or to transform the soil into a cemented mass with increased strength and durability. The amount of cement used will depend upon whether the soil is to be modified or stabilized (Joint Departments of the Army and Air force,1994). Portland cement is hydraulic cement made by heating a limestone and clay mixture in a kiln and pulverizing the resulting material (Kowalski et al., 2007)

(Moses and Saminu, 2012) had also studied the effect of cement (up to 16%) on some engineering properties of expansive soil. They found that the stabilized soil failed in UCS, CBR and durability test to be used as sub-base and base material in pavement.

(Sallahudeen et al., 2014) had also stabilized expansive soil using cement and had concluded that for improvement of the subgrade of lightly trafficked roads and in lime stabilization as admixture.

(Amadi and Lubern, 2014) had investigated the effect of cement on 10% quarry fine stabilized black cotton soil and had found reduction in Ip, maximum dry density (MDD) and increase in optimum moisture content (OMC) and CBR.

2.4 General Requirements

2.4.1 Natural materials and soils

In order to minimize construction costs, natural materials should be used as much as possible.

Every endeavour should be made to use the cheap local materials before considering the importation of material from some distance. It is therefore of prime importance to make a complete inventory of all available road making materials, such as stone, gravel, sand and clayey sand at the investigation stage, ikole has abundant resources of stone.

2.4.2 Soil types

Soils are sediments or other unconsolidated accumulation of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter. Soil has distinct advantages as a construction material, including its relative availability, low cost, simple construction techniques, and material properties, which can be modified by mixing, blending, and compaction. However, there are distinct disadvantages to the use of soil as a construction material, including its non-homogeneity, variation in properties in space and time, changes in stress-strain response with loading, erodability, weathering, and difficulties in transitions between soil and rock.

Prior to construction, engineers conduct site characterization, laboratory testing, and geotechnical analysis, design and engineering. During construction, engineers ensure that site conditions are as determined in the site characterization, provide quality control and quality assurance testing, and compare actual performance with predicted performance.

Numerous soil classification systems have been developed, including geological classification based on parent material or transportation mechanism, agricultural classification based on particle size and fertility, and engineering classification based on particle size and engineering behaviour. The purpose of engineering soil classification is to group soils with similar properties and to provide a common language by which to express general characteristics of soils. Selection of the type of soil for use in this project is based on prior knowledge of the widely used ikole Soils, especially in ekiti. Conclusions and recommendations of the project are meant to bring about an insight on any necessary improvements on the same.

2.4.3 Red soil/Laterite definition

Many conflicting definitions have been proposed in literature. (Bunchan, 1807) is the earliest and his definition is based on the ability of a soft red material to harden on exposure to air. Attempts at a more precise definition resulted in the application of chemical criteria to laterite, the potential of laterite as an iron or aluminium have helped to promote interest in their identification.

Several attempts at a more useful definition based on morphology have also been made. (Pendleton and Sharasuvana, 1946) have defined laterite soils as profiles in which a laterite horizon is found, and lateritic soils as profiles in which immature horizons are found which develop under appropriate conditions.

None of the above definitions, However, helps the field identification of useful engineering material, most researchers now prefer to use the definitions based on hardening, such as "Ferric" for iron- rich cemented crusts,"Calcrete" for calcium carbonate- rich crusts and " silcrete for silica rich cemented crusts"(Fookes,1997)

(Ola, 1978) used local terminology in defining laterite soils as all product of tropical weathering with reddish, brown colour with or without nodules or concretion but not exclusively found below hardened ferruginous crust of hardpan.

(Osula,1984) defined laterite as a highly weathered tropical soil; rich in secondary oxides of combination of iron, aluminium and manganese. Laterite (also known as "red soils") is used to cover all tropically weathered soil that has been involved in the accumulation of oxides of iron, aluminium or silica (Malomo, 1977).

In other words, red soil is a highly weathered material rich in secondary oxides of iron, aluminium, or both. According to (Alexander and Candy, 1962), it is nearly devoid of bases and primary silicate, but it may contain large amount of quartz and kaolite. It is either hard or capable of hardening on exposure to wetting and drying (Agbede, 1992).

Laterite covers have mostly a thickness of few meters but occasionally they can be much thicker. Their formations are favoured by a slight relief, which prevents erosion of the surface cover. Laterite occurring in non-tropical areas is products of former geological epochs. Lateritic soils from the uppermost part of the lateritic cover, in soil science are given specific names such as oxisol, latosol, ferallitic soil (Wikipedia, 2006)

2.4.3.1 Engineering properties of lateritic soil

Geotechnical characteristics and field performance of lateritic soils, as well as their reaction to different stabilizing agents may be interpreted in the light of all or some of the following parameters (Gidigasu,1976)

i. Genesis and pedological factors (parent material, climate, topography, vegetation, period of time in which the process have operated)
ii. Degree of weathering(decomposition, sesquioxides enrichment and clay-size content, degree of leaching)
iii. Position in the topographic site and
iv. Depth of soil in the profile

2.4.3.2 Particle size distribution of lateritic soils

Particle size distribution may provide the following information;

i. A basis for identification and classification of soils.
ii. The compactibility characteristics
iii. Permeability
iv. Swellability and
v. A rough idea of deformation characteristics of the soil mass

Texturally lateritic soil are very variable and may contain all fraction sizes, boulders, cobbles, gravel and silt, and clay as well as concretionary rocks.

Pre-testing preparation of lateritic soils for sieve analysis may have the following effect on the size distribution (Gidigasu,1976);

i. Re-molding and removal of free iron oxides increases the content of fines between 35% to 65%

ii. Degree of dying and time of mixing of the sample prior to testing influence the degree of dispersion of some lateritic soils.

iii. Cementing effects of sesquioxides, which bind the clay and silt fraction into coarser fraction

2.4.3.3 Plasticity characteristics of lateritic soils

The interaction of soil particles at the micro scale is reflected in the Atterberg limits of the soil at micro scale level. Knowledge of the atterberg limits may provide the following information;

i. A basis for identification and classification of given soil

ii. Texture

iii. Strength and compressibility characteristics swell potential of the soil or the water holding capacity.

Atterberg limit depend on;

i. The clay content, plasticity increases with increase in clay content (Plaskowski,1963)

ii. Nature of soil minerals only materials with sheet-like or plate-like structures exhibit plasticity.

iii. Chemical composition of the soil environment, the absorptive capacity of the colloidal surface of the cations and water molecules decreases as the ratio of silica to sesquioxides decreases(Baver,1930)

iv. Nature of exchangeable cations, this has a considerable influence upon the soil plasticity(Hough, 1959)

v. Organic matter, high organic matter increases plasticity (after skempton, 1953)

Pre-test preparation, degree of moulding and time mixing, dry and re-writing, and irreversible changes may affect plasticity test on drying.Drying drives off adsorbed water,which is not completely regained, on re-wetting (this is the case in both oven and air drying)(Fookes 1997)

Studies on the relationship between the natural moisture content and the liquid limits and normal lateritic soils(Vargas,1953). However, the lateritic soils from high rainfall areas may have moisture contents as high as the liquid limit (Hirashima,1948)

2.4.3.4 Compaction characteristics of Lateritic soil

The compaction characteristic of lateritic soils are determined by their grading characteristic plasticity of fines. These in turn can be traced to genetics and pedological factors

The significant characteristics of lateritic soils contain a mixture of quartz and concretionary coarse particles on compaction. Most lateritic soils contain a mixture of quartz and concretionary coarse particles, which may vary from very hard to very soft. The strength of these particles has major implications in terms of field and laboratory compaction results and their subsequent performance in road pavements. The higher the iron oxides content the more the degree of dehydration in the lateritic soil, the harder the concretionary particles become.

Placement variable (moisture content, amount of compaction, and type of compaction efforts) also influences the compaction charateristics. Varying each of these placement variables has an effect on permeability, compressibility, swellability, strength and stress-strain characteristics(Lambe,1958). For example, soil compacted on dry side of optimum moisture content swells more than soil compacted on wet side because the soils compacted on dry side have a greater moisture deficiency and a lower degree of saturation(Mitchel et al.,1969). On the other hand, soils compacted on wet side of the optimum moisture content will shrink more on drying than a soil compacted on the dry side (Lambe,1958)

2.5 Major Properties Required

2.5.1 Moisture content.

Properties such as load bearing capacity, shrinkage etc. are mostly affected by the variation of moisture content. Various things such as drainage, groundwater table elevation, infiltration, or pavement porosity etc. Influence the moisture content. Highly wet sub grades deform more under loading. The moisture content is required to be controlled during the special sub grade treatment operations. Fine grain or clay type soils are placed at moisture content within -2 and +1 percentage points of the optimum. Silts, silty loams, or loessial type soils are required to be within -3 percent of the optimum. Soils composed primarily of sand or sand and gravel may normally be compacted to the specified density at a moisture content several percentage points below optimum. Careful monitoring and control of the moisture content and density of the soil during the special sub grade treatment process is essential for attaining a uniformly dense and stable sub grade.

The actual moisture content of the sub grade soil under the road pavement will depend on many factors, principally:

1.) Local climate

2.) Depth of the water table

3.) Type of soil

4.) Topography and the drainage

5.) Permeability of the pavement materials

6.) Permeability of the shoulders

2.5.2 Shrinkage and/or swelling.

Shrinkage or swelling mainly depends on moisture content. Additionally, in frost conditions (in northern climate) soils with excessive fine content may be susceptible to frost heave. Shrinkage, swelling and frost heave are the factors whose tendency is to deform and crack any pavement structure construed over them.

Proper sub grade construction and treatment is one more step toward the completion of a good roadway. The specified moisture and density requirements are required when the sub grade is covered by any subsequent courses. Through careful schedule planning and construction, the Contractor may attain these results in the most economical way possible while providing a good, stable, sub grade.

2.5.3 Ease of compaction

2.5.3.1 Sub grade compaction

The compaction requirements are generally as follows:

The upper 300 mm of the sub grade shall be compacted to a dry density of at least 100%

MDD (Standard Compaction) in cuttings where there is no improved sub grade and on all fills.

In cuttings where an improved sub grade is to be placed, the upper 150 mm of the Sub grade, prior to placing the improved sub grade layer(s), shall be compacted to at least 100% MDD (Standard Compaction) and the lower 150 mm to at least 95% MDD (Standard Compaction).

All improved sub grade shall be compacted to a dry density of at least 100% MDD (Standard Compaction).

The maximum compacted thickness, which shall be paid, processed and compacted at one time, is generally 300 mm. The moisture content shall be adjusted in order that the required relative compaction is obtained, but the moisture content at the time of compaction shall not exceed 105% of the Optimum Moisture Content (Standard Compaction). If it proves feasible, dry compaction may be accepted, especially in dry areas.

In some cases, it is advantageous to obtain relative compactions higher than the above figures, since compaction not only improves the sub grade bearing strength, but also reduces permeability. This applies, in particular, to clayey sands, silty sands and granular materials, the coarse particles of which are hard enough not to crumble under heavy compaction.

2.5.4 Other desirable properties

According to (Nyamweya, 2015) the desirable properties of sub grade soil as a highway material are:

a.) Withstand capability (Stability).

b.) Strength permanency.

c.) Low change in volume during adverse conditions of weather and ground water.

d.) Superior drainage.

e.) Incompressibility.

2.6 Sub grade Requirements for Pavement Design

2.6.1 Materials suitable for pavement support

Materials forming the direct support of the pavement shall normally comply with the following requirements:

a.) CBR at 100% MDD (Standard Compaction) and 4 days soak: more than 5

b.) Swell at 100% MDD (Standard Compaction) and 4 days soak: less than 2%

c.) Organic matter (percentage by weight): less than 3%

This means that no pavement should be placed directly on Class SI soil and that an improved

Sub grade is required on such soil.

2.6.2 Improved sub grade

Placing an improved sub grade not only increases the bearing strength of the direct support of the pavement, but also:

1.) Protects the upper layers of earthworks against adverse weather conditions (protection against soaking and shrinkage)

2.) Facilitates the movement of construction traffic

3.) Permits proper compaction of the pavement layers

4.) Reduces the variation in the sub grade bearing strength

5.) Prevents pollution of open-textured sub bases by plastic fines from the natural sub grade.

It may prove technically and economically advantageous to lay an improved sub grade not only on SI, but also on S2 and S3 Class soils. The decision will generally depend on the respective costs of sub base and improved sub grade materials. An improved sub grade would generally not be economically justified on Class S4 soils. An improved sub grade placed on soils of any particular class must obviously be made of a material of a higher class (up to Class S5, since Class S6 is sub base quality).

2.7 Materials Sampling and Testing Programme

2.7.1 General

This phase describes the materials sampling and testing programmes applicable to the preliminary stage.

2.7.1.1 Mass of samples required

The total mass of sample required depends on the tests to be carried out, the grading of the material (its maximum particle size, in particular) and its susceptibility to crushing during compaction.

For general guidance, Table below shows the minimum mass of sample required for various sequences of tests and typical materials, namely:

1.) Fine grained soil (Maximum size: 2mm)

2.) Coarse-grained gravel (Maximum size: 40 mm), not susceptible to crushing during compaction.

3.) Coarse-grained gravel (Maximum size: 40 mm), susceptible to crushing during compaction.

CHAPTER THREE

METHODOLOGY

3.1 SAMPLING

Soil samples were taken at a depth of 1200mm, a disturbed sample,Samplings would be taken around FUOYE Ikole-ekiti campus, Asin –Ekiti, Ikoyi – Ekiti, ijesa isu roads .It should be noted that the samples obtained were disturbed samples that is those obtained using equipment that destroys the macrostructure of the soil without altering its mineralogical composition. Specimens from these samples can be used to determine the general lithology of soil deposits, identify soil components and general classification purposes, and determine grain size, Atterberg limits, and compaction characteristics of soils.

The project will involve sample collection and laboratory tests. Each test was conducted several times and the averaged results considered. Samples will be collected along campus, asin ekiti, ikoyi ekiti and ijesa isu road.

These are red soils obtained from earlier sampling and fieldwork. The aim is to attain geotechnical information, which is the composition and properties of the soil, which is essential to proper design and execution of engineering works (Capper, 1963). In this study, experimental design was employed and deductions derived purely from the obtained results

The size of each sample shall be sufficient for the following tests to be carried out.

a.) Grading to 0.075 mm sieve

b.) Atterberg Limits

c.) Compaction test (Standard Compaction: 2.5 kg rammer)

d.) CBR and swell on samples moulded at 100% MDD (Standard Compaction) and OMC

(Standard Compaction)

Note: CBR's' shall normally be measured after 4 days soak, the moisture contents after soaking shall be measured, both on the whole CBR specimen (by weighing it after soaking) and on a sample taken from beneath the plunger, after testing.

3.2 Tests performed

These are categorized under (Capper, 1963):

1.Classification and identification tests.

Including Particle size distribution (Sieve and Hydrometer analysis).

2. Engineering properties

These were permeability test.

3. Engineering construction works.

These were, California bearing ratio test for bearing capacity and Standard tests for compaction.

3.3 Laboratory Procedures.

3.3.1 Liquid limit (Cone penetrometer method)

3.3.1.2 Objective

The liquid limit is the empirically established moisture content at which a soil passes from the liquid state to the plastic state. The liquid limit provides a means of identifying and classifying fine-grained cohesive soils especially when also the plastic limit is known. Variations in the moisture content in a soil may have significant effect on its shear strength, especially on fine-grained soils.

3.3.1.3 Main principles

The cone penetrometer method is the preferred method to the Casagrande test as it is essentially a static test depending on soil shear strength. This method covers the determination of the liquid limit of a sample in its natural state, or a sample from which material retained on a 425 mm test sieve has been removed, it is based on the measurement of penetration into the soil of a standardized cone.

3.3.1.4 Required equipment

a. Test sieves of sizes 425 mm

b. An airtight container

c. A flat glass plate

d. Two palette knives or spatulas

e. A penetrometer

f. A cone of stainless steel, 35 mm long with a smooth, polished surface and an angle of 300 having a mass of 80 g.

g. A metal cup 55 mm in diameter and 40 mm deep with the rim parallel to the flat base

h. An evaporating dish or a damp cloth

i. Apparatus for moisture content determination

j. A wash bottle containing clean water

k. A metal straight edge

l. A stopwatch

3.3.1.5 Sample preparation

1. Take a sample of the soil of sufficient size to give a test specimen weighing about 400 g, which passes the 425 mm sieve. This should be enough material for both Plastic Limit and

Linear Shrinkage tests in addition to the Liquid Limit test.

2. Transfer the soil to a glass plate. Add water and mix thoroughly with two palette knives until the mass becomes a thick homogeneous paste.

3. Place the paste in an airtight container and allow to stand for 16-24 hours to enable the water to permeate through the soil.

3.3.1.6 Test procedure

1. Take the 400 g soil sample and place it on a glass plate. Mix the paste for at least 10 minutes using the two palette knives. Add more distilled water if necessary so that the first cone penetrometer reading is about 1-5 mm.

2. Push a portion of the mixed soil into the cup with a palette knife, taking care not to trap air, gently tapping the cup against a firm surface if necessary. Strike off excess soil with the straightedge to give a smooth level surface.

3. With the penetration, cone locked in the raised position lower the cone so that it just touches the surface of the soil. When the cone is in the correct position, a slight movement of cup will just mark the soil surface. Lower the dial gauge to contact the cone shaft and record the reading of the dial gauge to the nearest 0.1 mm.

4. Release the cone for a period of 5 ± I sec. After locking the cone in position, lower the dial gauge to contact the cone shaft and record the reading of the dial gauge to the nearest 0.1 mm.

Record the difference between the readings as the "cone penetration".

5. Lift out the cone and clean it carefully.

6. A little more wet soil shall be added to the cup and the process repeated. If the difference between the first and second penetration readings is less than 0.5 mm, the average of the two penetrations shall be recorded. If the second penetration is more than 0.5 mm and less than 1 mm different from the first, a third test shall be carried out. 1f the overall range is then not more than 1 mm. record the average of the 3 penetrations. If the overall range is more than 1 mm, the soil shall be removed from the cup, remixed and the test repeated until consistent results are obtained.

7. Take a moisture content sample of about 20 g from the area penetrated by the cone and determine the moisture content.

8. The penetration test shall be repeated at least three more times using the same sample of soil to which further increments of water have been added. The amount of water added shall be such that a range of penetration values of approximately 15 mm to 25 mm is covered by the four test runs.

9. Each time soil is removed from the cup for the addition of water, wash and dry the cup.

3.3.1.7 Calculations

Calculate the moisture content of each specimen.

W = (m2-m3/m3-m1) ×100%

Where:

m1 is the mass of the container (in g)

m2 is the mass of the container and wet soil (in g)

m3 is the mass of the container and dry soil (in g)

2. Plot the relationship between the moisture content and cone penetration with the moisture content as the abscissae and the cone penetration as ordinates, both on linear scales.

3. Draw the best straight line fitting the points.

4. The Liquid Limit (wL) of the soil sample is the moisture content corresponding to a cone penetration of 20 mm and shall be expressed to the nearest whole number.

3.3.1.8 Report

The test report shall include the following:

a) Type of material and sample identification

b) Reference to this procedure

e) Test result, i.e. the Liquid Limit of the soil sample

d) Whether the material was tested in the natural state or after sieving

3.3.1.9 Practical considerations

Take care not to damage the point of the cone by accidentally dropping the cone on the base plate.

To avoid corrosion on the cone, it must be kept clean at all times. The cone corrodes easily, and must could appear after just a few hours if it is left unclean.

3.3.1.10 Maintenance

Check the condition of the cone point with the test gauge.

Check that the cone is falling freely without friction when released.

Check the weight of the cone.

Keep the equipment clean at all times.

3.3.2 Plastic limit and plasticity index

3.3.2.1 Objective

The Plastic Limit is the empirically established moisture content at which a soil becomes too dry to be plastic. It is used together with the Liquid Limit to determine the Plasticity Index which when plotted against the Liquid Limit on the plasticity chart provides a means of classifying cohesive soils. The Plasticity index is the difference between the Liquid Limit and the Plastic Limit. The Plasticity index is the range of moisture content in which a soil is plastic; the finer the soil, the greater the Plasticity Index.

3.3.2.2 Main principles

This method covers the determination of the liquid limit of a sample in its natural state, or a sample from which material retained on a 425 mm test sieve has been removed.

3.3.2.3 Required equipment

a) Two flat glass plates, one for mixing soil and one for rolling threads

b) Two palette knives or spatulas

c) Apparatus for moisture content determination

d) Clean water

e) A length of rod, 3 mm in diameter and 100mm long

3.3.2.4 Sample preparation

This test commonly is performed as a continuance of the Liquid Limit test, and material for the test could conveniently be prepared as part of the Liquid Limit test. Otherwise, a 40 g sample should be prepared in the same way as specified for the Liquid Limit test.

3.3.2.5 Test Procedure

1.) Take the 40 g soil paste sample and place it on a glass plate.

2.) Allow the soil to dry partially until it becomes plastic enough to be shaped into a ball.

