

**EFFECT OF SOIL TYPES ON ROAD AS SUBGRADE ALONG WARRI AND SAPELE  
ROAD IN DELTA STATE, NIGERIA**

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BENIN CITY, NIGERIA**

**DECEMBER 2022.**

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**A RESEARCH PROJECT SUBMITTED TO THE  
DEPARTMENT OF SOIL SCIENCE AND LAND MANAGEMENT  
FACULTY OF AGRICULTURE  
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**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE  
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NIGERIA**

**DECEMBER, 2022.**

## CERTIFICATION

This is to certify that this work titled “**Effects of Soil Types on Road as Subgrade Along Warri and Sapele Road in Delta State, Nigeria**” was carried out by **Courage OAIKHENA (AGR1600616)** of the Department of Soil Science and Land Management, Faculty of Agriculture University of Benin, Benin-City.

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## **DEDICATION**

I dedicate this Project to Almighty God for His endless love, favor and mercy upon my life. I also dedicate this Project to my parents Mr. and Mrs. **OAIKHENA** for their moral and financial support.

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## **ABSTRACT**

This project was a detailed investigation on the properties of subgrade soils used in the construction of Warri-Sapele road in South South, Nigeria. Subgrade samples were collected at nine (9) different spots by doing auger borings examinations on the spots that are observed to have failed or are failing at about 5 and 10 meters away from the tarred road at one side. The samples were subjected to the following laboratory tests; Compaction test, California bearing ratio (CBR). According to O'Flaherty the range of value anticipated using standard proctor test method are MDD and OMC which range from 1.72g/cm<sup>3</sup> to 1.84g/cm<sup>3</sup> and 8.88% to 12.70% respectively, therefore the results indicated that all the samples were sandy clay in texture. The CBR values for the top unsoaked and soaked samples of the subgrade soil range from 21.9% to 37.5% and 5.0% to 26.1% respectively while bottom unsoaked and soaked range from 17.9% to 51.5% and 9.3% ((P2R3, Sapele) to 37.3% respectively. Therefore, the CBR test results obtained conform to the Federal Ministry of Works and Housing which confirmed that the subgrade sample materials are suitable for road construction except for subgrade materials P2R3 collected from Sapele which however can be stabilized to meet the standard requirement before being used. These data obtained from the analysis can be useful by civil engineers in the design and construction of the study area for maximum durability.

## **CHAPTER ONE**

### **INTRODUCTION**

Soil can be looked at as consisting of a wide range of relatively smaller particles derived from a parent rock through mechanical weathering process that includes air and/or abrasion, freeze-thaw cycles, temperature changes, plant and animal activity such as burrowing and by chemical weathering process that include oxidation and carbonation (Samtani and Nowatzki, 2006). Soil can also be defined as the solid material on the Earth's surface that results from the interaction of weathering and biological activity on the parent material or underlying hard rock. Different people define soil to suit their purpose. To a geologist it represents the products of past surface processes; to a pedologist it represents currently occurring physical and chemical processes; to an engineer it is a material that can be built on (foundations to buildings, bridges), building of (tunnels, culverts, basements), building of (roads, runways, embankments, dams) and supporting (retaining walls, quays). It was also noted by Sabat in 2012 that for an Engineer, there are a number of techniques available to improve the engineering properties of soil to make it suitable for construction purposes. These include stabilization using dust/powder like waste materials with and without a binder like lime, cement etc. Others include Quarry Dust, marble dust, baryte powder, pyroclastic dust and brick powder are some of the prominent dust/powder like waste materials which have been successfully utilized for stabilization of expansive soil.

Scientific research in the field of soil strengthening began in the 20-30 years of last century with the use of bitumen, lime, cement, and later synthetic resins as binders. As a result of many years of laboratory research and versatile studies in production conditions, a number of

very diverse methods of soil strengthening have been developed and are widely used in practice (Bezruk, 1971).

The most common method in the practice of road construction was the method of strengthening the soil with cement in combination with calcium chloride, caustic and sodium sulphide. Especially widespread in the practice of road construction is a complex method of soils stabilization with cement in combination with organic additives. This method was developed by Bezruk and his students. It helps to obtain optimal indicators of stabilized soil, which provide a long service life of the structural layer in the road structure. Bituminous emulsions and pastes, cutback bitumen, crude highly resinous oil and foamed bitumen have been used as organic additives in recent years (Krayushkina and Oliynyk, 2020).

In the practice of road construction, to improve the properties of soil cement, various surfactants are used; they are introduced into the mixture for plasticization and subsequent hydrophobicity of the material formed. The effectiveness of additives depends on the type of soil, its chemical and mineralogical composition, type of additive and its quantity. Improved design characteristics and physical and mechanical properties of stabilized soils can be achieved by introducing into the mixture of various synthetic materials in the form of strips or threads. Small scope of researches in this direction allowed to establish that introduction of reinforcement made of synthetic materials into cement soil positively influences its physical and mechanical properties and design characteristics. Cement content of the mixture is of great importance in this case. The most advanced method of soil strengthening is its stabilization, i.e. active influence on the clay-colloid part of the soil, which is the most sensitive to binders that are applied to the soil. The stabilizer is an active substance, usually of polymeric origin, which is introduced into the soil in micro-doses and improves its building properties. Stabilization of the soil is a set of

measures aimed at providing the soil with a stable condition, constancy, preservation of unchanged properties with the help of stabilizer. The strength of stabilized soil and its resistance to natural factors required to meet the above requirements may vary depending on the intensity of traffic and axle loads of cars and local natural conditions. This indicates the need for a differentiated approach in assessing the strength and deformation properties of stabilized soil (Krayushkina and Oliynyk, 2020).

### 1.1 **Justification of Study**

It is imperative to highlight that Nigeria roads have often being characterized with long cracks, potholes and other pavement defects. These posed a serious challenge and disaster such that in Nigeria one can hardly travel a kilometer without coming across a long cracks and potholes. These has resulted to increase the number of road accidents and a plunge on the nation's economic development. Geotechnical assessment of subsoils would help in comprehending the behavior of the soils that can cause remarkable impairment to road construction and also propose solutions in problems connected with both expansive and unexpansive soils (Daramola *et al.*, 2015; Amadi *et al.*, 2015). Past investigations have also emphasized the role of geophysical investigations and integrated geotechnical and geophysical investigations in the investigation of the significant factors responsible for ceaseless highway pavement failures in parts of southern Nigeria (Salami *et al.*, 2012; Adeyemi, 2013). However, not much work has been done on the effect of soil types on road construction. These study attempts to investigate the effect of stabilized soil on road construction.

### 1.2 **Aim and Objectives**

The aim of this study is to determine the effect of soil types on road as subgrade along warri and sapele road in Delta state. The following were the specific objectives of the study:

1. To determine the stability of different soil types used for road construction
2. To determine best method for stabilizing different soil type used for road construction
3. To determine the California bearing ratio (CBR) of the various soil sampling sites
4. To determine the compaction test of the various soil sampling sites

## **CHAPTER TWO**

### **LITERATURE REVIEWS**

#### **2.1 Soil stabilization**

Soil stabilization refers to the procedure in which a special soil, a cementing material, or other chemical or non-chemical materials are added to a natural soil or a technique use on a natural soil to improve one or more of its properties. One may achieve stabilization by physically mixing the natural soil and stabilizing materials together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposits and obtaining interaction by letting it permeate through soil voids (Abood *et al.*, 2007). Soil stabilizing additives are used to improve the properties of less desirable road soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents (Janathan, 2004).

Stabilization process includes compaction, pre-consolidation, drainage and many other processes. However, the foremost criteria for stabilization of a soil mass are its composition (Santosh, 1987) as pure sands and pure clays behave differently in the field. The sandy granular particles which are greater than 75 microns in size are responsible for giving strength and hardness to a soil but lack cohesion and binding power between its grains and as such are easily

washed away with relatively unstable slopes while clay soils containing particles less than 75 microns in size possess sufficient binding force between its grains but lacks the shear strength, more so when saturated (Santosh, 1987). Therefore, the presence of water is problematic with clay soils but provides an apparent cohesion for sandy soils. The mixing of these two distinct soil types in appropriate proportions generally yields a soil of far more superior engineering particles. The process of soil stabilization may be carried out without the addition of any admixture or with the addition of several such as lime, lime-pozzolana, cement, etc. It may also involve the use of geotextile or be reinforced with strips to make the soil suitable for the desired construction work. Although, the main purpose of soil stabilization is to improve the natural soil for the construction of highways and air fields (Arora, 2011), it is used to alter the permeability and compressibility of the soil mass in earth structures for controlling the grading of soils and aggregates in the construction of bases and sub-bases of the highways and air fields, parking areas, site development projects and many other situations where the sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub-grade materials varying from expansive clays to granular materials.

## **2.2 Components of Stabilization**

Soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders (cementitious materials).

### **2.2.1 Soils**

Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties. According to Sherwood (1993) fine-grained

granular materials are the easiest to stabilize due to their large surface area in relation to their particle diameter. A clay soil compared to others has a large surface area due to flat and elongated particle shapes. On the other hand, silty materials can be sensitive to small change in moisture and, therefore, may prove difficult during stabilization (Sherwood, 1993). Peat soils and organic soils are rich in water content of up to about 2000%, high porosity and high organic content. The consistency of peat soil can vary from muddy to fibrous, and in most cases, the deposit is shallow, but in worst cases, it can extend to several meters below the surface (Pousette, *et al* 1999). Organic soils have high exchange capacity; it can hinder the hydration process by retaining the calcium ions liberated during the hydration of calcium silicate and calcium aluminate in the cement to satisfy the exchange capacity. In such soils, successful stabilization has to depend on the proper selection of binder and amount of binder added (Ahnberg *et al*, 1999).