3.) Mold the ball of soil between the fingers and roll it 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.

4.) Divide this sample into 2 subsamples of about 20 g each and carry out separate determination on each portion. (Divide each of the 2 sub-samples into 4 more or less equal parts).

5.) Mould the soil in the fingers to equalize the distribution of moisture, and then form the soil into a thread about 6 mm diameter between the first finger and thumb of each hand.

6.) Roll the thread between the fingers, from finger-tip to the second joint, of one hand and the surface of the glass plate. Use enough pressure to reduce the diameter of the thread to about 3 mm in 5 to 10 complete, forward and back, movements of the hand.

7.) Pick up the soil, mould it between the fingers to dry it further, form it into a thread and roll it out again as specified above.

8.) The procedure shall be repeated until the thread shears both longitudinally and transversely when rolled to about 3 mm diameter. The metal rod may be used to gauge the diameter. The first crumbling point is the Plastic Limit.

9.) gather the pieces of crumbled soil thread, transfer them to a suitable container for determination of the moisture content, and replace the lid immediately.

10.) Repeat the rolling procedure on the other three portions of the sub sample, placing them all in the same container for determination of the moisture content.

Step 11: Repeat the rolling procedure on the 2nd sub-sample as described above so that two completely separate determinations are made.

3.3.2.6 Calculations

I) Calculate the moisture content of both samples. 1f the two results differ by more than 0.5 % moisture content, repeat the whole test.

2) Calculate the average of the two moisture content values and express the value to the nearest whole number. This is the Plastic Limit (we).

3.3.2.7 Report

The test report shall include the following:

a) Type of material and sample identification

b) Reference to this procedure

c) Test result, i.e. the Plastic Limit of the soil sample

d) Whether the material was tested in the natural state or after sieving

If it is not possible to perform the Plastic Limit, the soil is reported as non-plastic (NP).

3.3.2.8 Derivation of plasticity index

The Plasticity index (Ip) is defined as the difference between the Liquid Limit (wL) and the Plastic Limit (wp). and is calculated from the equation:

IP = WL-WP

This value is also reported to the nearest whole number.

3.3.2.9 Practical considerations

The hands of the operator should be clean and dry when performing the test.

3.3.2.10 Maintenance

The equipment shall be kept clean at all times.

3.3.3 Linear shrinkage

3.3.3.1 Objective

Shrinkage due to drying is significant in clays, but less so in silts and sands. If the drying process is prolonged after the plastic limit has been reached, the soil will continue to decrease in volume, which is also relevant to the converse condition of expansion due to wetting. The Linear Shrinkage value is a way of quantifying the amount of shrinkage likely to be experienced by clayey material. Such a value is also relevant to the converse condition of expansion due to wetting.

3.3.3.2 Main principles

Linear Shrinkage method covers the determination of the total linear shrinkage from linear measurements on a bar of soil of the fraction of a soil sample passing a 425 mm test sieve, originally having the moisture content of the Liquid Limit.

3.3.3.3 Required equipment

1. A flat glass plate
2. Two palette knives or spatulas
3. A drying oven capable of maintaining temperature of 105 °C - 110 °C
4. Clean water
5. A brass mould for Linear Shrinkage test
6. Silicone grease or petroleum jelly
7. Vernier callipers or steel rule with accuracy 0.5 mm

3.3.3.4 Sample preparation

This test commonly is performed as a continuance of the Liquid Limit and Plastic Limit tests, and material for the test could therefore conveniently be prepared as part of the Liquid Limit test. Otherwise, a 150 g sample should be prepared in the same way as specified for the Liquid Limit test. A sample of material passing through a 425 mm sieve, or alternatively a sample of natural soil without coarse particles, shall be thoroughly mixed with distilled water until the mass becomes a smooth homogeneous paste with moisture content at about the Liquid Limit of the soil.

3.3.3.5 Test procedure

1. Clean the mould thoroughly and apply a thin film of silicone grease or petroleum jelly to its inner faces to prevent the soil adhering to the mould.

2. Take the 150 g soil paste sample at approximately the Liquid Limit.

3. Place the soil/water mixture in the mould such that it is slightly proud of the sides of the mould. Gently jar the mould, or carefully tap the mould against a thin surface, to remove any air pockets in the mixture.

4. Level the soil along the top of the mould with the palette knife and remove all soil adhering to the rim of the mould by wiping with a damp cloth.

5. Place the mould where the paste can air dry slowly for 1 - 2 days until the soil has shrunk away from the walls of the mould.

6. Then complete the drying at 105 °c to 110 °c.

7. Cool the mould and measure the mean length of the soil bar by pressing it against the end of the mould where there is a better fit. While measuring the distance between the opposite side of the mould and the soil bar.

3.3.3.6 Calculations

1) Calculate the Linear Shrinkage of the soil as a percentage of the original length of the specimen, L0 (in mm), from the equation:

Percentage of Linear Shrinkage = (1-LD/LO) 100

Where:

LD is the length of the oven-dry specimen (in mm).

Report the Linear Shrinkage of the soil to the nearest whole percentage.

3.3.3.7 Report

The test report shall include the following:

a) Type of material and sample identification

b) Reference to this procedure

e) Test result. I.e. the Linear Shrinkage of the soil sample

d) Whether the material was tested in the natural state or after sieving

3.3.3.8 Practical considerations

Due to the long time required for air-drying, Linear Shrinkage is a time consuming test However, it is important to take the time required in order to produce reliable results.

3.3.3.9 Maintenance

The equipment shall be kept clean at all times.

3.3.4 Particle size distribution- Wet sieving

3.3.4.1 Objective

A particle size distribution analysis is a necessary classification test for soils, especially coarse soils, in that it presents the relative portions of different sizes of particles. From this, it is possible to determine whether the soil consists of predominantly gravel, sand, silt or clay sizes and, to a limited extent, which of these size ranges is likely to control the engineering properties of the soil.

3.3.4.2 Main principles

The procedure given involves preparation of the sample by wet sieving to remove silt and clay sized particles. Followed by dry sieving of the remaining coarse material. This method covers the quantitative determination of particle size distribution in an essentially cohesion less soil, down to fine sand size. The combined silt clay can be obtained by difference. If the soil does not contain particles retained on a 2 mm test sieve in significant quantity, the
hydrometer method shall be used.

3.3.4.2 Required equipment

Test sieves: 75 mm, 63 mm, 50 mm, 37.5 mm, 28 mm, 20 mm, 14 mm, 10 mm, 6.3 mm, 5 mm, 3.35 mm, 2 mm. 1.18 mm, 600 11m,425 m, 300 aim, 212 pm, 150 pm, 75 pm.

1. Lid and receiver.
2. A balance readable and accurate to 0.5 g.
3. Riffle boxes.
4. A drying oven capable of maintaining a temperature of 105°C to 11C.
5. Evaporating dishes.
6. Metal trays.
7. Scoop.
8. Sieve brushes.
9. Sodium hexametaphosphate.
10. Rubber tubing about 6mm bore.
11. Mechanical sieve shaker (optional).

3.3.4.3 Sample preparation

The test sample shall be obtained by air-drying for at least 12 hours depending on the type of the sample. A representative sample shall be obtained by riffling or quartering to give a minimum mass of about 2.5 kg.

3.3.4.4 Test procedure

1. Weigh the air-dried (or oven dried) test sample to 0.1 % of its total mass (m,).
2. Place the sample and sieve through a 20 mm sieve size, brush any particles too coarse to pass through the sieve with wire brush until the individual particles are clean of any finer material.
3. Sieve the fraction retained on the 20 mm test sieve on the appropriate larger test sieves and weigh the amount retained on each test sieve.
4. Weigh the material passing a 20 mm test sieve.
5. Riffle the sample to get a convenient fraction of about 0.5 kg and weigh that fraction (m3).
6. Spread the riffled fraction in the large tray or bucket and cover with water.
7. 1f the soil is cohesive add sodium hexametaphosphate to the water first, at a concentration of 2 g/liter. Stir the mixture well to wet the soil, allow the soil to stand for at least I hour in this solution stirring frequently.
8. Wash the material through a 75 micrometer sieve, allowing the material passing sieve 75 micrometre to run to waste. Ensure that neither test sieve is overloaded in the process, either with material or with water
9. Transfer all the material retained on the sieve into a tray or evaporating dish and dry in an oven at 1 05CC to 110°C. Allow it to cool and weigh (rn).
10. Sieve the dried fractions through the appropriate sieves down to.

3.3.4.5 Calculations

1. For samples containing particles larger than 20 mm in size, calculate the proportion by mass of material retained on each of the coarse sieves as a percentage of m1.

2. Calculate the corrected mass of material retained on each of the sieves between 20 mm and 75 micrometre by multiplying by m2/m3 ,then calculate this mass as a percentage of m1.

3. Calculate the cumulative percentage by mass of the sample passing each of the sieves, from the general relationship:

(% passing this sieve) = (% passing previous sieve) - (% retained on this sieve).

4. Calculate the fraction passing the 75 m.m test sieve by difference.

The mass of the fines lost by washing equals (m3 — m4). To this is added the mass of any fine material (mF) passing the 75 pm when dry sieved, and the percentage finer than 75 m.m is equal to:

$\{(m3-m4) + mF\}/m3 \times (m2/m1) \times 100$

5. Plot the grading as a curve on a semi-logarithmic chart.

3.3.4.6 Report

The test report shall include the following information:

a) Type of material and sample identification

b) Reference to this procedure

e) The particle size distribution curve

3.3.4.7 Practical considerations

Take care to ensure that sieving is complete; the minimum period of shaking should be 10 minutes.

Never put a sieve in the drying oven for drying the material, as this will destroy the sieve.

3.3.4.8 Maintenance

Test sieves should be inspected for defects before each use. A more detailed examination should be made at regular intervals to discover signs of wear, warping, tears, splits holes, blockages and any other defects in the mesh.

3.3.5 Particle size distribution- Hydrometer method

3.3.5.1 Objective

Hydrometer method combined with wet or dry sieving enable a continuous particle size distribution curve of a soil to be plotted from the size of the coarsest particles down to clay sizes.

3.3.5.2 Main principles

The Hydrometer method covers the quantitative determination of the particle size distribution in a soil from the coarse sand size to the clay size by means of sedimentation. The test is normally notrequired if less than 10% of the material passes the 75 pm test sieve in a wet or dry sieving analysis. The analysis requires that the particle density of the soil specimen is known or can be assumed

.

3.3.5.3 Required equipment

a) Hydrometer

b) 2 no.s, 1L graduated measuring glass cylinders of about 60 mm diameter

c) Thermometer readable to 0.5 oC

d) Mixer

e) Drying oven capable of maintaining temperature of 105 oC 110 °C

f) Distilled water

g) Test sieves comprising at least 2 mm, 600 p.m. 212 pm, 75 m.m and receiver.

h) A balance readable to 0.1 g.

i) Stopwatch

j) Plastic wash bottle

k) Evaporating dish

l) Dispersing agent, Sodium Hexametaphosphate solution

m) Nomographic chart (ref. Stoke's law).

3.3.5.4 Sample preparation

The dry mass of soil required depends on the type of soil. Appropriate quantities are about 100 g for a sandy soil and 50 g for a clay or silt.

3.3.5.5 Test Procedure

1. Weigh the sample to 0. 1 g to obtain its initial dry mass, m1
2. Place the sample in a wide-mouthed conical flask.

3.3.5.6 Dispersion

3. Add 100 mL of the dispersant solution to the soil. Shake the mixture thoroughly until all the soil is in suspension.

4. Mix the suspension in the mixing machine for about 5 minutes until the soil is broken down to individual particles.

5. Transfer the suspension from the flask to the 75 fine sieve placed on the receiver, and wash the soil using a jet of distilled water from the wash bottle. The amount of water used shall not exceed 500 ml.

6. Transfer the suspension that has passed through the sieve to the I L measuring cylinder, and make up to the I L graduation mark. This suspension shall be used for the sedimentation analysis.

7. The material retained on the 75 m.m sieve shall be transferred to an evaporating dish and oven-dried.

8. When cool, re-sieve this material on relevant sieves do to 75 m.m. Weigh the material retained on each sieve to 0.1 g.

9. Add any material passing the 75 pm sieve to the measuring cylinder.

3.3.5.7 Sedimentation

10. Make a separate solution in a I L measuring cylinder consisting of 100 mL of the dispersant solution and dilute with distilled water to the I L mark. This cylinder shall be placed alongside the cylinder with the soil suspension to achieve the same temperature.

11. Mix the soil suspension in the measuring cylinder by placing the palm of one hand over the open end and turn it vigorously end-over-end about 60 times in 2 minutes.

12. Place the cylinder quickly on a table and start the timer.

13. Immerse the Hydrometer in the suspension and allow it to float freely.

14. Take hydrometer readings at the upper ring of the meniscus after periods of approximately 1/2 min. I min. 2 min and 4 min without removing the Hydrometer.

15. Remove the Hydrometer slowly, and rinse it in distilled water and place it in the other cylinder with the dispersant solution.

Record the top of the meniscus reading, R0.

16. Reinsert the hydrometer in the soil suspension and record readings after periods of approximately 8 min., 15 min., 30 min.I h, 2 h, 4 h, and 24 h from the start of sedimentation. Insert and withdraw the hydrometer after each reading.

17. Observe and record the temperature of the suspension once during the first 15 min and then after each subsequent reading.

3.3.5.8 Calculations

3.3.5.9 Fine sieving

1. Calculate the proportion of soil retained on each sieve as a percentage of the dry mass of soil used.

2. Calculate the cumulative percentages by mass passing each of the sieves from the general relationship:

(Cumulative % passing this sieve) = (cumulative % passing previous sieve) — (% retained on this sieve)

3.3.5.10 Sedimentation

3. Calculate the true hydrometer reading, R0 (in mm).

4. Obtain the effective depth, H, (in mm), corresponding to the reading, R0 from the Hydrometer scale calibration curve.

5. The equivalent particle diameter, D (in mm), shall be determined by using the nomographic chart for the application of Stoke's law. Each Hydrometer has its own calibrated nomographic chart.

6. Calculate the modified hydrometer reading R

7. Calculate the percentage by mass, K, of particles smaller than the corresponding equivalent particle diameter, D (in mm)

3.3.5.11 Report

The test report shall include the following:

a) Type of material and sample identification

b) Reference to this procedure

e) Results of the sedimentation analysis shall be reported and plotted on a semi-logarithmic chart.

d) Results of the sieve analysis (if appropriate)

3.3.5.12 Practical considerations

The sodium hexametaphosphate solution is unstable and shall be freshly prepared (not older than 1 month). The date of preparation shall be written on the bottle.

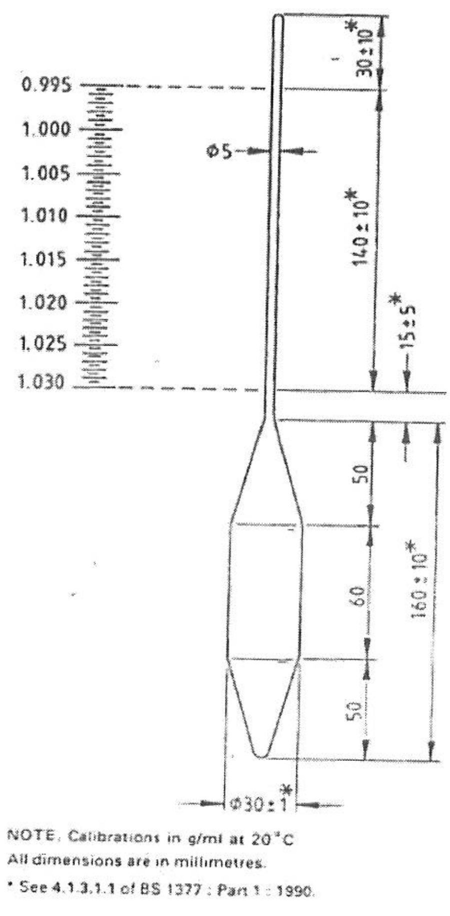


Figure 3.1: Hydrometer apparatus.

3.3.6 Compaction

The objective of this test is to obtain relationships between compacted dry density and soil moisture content, using two magnitudes of manual compactive effort. The test is used to provide a guide for specifications on field compaction. The first is a light compaction test using a 2.5 kg rammer (Standard Proctor). The second is a heavy compaction test using a 4.5 kg rammer with a greater drop on thinner layers of soil (Modified Proctor). For both tests, a compaction mould of 1 litre internal volume is used for soil in which all particles pass a 20 mm test sieve.

For soils containing upto 10% material coarser than 37.5mm and up to 30 % material coarser than 20 mm, equivalent tests are carried out in the larger CBR mould.

3.3.6.1 Main principles

The dry density which can be achieved for a soil depends on the degree of compaction applied and the moisture content. The moisture content, which gives the highest dry density, is called the optimum moisture content for that type of compaction. In general, the optimum moisture content is less than the Plastic Limit.

Method using 2.5 Kg rammer (BS Light)

3.3.6.2 Required equipment

1. A cylindrical compaction mould with internal diameter of 105 mm and internal height of 115 mm and a volume of 1.0 L (1000 cm3). The mould shall be fitted with a detachable baseplate and a removable extension (collar) approximately 50 mm height.
2. Subsidiary mould (CBR mould), diameter 152 mm, height 127 mm.

3. A metal rammer having a 50 mm diameter circular face and weighing 2.5 kg. The rammer shall be equipped with an arrangement for controlling the height of drop to 300 mm.
4. A balance readable to 1 g.
5. Palette knives or spatulas
6. A straightedge. e.g. a steel strip
7. A 20 mm and 37.5 mm test sieves and receiver
8. A container suitable for mixing the quantity of material to be used
9. Water proof containers and scoop

10. A large metal tray
11. Measuring cylinder, 200 ml or 500 ml
12. Suitable tools for extracting specimen from mould
13. Apparatus for moisture content determination

3.3.6.3 Sample preparation

Prepare five representative samples each of about 3 kg of material passing the 20 mm test sieve. (For the use of the 1 litre mould). Break up lumps of fine material by rolling on a flat surface. For coarser material where max. 10% is retained on the 37.5 mm sieve and max. 30 % is retained on the 20 mm sieve; a CBR mould shall be used. The material coarser than 37.5 mm shall be removed and weighed, and replaced by the same quantity of material of the fraction
20mm -37.5 mm. In this case, each of the 5 samples should be of about 6 kg.
Mix each sample thoroughly with different amounts of water to give a suitable range of moisture contents. The range of moisture contents shall be such that at least two values lay either side of the optimum moisture content. Seal each of the five portions in an airtight container and allow curing for a minimum of 4 hours.

3.3.6.4 Test procedure - 1 litre mould

1. The mould with the base plate attached shall be weighed to the nearest I g (ml).
2. Attach the extension collar and place the mould on a solid base, e.g. a concrete floor.
3. Place a quantity of moist soil in the mould such that when compacted it occupies a little over 1/3 of the height of the mould body.
4. Place the rammer with guide on the material in the mould. Lift the rammer handle until it reaches the top of the guide, and then release handle allowing to drop freely on the sample.
5. Change position of guide and again drop rammer. Repeat the process, systematically covering entire surface of sample. A total of 25 blows shall be applied.
6. Remove rammer and fill next layer of soil in the mould, and repeat the above process twice more by applying 25 blows to both the second and the third layer. The

mould should be filled, but surface should not be more than 6 mm proud of the upper edge of the mould body.

7. When all three layers are compacted, remove the extension collar, strike off excess soil and level the surface of the compacted soil to the top of the mould using the straightedge. Replace any coarse particles removed in the levelling process by finer material from the sample well pressed in.

8. Weigh the soil and the mould with baseplate attached to I g (m2)

9. Remove the compacted sample from the mould. Take a representative sample of min. 300 g of the soil for determination of its moisture content.

10. Discard the remainder of the sample. (The sample must not be reused in a later test).

11. This whole process shall be carried out for all five portions of the sample.

3.3.6.5 Calculations

Calculate the Bulk Density of each compacted specimen.

2. Calculate the Dry Density, Pd (in kg/rn3), of each specimen.

3. Plot the Dry Densities obtained from a series of determinations as ordinates against the corresponding Moisture Contents as abscissae. Draw a curve of best fit to the plotted points and identify the position of the maximum on this curve. Read off the values of dry density and moisture content, to three significant figures corresponding to that point.

4. On the same graph, plot the curves corresponding to the 0 %, 5 % and 10 % air voids, calculated from the equation.

3.3.6.6 Report.

The test report shall include the following:

a) Type of material and sample identification

b) Reference to this procedure

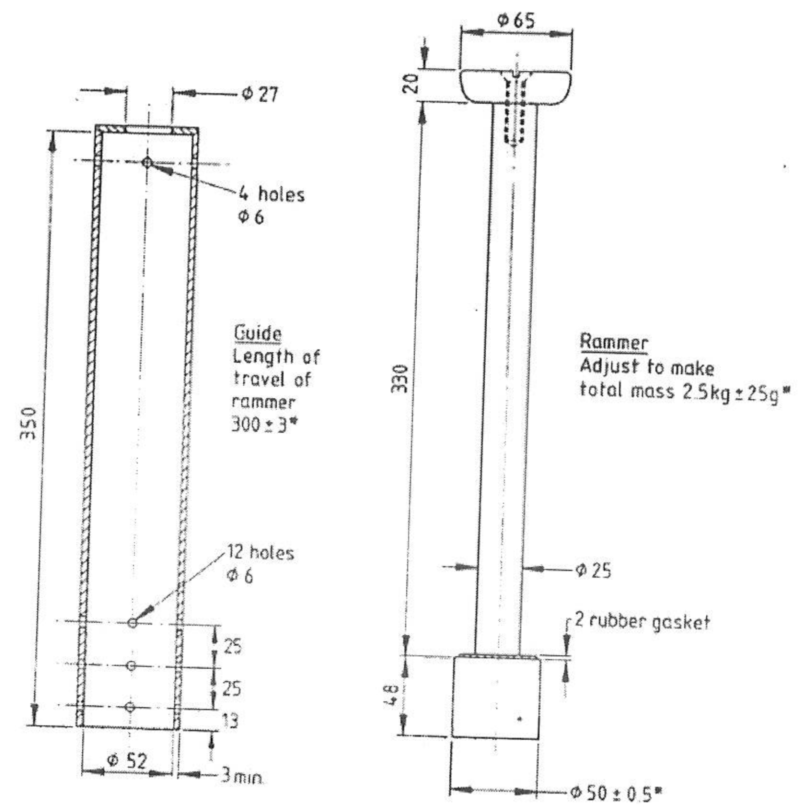
e) The experimental points and the smooth curve drawn through them showing the relationship between Moisture Content and Dry Density.

d) The Dry Density corresponding to the maximum Dry Density on the curve, reported as the Maximum Dry Density to the nearest whole number (in kg/m3).

e) The corresponding Moisture Content reported as the Optimum moisture Content to two significant figures (in %).

f) The amount of material (stone) retained on the 20 mm and 37.5 mm sieves reported to nearest 1 % by dry mass.

g) The particle density and whether measured or assumed



All dimensions shown are in millimetres.

This design has been found satisfactory, but alternative designs may be used provided that the essential requirements are fulfilled.

*See 4.1.3.1.1 of BS 1377 : Part 1 : 1990.

Figure3. 2: Hammer for compaction test.

3.3.7 CBR - California bearing ratio test - One Point

3.3.7.1 Objective

The strength of the subgrade is the main factor in determining the required thickness of flexible pavements for roads and airfields. The strength of a subgrade, sub base and base course materials are expressed in terms of their California Bearing Ratio (CBR) value.

The CBR-value is a requirement in design for pavement materials of natural gravel.

3.3.7.2 Main principles

This method covers the laboratory determination of the California Bearing Ratio (CBR) of a compacted sample of soil dynamically compacted by metal rammers - one point method. The CBR value is the resistance to a penetration of 2.5 mm of a standard cylindrical plunger of 50 mm diameter, expressed as a percentage of the known resistance of the plunger to 2.5 mm in penetration in crushed aggregate, (taken as 13.2 KN).

3.3.7.3 Required equipment

1.Test sieves, sizes 20 mm and 5 mm.

2. A cylindrical metal mould, i.e. the CBR mould, having a nominal internal diameter of 152 mm and a height of 127 mm. The mould shall be fitted with a detachable baseplate and a removable extension. The internal face shall be smooth, clean and dry before use.

3. A metal rammer of either 2,5 kg or 4,5 kg

4. A steel rod

5. A steel straightedge

6. A spatula

7. A balance, capable of weighing up to 25 kg readable to 5 g.

8. Apparatus for moisture content detlermination.

9. Filter papers 150mm in diameter.

3.3.7.4 Sample preparation

The CBR test shall be carried out on material passing the 20 mm test sieve. 1f the soil contains particles larger than this, the fraction retained on the 20 mm test sieve shall be removed and weighed before preparing the test sample. 1f this fraction is greater than 25 %, the test is not applicable. The moisture content of the soil shall be chosen to represent the design condition for which the test results are required.

Take a portion of material large enough to provide about 6 kg of material passing a 20 mm sieve. Bring the sample to the required moisture content. The soil shall be thoroughly mixed and shall normally be sealed and stored for at last 24h before compacting into the mould.

The specified effort of compaction shall correspond to the 2.5 kg rammer method - BS Light or the 4.5 kg rammer method - BS Heavy (or to an intermediate value).

3.3.7.5 Test procedure

1. Divide the prepared quantlity of soil into three (or five) portions equal to within 50 g and seal each portion in an airtight container until required for use, to prevent loss of
moisture.
2. Stand the mould assembly on a solid base, e.g. a concrete floor.
3. Place the first portion of soil into the mould and compact it, so that after 62 blows of the appropriate rammer the layer occupies about or a little more than one-third (or one-fifth) of the height of the mould. Ensure that the blows are evenly distributed over the surface.
4. Repeat using the other two (or four) portions of soil in turn, so that the final level of the soil surface is not more than 6 mm above the top of the mould body.
5. Remove the collar and trim the soil flush with the top of the mould with the scraper, checking with the steel straightedge.
6. Weigh the mould, soil and baseplate to the nearest 5 g (m3).

3.3.7.6 Soaking

3.3.7.6.1 Required equipment

1. A perforated baseplate, fitted to the CBR mould in place of the normal baseplate.

2. A perforated swell plate, with an adjustable stern to provide a seating for a dial gauge.

3. Tripod, mounting to support the dial gauge.

4. A dial gauge, having a travel of 25 mm and reading to 0,01 mm.

5. A soaking tank, large enough to allow the CBR mould with baseplate to be submerged, preferably supported on an open mesh platform.

6. Annular surcharge discs, each having a mass known to + 50 g.

7. Half-circular segments may be used.

8. Petroleum jelly.

3.3.7.7 Soaking procedure

1. If a solid baseplate have been used, this shall be removed from the mould and replaced with a perforated baseplate.

2. Fit the collar to the other end of the mould, packing the screw threads with petroleum jelly to obtain a watertight joint.

3. Place the mould assembly in the empty soaking tank. Place a filter paper on top of the sample followed by the perforated swell plate. Fit the required number of annular surcharge discs around the stem on the perforated plate.

4. Mount the dial gauge support on top of the extension collar, secure the dial gauge in place and adjust the stem on the perforated plate to give a convenient zero reading.

5. Fill the soaking tank with water to just below the top of the mould extension collar. Start the timer when the water has just covered the baseplate.

6. Record readings of the dial gauge each day.

7. Take off the dial gauge and its support, remove the mould assembly from the soaking tank and allow the sample to drain for 15 min.

8. Remove the surcharge discs, perforated plate and extension collar. Remove the perforated baseplate and refit the solid baseplate if available.

9. lithe sample has swollen, trim it level with the end of the mould.

The sample is then ready for test in the soaked condition.

3.3.7.8 Penetration test procedure

3.3.7.8.1 Required equipment

1. A cylindrical metal plunger.
2. A CBR compression machine. The machine shall be capable of applying at least 45 kN at a rate of penetration of the plunger of 1 mm/mm to within ± 0,2 mm/mm.
3. A loading ring.
4. A dial gauge with 25 mm travel, reading to 0.01 mm for measuring the penetration of the plunger into the specimen.
5. A stopwatch
6. The CBR mould
7. Surcharge discs

3.3.7.9 Procedure

1. Place the mould with base plate containing the sample, with the top face of the sample exposed, centrally on the lower plate of the testing machine.

2. Place the appropriate annular surcharge discs on top of the sample

3. Fit into place the cylindrical plunger on the surface of the sample.

4. Apply a seating force to the plunger, depending on the expected CBR value as follows:

For CBR value up to 5%, apply 10 N

For CBR value from 5% to 30%, apply 50 N

For CBR value above 30%, apply 250 N

5. Record the reading of the loading ring as the initial zero reading (or reset the loading ring to read zero).

6. Secure the penetration dial gauge in position. Record its initial zero reading, or reset it to zero.

7. Start the test so that the plunger penetrates the sample at a uniform rate 1 mm/mm.

8. Record readings of the force gauge at intervals of penetration of 0, 25 nail, to a total penetration not exceeding 7, 5 mm (see form F).

9. If a test is to be carried out on both ends of the sample, raise the plunger and level the surface of the sample by filling in the depression left by the plunger. Check for flatness with the straightedge.

10. Remove the baseplate from the lower end of the mould, fit it securely on the top end and invert the mould. Trim the exposed surface if necessary.

11. Carry out the test on the base by repeating steps 1- 8.

12. After completing the penetration test or tests, determine the moisture content of the test sample.

3.3.7.10 Calculation and plotting

Force-penetration curve

1) Calculate the force applied to the plunger from each reading of the loading ring observed during the penetration test.

2) Plot each value of force as ordinate against the corresponding penetration as abscissa and draw a smooth curve through the points.

The normal curve is convex and needs no correction. If the initial part of the curve is concave, correction is necessary. Draw a tangent at the point of the steepest slope, and produce it to intersect the abscissa. This is the corrected zero point. If the curve continues to curve upwards, it is considered that the penetration of the plunger is increasing the soil density and subsequently its strength. No correction is necessary.

3.3.7.11 Calculation of california bearing ratio (CBR)

Penetrations of 2.5 mm and 5.0 mm are used for calculating the CBR value.

3.3.7.12 Practical considerations

Use an extruder for removing the sample (no hammering).

Make certain that the mould is fastened tightly to the baseplate.

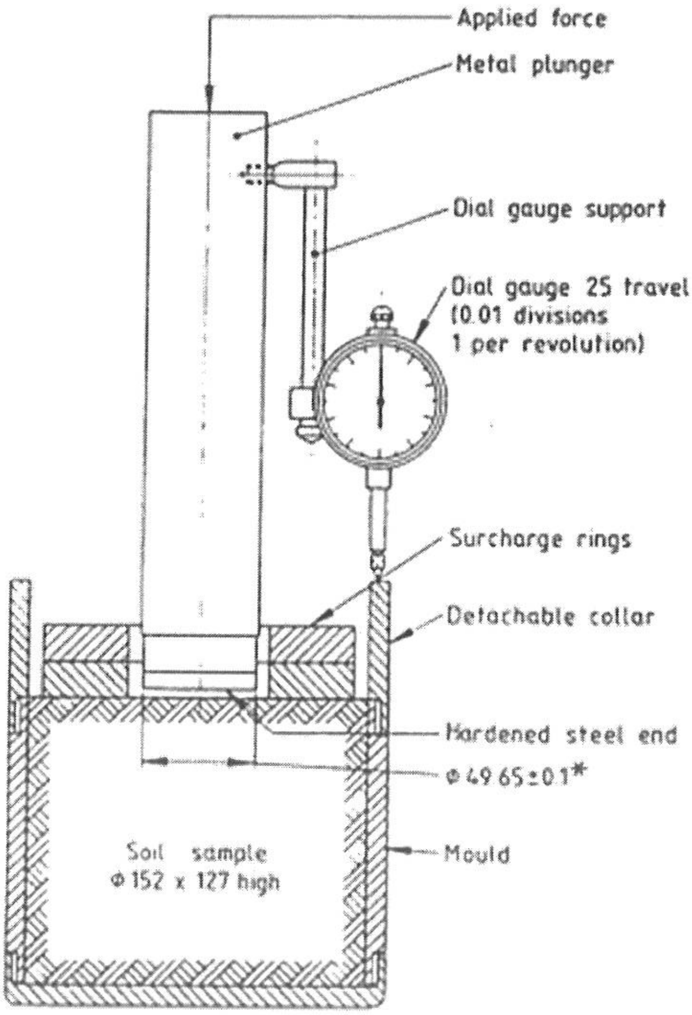


Figure 3.3: General arrangement of the CBR Apparatus.

3.3.8 Summary

The quality of any pavement is affected by the materials used for construction. Coming to the sub grade, soil is the most important material. Here we have seen various tests used for finding the strength of soil, the prominent ones being CBR and plate load test. CBR test assesses the strength of soil, whereas plate load test is used to evaluate its support capability

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Characteristics of Natural Samples;

After the collection and treatment of the samples as described in chapter three, their properties were determined to ensure that all relevant factors could be available to establish differences between the natural sample and the two grade of cement treated soils. Below are the results of tests performed on the four samples.

4.2 Identification and Classification Tests

The summary of the results of preliminary analysis on the samples are shown below

Table 4.1: Summary table of preliminary analysis

Sample	location	Natural Moisture Content (%)	Specific gravity	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)	AASHTO Classification	Soil type
A	ASIN	17.5	2.35	43.5	19.1	19.1	A-2-7(2)	Silty
B	CAMPUS	15	2.42	43.43	20.02	20.2	A-7-6(3)	Clayey
C	IKOYI	14.3	2.59	32.48	15.18	15.18	A-2-6(0)	Silty
D	OKE-ORIN	14.6	2.59	43.65	16.85	16.85	A-2-7(1)	Silty

the particle size distribution of the samples are shown in the table above and the average distributions are as follow, IKOYI; gravel is 28.5%, sand is 49.6%, clay is 21.9% ASIN; gravel is 12.8%,sand is 53.2%,clay is 34.0% for OKE –ORIN gravel is 17.4%,sand is 51.4%, and clay is 31.2% for CAMPUS; gravel is 7.2%, sand is 48.0% and clay is 44.8%. Hence soil from IKOYI consists of 78.1% coarse material and 21.9% fine. The liquid limit, plastic limit and plasticity index values are 32.48%, 17.3% and 15.18% respectively. This soil can be classified as A-2-6(0) according to AASHTO soil classification. Soil sample from ASIN contains 66% coarse material and 34% fine, with a liquid limit, plastic limit and plasticity index of 43.50%, 24.4% and 19.1% respectively. The soil can be classified as A-2-7(2), CAMPUS soil samples contains 55.2% coarse material and 44.8% fine, it have a liquid limit, plastic limit and plastic index of 43.43%, 23.4%, 20.02% respectively. The soil can be classified as A-7-6(3) while OKE-ORIN soil samples contains 68.8% coarse materials and31.2% fine. It have a liquid limit, plastic limit and a plasticity index of 43.65%,26.8%, 16.85% respectively, the soil can be classified as A-2-7(1).

4.2.1 Compaction test

The results obtained from the compaction on the natural samples were shown in the table of summary above and the respecter cement treated soil from the laboratory. The analysis is as follows, samples from IKOYI has a maximum dry density of 1.56kg/m3 with optimum moisture content (omc) of 18%, CAMPUS soil samples has 1.66kg/m3 as the maximum dry density with 15% as optimum moisture content, ASIN sample has 1.76kg/m3 as the maximum dry density and a optimum moisture content of 15%, while OKE- ORIN possess a maximum dry density of 1.66kg/m3 and a optimum moisture content of 21%.

4.2.2 California bearing ratio (Cbr)

The natural forms of the soil were investigated using California bearing ratio test, to determine suitability as highway materials. The results gotten during the test were range within 40.1% to75.65% respectively. Those results show that the soils fall into the earlier classified soil category.

4.2.3 Natural moisture content

The natural moisture content of samples form ASIN, IKOYI, CAMPUS, OKE-ORIN are 17.75%, 14.3%, 15%,14.6% respectively. IKOYI had the lowest natural moisture content while ASIN had the highest. This is a function of void ratios and the specific gravities of the samples. This showed that the soil samples contained appreciable amount of moisture which is largely affected by the climatic condition.

4.2.4 Specific gravity

The specific gravities of samples from ASIN, IKOYI, CAMPUS and OKE-ORIN are 2.35, 2.59, 2.42 and 2.59 respectively. This values fall within that given in Das, (2000) for clay minerals, as halloysite (2.0-2.55) and the ones with 2.59 are kaolinites.

4.3.0 Characteristics of samples stabilized

The four samples were treated with cements of different grades, 32.5grade cement and 42.5grade cement as additives to improve their engineering properties, and also to compare the effects of those two grades on the strength properties of the samples. The followings tests were carried out on the treated samples; compaction test, California bearing ratio (CBR) test and the atterberg limit tests.

4.3.1 Compaction

Compaction tests were carried out on treated samples to know the relationship between the strength and density for treated soil mixtures compacted at different moisture contents and using two cement grades. The results of the treated soil are shown in the table below with the variation of their maximum dry density and moisture contents.

Table 4.2: Compaction Summary table for the treated soil using 32.5 grade cement

Locations	Percentage	OMC (%)	MDD(kg/m3)
ASIN	0%	15	1.76
	2%	20	1.78
	4%	15	1.78
	6%	16	1.78
	8%	18	1.85
IKOYI	0%	18	1.56
	2%	20	1.66
	4%	16	1.70
	6%	16	1.78
	8%	20	1.80
OKE-ORIN	0%	21	1.66
	2%	20	1.78
	4%	19	1.84
	6%	19	1.92
	8%	21	1.96
CAMPUS	0%	15	1.66
	2%	20	1.68
	4%	16	1.74
	6%	18	1.78
	8%	18	1.84

Table 4.3: Summary table of compaction test for the treated soil samples using 42.5 grade cement

Locations	Percentage	OMC (%)	MDD(kg/m3)
ASIN	2%	17	1.78
	4%	20	1.78
	6%	20	1.78
	8%	23	1.84
	-	-	-
	2%	17	1.56
IKOYI	4%	18	1.70
	6%	18	1.74
	8%	18	1.86
	-	-	-
	2%	21	1.68
	4%	21	1.78
OKE-ORIN	6%	20	1.82
	8%	20	1.86
	-	-	-
	2%	18	1.68
	4%	20	1.70
CAMPUS	6%	18	1.78
	8%	20	1.80

The two grades of cement used for treating the samples increased the maximum dry density and decrease the optimum moisture content. Sample from OKE-ORIN, the OMC% and MDD changed from MDD of 1.66kg/m3 and OMC of 21% at 0% (untreated sample) to MDD of 1.96kg/m3 and 21% OMC for 32.5 grade cement at 8% while OMC of 20% and MDD of 1.86kg/m3 at 8% for 42.5grade cement. CAMPUS soil sample OMC% and MDD changed from MDD of 1.66kg/m3 and OMC of 15% at 0% (untreated sample) to MDD of 1.84kg/m3 and 18% OMC for 32.5 grade cement at 8% while OMC of 20% and MDD of 1.80kg/m3 at 8% for 42.5 grade cement. IKOYI soil sample OMC% and MDD changed from MDD of 1.56kg/m3 and OMC of 18% at 0% (untreated sample) to MDD of 1.80kg/m3 and 20% OMC for 32.5 grade cement at 8% while OMC of 18% and MDD of 1.86kg/m3 at 8% for 42.5 grade cement. ASIN soil sample OMC% and MDD changed from MDD of 1.76kg/m3 and OMC of 15% at 0% (untreated sample) to MDD of 1.85kg/m3 and 18% OMC for 32.5 grade cement at 8% while OMC of 23% and MDD of 1.84kg/m3 at 8% for 42.5 grade cement. An increase in MDD is a general indication of soil improvement, the opinion of Das, (2000) revealed that a change down in dry density might occur due to both the particle size and specific gravity of the soil and stabilizer.

4.3.2 California bearing ratio (Cbr)

CBR test were carried out at varied proportion at their optimum moisture contents, the following results were obtained from the two cement grades.

Table 4.4: Summary table of the CBR values for both 32.5 and 42.5 grade cements are below;

SAMPLES	0%	2%	4%	6%	8%
OKE-ORIN	72.64	70.14	80.16	88.18	83.66
ASIN	75.65	77.15	79.16	80.16	84.67
IKOYI	52.1	54.1	72.14	80.16	80.16
CAMPUS	40.1	50.1	51.6	77.2	79.7

Table 4.5: For Grade 35cement

SAMPLES	4%	6%	8%
ASIN	76.2	86.2	84.5
OKE-ORIN	62.63	78.66	81.16
IKOYI	62.63	78.66	81.16
CAMPUS	40.58	60.12	68.64

For OKE-ORIN soil sample its CBR value changes from 72.64% at 0% (untreated sample) to 83.66% for 32.5grade cement at 8% while for 42.5grade cement at 8% is 84.5%.For CAMPUS soil sample its CBR value changes from 40.1% at 0% (untreated sample) to 79.7% for 32.5grade cement at 8% while for 42.5grade cement at 8% is 68.64%.For ASIN soil sample its CBR value changes from 75.65% at 0% (untreated sample) to 84.67% for 32.5grade cement at 8% while for 42.5grade cement at 8% is 84.5%. For IKOYI soil sample its CBR value changes from 52.1% at 0% (untreated sample) to 80.16% for 42.5grade cement at 8% while for 42.5grade cement at 8% is 81.16% .