### **2.2.2 Stabilizing Agents**

These are hydraulic (primary binders) or non-hydraulic (secondary binders) materials that when in contact with water or in the presence of pozzolanic minerals reacts with water to form cementitious composite materials. The types of additives include cementing agents, modifiers, water proofing agents, water retaining agents, water retarding agents and several miscellaneous chemicals. The behavior of each of these additives is different than that of the others and as such, possesses certain suitable or particular use and limitations. In the case of cementing agents, Portland cement, lime, lime-pozzolana and sodium silicate are some examples. Portland cement has been used extensively in many states in the improvement of existing gravel road as well as in stabilizing the natural sub-grade soils. Hydrated lime can also play the role of cementing agent through a chemical reaction between the free lime and the silica alumina content contained in the

soil. Hydrated lime is best suitable in granular materials and lean clays than in expansive or fat clays. The quantity required for a proper hydration is generally relatively low. One major downside to the use of cementing materials in soil stabilization is its cost which results in low or small quantities of the material being added to the soil which merely modifies it rather than undergo actual cementing action. Modifiers which are often used are also Portland cement, lime and bitumen. Relatively small quantities of cement and lime will change the water film on the soil particles, modify the clay minerals to some extent and will decrease the plasticity index of the given soil. In the case of water proofing materials, bituminous materials are the foremost which coat the soil or aggregate grains retarding and in some cases completely preventing the absorption of moisture. Bituminous stabilization is best suited for sandy soils or poor quality base course materials with its benefit derived by driving off the volatile constituents of the bitumen just prior to compaction (Achibong *et al.*, 2020).

### **2.3 Basic Principles of Soil Stabilization**

Different methods of soil stabilization are controlled by different factors and variables, as such an all governing principle cannot easily be described which encompasses all the methods of soil stabilization. However, it is generally accepted that before any method of soil stabilization is used irrespective of which certain factors should be considered such as (Achibong *et al.*, 2020):

1. Evaluate the properties of the given soil type – As earlier stated, the first and foremost criteria for the stabilization of any soil is its composition. The engineering properties possessed by a given soil depend largely on the composition of the soil. By understanding and evaluating the composition of the given soil, and in so doing, its engineering properties, the appropriate method to be employed in the stabilization of the soil can be identified.

2. Decide the most suitable, effective and economical method of soil stabilization for supplementing the lacking properties – Due to differing engineering properties, the stabilization method used for clay soils may not be suitable when employed for sandy soil. In the event that it is, which is highly unlikely, it may not be economical in both situations. As such, proper thoughts and considerations need to be put in place in deciding the most appropriate method or methods to be utilized in the stabilization process.

3. Design the soil mix with stability and durability values.

4. Considering the construction procedure by adequately compacting the stabilized layers.

#### **2.4 Soil Stabilization Methods**

In road construction projects, soil or gravelly material is used as the road main body in pavement layers. To have required strength against tensile stresses and strains spectrum, the soil used for constructing pavement should have special specification. Through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil (Keller, 2011). The method can be achieved in two ways, namely;

1) In-situ stabilization: It is used to limit the spread of contaminants in soil and groundwater by stabilizing the contaminated soil

2) Ex-situ stabilization: Excavation of contaminated soil for mixing with additives.

Stabilization however is not necessarily a magic wand by which every soil property can be improved for better. The decision to technological usage depends on which soil properties have to be modified. The chief properties of soil which are of interest to engineers are volume stability,

strength, compressibility, permeability and durability (Sherwood, 1993; Al-Tabba and Evans, 2005). Some stabilization techniques are listed below

**a Mechanical Stabilization**

**b Stabilization by using different types admixers**

- (1) Lime Stabilization
- (2) Cement Stabilization
- (3) Chemical Stabilization
- (4) Fly ash Stabilization
- (5) Rice Husk Ash Stabilization
- (6) Bituminous Stabilization
- (7) Thermal Stabilization
- (8) Electrical Stabilization
- (9) Stabilization by Geo-textile and Fabrics
- (10) Recycled and Waste Products etc.

**2.4.1 Mechanical Stabilization**

Mechanical Stabilization is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, rammers, vibration techniques and sometime blasting. The stability of the soil in this method relies on the inherent properties of the soil material. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components. Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification (Afrin, 2017).

**2.4.1.1 Factors Affecting Mechanical Stabilization**

a. **Strength of aggregate used:** With increasing strength of aggregates used, the stability of the mixed soil increases as well, although properly designed and compacted mixtures can sometimes accommodate for the relatively low strength of the aggregate.

b. **Basic mineral composition:** The basic mineral composition of the mixed soils plays a fundamental role as it pertains to the stability of the mixture. Generally, weather resistant minerals usually yield mixtures with greater mechanical stability, for instance sodium sulphates and sodium carbonates can result in large volume changes due to hydration and dehydration and thus greatly reduce stabilization.

c. **Gradation of mixture:** Proper design of the soil mixture is a key to greater mechanical stability as the gradation should be such that the pore spaces of the coarser grains or aggregates are effectively filled with the finer particles of the binders.

d. **Plasticity characteristics of the soil mixture:** Binders are generally soils like clay and silt possessing high liquid limit and plasticity index thus possessing greater cohesion and moisture retention capacity providing a good seal against the downward movement of surface water. However, in terms of plasticity, the requirements somewhat differ with the envisaged use for the soil moisture. For instance, soils meant to serve as base course possess a different plasticity characteristics requirement from those to be used for surfacing, as that of base course is expected to have low plasticity to avoid excessive accumulation of water and the resulting loss of strength as compared to that for surfacing.

e. **Adequate compaction of soil moisture:** The stability of a good soil mixture can be undermined if poorly compacted as the mechanical stability of the soil mass depends on the extent of compaction attained in the field.

Mechanical stabilization is one of the simplest methods soil stabilization generally used to improve the subgrades of low bearing capacity and has very little environmental side effect, although for deep soil compaction method such heavy weight compaction, due to the substantial amount of shockwaves generated, can be harmful to buildings and other engineering structures and as such cannot be utilized close to existing structures (Achibong *et al.*, 2020).

#### **2.4.2 Lime Stabilization**

Lime provides an economical way of soil stabilization. The method of soil improvement in which lime is added to the soil to improve its properties is known as lime stabilization. The types of lime used to the soil are hydrated high calcium lime, monohydrated dolomite lime, calcite quick lime, dolomite lime. The quantity of lime used in most soil stabilizer is in the range of 5% to 10%. Lime modification describes an increase in strength brought by cation exchange capacity rather than cementing effect brought by pozzolanic reaction (Sherwood, 1993). In soil modification, as clay particles flocculates, transforms natural plate like clays particles into needle like interlocking metalline structures. Clay soils turn drier and less susceptible to water content changes. Lime stabilization may refer to pozzolanic reaction in which pozzolana materials reacts with lime in presence of water to produce cementitious compounds (White, 2005). The effect can be brought by either quicklime, CaO or hydrated lime, Ca(OH)<sub>2</sub>. Slurry lime also can be used in dry soils conditions where water may be required to achieve effective compaction (Rogers and Glendinning, 1993). Quicklime is the most commonly used lime; the followings are the advantages of quicklime over hydrated lime (White, 2005) higher available free lime content per unit mass - denser than hydrated lime (less storage space is required) and less dust - generates heat which accelerate strength gain and large reduction in moisture content according to the reaction equation below



Quicklime when mixed with wet soils, immediately takes up to 32% of its own weight of water from the surrounding soil to form hydrated lime; the generated heat accompanied by this reaction will further cause loss of water due to evaporation which in turn results into increased plastic limit of soil i.e. drying out and absorption (Shearwood, 1993). Soils at a moisture content of 35% and plastic limit 25%. Addition of 2% lime will change the plastic limit to 40% so that the moisture content of the soil will be 5% below plastic limit instead of 10% above plastic limit (Shearwood, 1993). Sherwood investigated the decrease in plasticity as brought about in first instance by cation exchange in which cations of sodium and hydrogen are replaced by calcium ions for which the clay mineral has a greater water affinity. Even in soils (e.g. calcareous soils) where, clay may be saturated with calcium ions, addition of lime will increase pH and hence increase the exchange capacity. Like cement, lime when reacts with wet clay minerals result into increased pH which favors solubility of siliceous and aluminous compounds. These compounds react with calcium to form calcium silica and calcium alumina hydrates, a cementitious product similar to those of cement paste. Natural pozzolanas materials containing silica and alumina (e.g. clay minerals, pulverized fly ash, PFA, blast furnace slag) have great potential to react with lime. Lime stabilizations technology is mostly widely used in geotechnical and environmental applications. Some of applications include encapsulation of contaminants, rendering of backfill (e.g. wet cohesive soil), highway capping, slope stabilization and foundation improvement such as in use of lime pile or lime-stabilized soil columns. However, presence of sulphur and organic materials may inhibit the lime stabilization process. Sulphate (e.g. gypsum) will react with lime and swell, which may have effect on soil (Afrin, 2017).

strength.

### 2.4.3 Cement Stabilization

Soil cement stabilization is soil particles bonding caused by hydration of the cement particles which grow into crystals that can interlock with one another giving a high compressive strength. In order to achieve a successful bond, the cement particles need to coat most of the material particles. To provide good contact between soil particles and cement, and thus efficient soil cement stabilization, mixing the cement and soil with certain particle size distribution is necessary. Soil-cement is a highly compacted mixture of soil/aggregate, cement, and water. Soil-cement is sometimes called cement-stabilized base, or cement-treated aggregate base. Soil-cement becomes a hard and durable material as the cement hydrates and develops strength. Cement stabilization is done when the compaction process is continuing. As the cement fills the void between the soil particles, the void ratio of soil is reduced. After this when water is added to the soil, cement reacts with water and goes hard. So, unit weight of soil is increased. Because of hardening of cement shear strength and bearing capacity is also increased. Cement helps decrease the liquid limit and increase the plasticity index and workability of clayey soils. Cement reaction is not dependent on soil minerals, and the key role is its reaction with water that may be available in any soil. This can be the reason why cement is used to stabilize a wide range of soils. Numerous types of cement are available in the market; these are ordinary Portland cement, blast furnace cement, sulfate resistant cement and high alumina cement. Usually the choice of cement depends on type of soil to be treated and desired final strength. Hydration process is a process under which cement reaction takes place. The process starts when cement is mixed with water and other components for a desired application resulting into hardening phenomena. The hardening (setting) of cement will enclose soil as glue, but it will not change the structure of soil.