4.3.3 Plasticity and workability

Table 4.6: The table below shows the summary of the atterberg limits for 32.5grade cement

Samples	%	LL%	PL%	PI%	SL%
	2%	44.3	22.5	21.8	9.3
ASIN	4%	41.7	25.4	16.3	10.0
	6%	42.9	21.5	21.4	8.6
	8%	37.5	21.1	16.4	7.3
	2%	41.57	24.95	16.67	9.3
	4%	42.7	22.4	20.3	9.3
CAMPUS	6%	43.9	34.9	10.6	7.9
	8%	43.9	34.9	9.0	7.9
	2%	31.6	25.2	6.4	9.3
	4%	29.8	21.0	8.8	9.3
IKOYI	6%	29.05	19.5	9.55	8.6
	8%	28.7	18.9	9.17	7.1
	2%	44.25	24.4	19.85	7.1
	4%	40.6	26.1	14.5	7.9
OKEORIN	6%	39.7	21.9	17.8	7.9
	8%	36.3	18.6	17.68	7.8

Table 4.7: For 42.5 grade cement atterberg limit

Samples	%	LL%	PL%	PI%	SL%
	4%	40.4	22.5	17.9	10.0
ASIN	6%	36.2	19.2	17.0	7.8
	8%	40.57	20.2	20.37	9.3
	4%	40.1	23.4	16.73	9.3
CAMPUS	6%	41.3	31.3	10.0	7.0
	8%	43.4	35.4	8.0	7.9
	4%	30.4	19.7	10.7	9.3
IKOYI	6%	29.5	22.0	7.5	9.3
	8%	29.3	20.7	8.57	8.7
	4%	41.4	21.8	19.6	8.7
OKE-ORIN	6%	38.3	20.6	17.7	8.7
	8%	36.7	18.9	17.8	8.7

From the summary results above the four samples treated with cement some of their plasticity index decreased while some were inconsistency in the rate of increase of the plasticity index in both grades of cement.

4.4.0 Discussion of the results

The results of the various tests carried out on the samples show that the addition of cement to natural samples lead to increase in strength over the natural samples. This is in accordance with the works of investigation of (winterkorn and chandraserkharan 1951).

The physical inspection of the samples revealed that their colour varies. OKE-ORIN was light brown, CAMPUS has reddish brown, ASIN has reddish brown while IKOYI reddish dark in colour.

The natural samples have the following characteristics; the percentage of fine grains ranges from 21.9% to 44.8%, their plastic limit, liquid limit and plasticity index range from 17.3% to 26.8%, 32.48% to 43.65% and 15.18% to 20.02% respectively. And their maximum dry density and optimum moisture contents ranges from 1.56kg/m3 to 1.66kg/m3 and15% to20% respectively. The soils are A-2-7(2), A-7-6(3), A-2-6(0) and A-2-7(1) based on AASHTO soil classification system.

Also addition of cement of the two different grades to the four locations increase the MDD and their OMC at 6% and 8%, while MDD and OMC values for 2%, 4% were inconsistent.

Atterberg limits of the treated soil, the liquid limits ranges from 28.7% to 43.9% for 32.5 grade cement 8% and 29.7% to 43.4% for 42.5 grade cement at 8%the federal ministry of works and housing(1972) for road works recommend a liquid limit of 50% maximum for sub base and base materials. All the studies soil samples falls within this specification, thus making them suitable for sub base and base materials.

The plasticity indices of all the treated samples at 6% and 8 % decreased. These reductions in the plasticity indices are indicators of soil improvement.

CHAPTER FIVE

5.1 Conclusion

The characteristics and properties of cement treated lateritic soils mainly depend on the types of soil and the amount and type of additive used.The results of this laboratory work showed that beneficial effects are obtained by the addition of some amounts cement to lateritic soils and the following conclusions were deduced;

i.)The natural soil samples from the four locations, ASIN, CAMPUS, IKOYI, OKE-ORIN falls within the A-2-7(2), A-7-6(3), A-2-6(0) and A-2-7(1) respectively as according to AASHTO system classification. This classification reveals the rating of the samples as fair to poor as subgrade materials hence it was treated with cements of 32.5grade and 42.5grade for suitability as road constructions materials

ii.)The cement treated lateritic soil using 32.5grade cement has the highest values compare with 42.5 grade cement

iii.)Addition of cement, results in increase in MDD and decrease in OMC, in the four locations

iv.)It was discovered that the two cement grades used has high CBR values at 6% and 8% that makes it suitable for highway construction.

5.2 Recommendation

On the basis of the test results, observation and conclusions, the following recommendations are being proffered.

i.)The use of at least two or more grades of cement as soil improvement technique for laterites and lateritic soils should be encouraged in the construction industries.

ii.) The type of research work done should be extended to other types of lateritic soils deposit in Nigeria.

iii.) The field tests on the roads with cement stabilized lateritic soils should be encouraged greatly.

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APPENDICES

NOTE; CEMENT A, 32.5 grade cement

CEMENT B, is 42.5 grade cement

Table 1:**OKE ORIN CBR TEST DATA FOR CEMENT A**

P.D.G	0% DGR	0% LOAD	2% DGR	2% LOAD	4% DGR	4% LOAD	6% DGR	6% LOAD	8% DGR	8% LOAD
50	151	3.8	98	2.5	222	5.6	138	3.5	197	4.73
100	215	5.4	173	4.4	274	6.9	253	6.3	272	6.8
150	261	6.5	215	5.4	319	8.0	325	8.1	339	8.5
200	309	7.7	284	7.1	364	9.1	405	10.1	399	9.98
250	355	8.9	327	8.2	416	10.4	473	11.8	432	10.8
300	397	9.9	370	9.3	472	11.8	512	12.8	471	11.8
350	448	11.2	410	10.3	506	12.7	587	14.7	519	12.98
400	494	12.4	463	11.6	557	13.9	632	15.8	579	14.5
450	532	13.3	512	12.8	600	15.0	6.79	17.0	620	15.5
500	579	14.5	559	14.0	639	16.0	702	17.6	668	16.7
550	582	14.6	578	14.5	671	16.8	729	18.2	696	17.4
600	602	15.1	593	14.8	699	17.5	761	19.0	715	17.9
650	619	15.5	610	15.3	718	18.0	800	20.0	728	18.2
700	633	15.8	620	15.5	731	18.3	822	20.55	744	18.6
750	641	16.0	628	15.7	747	18.7	838	20.95	761	19

NB: Load is gotten by multiplying DGR values by the PRF(Proving ring factor) the of the machine, the PRF use is 0.025

Table 2 **ASIN CBR DATA FOR CEMENT A**

P.D.G	0% DGR	0% LOAD	2% DGR	2% LOAD	4% DGR	4% LOAD	6% DGR	6% LOAD	8% DGR	8% LOAD
50	251	6.3	197	4.9	155	3.9	273	6.8	125	3.1
100	286	7.2	265	6.6	215	5.4	315	7.9	257	6.4
150	339	8.5	307	7.7	275	6.9	377	9.4	310	7.8
200	378	9.5	312	8.4	334	7.3	377	9.5	323	8.4
250	401	10.0	359	9.0	358	10.0	412	10.3	397	9.9
300	439	11.0	395	9.9	451	11.3	469	11.7	466	11.7
350	481	12.0	461	11.5	492	12.3	501	12.5	520	13.0
400	526	13.2	502	12.6	538	13.5	563	14.1	590	14.8

450	569	14.2	559	14.0	587	14.7	600	15.0	645	16.1
500	605	15.1	615	15.4	631	15.8	638	16.0	674	16.9
550	618	15.5	621	15.5	654	15.9	653	16.3	698	17.5
600	628	15.7	630	15.8	679	17.0	681	17.0	721	18.8
650	641	16.0	645	16.1	688	17.2	699	17.5	755	18.9
700	660	16.5	668	16.7	790	17.8	715	17.9	783	19.6
750	668	16.7	677	16.9	725	18.1	731	18.3	805	20.1

Table 3: **DETERMINATION OF CBR VALUES FROM THE ABOVE FOR CEMENT**;

FOR OKE ORIN

PRF	0%	2%	4%	6%	8%
250	67.22	61.93	78.55	89.12	81.57
500	72.64	70.14	80.16	88.18	83.66

FOR ASIN

PRF	0%	2%	4%	6%	8%
250	75.5	67.98	75.5	77.79	74.77
500	75.65	77.15	79.16	80.16	84.67

Table 4: **IKOYI CBR DATA FOR CEMENT A**

	0%	0%	2%	2%	4%	4%	6%	6%	8%	8%
P.D.G	DGR	LOAD	DGR	LOAD	DGR	LOAD	DGR	LOAD	DGR	LOAD
50	49	1.2	98	2.45	193	4.8	155	3.9	137	3.4
100	75	1.9	145	3.6	247	6.2	218	5.5	245	6.1
150	112	2.8	188	4.7	287	7.2	289	7.2	320	8
200	150	3.8	205	5.1	331	8.3	335	8.4	372	9.3
250	197	4.9	239	6.0	372	9.3	389	9.7	419	10.5
300	234	5.85	274	6.9	408	10.2	441	11	478	12
350	271	6.8	311	7.8	448	11.2	490	12.3	531	13.3
400	329	8.2	342	8.6	497	12.4	547	13.7	577	14.4
450	381	9.5	391	9.8	533	13.3	594	14.9	602	15.1
500	415	10.4	433	10.8	576	14.4	641	16	638	16
550	429	10.7	464	11.6	595	14.9	679	17	667	16.7
600	450	11.5	497	12.4	638	16	704	17.6	695	17.4
650	468	11.7	519	13	667	16.7	734	18.4	720	18
700	483	12.1	536	13.4	701	17.5	758	19	731	18.3
750	491	12.3	553	13.8	719	18	766	19.2	748	18.7

Table 5: **CAMPUS CBR DATA FOR CEMENT A**

	0%	0%	2%	2%	4%	4%	6%	6%	8%	8%
P.D.G	DGR	LOAD	DGR	LOAD	DGR	LOAD	DGR	LOAD	DGR	LOAD
50	58	1.45	78	2	95	2.4	177	4.4	181	4.5
100	112	2.8	101	2.5	110	2.8	235	5.9	227	5.7
150	126	3.15	130	3.3	148	3.7	287	7.2	291	7.3
200	147	3.7	161	4	178	4.3	326	8.2	330	8.3
250	182	4.6	199	5.0	202	5.1	373	9.3	374	9.4

300	211	5.3	231	5.8	244	6.1	428	10.7	429	10.7
350	239	6	279	7	281	7	468	11.7	472	11.8
400	289	7.2	315	7.9	322	8.1	527	13.2	520	12.7
450	309	7.7	351	8.8	374	9.4	581	14.5	588	14.7
500	321	8.0	398	10	410	10.3	615	15.4	636	15.9
550	346	8.7	422	10.6	435	10.9	641	16	659	16.5
600	371	9.3	451	11.3	463	11.6	666	16.7	684	17.1
650	393	9.8	467	11.7	494	12.4	691	17.3	700	17.5
700	409	10.2	479	12	520	13	717	18	739	18.5
750	422	10.6	493	12.3	537	13.4	734	18.4	756	18.9

Table 6: **ASIN CBR DATA FOR CEMENT B**

P.D.G	4% DGR	4% LOAD	6% DGR	6% LOAD	8% DGR	8% LOAD
50	172	4.3	159	3.9	189	4.7
100	245	6.1	221	5.5	249	6.2
150	315	7.88	273	6.8	300	7.5
200	361	9.0	341	8.5	358	8.95
250	400	10	399	9.9	402	10
300	430	10.8	455	11.3	467	11.7
350	489	12.2	491	12.3	501	12.5
400	502	12.6	548	13.7	557	13.9
450	544	13.6	610	15.3	620	15.5
500	608	15.2	686	17.2	675	16.8
550	625	15.6	701	17.5	688	17.2
600	641	16.0	718	17.9	699	17.5
650	651	16.3	733	18.3	715	17.9

700	659	16.5	741	18.5	723	18
750	667	16.7	750	18.7	731	18.3

Table 7:**OKE ORIN CBR DATA FOR CEMENT B**

P.D.G	4% DGR	4% LOAD	6% DGR	6% LOAD	8% DGR	8% LOAD
50	130	3.3	10	0.3	179	4.5
100	171	4.3	157	3.9	241	6.0
150	207	5.2	200	5.0	289	7.2
200	246	6.2	248	6.2	347	8.7
250	289	7.2	392	9.8	398	9.9
300	354	8.9	432	10.8	466	11.7
350	439	10.9	466	11.4	420	10.5
400	488	12.2	510	12.8	547	13.7
450	537	13.4	558	13.9	578	14.5
500	591	14.8	604	15.1	625	15.6
550	621	15.5	619	15.5	641	16.0
600	634	15.9	629	15.7	650	16.3
650	645	16.1	640	16	659	16.5
700	651	16.3	657	16.4	662	16.6
750	659	16.7	674	16.8	674	16.9

Table 8: CBR values for the above, Ikoyi, campus,Asin, Oke-orin

IKOYE

	0%	2%	4%	6%	8%
PRF of 250	36.7	44.98	69.71	72.7	78.7
PRF of 500	52.1	54.1	72.14	80.16	80.16

CAMPUS

	0%	2%	4%	6%	8%
PRF of 250	34.5	37.5	38.2	69.71	70.5
PRF of 500	40.1	50.1	51.6	77.2	79.7

ASIN

	4%	6%	8%
PRF of 250	74.9	74.2	74.9
PRF of 500	76.2	86.2	84.5

OKE ORIN

	4%	6%	8%
PRF of 250	53.9	73.46	74.2
PRF of 500	74.14	75.65	78.15

Table 9:IKOYI CBR TEST DATA FOR CEMENT B

	4%		6%		8%	
P.P	**D.R**	**LOAD**	**D.R**	**LOAD**	**D.R**	**LOAD**
50	168	4.2	265	6.6	297	7.4
100	207	5.2	326	8.2	343	8.6
150	234	5.9	378	9.5	397	9.9
200	269	6.7	415	10.4	434	10.9
250	309	7.7	445	11.4	477	11.9
300	347	8.7	479	12.0	515	12.9
350	380	9.7	502	12.6	543	13.6
400	420	10.5	536	13.4	592	14.8
450	462	11.6	589	14.7	620	15.5
500	498	12.5	628	15.7	649	16.2
550	531	13.3	651	16.3	694	17.4
600	559	14.0	677	16.9	721	18.0
650	583	94.6	682	17.1	743	18.6
700	604	15.1	701	17.5	759	19.0
750	618	15.5	720	18.0	762	19.1

Table 10: CAMPUS CBR DATA FOR CEMENT B

	4%		6%		8%	
P.P	**D.R**	**LOAD**	**D.R**	**LOAD**	**D.R**	**LOAD**
50	44	1.1	148	3.7	198	5.0
100	81	2.0	199	5.0	231	5.8
150	107	2.7	233	5.8	289	9.2
200	127	3.2	271	6.8	322	8.1
250	169	4.2	296	7.8	369	9.2
300	197	4.9	325	8.1	401	10.0
350	222	5.6	369	9.2	428	10.7
400	258	6.5	402	10.1	472	11.8
450	299	7.5	448	11.2	506	12.7
500	325	8.1	478	12.0	549	13.7
550	339	8.5	507	12.7	572	14.3
600	361	9.0	533	13.3	597	14.9
650	387	9.7	570	14.3	622	15.9
700	408	10.2	589	14.7	644	16.1
750	421	10.5	606	15.1	665	1.66

Table 11: THE CBR VALUES FOR THE ABOVE CEMENT B, IKOYI AND CAMPUS ARE BELOW;