The hydration reaction is slow proceeding from the surface of the cement grains and the center of the grains may remain unhydrated (Afrin, 2017).

Cement hydration is a complex process with a complex series of unknown chemical reactions. However, this process can be affected by

- (a) presence of foreign matters or impurities
- (b) water-cement ratio
- (c) curing temperature
- (d) presence of additives
- (e) Specific surface of the mixture.

Depending on factor(s) involved, the ultimate effect on setting and gain in strength of cement stabilized soil may vary. Therefore, this should be taken into account during mix design in order to achieve the desired strength. Calcium silicates, *C3S* and *C2S* are the two main cementitious properties of ordinary Portland cement responsible for strength development (MacLaren and White, 2003). Calcium hydroxide is another hydration product of Portland cement that further reacts with pozzolanic fine materials available in stabilized soil to produce further cementitious material. Normally the amount of cement used is small but sufficient to improve the engineering properties of the soil and further improved cation exchange of clay. Cement stabilized soils have the following improved properties:

- (a) decreased cohesiveness (Plasticity)
- (b) decreased volume expansion or compressibility
- (c) Increased strength.

### **2.4.3. Factors Affecting Stabilization with Cements**

According to Arora (2011), the following factors affect stabilization using soil cements:

**a. Soil type:** Granular soils such as sands in the presence of a sizable amount of fines thus far have proved ideal for cement stabilization and require the least amount of cement. Sands lacking the required quantity of fines can also be stabilized but however would require more cement. Although fines such as silty and clayey soils have the potential to produce satisfactory soil cement, those with high clayey contents however are difficult to pulverize with the quantity of clay content and a resultant poor quality of soil cement possessing high shrinkage properties. The presence of organic matter in colloidal form interferes with the hydration of cement and causes a reduction in the strength of the soil cement usually encountered in sandy soils. In such cases, these sandy soils should first be treated with calcium chloride or sodium hydroxide before cementing is carried out.

**b. Quality of cement:** Well graded sands usually require about 5% cement while poorly graded uniform sand may require about 9% cement, non-plastic silts about 10% and plastic clay about 13% of cement is required for a particular soil is determined from a laboratory test. For base course, samples are subjected to durability test consisting of 12 cycles of freezing and thawing or 12 cycles of wetting and drying with an allowable maximum volume change of 2%. The quantity of cement can also be determined from the minimum unconfined compressive strength with high strength obtained by decreasing the water cement ratio through increase in its cement content.

**c. Quantity and quality of water:** Sufficient water is required for the effective hydration of cement and the silt-clay cement for making them workable. Generally, the amount of water determined from compaction consideration can serve for hydration while ensuring that the water used is both clean and free from harmful salts, alkalis, acids or organic matter.

**d. Adequate mixing, compaction and curing:** The soil, water and cement mixture has to be thoroughly mixed as it may affect the stability of the material, if not mixed properly may result

in a non-homogenous and weak product, at least until hydration begins when all mixing should be ceased to avoid a loss of strength.

e. **Use of additives:** Sometimes other additives can be added to the soil cement in order to increase its effectiveness, reduce the amount of cement required and assist in the stabilization of soil which is not responsive to cement alone.

#### **2.4.4 Chemical Stabilization**

Chemical stabilization of soil comprises of changing the physico-synthetic around and within clay particles where by the earth obliges less water to fulfill the static imbalance. Calcium chloride being hygroscopic and deliquescent is used as a water retentive additive in mechanically stabilized soil bases and surfacing. The vapor pressure gets lowered, surface tension increases and rate of evaporation decreases. The freezing point of pure water gets lowered and it results in prevention or reduction of frost heave. The depressing the electric double layer, the salt reduces the water pick up and thus the loss of strength of fine grained soils. Calcium chloride acts as a soil flocculent and facilitates compaction. Frequent application of calcium chloride may be necessary to make up for the loss of chemical by leaching action. For the salt to be effective, the relative humidity of the atmosphere should be above 30%. Sodium chloride is the other chemical that can be used for this purpose with a stabilizing action similar to that of calcium chloride. Sodium silicate is yet another chemical used for this purpose in combination with other chemicals such as calcium chloride, polymers, chrome, lignin, alkyl chlorosilanes, siliconites, amines and quaternary ammonium salts, sodium hexametaphosphate, phosphoric acid combined with a wetting agent (Rogers and Glendinning, 1993).

#### **2.4.5 Bituminous Stabilization**

Bituminous soil stabilization refers to a process by which a controlled amount of bituminous material is thoroughly mixed with an existing soil or aggregate material to form a stable base or wearing surface. Bitumen increases the cohesion and load-bearing capacity of the soil and renders it resistant to the action of water. Bitumen stabilization accomplished by using asphalt cement, asphalt cutback or asphalt emulsions. The type of bitumen to be used depends on the type of soil to be stabilized, method of construction and weather conditions. In frost areas, the use of tar as binder must be avoided because of its high temperature maximum susceptibility. Asphalts and tars are bituminous materials which are used for stabilization of soil, generally for pavement construction. Bituminous materials when added to a soil, it imparts both cohesion and reduced water absorption (Afrin, 2017).

#### **2.4.5.1 Factors Affecting Bituminous Stabilization**

- a. **Type soil:** Bituminous stabilization is very effective in stabilizing sandy soils having little or no fines. If a cohesive soil has the plastic limit less than about 20% and liquid limit less than 40%, it can be effectively stabilized. However plastic clays cannot be properly treated because of the mixing problem and large quantity of asphalt required. Fine grained soils of the arid regions have values and contain dissolved component which do not respond to bituminous stabilization.
- b. **Amount of asphalt:** The quality of the bitumen stabilized soil improves with the amount of asphalt up to a certain limit. However, if the amount of the asphalt is excessive, it results in a highly fluid mixture that cannot be properly compacted.
- c. **Mixing:** The quality of the product improves with more thorough mixing.

d. **Compaction:** The dry density of the bitumen soil depends on the amount and type of compaction. It also depends upon the volatile content.

#### **2.4.6 Thermal Stabilization**

Thermal change causes a marked improvement in the properties of the soil. Thermal stabilization is done either by heating the soil or by cooling it.

**Heating:** As the soil is heated, its water content decreases. Electric repulsion between clay particles is decreased and the strength of the soil is increased.

**Freezing:** cooling causes a small loss of strength of clayey soils due to an increase in inter particles repulsion. However, if the temperature is reduced to the freezing point, the pore water freezes and the soil is stabilized.

#### **2.4.7 Electrical Stabilization**

Electrical stabilization of clayey soils is done by a process known as electro-osmosis. As a direct current (DC) is passed through a clayey soil, pore water migrates to the negative electrode (cathode). It occurs because of attraction of positive ions (cations) that are present in water towards cathode. The strength of the soil is considerably increased due to removal of water. Electro-osmosis is an expensive method, and is mainly used for drainage of cohesive soils. Incidentally, the properties of the soil are also improved (Afrin, 2017).

#### **2.4.8 Use of Organic Stabilizers**

A number of organic stabilizers have been used for chemical stabilization of soils, some of which are sodium silicate, lignin, resins, molasses, etc. Sodium silicates react in aqueous situations with soluble calcium salts forming insoluble and gelatinous calcium silicates. Calcium needed for the reaction can either be present in the soil itself or be added in aqueous solutions. The amount of chemical needed may vary from 1 to 10%. The natural binding material that holds

together the fibres in wood is lignin. The stabilization is by the cementing bond that develops between the soils particles due to the presence of binder. The material also closes the voids and thus reduces penetration of water through the layer. It retards the rate of evaporation of water and arrests loss of moisture. Molasses is a waste product from the process of manufacturing sugar from sugarcane. A thick syrupy liquid, it is hygroscopic and can be used as a dust palliative and as a binder for incorporation during compaction.

## **2.5 Factors Affecting the Strength of Stabilized Soil**

Presence of organic matters, sulphates, sulphides and carbon dioxide in the stabilized soils may contribute to undesirable strength of stabilized materials (Afrin, 2017).

### **2.5.1 Organic Matter**

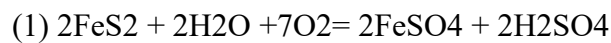
In many cases, the top layers of most soil constitute large amount of organic matters. However, in well drained soils organic matter may extend to a depth of 1.5 m. Soil organic matters react with hydration product e.g. calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) resulting into low pH value. The resulting low pH value may retard the hydration process and affect the hardening of stabilized soils making it difficult or impossible to compact.

### **2.5.2 Sulphates**

The use of calcium-based stabilizer in sulphate-rich soils causes the stabilized sulphate rich soil in the presence of excess moisture to react and form calcium sulfoaluminate (ettringite) and or thamausite, the product which occupy a greater volume than the combined volume of reactants. However, excess water to one initially present during the time of mixing may be required to dissolve sulphate in order to allow the reaction to proceed (Hicks, 2002).

### **2.5.3 Sulphides**

In many of waste materials and industrial by-product, sulphides in form of iron pyrites ( $\text{FeS}_2$ ) may be present. Oxidation of  $\text{FeS}_2$  will produce sulphuric acid, which in the presence of calcium carbonate, may react to form gypsum (hydrated calcium sulphate) according to the reactions (1) and (2) below



The hydrated sulphate so formed, and in the presence of excess water may attack the stabilized material in a similar way as sulphate. Even so, gypsum can also be found in natural soil (Al-Tabbaa and Evans, 2005).