FOR IKOYI

	4%	**6%**	**8%**
250	58.2	83.84	89.88
500	62.63	78.66	81.16

FOR CAMPUS

	4%	**6%**	**8%**
250	31.7	58.91	69.49
500	40.58	60.12	68.64

CALIFORNIA BEARING RATIO GRAPH FOR BOTH 32.5 AND 42.5 GRADE CEMENTS, 32.5 IS CEMENT A AND 42.5 IS CEMENT B

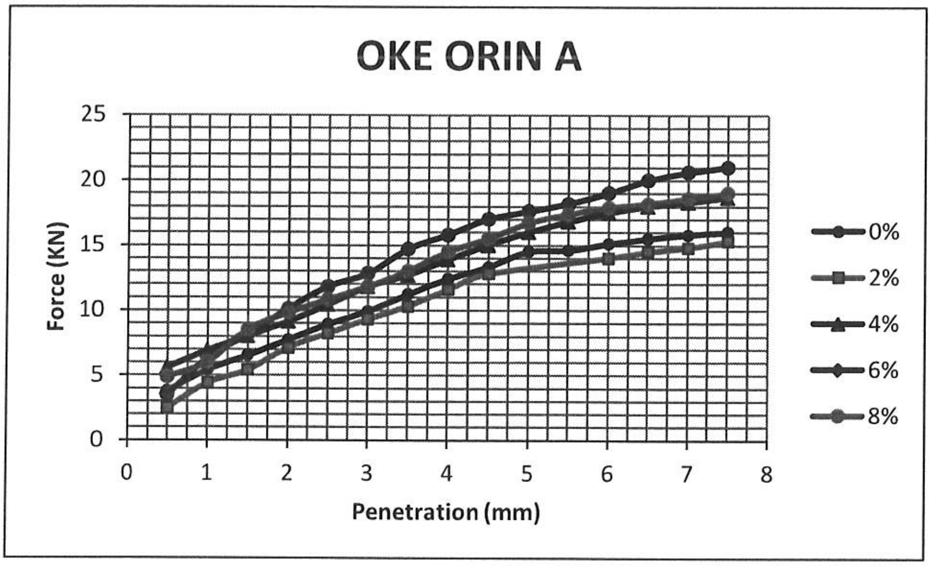

Figure1:CBR Test Graph

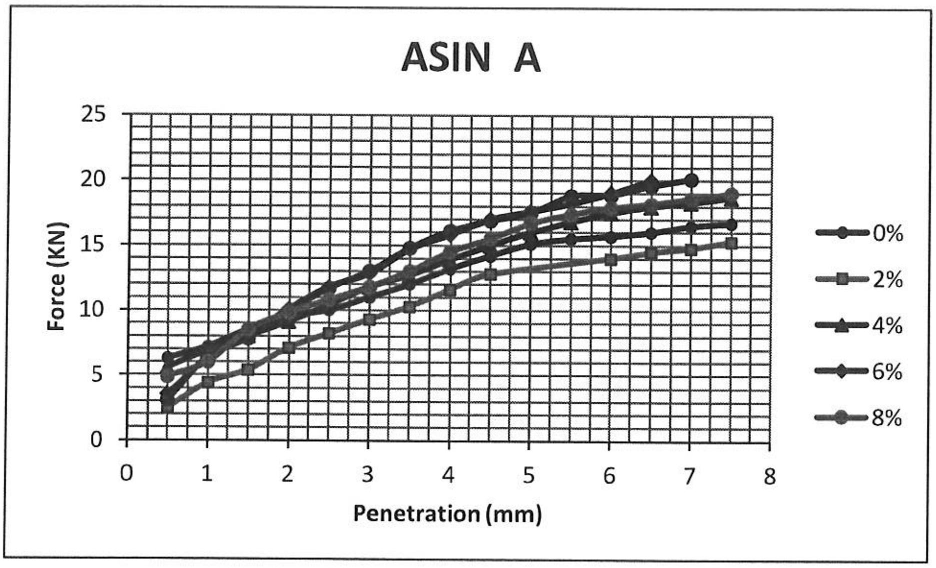

Figure 2: CBR TEST

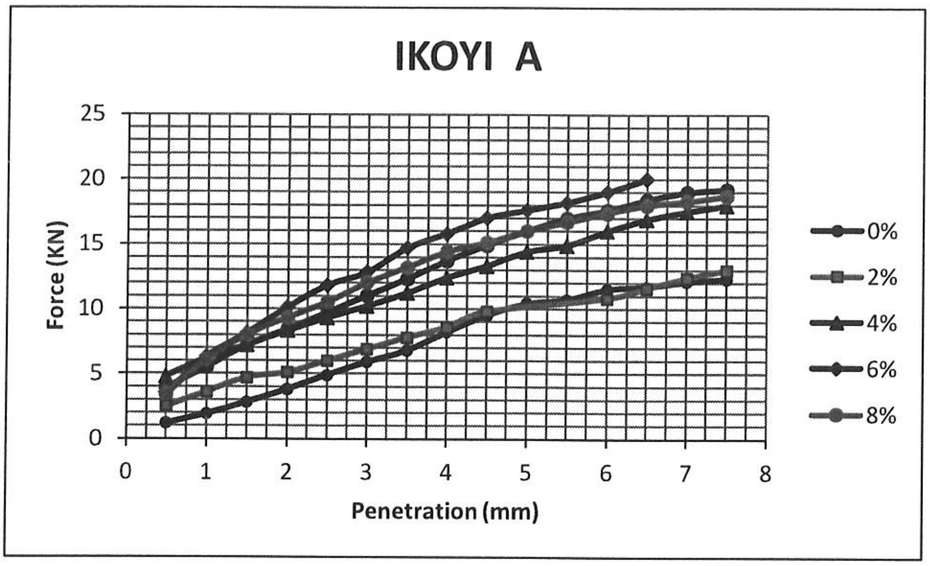

Figure 3: CBR test

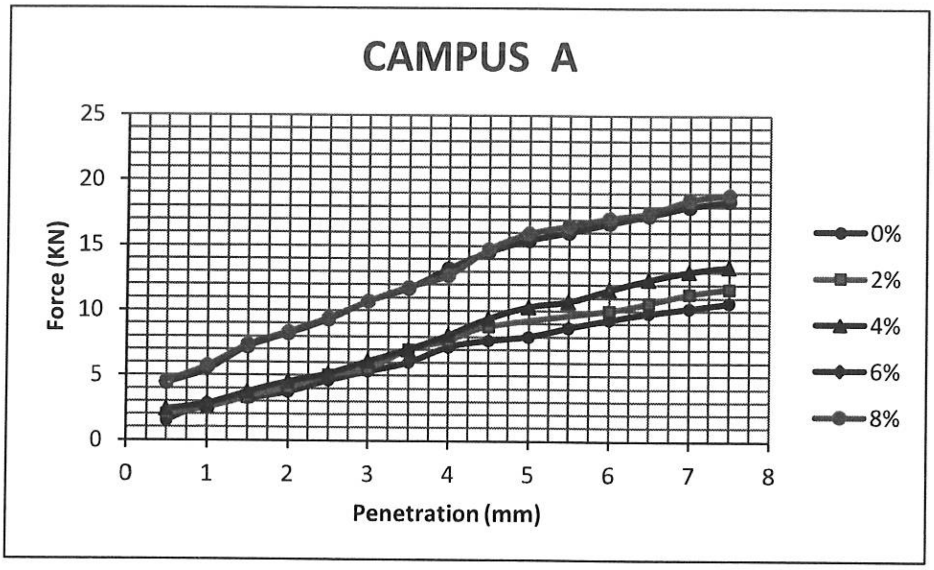

Figure 4: CBR test

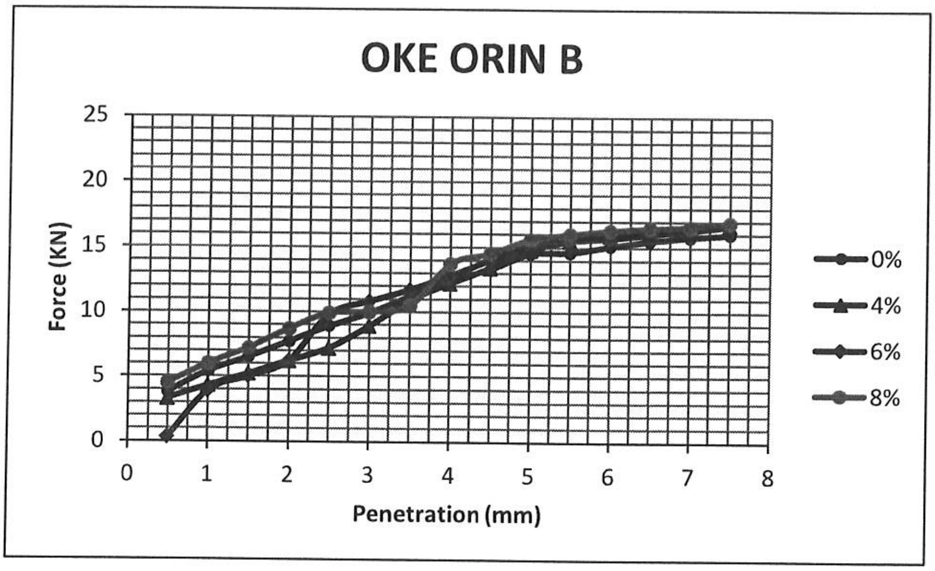

Figure 5: CBR test

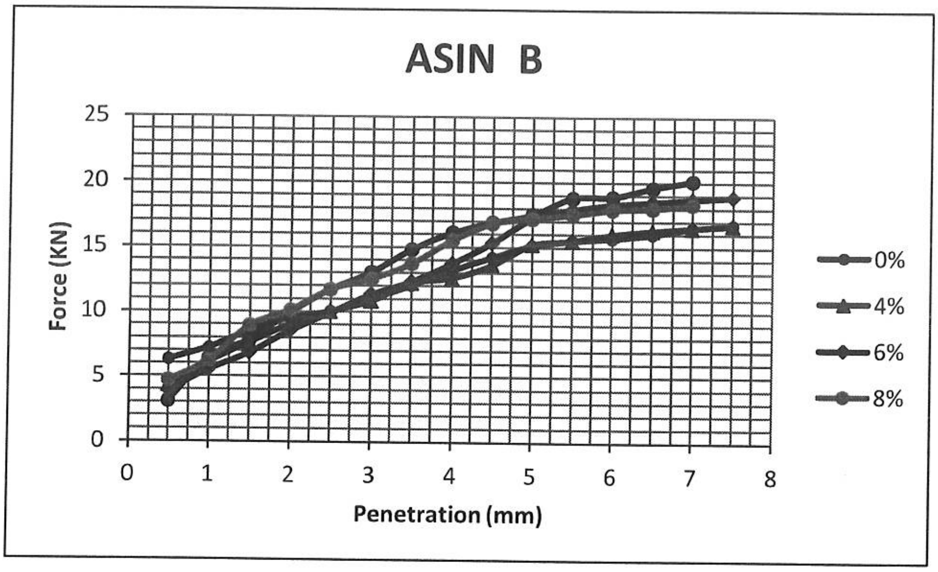

Figure 6: CBR test

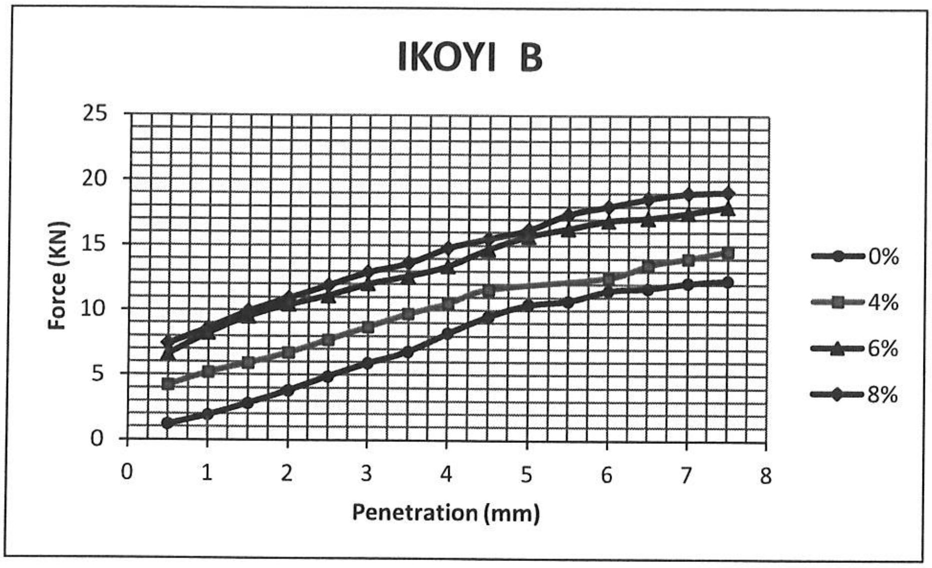

Figure 7: CBR test

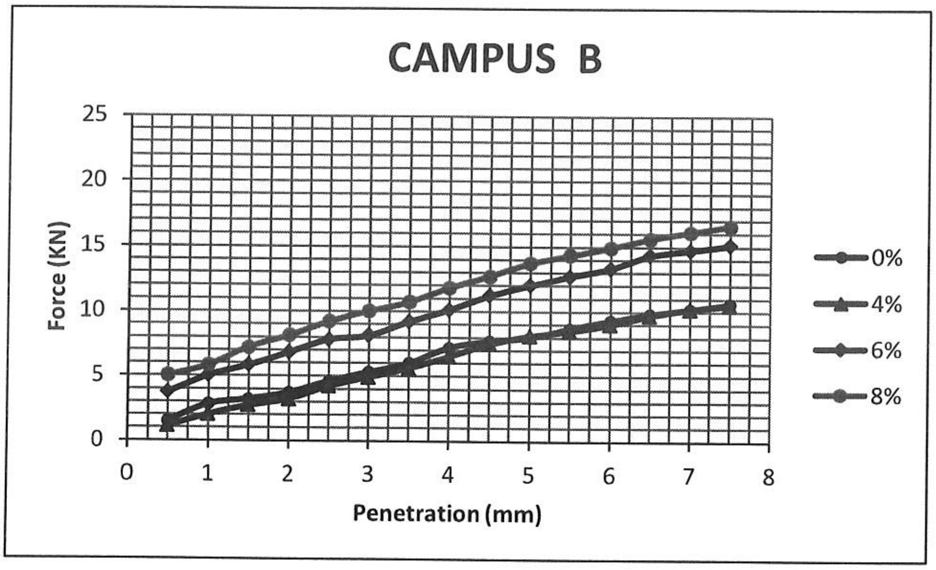

Figure 8: CBR test

Table 12: IKOYI COMPACTION TEST DATA FOR CEMENT B

	4%				6%				8%			
	1	2	3	4	1	2	3	4	1	2	3	4
Mass of mould + wet soil(g)	5000	5200	5450	5400	4950	5200	5450	5350	5150	5350	5600	5500
Mass of mould (g)	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
Mass of compacted soil (g)	1600	1800	2058	2000	1550	1800	2050	1950	1750	1950	2200	2100
Wet density (kg/m3)	1.60	1.80	2.05	2.00	1.55	1.80	2.05	1.95	1.75	1.95	2.20	2.10
Container number	A11	A12	A13	A14	B15	B16	B17	B18	C19	C20	C21	C22
Mass of containers(g)	9.9	10.9	15.5	16.0	19.5	26.7	20.1	25.4	26.7	26.7	18.5	21.9
Mass of container + wet soil	52.8	48.9	56.0	59.0	78.1	76.0	66.4	55.7	81.9	74.6	72.2	76.8
Mass of container + dry soil	48.1	43.6	49.4	51.1	73.2	70.2	59.4	46.8	75.6	68.2	63.6	66.6
Mass of water(g)	4.7	5.3	6.6	7.9	4.9	5.8	7.0	8.9	5.5	6.4	8.6	10.2
Mass of dry soil (g)	38.2	32.9	33.9	35.1	53.7	43.5	39.3	41.6	48.9	41.5	45.1	44.7
Moisture content (%)	12.3	16.1	19.4	22.5	9.1	13.3	17.8	21.4	11.2	15.4	19.1	22.8
Dry density (kg/m3)	1.42	1.55	1.72	1.63	1.42	1.59	1.74	1.61	1.57	1.69	1.85	1.71

Table 13: CAMPUS COMPACTION TEST DATA FOR CEMENT B

	4%				6%				8%			
	1	2	3	4	1	2	3	4	1	2	3	4
Mass of mould + wet soil (g)	515 0	525 0	545 0	540 0	515 0	530 0	550 0	545 0	505 0	530 0	555 0	545 0
Mass of mould (g)	340 0	340 0	340 0	340 0	340 0	340 0	340 0	340 0	340 0	340 0	340 0	340 0
Mass of	175	185	205	200	175	190	210	205	165	190	215	205

compacted soil(g)	0	0	0	0	0	0	0	0	0	0	0	0
Wet density (kg/m3)	1.75	1.85	2.05	2.0	1.75	1.90	2.10	2.05	1.65	1.90	2.15	2.05
Container number	V21	V22	V23	V24	D1	D2	D3	D4	K1	K2	K3	K4
Mass of container (g)	24.1	19.9	12.7	19.9	17.6	20.1	18.7	22.4	10.8	15.6	17.8	16.9
Mass of container +wet soil	70.0	75.7	61.4	66.8	66.5	80.3	76.5	76.6	77.5	75.3	80.1	80.0
Mass of container + dry soil	65.0	59.9	53.3	57.7	61.7	73.0	67.3	66.4	64.4	67.0	69.9	67.6
Mass of water (g)	5.0	6.3	8.1	9.1	4.8	7.3	9.2	10.2	6.5	8.3	10.2	12.4
Mass of dry soil (g)	40.9	40.0	40.6	37.8	44.1	52.9	48.6	44.0	53.6	51.4	52.1	50.8
Moisture content	12.2	15.8	20.0	24.1	10.9	14.0	18.9	23.2	12.1	16.1	19.6	24.4
Dry density (kg/m3)	1.55	1.60	1.70	1.61	1.58	1.67	1.76	1.66	1.47	1.64	1.80	1.66

Table 14:OKE ORIN COMPACTION TEST DATA FOR CEMENT B

	4%				6%				8%			
	1	2	3	4	1	2	3	4	1	2	3	4
Mass of mould + wet soil (g)	5250	5400	5600	5500	5100	5300	5500	5450	5100	5300	5600	5500
Mass of mould (g)	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
Mass of compacted soil (g)	1850	2000	2200	2100	1700	1900	2100	2050	1700	1900	2200	2100

Wet density (kg/m3)	1.85	2.00	2.20	2.10	1.70	1.90	2.10	2.05	1.70	1.9	2.20	2.10
Container number	Z1	Z2	Z3	Z4	Q4	Q5	Q6	Q7	Q1	Q2	Q3	Q4
Mass of container (g)	13.6	12.4	15.8	11.7	19.6	20.0	19.9	9.9	9.9	10.9	21.2	26.7
Mass of container + wet soil	64.1	65.3	69.8	64.6	76.3	69.6	66.6	57.4	59.3	61.7	73.5	79.3
Mass of container + dry soil	58.6	58.0	60.9	54.8	71.4	63.7	59.5	48.9	54.2	54.5	65.2	69.7
Mass of water (g)	5.5	7.3	8.9	9.8	4.9	5.9	7.1	8.5	5.1	7.2	8.3	9.6
Mass of dry soil (g)	45.0	45.6	45.1	43.1	51.8	48.7	39.6	39.0	44.3	43.6	44.0	43.0
Moisture content (%)	12.2	16.0	19.7	22.7	9.5	13.5	17.9	21.8	11.9	15.5	18.9	22.3
Dry density (kg/m3)	1.65	1.72	1.83	1.71	1.58	1.67	1.78	1.68	1.52	1.65	1.85	1.72

Table 15: ASIN COMPACTION TEST DATA FOR CEMENT B

	4%				6%				8%			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Mass of mould +wet soil(g)	5100	5300	5500	5450	5100	5300	5550	5450	5200	5400	5600	5400
Mass of mould(g)	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400	3400
Mass of compacted soil(g)	1700	1900	2100	2050	1700	1900	2150	2050	1800	2000	2200	2000
Wet density(kg/m3)	1.70	1.90	2.10	2.05	1.70	1.90	2.15	2.05	1.80	2.00	2.20	2.0
Container number	T5	T6	T7	T8	W1	W2	W3	W4	Y1	Y2	Y3	Y4
Mass of container (g)	19.6	20.0	19.9	9.90	15.5	18.8	26.7	17.9	18.9	17.7	19.9	19.9

Mass of container + wet soil	76.3	69.6	66.6	57.4	55.2	65.6	76.1	67.7	73.8	69.2	70.2	72.0
Mass of container + dry soil	71.4	63.7	59.5	48.9	50.6	58.8	67.7	58.2	67.6	61.3	61.1	61.5
Mass of water(g)	4.9	5.9	7.1	8.5	4.6	6.8	8.4	9.5	6.2	7.9	9.1	10.5
Mass of dry soil(g)	51.8	43.7	39.6	39.0	35.1	40.0	41.0	40.3	48.7	43.6	41.2	41.6
Moisture content (%)	9.5	13.5	17.9	21.8	13.1	17.0	20.5	23.6	12.7	17.9	22.0	25.2
Dry density (kg/m3)	1.58	1.67	1.78	1.68	1.50	1.62	1.78	1.60	1.60	1.69	1.83	1.60

Table 16: CAMPUS COMPACTION TEST DATA FOR CEMENT A

	0%				2%			
	1	2	3	4	1	2	3	4
Mass of mould +wet soil(g)	6350	6500	6600	6550	6300	6450	6600	6550
Mass of mould (g)	4600	4600	4600	4600	4600	4600	4600	4600
Mass of compacted soil (g)	1750	1900	2000	1950	1850	1850	2000	1950
Wet density (kg/m3)	1.75	1.90	2.0	1.95	1.85	1.85	2.0	1.95
Container number	R1	R2	R3	R4	S1	S2	S3	S4
Mass of container (g)	19.4	24.5	14.6	18.7	8.8	21.8	16.7	20.0
Mass of container + wet soil	68.0	74.4	70.3	73.4	61.6	68.8	64.6	59.4
Mass of container + dry soil	62.7	67.5	61.2	63.2	56.7	62.7	56.7	50.5
Mass of water(g)	5.3	7.1	9.1	10.2	4.9	6.1	7.9	8.9
Mass of dry soil(g)	43.3	42.8	46.6	44.5	47.9	40.9	40.0	38.0
Moisture content (%)	12.2	16.8	18.1	22.9	10.2	14.9	19.8	23.4
Dry density (kg/m3)	1.56	1.63	1.67	1.51	1.54	1.61	1.67	1.58

Table 18: IKOYI COMPACTION TEST DATA FOR CEMENT A

	0%				2%			
	1	2	3	4	1	2	3	4
Mass of mould + wet soil(g)	5050	5150	5250	5100	5050	5200	5400	5250
Mass of mould (g)	3400	3400	3400	3400	3400	3400	3400	3400
Mass of compacted soil (g)	1650	1750	1850	1700	1650	1800	2000	1850
Wet density (kg/m3)	1.65	1.75	1.85	1.70	1.65	1.80	2.0	1.85
Container number	L1	L2	L3	L4	A5	A6	A7	A8
Mass of container (g)	21.1	20.3	27.5	7.6	15.5	23.1	26.9	19.9
Mass of container + wet soil	64.6	62.6	70.6	50.4	60.2	91.0	60.8	55.2
Mass of container + dry soil	60.0	56.7	68.9	42.6	52.1	81.7	36.1	49.1
Mass of water(g)	4.6	5.9	6.7	7.8	4.7	9.3	4.7	6.1
Mass of dry soil(g)	38.9	36.4	36.4	35.0	41.6	40.9	39.2	37.5
Moisture content (%)	11.8	16.2	18.4	22.2	11.3	15.5	19.9	24.0
Dry density (kg/m3)	1.48	1.51	1.66	1.39	1.48	1.56	1.67	1.49

Table 19: Ikoyi compaction data for 4%, 6% and 8%

	4%				6%				8%			
	1	2	3	4	1	2	3	4	1	2	3	4
Mass of mould+ wet soil(g)	6400	6550	6650	6500	6350	6500	6650	6500	6350	6550	6750	6600
Mass of mould(g)	4600	4600	4600	4600	4600	4600	4699	4600	4600	4600	4600	4600
Mass of compacted soil(g)	1650	1800	2050	1900	1750	1900	2050	1950	1750	1950	2150	2000
Wet density(kg/m3)	1.65	1.80	2.05	1.90	1.75	1.90	2.05	1.95	1.75	1.95	2.15	2.0
Container number	B5	B6	B7	B8	C5	C6	C7	C8	D5	D6	D7	D8
Mass of container(g)	26.8	26.9	15.2	20.0	17.6	20.1	27.0	21.0	26.7	18.6	19.4	15.5
Mass of container +wet soil	74.2	76.2	54.8	59.6	72.0	60.7	78.5	74.2	81.2	71.9	73.7	68.3
Mass of container+ dry soil	69.8	70.2	48.0	52.1	67.6	55.1	41.5	65.4	75.3	64.5	64.6	58.3
Mass of water(g)	4.4	5.6	6.8	7.5	4.4	5.6	7.0	8.8	5.9	7.4	9.1	10.0
Mass of dry soil(g)	43.0	43.3	32.8	32.1	50.0	47.8	44.3	44.4	48.6	45.9	45.2	42.8
Moisture content (%)	10.5	12.9	20.7	23.4	8.8	11.7	15.8	19.8	12.1	16.4	20.1	23.4
Dry density (kg/m3)	1.49	1.59	1.70	1.54	1.61	1.70	1.77	1.63	1.51	1.68	1.79	1.62

Table 20: OKE ORIN COMPACTION TEST DATA FOR CEMENT A

	0%				2%			
	1	2	3	4	1	2	3	4
Mass of mould + wet soil(g)	6250	6400	6600	6500	6400	6600	6750	6650
Mass of mould(g)	4600	4600	4600	4600	4600	4600	4600	4600
Mass of compacted soil(g)	1650	1800	2000	1900	1800	2000	2150	2050
Wet density(kg/m3)	1.65	1.80	2.00	1.90	1.80	2.0	2.15	2.05
Container number	L1	L2	L3	L4	M1	M2	M3	M4
Mass of container(g)	20.1	8.2	13.9	14.3	26.7	19.6	21.6	27.2
Mass of container + wet soil	54.1	54.8	61.8	70.5	72.3	66.0	69.3	76.6
Mass of container + dry soil	50.1	47.9	53.8	60.7	67.3	59.3	60.5	67.2
Mass of water(g)	4.0	6.9	8.0	9.8	5.0	6.7	8.8	9.4
Mass of dry soil(g)	30.0	39.7	37.9	40.8	40.6	39.7	38.9	40.0
Moisture content (%)	13.3	17.4	21.1	24.0	12.3	16.9	20.1	23.5
Dry density	1.46	1.53	1.65	1.53	1.60	1.71	1.79	1.66

	4%				6%				8%			
	1	2	3	4	1	2	3	4	1	2	3	4
Mass of mould + wet soil(g)	6500	6650	6800	6700	6450	6600	6800	6750	6500	6650	6800	6750
Mass of mould(g)	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600
Mass of compacted soil(g)	1900	2050	2200	2100	1850	2000	2200	2150	1900	2050	2200	2150
Wet density(kg/m3)	1.90	2.05	2.20	2.10	1.85	2.00	2.20	2.15	1.90	2.05	2.20	2.15
Container number	Y1	Y2	Y3	Y4	U1	U2	U3	U4	T1	T2	T3	T4
Mass of container(g)	10.0	15.2	9.8	26.8	20.0	27.0	19.7	12.5	30.3	7.5	10.5	19.9
Mass of container + wet soil	59.1	65.7	62.0	79.0	69.2	67.4	81.5	59.0	61.5	44.7	51.0	67.1
Mass of container + dry soil	53.7	57.1	53.8	69.0	66.4	63.9	59.6	52.1	58.1	39.5	44.2	58.2
Mass of water(g)	5.4	6.8	8.2	10	2.8	3.5	5.4	6.9	3.4	5.2	6.8	8.9
Mass of dry soil(g)	43.7	43.9	44.0	42.2	46.4	36.9	39.9	39.6	27.8	32.0	33.7	38.3
Moisture content (%)	12.3	15.5	18.6	23.7	6.0	9.5	13.5	17.4	12.2	16.3	20.3	23.2
Dry density(kg/m3)	1.69	1.77	1.85	1.70	1.75	1.83	1.94	1.83	1.69	1.76	1.83	1.75

COMPACTION GRAPH FOR CEMENT A AND B, THAT IS 32.5 GRADE CEMENT AND 42.5 GRADE CEMENT RESPECTIVELY ARE BELOW;

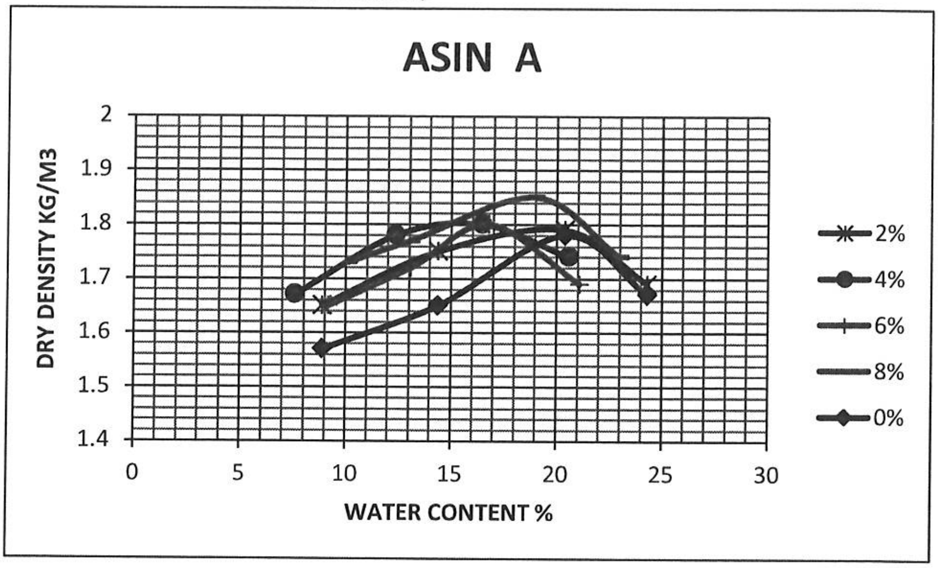

Figure 9: OMC and MDD

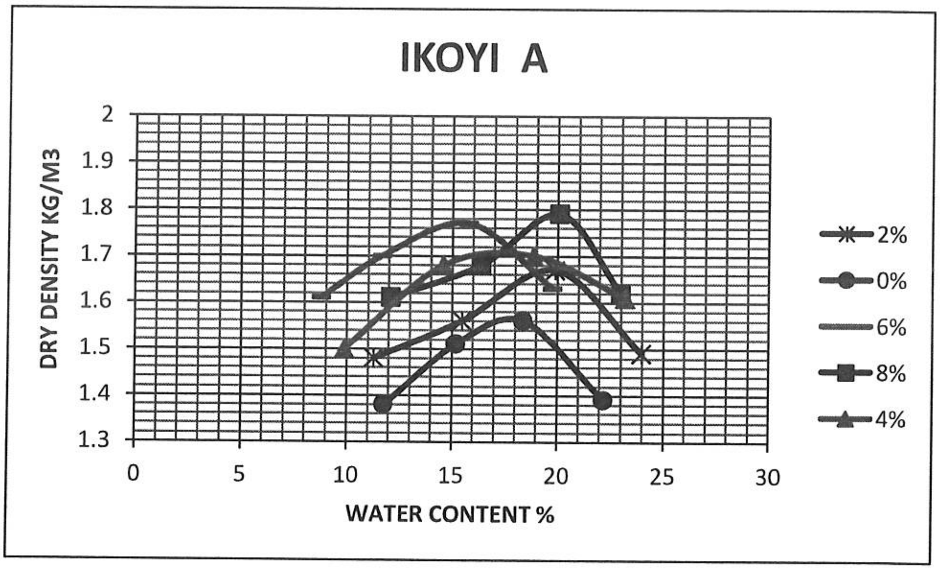

Figure10: OMC and MDD

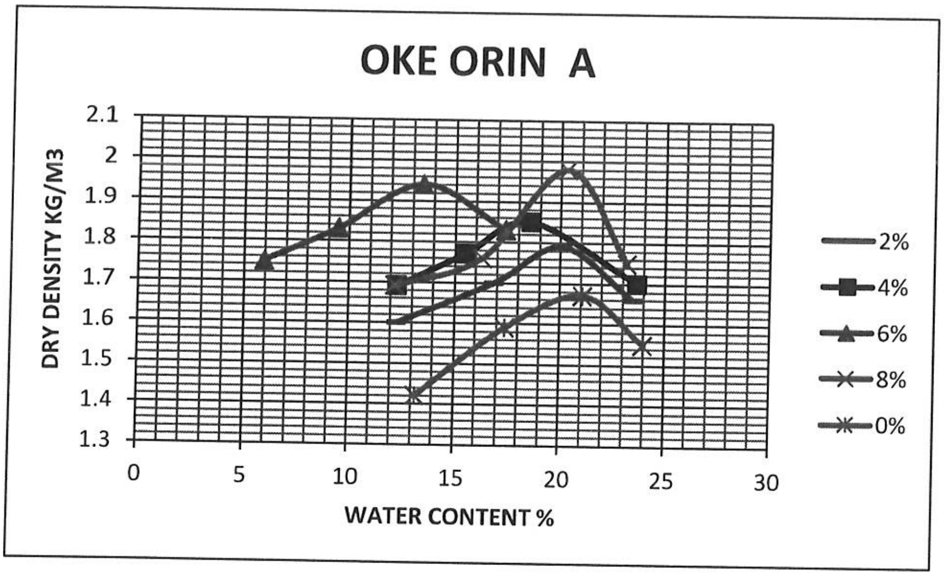

Figure11: OMC and MDD

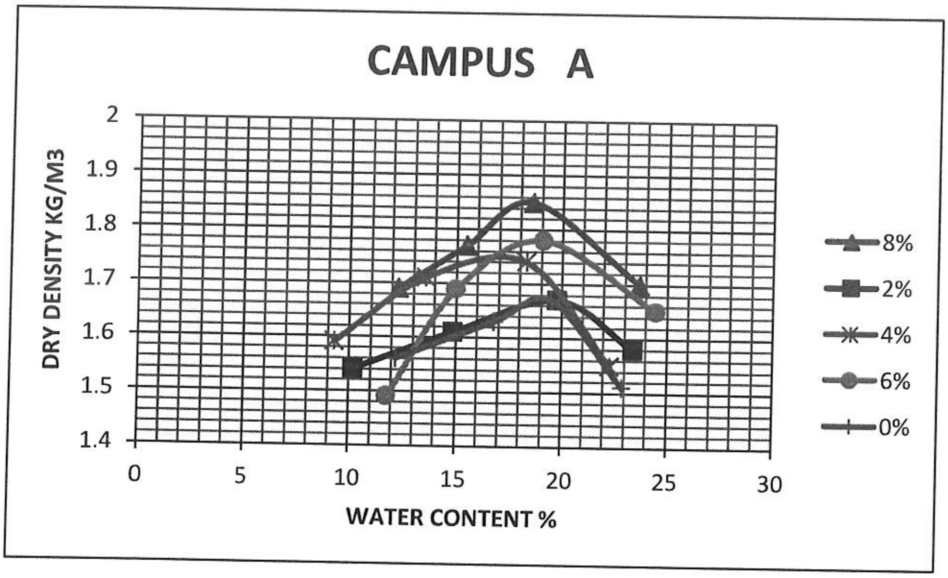

Figure 12: OMC and MDD

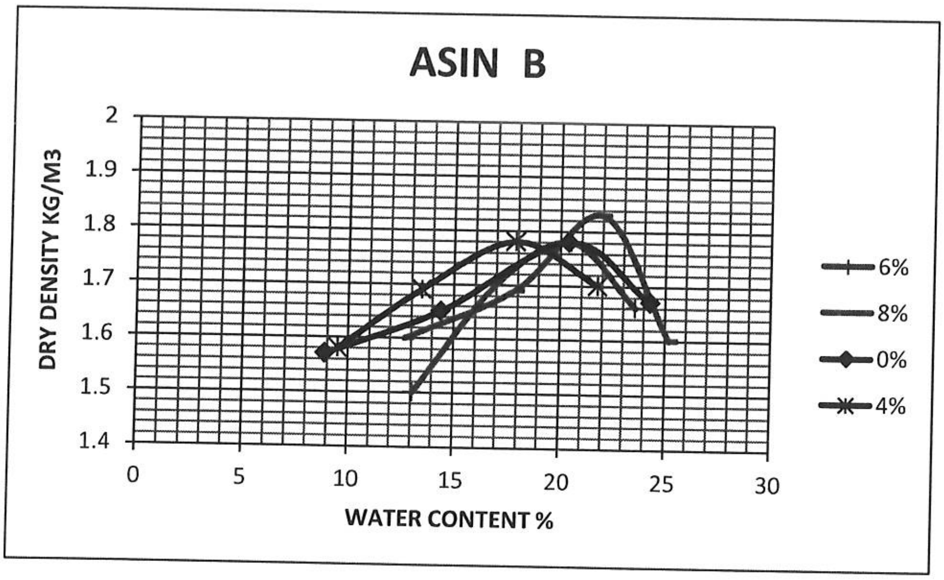

Figure 13: OMC and MDD

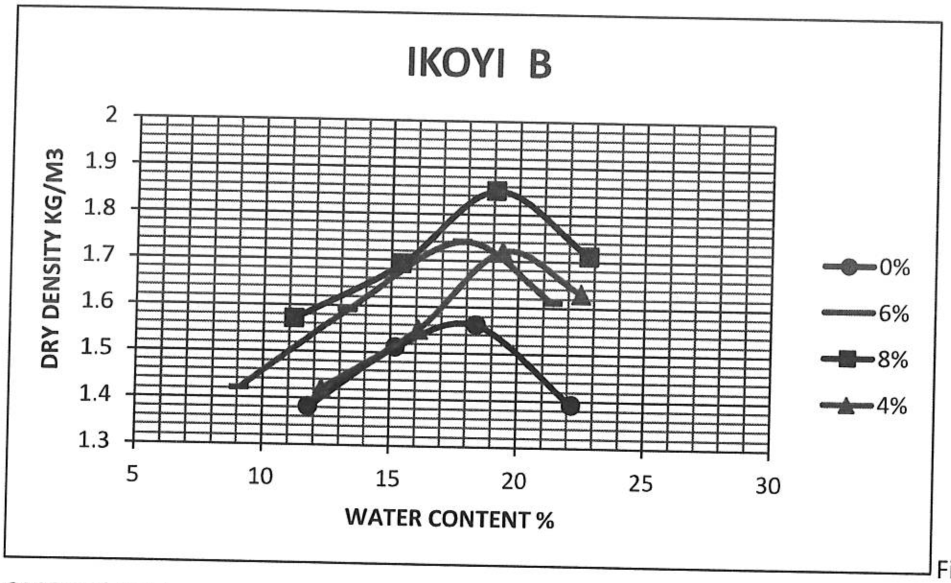

Figure 14: OMC and mdd

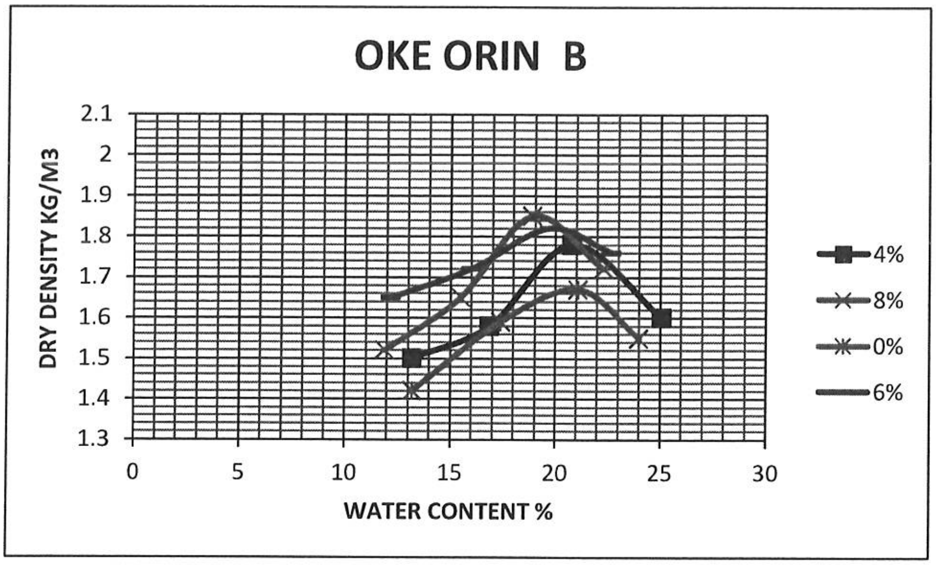

Figure 15: OMC and MDD

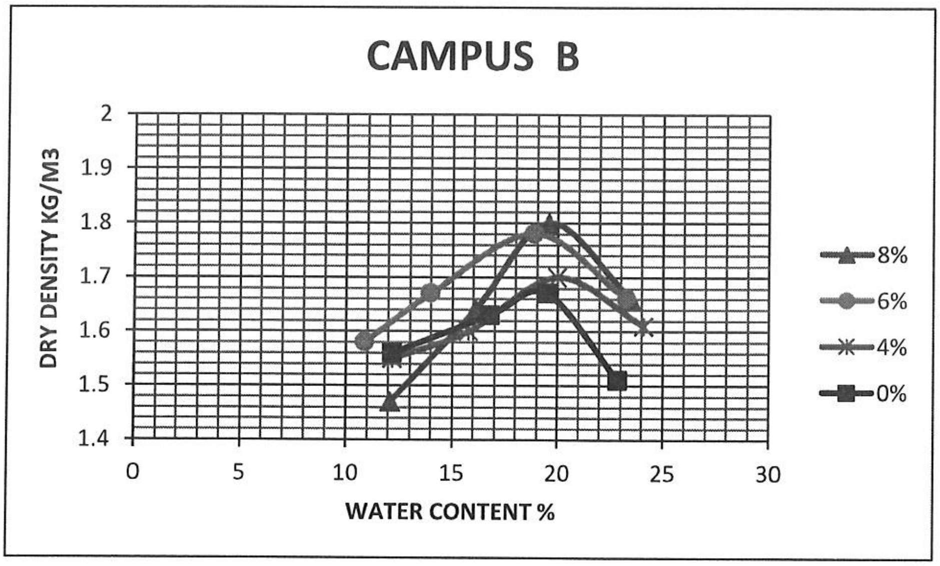

Figure 16: OMC and MDD

Table 21: ATTERBERG LIMIT DATA FOR OKE ORIN CEMENT A

	2%			
	1	2	3	4
Number of blow	49	38	24	14
Container number	AJ	AZ	A1	A
Mass of container	8.4	10.6	13.7	11.7
Mass of container+ wet soil	28.4	31.9	39.9	40.5
Mass of container + dry soil	22.6	25.6	31.7	31.1
Mass of water(g)	5.8	6.3	8.2	9.4
Mass of dry soil (g)	14.2	15.0	18.0	19.4
Moisture content(%)	40.8	42.0	45.6	48.5

A	B
F2	K5
19.7	14.4
32.2	23.4
29.8	21.6
2.4	1.8
10.1	7.2
25.8	25.0

PL= 24.4%, SL= 7.1%

Table 22

	4%			
	1	2	3	4
Number of blow	48	35	22	13
Container number	M9	M10	M11	M12
Mass of container	24.9	26.8	19.8	19.9
Mass of container+ wet soil	44.1	51.3	49.5	48.9
Mass of container + dry soil	39.0	44.4	40.7	39.9
Mass of water(g)	5.1	6.9	8.0	9.0
Mass of dry soil (g)	14.1	17.6	20.9	20.0
Moisture content(%)	36.2	39.2	42.1	45

PL

A	B
M13	M14
19.8	13.7
32.3	25.9
29.7	23.4
2.6	2.5
9.9	9.7
26.3	25.8

PL=26.1%, SL=7.9%

Table 23

	6%			
	1	2	3	4

Number of blow	49	38	23	14
Container number	B9	B10	B11	B12
Mass of container	14.1	9.1	19.5	26.7
Mass of container+ wet soil	35.7	33.6	45.9	53.5
Mass of container + dry soil	30.0	26.8	38.2	45.5
Mass of water(g)	5.7	6.8	7.7	8.1
Mass of dry soil (g)	15.9	17.7	18.7	18.7
Moisture content(%)	35.8	38.4	41.2	43.5

A	B
B13	B14
8.0	15.2
20.4	28.1
19.0	26.6
2.4	2.5
11.0	11.4
21.8	21.9

PL= 21.9, SL= 7.9

Table 24

	8%			
	1	2	3	4
Number of blow	46	37	22	12
Container number	F9	F10	F11	F12
Mass of container	10.2	26.9	19.9	18.4
Mass of container+ wet soil	39.2	58.3	56.3	54.7
Mass of container + dry soil	32.2	50.2	46.3	44.2
Mass of water(g)	7.0	8.1	10.0	11.5
Mass of dry soil (g)	22.0	23.3	26.4	25.8
Moisture content(%)	31.8	34.8	37.8	40.7

A	B
F13	F14
17.1	19.9
32.4	36.5
30.0	33.9
2.4	2.6
12.9	14.0
18.6	18.6

PL=18.6%, SL=7.9

Table 25: **ATTERBERG LIMIT TEST DATA FOR ASIN CEMENT A**

	2%			
	1	2	3	4
Number of blow	50	37	23	14
Container number	P9	P10	P11	P12
Mass of container	21.2	10.5	19.3	20.4

Mass of container+ wet soil	45.0	34.9	47.8	51.7
Mass of container + dry soil	38.4	27.6	38.9	41.4
Mass of water(g)	6.6	7.3	8.9	10.3
Mass of dry soil (g)	17.2	17.1	19.6	20.4
Moisture content(%)	38.4	42.7	45.5	50.5

PL

A	B
P13	P14
19.4	12.4
31.4	23.3
2.2	2.0
9.8	8.9
22.4	22.5

PL=22.5%, SL=9.3%

Table 26

	4%			
	1	2	3	4
Number of blow	49	38	26	15
Container number	E9	E10	E11	E12
Mass of container	13.8	15.4	19.0	13.8
Mass of container+ wet soil	35.9	42.7	47.6	41.2
Mass of container + dry soil	29.9	34.8	39.1	32.5
Mass of water(g)	6.0	7.9	8.5	8.7
Mass of dry soil (g)	16.1	19.4	20.1	18.7
Moisture content(%)	37.3	40.7	42.3	46.5

PL

A	B
E13	**E14**
22.1	20.8
39.7	36.8
36.1	33.6
3.6	3.2
14.0	12.8
25.7	25.0

PL=25.4%, SL= 10.0%

Table 27

	6%			
	1	2	3	4
Number of blow	46	32	22	12
Container number	M9	M10	M11	M12
Mass of container	10.2	26.7	19.6	26.8
Mass of container+ wet soil	36.1	54.0	44.7	59.7
Mass of container + dry soil	28.7	45.8	37.3	36.5
Mass of water(g)	7.4	8.2	9.4	10.5
Mass of dry soil (g)	18.5	19.1	47.7	22.4
Moisture content(%)	40	42.9	41.8	46.9