#### **2.5.4 Compaction**

In practice, the effect of addition of binder to the density of soil is of significant importance. Stabilized mixture has lower maximum dry density than that of unstabilized soil for a given degree of compaction. The optimum moisture content increases with increasing binders (Sherwood, 1993). In cement stabilized soils, hydration process takes place immediately after cement comes into contact with water. This process involves hardening of soil mix which means that it is necessary to compact the soil mix as soon as possible. Any delay in compaction may result in hardening of stabilized soil mass and therefore extra compaction effort may be required to bring the same effect. That may lead to serious bond breakage and hence loss of strength. In contrary to cement, delay in compaction for lime-stabilized soils may have some advantages. Lime stabilized soil require mellowing period to allow lime to diffuse through the soil thus producing maximum effects on plasticity. After this period, lime stabilized soil may be remixed and given its final compaction resulting into remarkable strength than otherwise (Sherwood, 1993).

### **2.5.5 Moisture Content**

In stabilized soils, enough moisture content is essential not only for hydration process to proceed but also for efficient compaction. Fully hydrated cement takes up about 20% of its own weight of water from the surrounding (Sherwood, 1993); on other hand, Quicklime (CaO) takes up about 32% of its own weight of water from the surrounding (Sherwood, 1993). Insufficient moisture content will cause binders to compete with soils in order to gain these amounts of moisture. For soils with great soil water affinity (such as clay, peat and organic soils), the hydration process may be retarded due to insufficient moisture content, which will ultimately affect the final strength (Afrin, 2017).

### **2.5.6 Temperature**

Pozzolanic reaction is sensitive to changes in temperature. In the field, temperature varies continuously throughout the day. Pozzolanic reactions between binders and soil particles will slow down at low temperature and result into lower strength of the stabilized mass. In cold regions, it may be advisable to stabilize the soil during the warm season (Sherwood, 1993).

## **2.6 Impact of Stabilization on The Environment**

In the case of lime stabilization, the production of calcium-based material during its process involves the calcinations of calcium carbonate (Ibtehaj *et al.*, 2014), which takes place at high temperatures resulting in the production of a considerable quantity of carbon dioxide emission in addition to high energy consumption (Birchal *et al.*, 2000; Shand, 2005). Thus, the production of calcium-based additives affects the environment negatively. Cement stabilization within aquatic region could result in an increase in the pH of the water which may affect plant growth and alter the species composition. This could have a subsequent impact on aquatic fauna. For fishes, although less susceptible to pH changes can be indirectly affected by the alteration of

the food supply chain and the sedimentation of the water courses can smother fish eggs and damage fish gills through abrasion. The handling and mixing of the soil-cement may result in a localized increase in dust particles. Fresh cement may contain traces of hexavalent chromium, a known allergen to certain individuals which may affect their health. Soils stabilized with the use of bitumen cannot support plant growth around its immediate adjoining regions but rather have harmful impact of the environment, making the land unsuitable for agricultural purposes. Water around the region becomes toxic and may be harmful to humans as well as animals and other aquatic organisms if taken. Consumption of such water may most likely cause certain water related diseases and even death in the case of animals (Ogedengbe, 2009).

## CHAPTER THREE

### MATERIAL AND METHOD

#### 3.1 Description of Study Area

The flexible pavement structure axis along Warri-Sapele road in South South, Nigeria is the area to be investigated for this study (Fig. 1). The location lies within Longitude  $5^{\circ} 47' 0''$ E, Latitude  $5^{\circ} 34' 25''$ N (Effurun) and Longitude  $5^{\circ} 42' 4''$  E and Latitude  $5^{\circ} 55' 7''$  N (Sapele). The highway is located within the tropical climatic region. The region experiences two seasons-dry and wet seasons. The mean annual rainfall is 2770mm. Relative humidity is about 60-85% from November to March and 80-90% around August. The mean temperature varies between  $28^{\circ}\text{C}$  and  $32^{\circ}\text{C}$ . According to the Federal Survey (1978), the area lies in the rain forest zone. The vegetation is dense and made up of broad leaved trees that are mostly evergreen



Figure 1: Google Map of the Sapele-Warri Express-Way (*Source: Google Map*)

### **3.2 Sampling**

The field aspect will involve extensive road travel in order to record highway pavement failure features. The geological settings of the immediate environment of the road including drainage conditions will also be investigated. Bulk disturbed representative soil samples will be collected under the failed sections of the road including the base level material, because the base is the most vitally important layer of the highway prism or configuration.

Auger borings examinations will be done on spots that are observed to have failed or are failing at about 5 and 10 meters away from the tarred road at one side, considering the toposequence of the nature of the road and within the parent material present in that area, profile pits will be dug at different locations, 100m away from the road representing the parent material identified. The physical state of the route from Benin to Sapele will also be assessed by visual and qualitative assessment of the extent of road failure and other accessory deterioration. The profile pits will be read; both regular and core samples will be collected, properly preserved, labeled and will be taken to the laboratory for both pedological and geotechnical properties analysis. Using the results of both the morphological description of the profile pits, physical and chemical properties from laboratory analysis, classification of the soils will be done pedologically according to USDA soil taxonomy and AASHTO classification system. Results of the physical properties were used to classify the soils and to check the physical condition of the soils as regards the use of soil for road construction. The results were compared among the parent materials using standard guidelines to make predictions of road failure.

### **3.3 Laboratory Analysis**

The following soil tests will be carried out on the collected soil samples. The tests include the following;

#### **3.3.1 Soil Particle Size Distribution**

Soil particle size distribution will be determined by the Bouyoucous hydrometer method (Bouyoucous 1951) as modified by Day (1965) after extraction of organic matter using hydrogen peroxide and dispersing the soil with sodium hexametaphosphate.

#### **3.3.2 California Bearing Ratio**

California Bearing Ratio test is conducted to provide the load penetration resistance of the soil. CBR value is obtained by measuring the force of penetration when a cylindrical plunger is made to penetrate the soil at a standard rate of 1.25mm/min to that required for a corresponding penetration of a standard material (well graded crushed stone material). The CBR test is used for the evaluation of the subgrade strength of the road pavement. The CBR test is used with the empirical curves to determine the thickness of the pavement and its component layers. Soil CBR will be determined by the method proposed by American Society for Testing and Materials, ASTM (1883) as modified by California Highway Division (1945). The following steps will be followed to conduct the soaked and unsoaked California bearing ratio test:

- i. The specimen weighing 4.5kg will be compacted so that their compacted densities will range from 95-100% generally with 10, 30 and 65 blows
- ii. The empty mould will be weighed
- iii. Water will be added to the first specimen (compact it in five layer by giving 10 blows per layer)

- iv. After compaction, the collar will be removed and the surface will be leveled.
- v. Moisture content of each specimen will be taken
- vi. Weight of mould and compacted specimen will be recorded
- vii. The mould will be placed in a tank for 4 days (this step will be ignored when carrying out the unsoaked CBR test).
- viii. After 4 days, the measure of swell reading will be taken and swell percentage will be calculated
- ix. The mould will be removed from the tank and allowed to drain
- x. The sample is placed under the penetration piston and a surcharge load of weight (10lb=4.5kg) is placed on the sample
- xi. The load will be applied and the penetration load value will be taken note off
- xii. A graph of penetration against penetration load will be drawn and the CBR values will be found
- xiii. A graph will be drawn between the percentage CBR and dry density and CBR at the required degree of compaction

### **3.3.3 Moisture content**

Moisture content is defined as the ratio of the weight of the water in a soil specimen to the dry weight of the specimen. The moisture content of lateritic soil can be influenced by the mineralogy and formation environment.

### **3.3.4 Compaction Test**

The densification of soil with mechanical equipment thereby rearranging the soil particles which makes them more closely packed resulting in an increase of the ratio horizontal effective size to the vertical effective stress. The degree of compaction is measured in term of its dry weight and

it increasing the bearing capacity of road foundation, stability slopes, controls undesirable volume changes and curb undesirable settlement of structures. The mould is filled and compacted with soil in five layer via 25 blows of a 4.5 rammer.

### **3.4 Laboratory Analysis**

#### **Selected Physical-Chemical Properties Analysis**

Sample preparation: wet soil samples was air dried, crushed with wooden roller and passed through a 2mm plastic sieve and stored in polypropylene bottles for analysis.

##### **3.4.1 pH**

20g of soil sample of fine tilt was weighed in 50ml beaker and 40ml of distilled water was added and the mixture was stirred intermittently for 30 minutes. The pH was measured in a standardized pH meter and pH was recorded as soil pH in H<sub>2</sub>O 1:2 (Tan, 2002).

##### **3.4.2 Percentage Nitrogen**

Percentage of Nitrogen was measured using Kjeldahl method by Black, (1993) as reported by Carter, (1993). 0.20g of fine earth was weighed into 10ml conical flask. A catalyst mixture of K<sub>2</sub>SO<sub>4</sub> + CuSO<sub>4</sub> + ScO<sub>2</sub> was added to aid quick digestion. 15ml of conc. H<sub>2</sub>SO<sub>4</sub> was added and a glass curved funnel (specially made to prevent direct escape of ammonia (NH<sub>3</sub>) the heating was done on an electric cooker till the solution become very clear. It was left to cool down to room temperature. The digested soil was filtered into 100ml volumetric flask and was made up to mark. The mixture was turned thoroughly and severally and was kept waiting for distillation. During distillation, 10ml aliquot was taken into a 500ml Kjeldahl flask and 30ml of distilled water was added. 15ml of 10N NaOH was also added and it was set-up in the distillation apparatus. 25ml distillate was collected and was titrated back with 0.01N HCl.

Total % nitrogen was calculated as follows:

of sample

Where:

- M -Molarity of acid
- T -Control titre value
- V<sub>1</sub> - Final volume of digest.
- V<sub>2</sub> - Volume of digest used for distillation

### 3.4.3 Percentage Organic Carbon

This was determined using Walkley-Black method of chromic acid wet oxidation method as reported by Tan, (2002). 1g of soil sample was weighed into 250ml conical flask. 10ml of 1N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution was added and the mixture swirl for proper mixing. 20ml of conical H<sub>2</sub>SO<sub>4</sub> was added carefully. The mixture was again swirl to mix up and was left for 30 minutes and thereafter 100ml of distilled water was added. The mixture was again swirl round. 5 drops of ferroin indicator was added. The excess chromic acid was titrated with 0.5N ferrous sulfate to dirty brown end-point (Tml). A blank was run, using the sample procedure, but without soil sample (Bml). The blank measure the amount of reducing substance present in the reagents as impurities.