A	B
M13	M14
21.1	19.8
39.7	36.6
36.5	33.6
3.2	3.0
15.0	13.8
21.3	21.7

PL= 21.5%, SL= 8.6%

Table 28

	8%			
	1	2	3	4
Number of blow	48	32	22	12
Container number	Z9	Z10	Z11	Z12
Mass of container	21.0	20.2	10.7	19.9
Mass of container+ wet soil	40.9	38.3	35.0	48.4
Mass of container + dry soil	36.5	33.1	27.9	39.9
Mass of water(g)	4.4	5.2	7.1	8.5
Mass of dry soil (g)	13.1	17.2	20.0	12.8
Moisture content(%)	31.8	34.7	41.3	42.5

A	B
Z13	Z14
20.1	20.0
35.5	35.6
32.9	32.8
2.6	2.8
12.8	12.0
20.3	21.8

PL= 21.1%, SL= 7.3%

Table 29: ATTERBERG LIMIT DATA OF CAMPUS FOR CEMENT A

	2%			
	1	2	3	4
Number of blow	45	32	22	12

					A	B
Container number	N9	N10	N11	N12	N13	N14
Mass of container	21.8	19.6	26.8	23.4	6.7	6.7
Mass of container+ wet soil	35.5	34.8	46.3	45.2	27.7	21.7
Mass of container + dry soil	39.9	30.5	40.5	38.4	23.7	18.7
Mass of water(g)	3.6	4.3	5.8	6.8	4.0	3.0
Mass of dry soil (g)	10.1	10.9	13.7	15.0	17.0	12.0
Moisture content(%)	36.4	39.4	42.3	48.2	24.5	25.3

PL=24.9%, SL=9.3%

Table 30

	4%					
	1	2	3	4	A	B
Number of blow	48	34	22	12		
Container number	W9	W10	W11	W12	W13	W14
Mass of container	19.6	26.7	26.7	18.7	20.0	20.0
Mass of container+ wet soil	39.5	50.0	55.5	49.4	32.6	33.5
Mass of container + dry soil	34.0	43.3	46.6	39.5	30.2	31.1
Mass of water(g)	5.5	6.7	8.9	9.9	2.4	2.4
Mass of dry soil (g)	14.4	16.6	19.9	20.8	10.4	11.1
Moisture content(%)	38.2	40.4	44.7	47.6	23.1	21.6

PL= 22.4%, SL=9.3%

Table 31

	6%			
	1	2	3	4
Number of blow	37	35	23	13
Container number	V9	V10	V11	V12
Mass of container	25.6	19.6	9.1	19.9
Mass of container+ wet soil	46.9	41.5	35.4	47.6
Mass of container + dry soil	41.4	35.4	27.5	38.2
Mass of water(g)	5.5	6.1	7.9	9.4
Mass of dry soil (g)	15.8	15.8	18.4	18.3

Moisture content(%)	34.8	38.6	41.9	45.0

Table 32

	8%			
	1	2	3	4
Number of blow	48	36	22	11
Container number	Q9	Q10	Q11	Q12
Mass of container	21.4	26.8	20.2	19.9
Mass of container+ wet soil	50.2	56.8	51.4	50.4
Mass of container + dry soil	42.8	48.7	42.4	40.0
Mass of water(g)	7.4	8.1	9.0	10.4
Mass of dry soil (g)	21.4	21.9	22.2	20.1
Moisture content(%)	34.6	37.0	40.5	43.9

A	B
Q13	Q14
6.7	6.7
35.8	30.2
31.7	26.7
4.1	3.5
25.0	20.0
16.4	17.5

PL=17.0, SL=7.9%

Table 33: ATTERBERG LIMIT TEST FOR IKOYI, CEMENT A

	2%			
	1	2	3	4
Number of blow	49	38	23	14
Container number	E9	E10	E11	E12
Mass of container	19.9	19.9	10.8	26.7
Mass of container+ wet soil	41.0	44.0	39.4	58.9
Mass of container + dry soil	36.5	38.4	32.3	50.3
Mass of water(g)	4.5	5.6	7.1	8.6
Mass of dry soil (g)	16.6	18.5	21.5	23.6
Moisture content(%)	27.1	30.3	33.0	36.0

A	B
E13	E14
11.6	8.3
26.8	23.9
23.7	20.8
3.1	3.1
12.1	12.5
25.6	24.8

PL=25.2%, SL=9.3%

Table 34

	4%					
	1	2	3	4	A	B
Number of blow	45	36	22	13		
Container number	S9	S10	S11	S12	S13	S14
Mass of container	15.4	19.5	13.9	18.7	27.0	26.8
Mass of container+ wet soil	39.1	45.1	43.7	51.6	44.3	44.0
Mass of container + dry soil	34.3	39.5	36.8	41.7	41.3	41.0
Mass of water(g)	4.8	5.6	6.9	7.9	3.0	3.0
Mass of dry soil (g)	18.9	20.0	22.9	23.0	14.3	14.2
Moisture content(%)	25.4	28.0.	31.5	34.3	20.9	21.1

PL=21.0%, SL=9.3%

Table 35

	6%					
	1	2	3	4	A	B
Number of blow	48	36	24	13		
Container number	H9	H10	H11	H12	H13	H14
Mass of container	18.7	10.8	26.5	17.7	28.6	20.0
Mass of container+ wet soil	43.3	41.4	64.6	54.9	44.4	39.7
Mass of container + dry soil	38.5	34.8	55.8	45.4	41.9	37.2
Mass of water(g)	4.8	6.6	8.8	9.5	2.5	2.5
Mass of dry soil (g)	19.8	24.0	29.3	27.7	13.3	12.5
Moisture content(%)	24.2	27.5	30.2	34.3	18.9	20.0

PL=19.5%, SL=8.6%

Table 36

	8%			
	1	2	3	4
Number of blow	50	39	26	15
Container number	Y9	Y10	Y11	Y12
Mass of container	20.4	20.1	20.0	19.9
Mass of container+ wet soil	51.6	57.8	59.9	52.0
Mass of container + dry soil	45.6	50.0	50.9	41.9
Mass of water(g)	6.0	7.8	9.0	10.1
Mass of dry soil (g)	25.2	29.9	30.9	30.0
Moisture content(%)	23.8	26.1	29.1	33.3

A	B
Y13	Y14
10.6	8.1
23.8	25.4
21.7	22.9
2.1	2.5
13.1	14.8
16.0	16.9

PL=18.9%, SL= 7.1%

GRAPH FOR ATTERBERG LIMIT CEMENT A ABOVE;

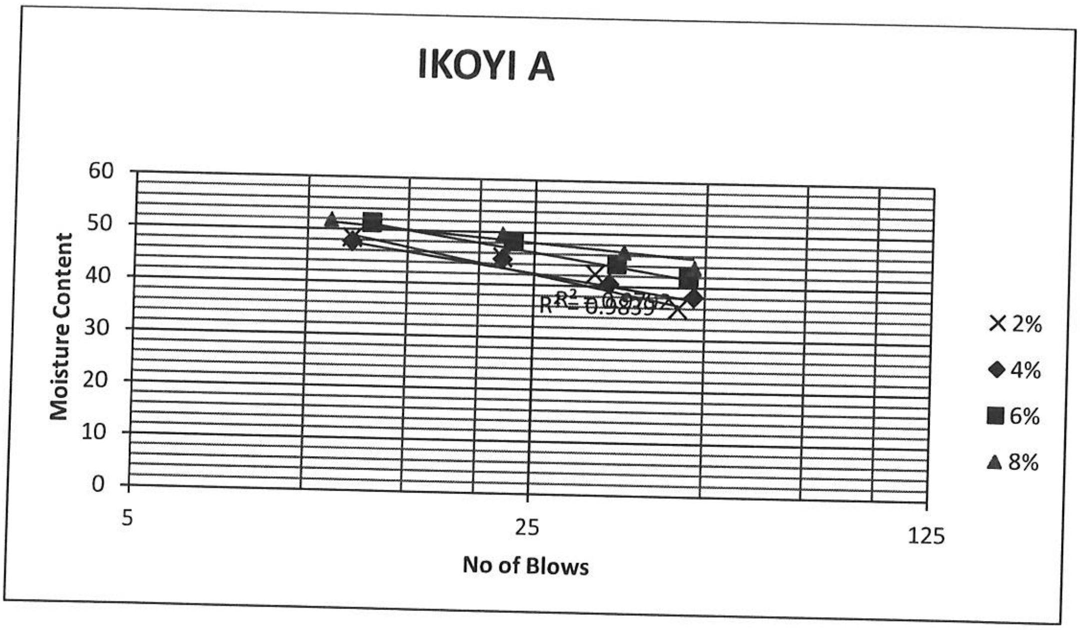

Figure 17

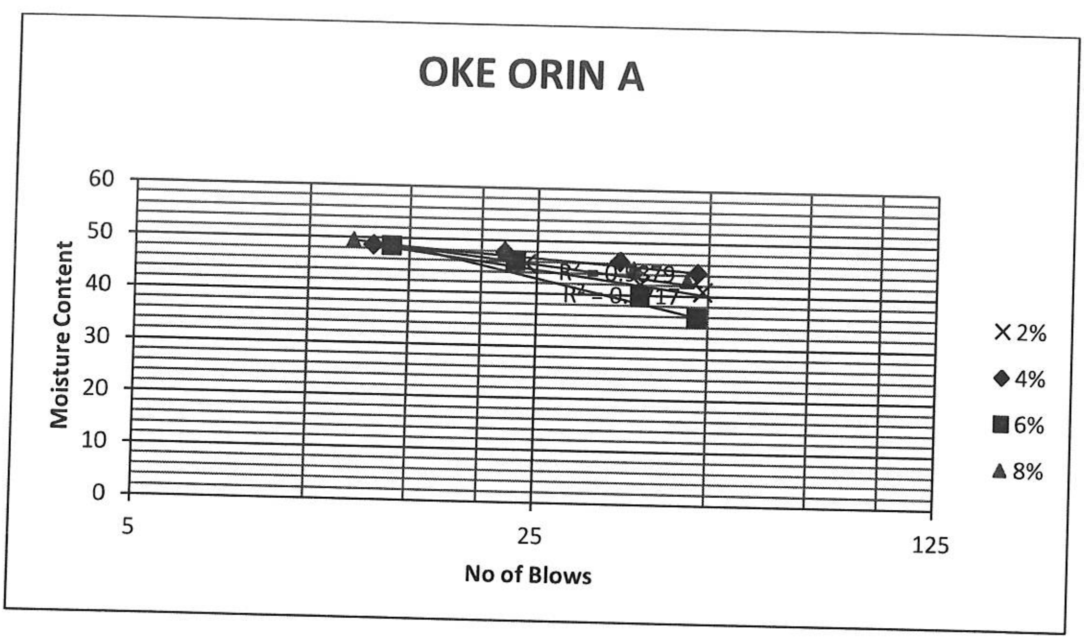

Figure 18

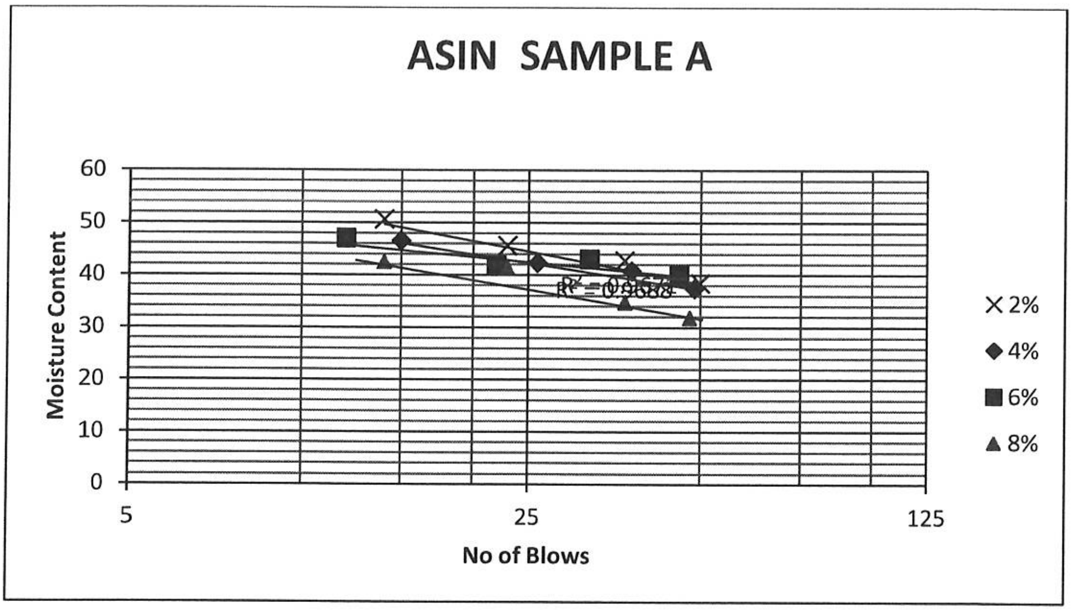

Figure 18

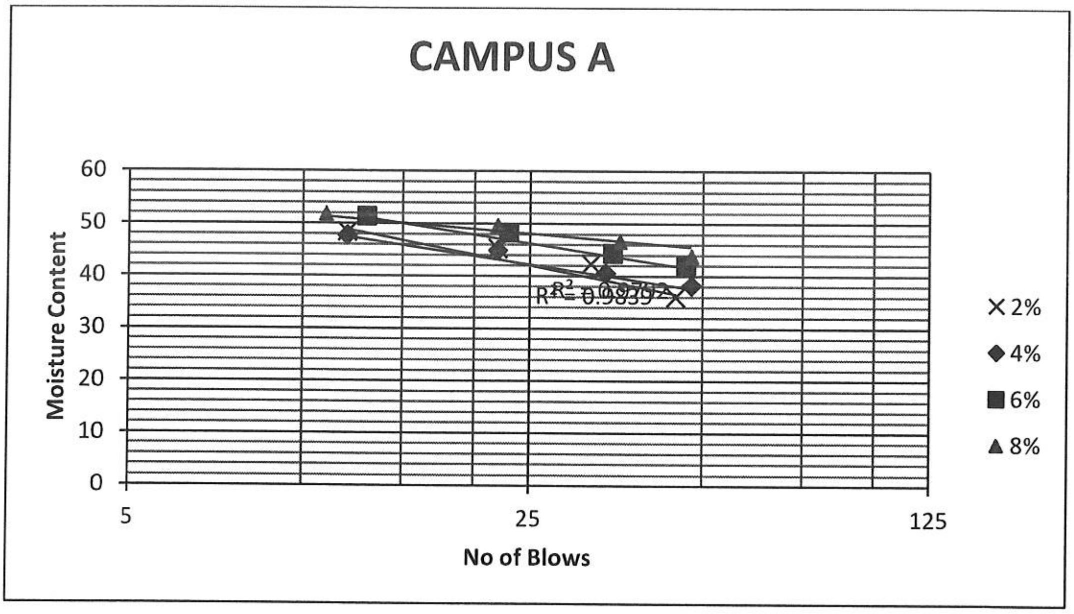

Figure 19

ATTERBERG LIMIT TEST RESULTS FOR CEMENT B

Table 37: FOR OKE ORIN

	4%			
	1	2	3	4
Number of blow	49	37	23	13
Container number	A1	A2	A3	A4
Mass of container	9.8	20.1	15.6	26.7
Mass of container+ wet soil	44.1	45.2	43.6	55.8
Mass of container + dry soil	37.7	38.0	35.1	46.7
Mass of water(g)	6.4	7.2	8.4	9.1
Mass of dry soil (g)	17.4	17.9	19.5	20.0
Moisture content(%)	36.8	40.2	43.1	45.5

PL

A	B
A5	A6
18.6	17.7
35.2	34.1
32.2	31.2
3.0	2.9
13.6	13.5
22.1	21.5

PL=21.8%, SL=8.9%

Table 38

	6%			
	1	2	3	4
Number of blow	48	38	22	12
Container number	B1	B2	B3	B4
Mass of container	26.7	27.8	27.6	21.8
Mass of container+ wet soil	49.9	53.7	55.4	53.6
Mass of container + dry soil	44.2	46.8	47.4	43.9
Mass of water(g)	5.7	6.9	8.0	9.7
Mass of dry soil (g)	17.5	19.0	19.8	22.1
Moisture content(%)	32.6	36.3	40.4	43.9

PL

A	B
B5	B6
11.5	12.4
29.7	30.6
26.6	27.5
3.1	3.1
15.0	15.1
20.7	20.5

PL=20.6%, SL=8.7%

Table 39

	8%			
	1	2	3	4
Number of blow	47	36	22	12
Container number	C1	C2	C3	C4
Mass of container	17.9	15.4	9.9	13.7
Mass of container+ wet soil	44.1	46.1	42.4	47.9
Mass of container + dry soil	38.0	38.2	33.3	37.6
Mass of water(g)	6.1	7.9	9.1	10.3
Mass of dry soil (g)	20.1	22.8	23.4	23.9
Moisture content(%)	30.3	34.5	38.9	43.1

PL

A	B
C4	C5
18.1	17.8
34.8	34.7
32.3	31.9
2.5	2.8
14.2	14.1
17.9	19.9

PL=18.9%, SL=7.9%

Table 40: FOR ASIN

	4%			
	1	2	3	4
Number of blow	48	38	23	12
Container number	D1	D2	D3	D4
Mass of container	26.8	19.9	19.7	20.2
Mass of container+ wet soil	46.1	42.3	44.7	48.3
Mass of container + dry soil	41.2	36.1	37.2	39.4
Mass of water(g)	4.9	6.2	7.5	8.9
Mass of dry soil (g)	14.4	16.2	17.5	19.2
Moisture content(%)	34.0	38.3	42.9	46.4

PL

A	B
D4	D5
19.6	11.9
33.3	30.6
30.7	27.3
2.6	3.3
11.1	15.3
23.4	21.6

PL=22.55, SL=10.0%

Table 41

	6%			
	1	2	3	4
Number of blow	48	36	22	12

Container number	V1	V2	V3	V4
Mass of container	15.8	26.6	19.5	15.4
Mass of container+ wet soil	44.8	58.6	52.9	50.5
Mass of container + dry soil	38.0	50.4	43.7	41.6
Mass of water(g)	6.8	8.2	9.2	10.9
Mass of dry soil (g)	22.2	23.8	24.2	26.2
Moisture content(%)	30.8	34.5	38.0	41.6

A	B
V5	V6
26.6	20.0
43.7	34.5
40.9	32.2
2.8	2.3
14.3	12.3
19.6	18.7

PL=19.2%, SL=7.8%

Table 42

	8%			
	1	2	3	4
Number of blow	49	38	24	13
Container number	F1	F2	F3	F4
Mass of container	24.4	19.5	16.6	14.7
Mass of container+ wet soil	43.6	43.9	45.8	46.7
Mass of container + dry soil	38.6	37.1	37.1	36.6
Mass of water(g)	5.0	6.8	8.7	10.1
Mass of dry soil (g)	14.2	17.6	20.5	21.9
Moisture content(%)	35.2	38.6	42.4	46.1

A	B
F5	F6
11.7	14.9
30.4	30.6
27.3	28.3
3.1	2.3
15.6	11.3
19.9	20.4

PL=20.2%, 9.3%

Table 43: FOR IKOYI;

	4%			
	1	2	3	4
Number of blow	47	36	22	12
Container number	G1	G2	G3	G4
Mass of container	18.7	20.0	15.8	10.9
Mass of container+ wet soil	41.5	44.4	41.4	38.9
Mass of container + dry soil	37.0	39.0	35.2	31.2
Mass of water(g)	4.5	5.4	6.2	7.4

Mass of dry soil (g)	18.3	19.0	19.4	20.3
Moisture content(%)	24.6	28.4	32.0	36.5

A	B
G5	G6
15.5	17.1
37.1	31.5
34.9	29.1
2.2	2.4
11.2	12.0
19.4	20.0

PL=19.7%, SL=9.3%

Table 44

	4%			
	1	2	3	4
Number of blow	48	37	22	12
Container number	H1	H2	H3	H4
Mass of container	18.5	21.7	18.5	23.1
Mass of container+ wet soil	45.2	49.9	48.9	55.8
Mass of container + dry soil	40.1	43.9	41.6	47.2
Mass of water(g)	5.1	6.0	7.3	8.6
Mass of dry soil (g)	21.6	22.2	23.1	24.1
Moisture content(%)	23.6	27.0	31.6	35.8

A	B
H5	H6
12.3	10.8
26.4	26.7
23.8	23.9
2.6	2.8
11.5	13.1
22.6	21.4

PL=22.0%, SL=9.3%

Table 45

	8%			
	1	2	3	4
Number of blow	47	37	22	13
Container number	I1	I2	I3	I4
Mass of container	20.7	18.8	12.1	11.5
Mass of container+ wet soil	45.8	49.3	45.9	46.8
Mass of container + dry soil	40.6	42.8	38.0	37.6
Mass of water(g)	4.9	6.5	7.9	9.2
Mass of dry soil (g)	19.9	24.0	25.9	26.1