% organic carbon was calculated as follows:

=

### 3.4.4 Exchangeable Cations

10g of soil sample was weighed into 250ml shaking bottle and left overnight after adding 1M NH<sub>4</sub>OAC. The mixture was filtered using Whatman No. 1 filter paper into 100ml volumetric flask and was made up to mark with NH<sub>4</sub>OAC. From the leachate, Ca and Mg will be determined titrimetrically, while Na and K were read in a flame photometer, and each element is expressed in cmol/kg.

### 3.4.5 Determination of Ca and Mg (EDTA Titration)

10ml of the 1MNH<sub>4</sub>OAC extracted leachate was pipetted into a 250ml conical flask (V<sub>2</sub>). 50ml of distilled water was added. 8ml of NH<sub>3</sub> solution (conical) was added. 5 drops of 2% KCN was also added; followed by 5 drops of 5% hydroxyl ammonium chloride (OHNH<sub>3</sub>Cl). 3 drops Eriochrome Black T indicator (EBT) was added. The mixture was then titrated with 0.01M EDTA, from red-wine-blue.

### 3.4.5 Ca Determination

10ml of extract was pipetted into 250ml conical flask (V<sub>2</sub>). 50ml of distilled water was added. 2ml 2% KOH was also added. 5 drops of 2% KCN followed by 5 drops of OHNH<sub>3</sub>Cl. 5 drops of calgmit was added and the mixture titrated also using EDTA (0.01M).

#### Calculation:

Ca in mmol / =

Where:

T - titre value

M (EDTA) - Molarity of EDTA

V<sub>1</sub> - Volume of extract

V<sub>2</sub> - Volume of aliquot

40 - Molecular weight of Ca

While that of Mg go same.

### 3.4.6 Exchangeable Acidity (EA)

5g of soil sample was weighed into a 250ml soil shaking bottle. 100ml of 1M KCl was added as the extracting solution. It was shaken for 1 hour. The mixture was filtered into a 100ml volumetric flask with 1M KCl. 25ml of KCl extract was pipette into 250ml conical flask. 100ml of distilled water was added. 5 drops of phenolphthalein indicator were added and the solution was titrated with 0.0 1N NaOH to a first permanent pink end-point with alternate stirring and standing.

Note: The volume of base used should not be  $<0.5\text{ml}$  under normal condition, because of the low acidity content of some soils. Other tissues can be run to find the mean. The mean value base (NaOH) is equivalent to the total amount acidity (H + Al) in the aliquot taken.

**Calculation:**

Acidity in mmol / =

Where:

- M - Molarity of NaOH
- T - Titre value of base
- $V_1$  - Volume of extract
- $V_2$  - Volume of aliquot
- wt - Weight of sample used

**Summation method:**

- (a) EB = Exchangeable bases  
=  $\text{cmol/kg (Ca + Mg + K + Na)}$
- (b) ECEC = Exchangeable bases + Exchangeable acidity  
i.e =  $\text{cmol (Ca + Mg + K + Na) + cmol (H + Al)}$   
= TEB + EA

**3.4.7 Particle size Determination**

The particle sizes were determined using Hydrometer method of Bouyoucos (1951) as modified by Day (1965). 50g of air-dry soil into a soil shaking bottle. 100ml of calgon was added and will be allowed to soak for 30 minutes. The mixture was stirred with a mechanical stirrer. The soil suspension was transferred into a sedimentation cylinder and was filled to mark with distilled  $\text{H}_2\text{O}$ . A plunger was inserted and was moved up and down to mix the content thoroughly, while the sediment was dislodged with their upward strokes of the plunger near the bottom, the hydrometer was lowered carefully into the suspension and readings was taken after 40 seconds (R40 sec.). The temperature reading was taken thereafter with a thermometer. The second reading came up in 120 minutes' time, while the first (R40 sec.) reading calculate for % silt + clay, the second reading was calculated for % clay and subtracted from % silt clay and both subtracted from 100 to get % sand.

### 3.4.8 Available Phosphorous (using Bray P-1 method)

5g of soil was weighed into a 250ml shaking bottle. 35ml of extracting solution (1M NH<sub>4</sub>F). The mixture was shaken for 3 minutes and was filtered into 100ml volumetric flask and the leachate determined in a spectrophotometer.

#### Calculation:

Weight of sample to be used - 5g  
Volume of extract to be used (V) - 35ml  
Volume of extract to be used - 250 diluted to 50ml  
Therefore ppm soil = ppm graph x

## CHAPTER FOUR

### RESULT AND DISCUSSION

#### 4.1 Compaction Test

From the results obtained from the compaction test, subgrade samples obtained from Warri (Effurum) are P1R1, P1R2, P1R3, P1R4 while those obtained from Sapele are P2R1, P2R2, P2R3, P2R4, P2R5. The following are the maximum dry density (MDD) respectively 1.76 g/cm<sup>3</sup>, 1.76 g/cm<sup>3</sup>, 1.77g/cm<sup>3</sup>, 1.84g/cm<sup>3</sup>, 1.77 g/cm<sup>3</sup>, 1.72g/cm<sup>3</sup>, 1.78g/cm<sup>3</sup>, and 1.77g/cm<sup>3</sup> and Optimum Moisture Content (OMC), have respectively 8.88%, 9.88%, 12.00%, 9.55%, 9.50%, 12.70%, 9.28%, 11.86%, and 12.00%. The MDD and OMC ranges from 1.72g/cm<sup>3</sup> to 1.84g/cm<sup>3</sup> and 8.88% to 12.70% respectively. The samples have affinity to absorb more water and swell on

drying which is not healthy for Civil Engineering works. According to O'Flaherty (1988) the range of values that may be anticipated when using the standard proctor test methods are: for clay, maximum dry density (MDD) may fall before  $1.44\text{mg/m}^3$  and  $1.685\text{mg/m}^3$  and optimum moisture content (OMC) may fall between 20-30%. For silty clay MDD is usually between  $1.6\text{mg/m}^3$  and  $1.845\text{mg/m}^3$  and OMC ranged between 15-25%. For sandy clay, MDD usually ranged between  $1.76\text{mg/m}^3$  and  $2.165\text{mg/m}^3$  and OMC between 8 and 15%. Thus, looking at the results of the soil samples, it could be noticed that they are sandyclay. The moisture content from the compaction test in ranged from 8.88% to 12.70% with an average value of 10.63% (Figure 4.1 to 4.9) indicating that the soil is generally poorly graded and sandyclay with plastic fines (material passing sieve No. 200) and this finding is in agreement with other determined geotechnical parameters. Federal Ministry of Works and Housing (1972) for road works recommend liquid limits of 50% maximum for subbase and base materials. All the studies soil samples fall within this specification, thus making them suitable for subbase and base materials.

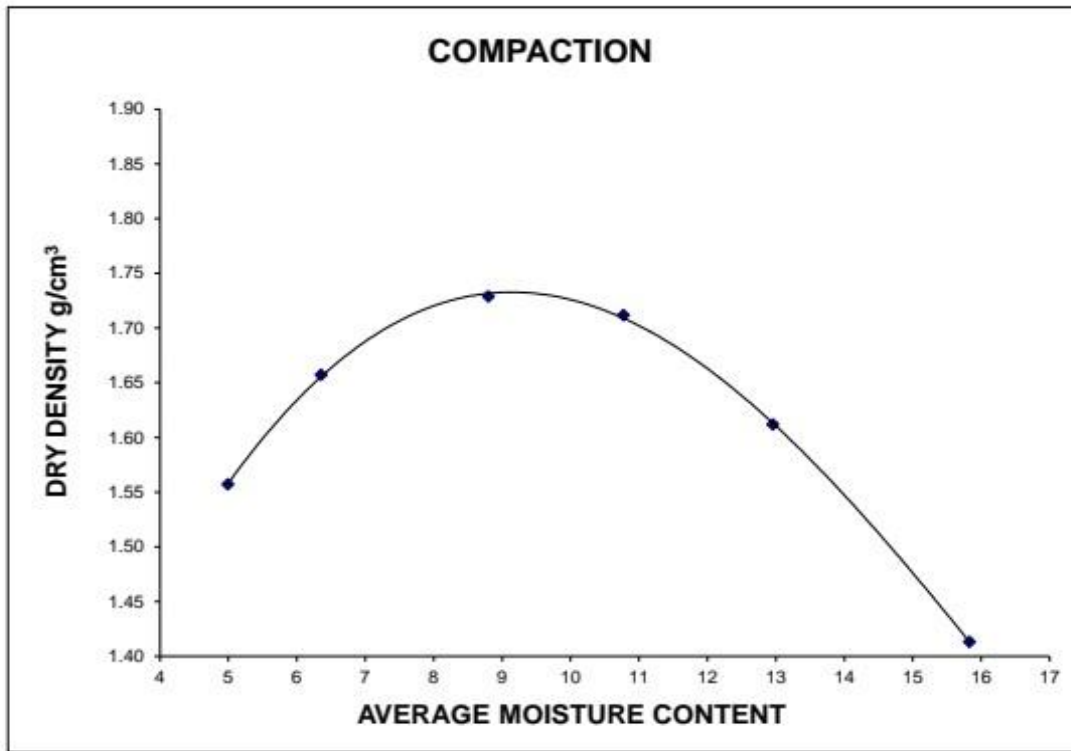


Figure 4.1.1: Dry density vs Moisture content in laboratory test for determination of MDD at P1R1

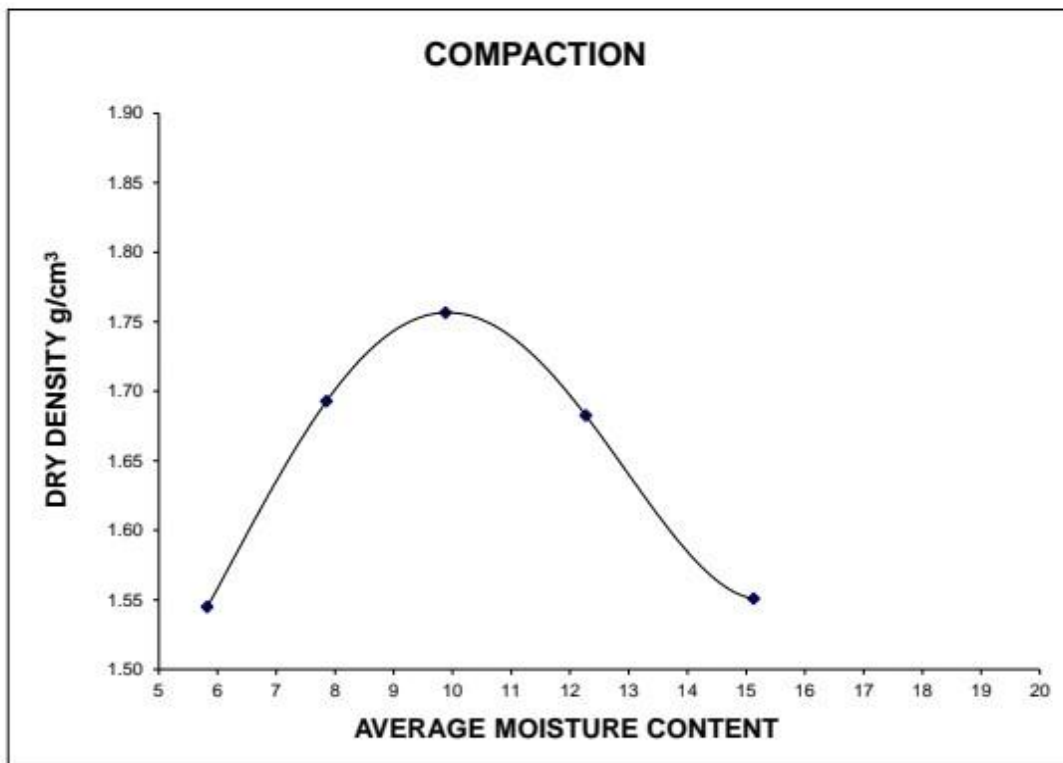


Figure 4.1.2: Dry density vs Moisture content in laboratory test for determination of MDD at P1R2

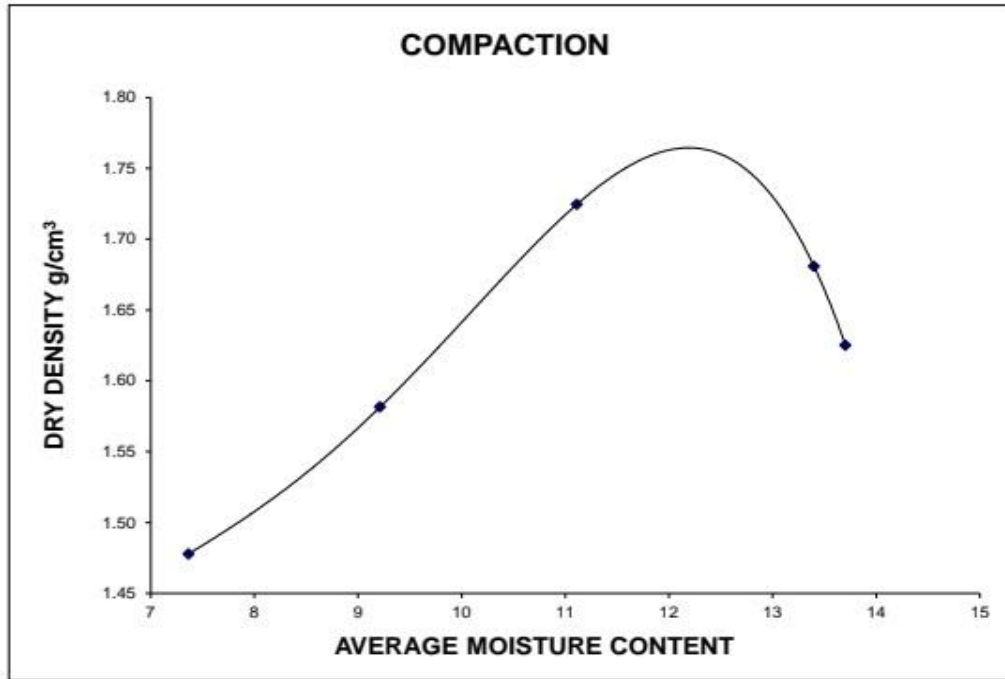


Figure 4.1.3: Dry density vs Moisture content in laboratory test for determination of MDD at PIR3

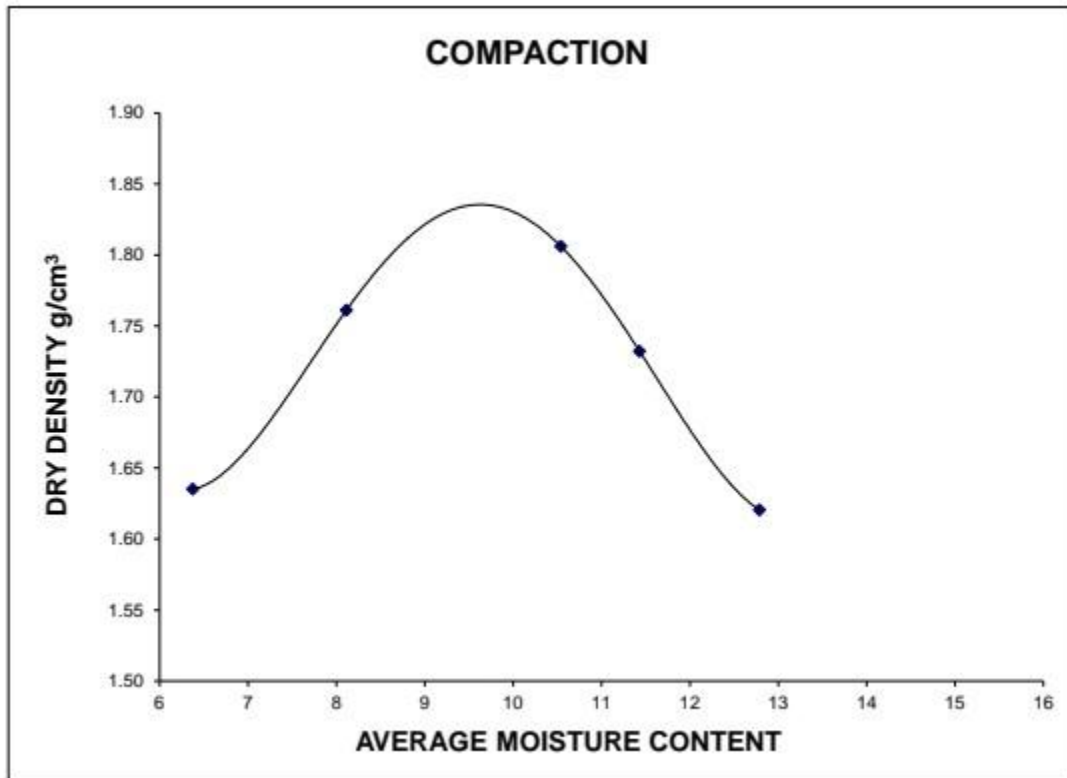


Figure 4.1.4: Dry density vs Moisture content in laboratory test for determination of MDD at P1R4

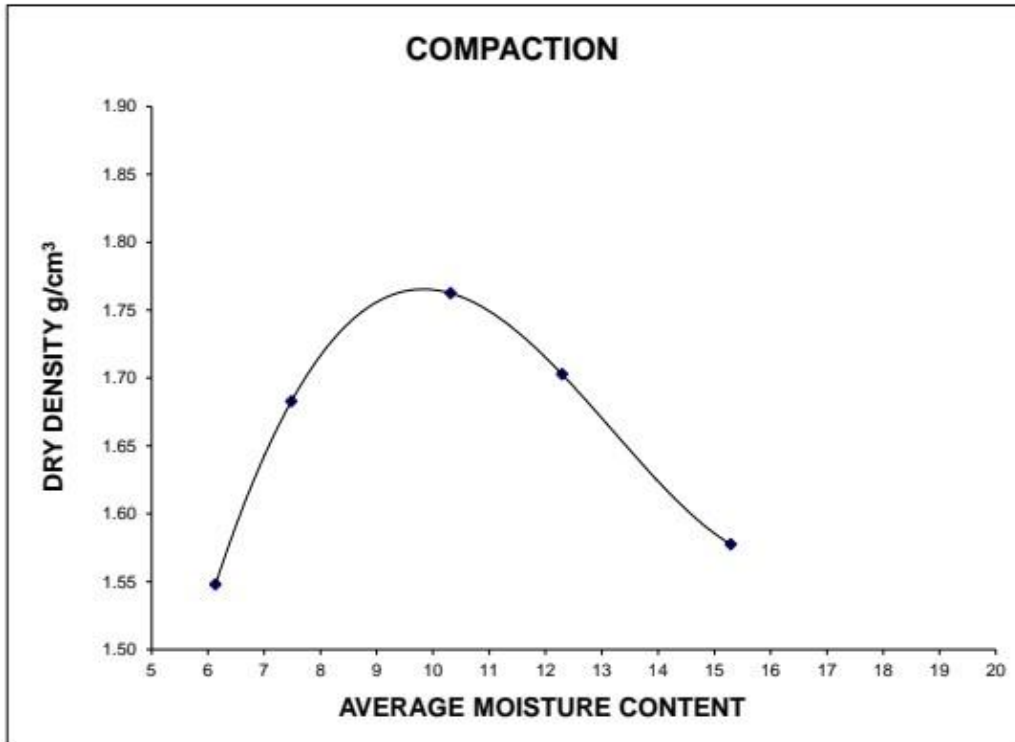


Figure 4.1.5: Dry density vs Moisture content in laboratory test for determination of MDD at P2R1