Moisture content(%)	24.6	27.1	30.5	34.9

A	B
I5	I6
9.9	9.9
25.4	25.9
22.7	23.2
2.7	2.7
12.8	13.3
21.1	20.3

PL=20.7%, SL=8.7%

Table 46: FOR CAMPUS

	4%			
	1	2	3	4
Number of blow	49	38	24	14
Container number	L1	L2	L3	L4
Mass of container	18.8	17.6	20.2	18.9
Mass of container+ wet soil	38.4	41.0	45.5	45.7
Mass of container + dry soil	33.4	34.5	38.0	37.3
Mass of water(g)	5.0	6.5	7.5	8.4
Mass of dry soil (g)	14.6	16.9	17.8	18.4
Moisture content(%)	34.2	38.5	42.1	45.7

A	B
L5	L6
19.6	19.6
38.9	33.3
31.2	30.7
2.7	2.6
11.6	11.1
23.3	23.4

PL=23.45%, SL=9.3%

Table 47

	6%			
	1	2	3	4
Number of blow	49	38	22	12
Container number	K1	K2	K3	K4
Mass of container	28.6	27.6	22.9	19.8

Mass of container+ wet soil	47.0	48.7	47.2	47.5
Mass of container + dry soil	42.3	42.9	40.1	38.9
Mass of water(g)	4.7	5.8	7.1	8.6
Mass of dry soil (g)	13.7	15.3	17.2	19.1
Moisture content(%)	34.3	37.9	41.3	45.0

A	B
K5	K6
20.0	21.0
34.0	35.1
31.5	32.8
2.5	2.3
11.5	11.8
21.7	21.3

PL=21.5%, SL=10.0%

Table 48

	8%			
	1	2	3	4
Number of blow	48	38	23	14
Container number	J1	J2	J3	J4
Mass of container	20.7	18.9	10.5	10.5
Mass of container+ wet soil	45.7	40.0	40.4	43.2
Mass of container + dry soil	39.8	39.0	31.9	33.3
Mass of water(g)	5.9	7.0	8.5	9.9
Mass of dry soil (g)	19.1	20.1	21.4	22.8
Moisture content(%)	30.9	34.8	39.7	43.4

A	B
J5	J6
9.2	9.8
22.9	24.7
20.6	22.3
2.3	2.4
11.4	12.5
20.2	19.2

PL=19.7%, SL=7.9

GRAPH FOR ATTERBERG LIMIT 42.5 GRADE CEMENT, CEMENT B

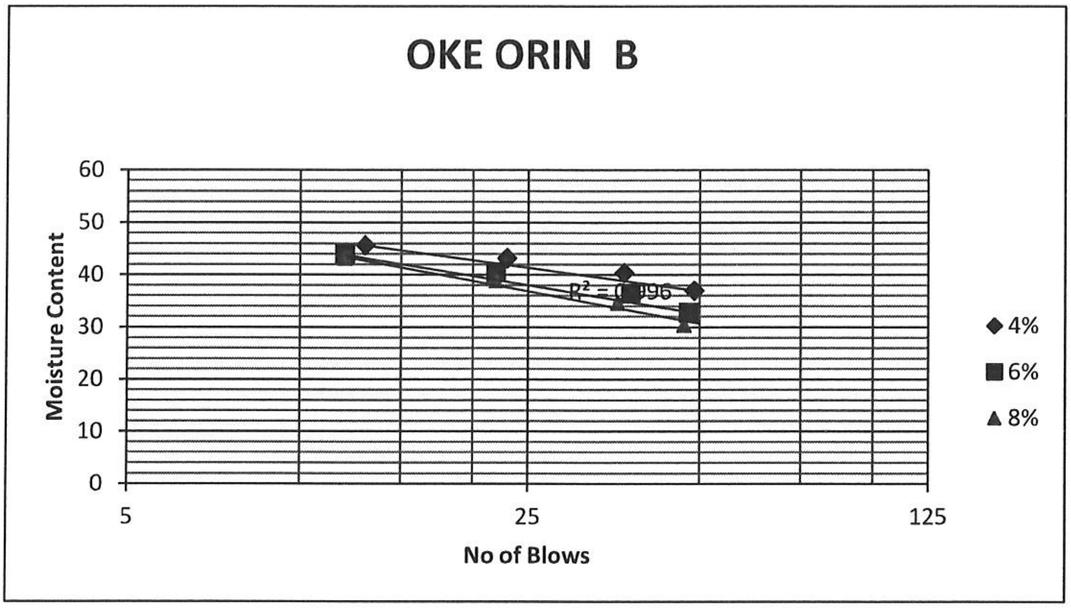

Figure 20

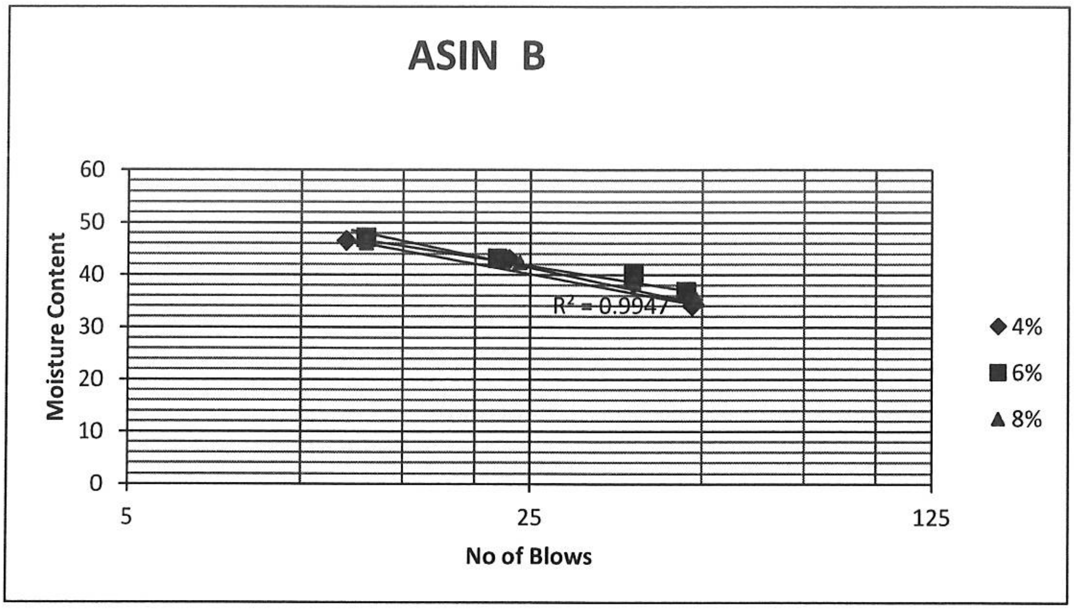

Figure 21

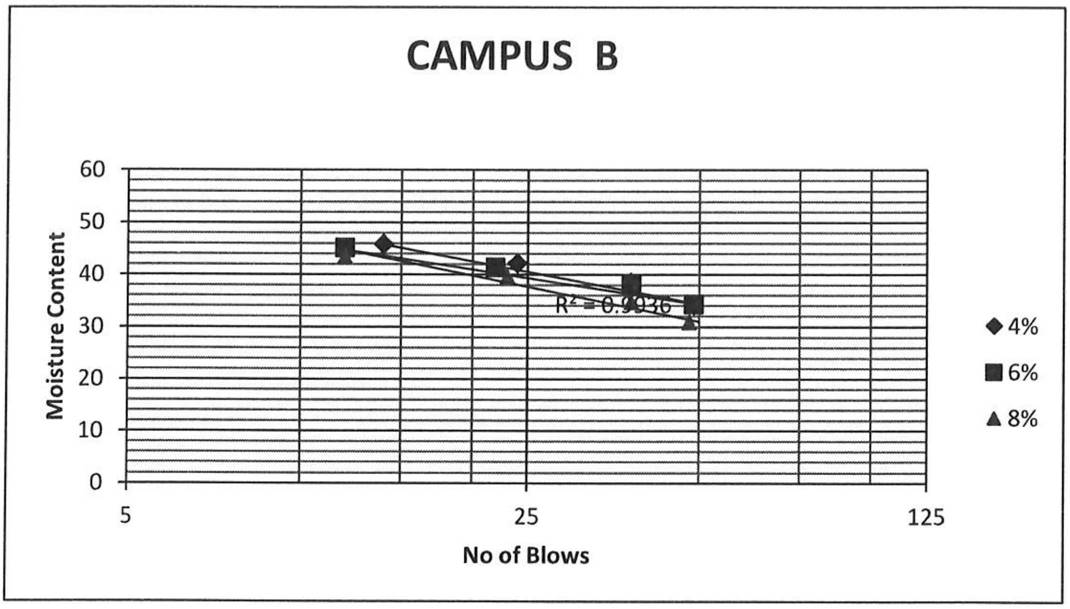

Figure 22

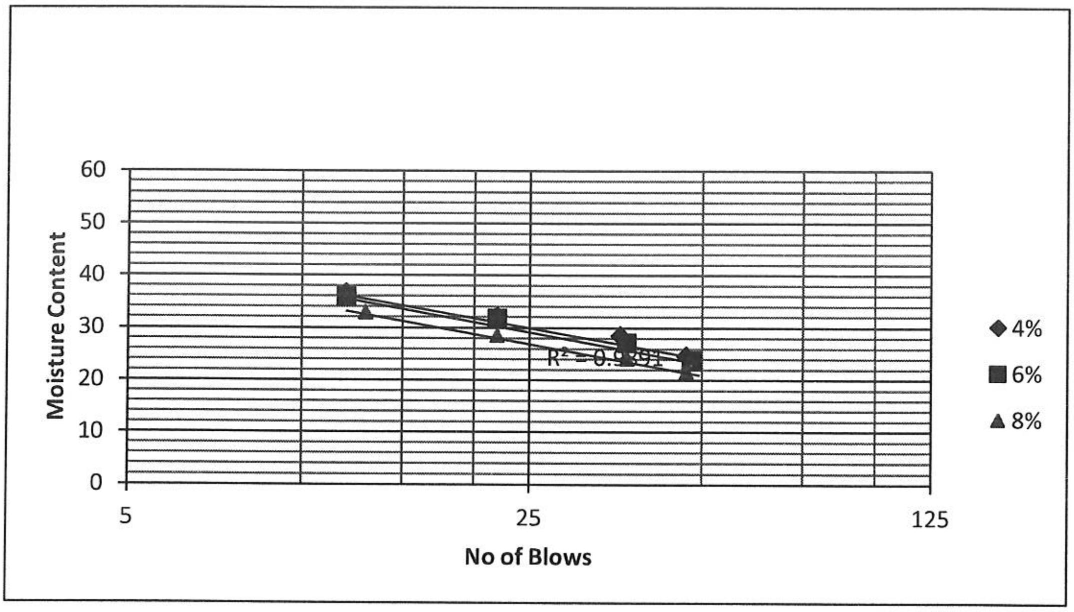

Figure 23

RESULTS FOR THE NATURAL MOISTURE CONTENT

Table 49: FOR CAMPUS;

	1	2
Can number/label	H	I
Weight of can	19.9	19.9
Can + weight of wet soil	59.0	47.2
Can + weight of dry soil	53.2	43.3
Weight of water	4.8	3.9
Weight of dry soil	33.3	23.4
Moisture content (%)	14	16

Table 50: FOR ASIN

	1	2
Can number /label	H5	V
Weight of c an	26.6	19.8
Can + weig ht of wet soil	61.2	56.9
Can + wei ght of dry soil	56.0	51.3
Weight of water	5.2	5.6
Weight of dry soil	29.4	31.5
Moisture content (%)	17.7	17.8

Table 51: FOR IKOYI

	1	2
Can number/label	F1	B4
Weight of can	27.4	21.6
Can + weight of wet soil	71.0	61.0
Can + weight of dry soil	65.5	56.1
Weight of water	5.5	4.9
Weight of dry soil	38.1	34.5
Moisture content (%)	14.4	14.2

Table 52: FOR OKE-ORIN

	1	2
Can number/label	A4	A1
Weight of can	14.2	11.7
Can + weight of wet soil	46.3	43.3
Can + weight of dry soil	42.1	39.4
Weight of water	4.2	3.9
Weight of dry soil	27.9	27.7
Moisture content (%)	15.1	14.1

Table 53: RESULTS FOR THE SPECIFIC GRAVITY

SAMPLES	A	B
ASIN	2.33	2.36
OKEORIN	2.72	2.45
CAMPUS	2.45	2.38
IKOYI	2.46	2.72

Table 54: RESULTS FOR PARTICLE SIZE DISTRIBUTION

OKE ORIN

SIEVE SIZE	MASS OF SOIL RETAINED	PERCENTAGE RETAINED	PERCENTAGE PASSING
9.5	12.65	2.5	97.5
4.8	28.43	5.7	91.8
2.4	45.18	9.2	82.6
1.2	46.76	9.4	73.2
600	41.06	8.3	64.9
300	73.2	14.6	50.3
150	60.60	12.1	38.2
75	35.02	7.0	31.2

ASIN

MASS OF SOIL REATINED	PERCENTAGE RETAINED	PERCENTAGE PASSING
3.4	0.7	99.3
20.5	4.1	95.2
40.0	8.0	57.2
54.0	10.8	16.4
64.8	13.0	63.4
67.6	13.6	49.9
50.5	10.1	39.8
28.8	5.8	34.0

IKOYI

MASS OF SOIL RETAINED	PERCENTAGE RETAINED	PERCENTAGE PASSING
20.75	4.2	95.8
57.5	11.5	84.3
63.84	12.8	71.5
49.31	9.9	61.6
38.33	7.7	53.9
65.91	13.2	40.7
64.8	13.0	27.7
29.24	5.8	21,9

CAMPUS

MASS OF SOIL RETAINED	PERCENTAGE RETAINED	PERCENTAGE PASSING
9.51	1.9	98.1
11.06	2.2	95.9
15.31	3.1	92.8
28.42	5.7	87.1
51.28	10.3	76.8
68.32	13.7	63.1
59.47	11.9	51.2
31.92	6.4	44.8

GRAPH FOR THE PARTICLE SIZE DISTRIBUTION

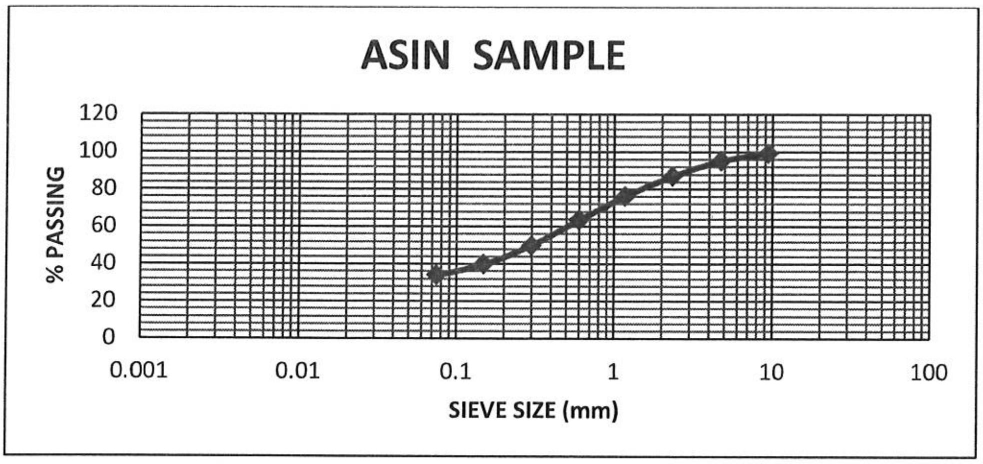

Figure 24

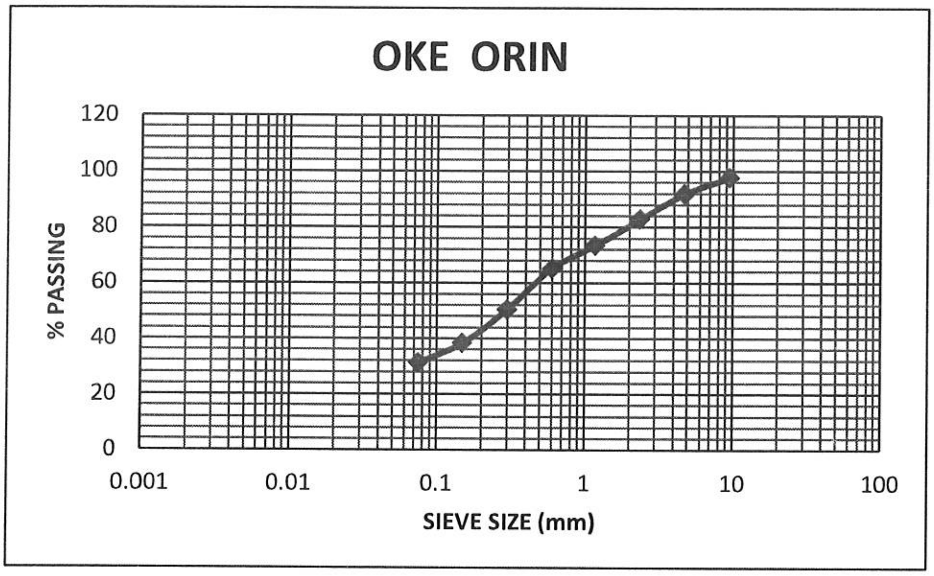

Figure 25

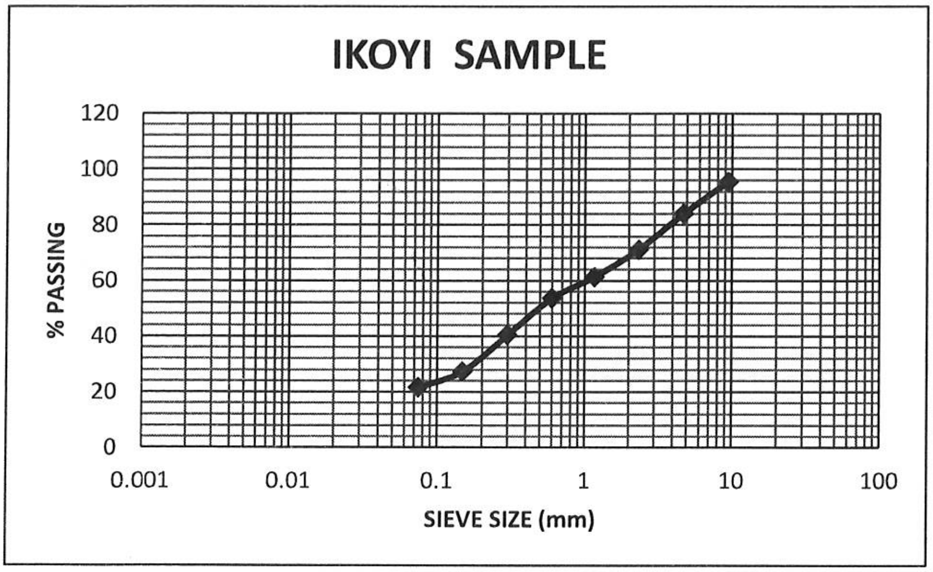

Figure 26

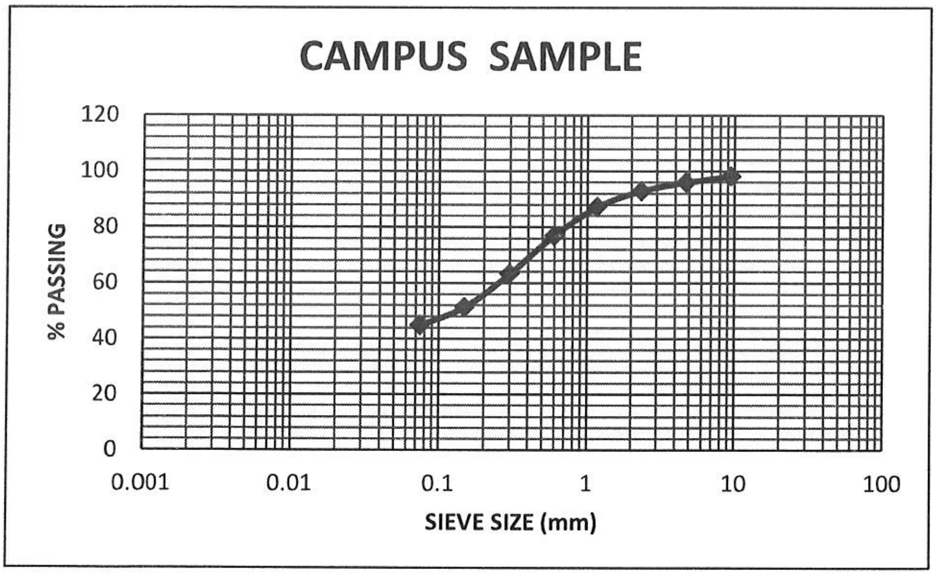

Figure 27.