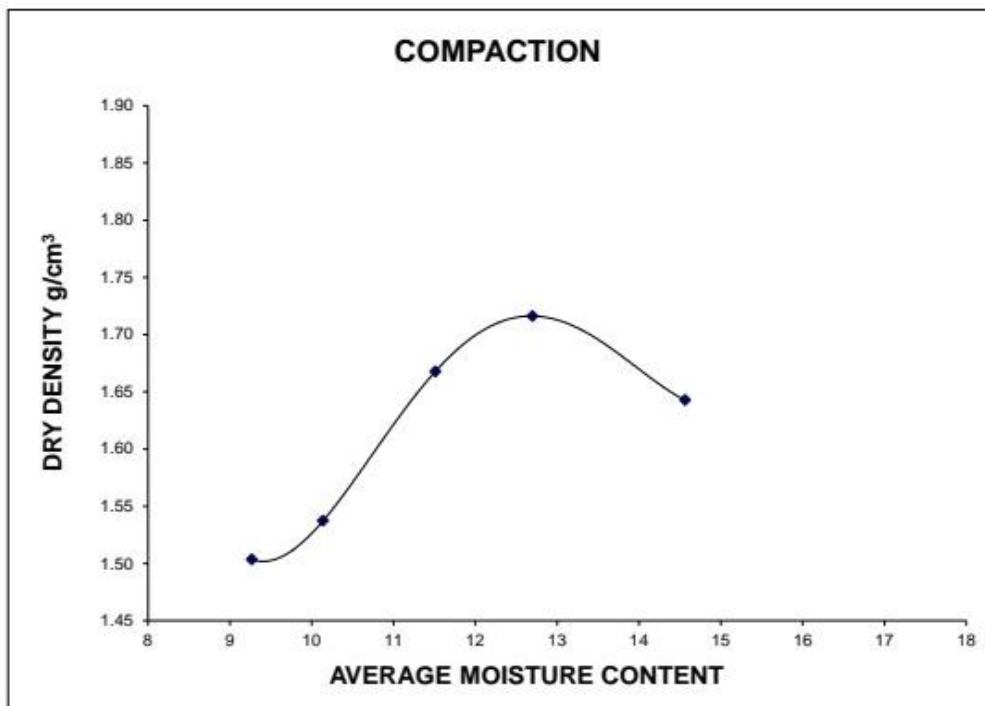


Figure 4.1.6: Dry density vs Moisture content in laboratory test for determination of MDD at P2R2

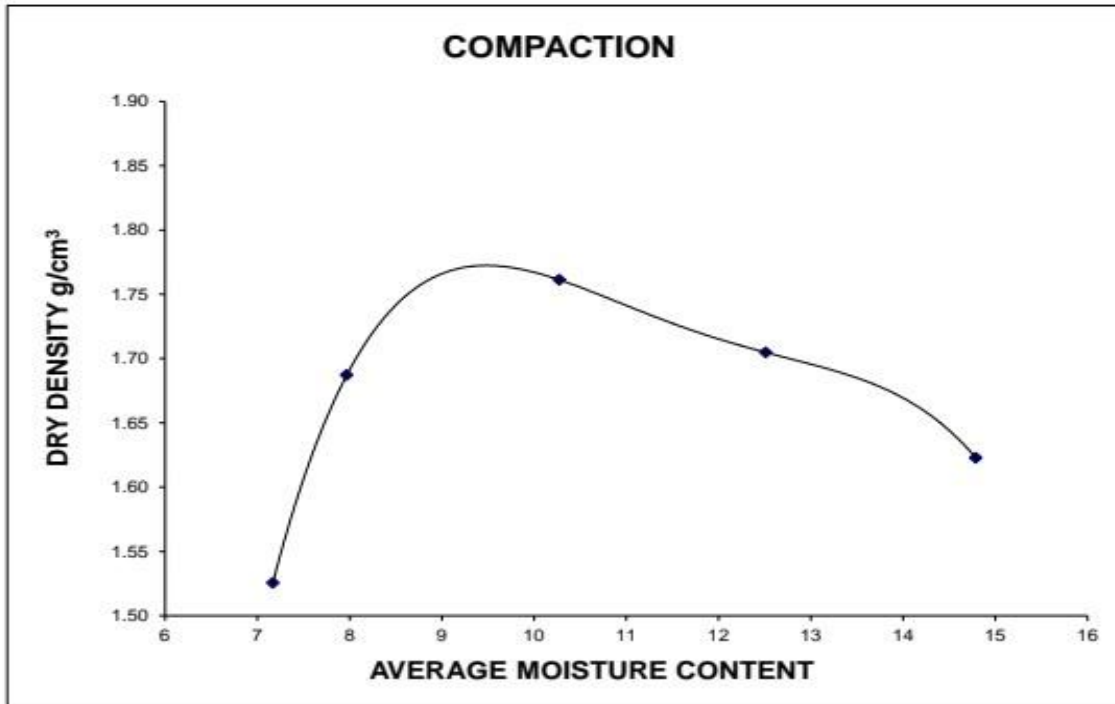


Figure 4.1.7: Dry density vs Moisture content in laboratory test for determination of MDD at P2R3

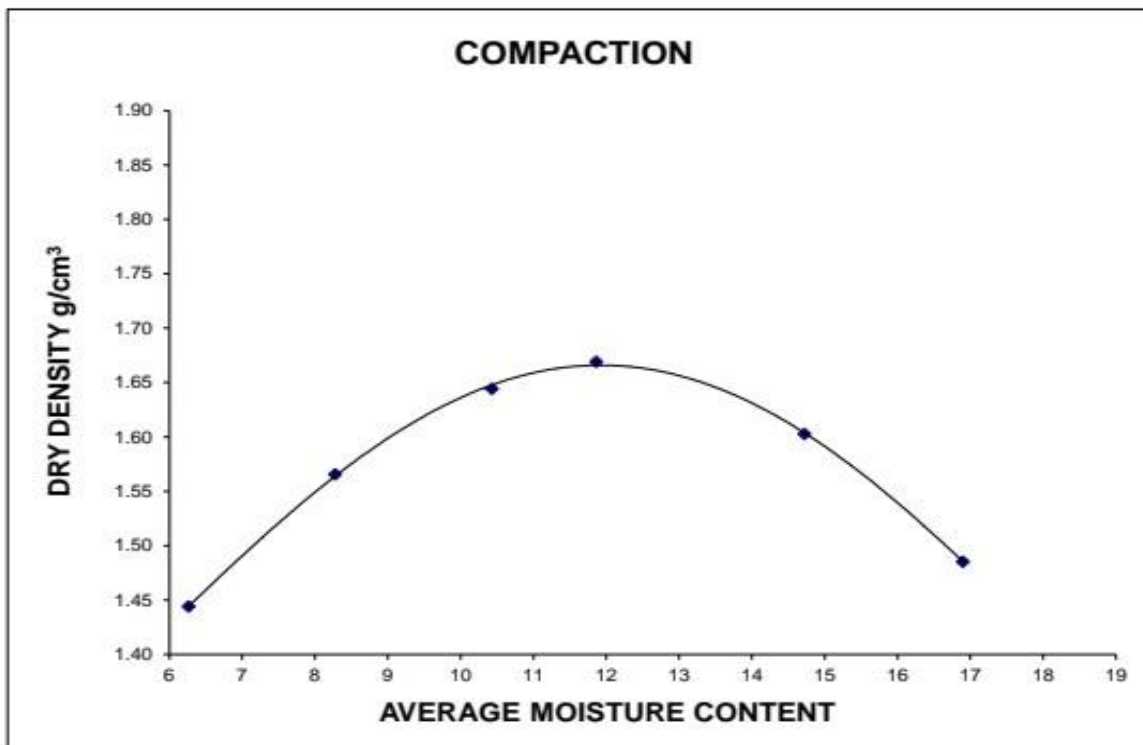
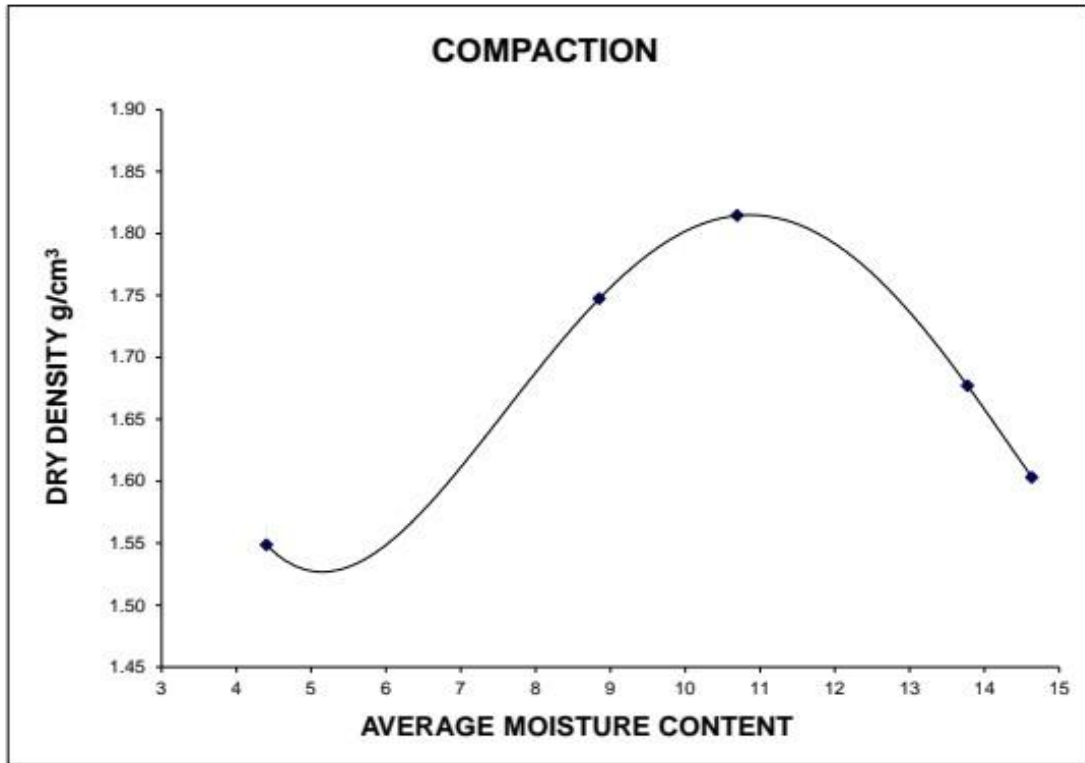


Figure 4.1.8: Dry density vs Moisture content in laboratory test for determination of MDD at P2R4



**Figure 4.1.9: Dry density vs Moisture content in laboratory test for determination of MDD at P2R5**

#### **4.2 California Bearing Ratio (CBR)**

The results of California bearing ratio test revealed that soil samples collected from P1R1, P1R2, P1R3, P1R4, P2R1, P2R2, P2R3, P2R4, P2R5 have CBR values of 22.9%, 35.2%, 24.6%, 26.5%, 27.4%, 28.5%, 25.8%, 21.9%, and 37.5% respectively for the unsoaked top while 27.1%, 35.5%, 36.3%, 47.62%, 18.0%, 30.0%, 17.92%, 39.5%, and 51.5% respectively for the unsoaked bottom. Soaked top have the following CBR values respectively 9.6%, 13.3%, 13.5%, 26.1%, 5.0%, 18.5%, 6.4%, 18.0%, and 6.6% while 23.8%, 29.5%, 37.3%, 29.5%, 20.6%, 16.9%, 9.3%, 25.6%, and 26.2% respectively for the soaked bottom. According to clause 6201 of Federal Ministry of Works and Housing (F.M.W & H) Specification Requirement, the minimum strength of base course material shall not be less than 80% C.B.R (unsoaked) while minimum strength for subgrade/fill shall not be less than 10% after at least 48 hours soaking. In light of the above, the

subgrade samples from P1R1, P1R2, P1R3, P1R4, P2R1, P2R2, P2R4, and P2R5 are good because they exhibit CBR (soaked) value of (10) that are even higher than what is stipulated in the specification. Based on this, the subgrade samples collected from P1R1, P1R2, P1R3, P1R4, P2R1, P2R2, P2R4, and P2R5 are better used for the construction of the road which is evident in their CBR values while subgrades P2R3 collected from Sapele is not good for road construction has its CBR value is lower than the recommended soaked value of (10). The CBR value obtained from the test is presented below;

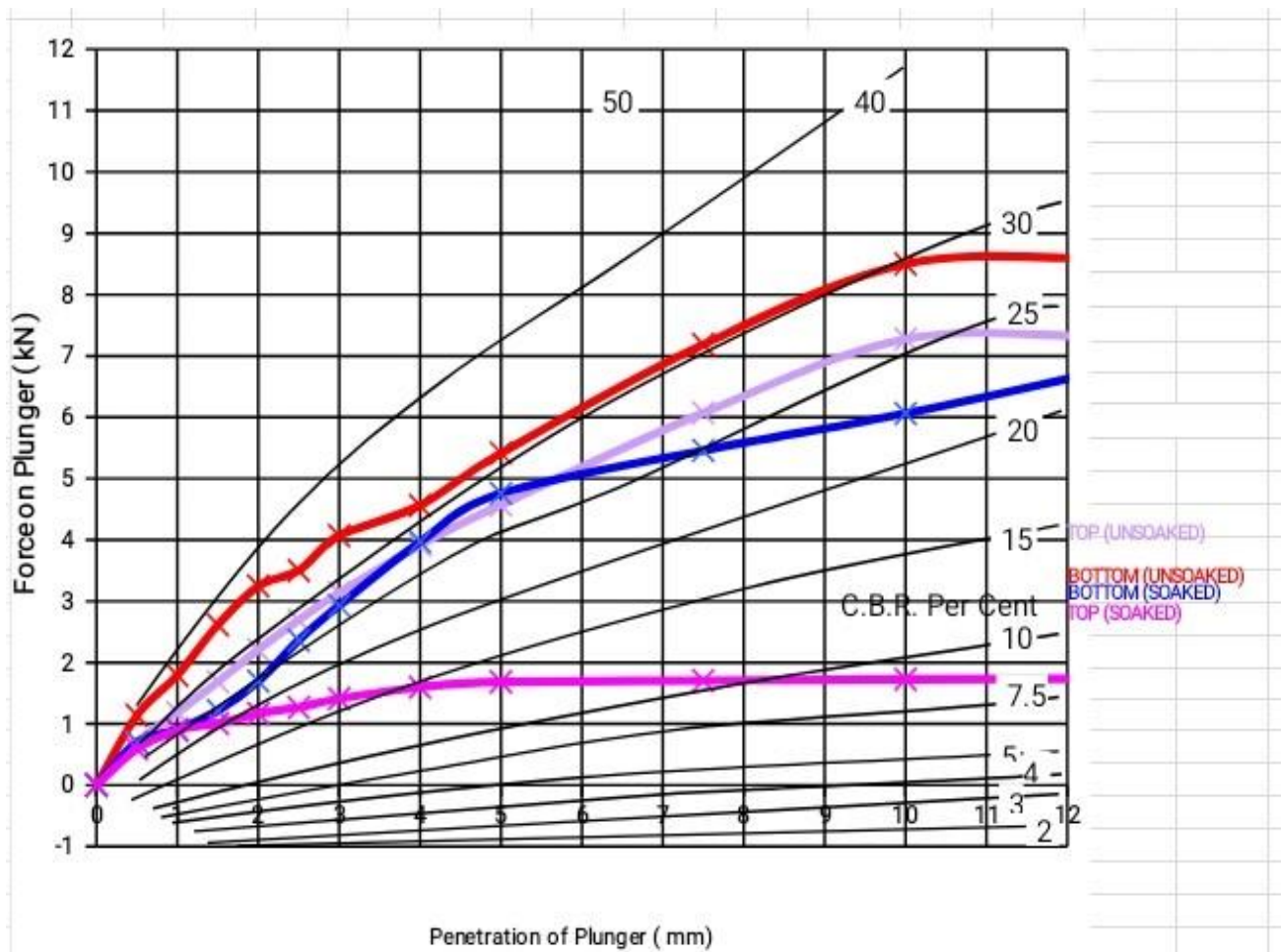


Figure 4.2.1 Force on plunger versus penetration of plunger (mm) subgrade P1R1

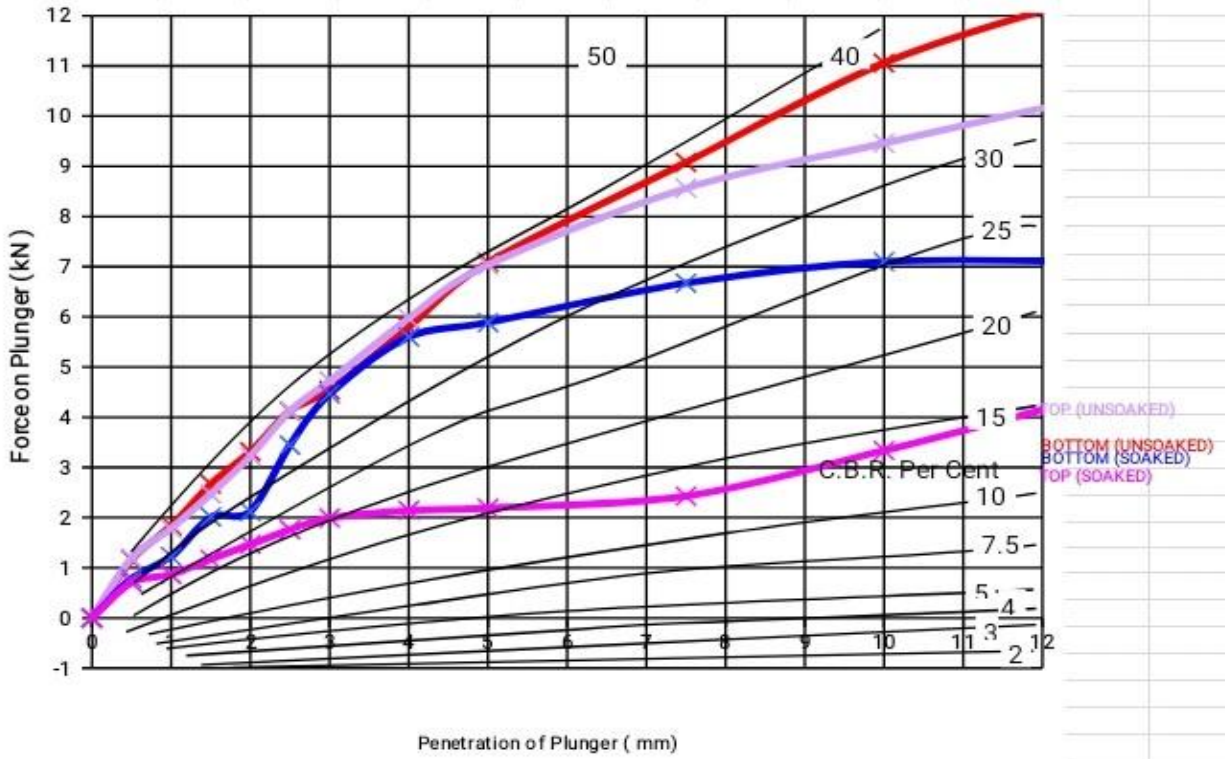


Figure 4.2.2 Force on plunger versus penetration of plunger (mm) subgrade P1R2

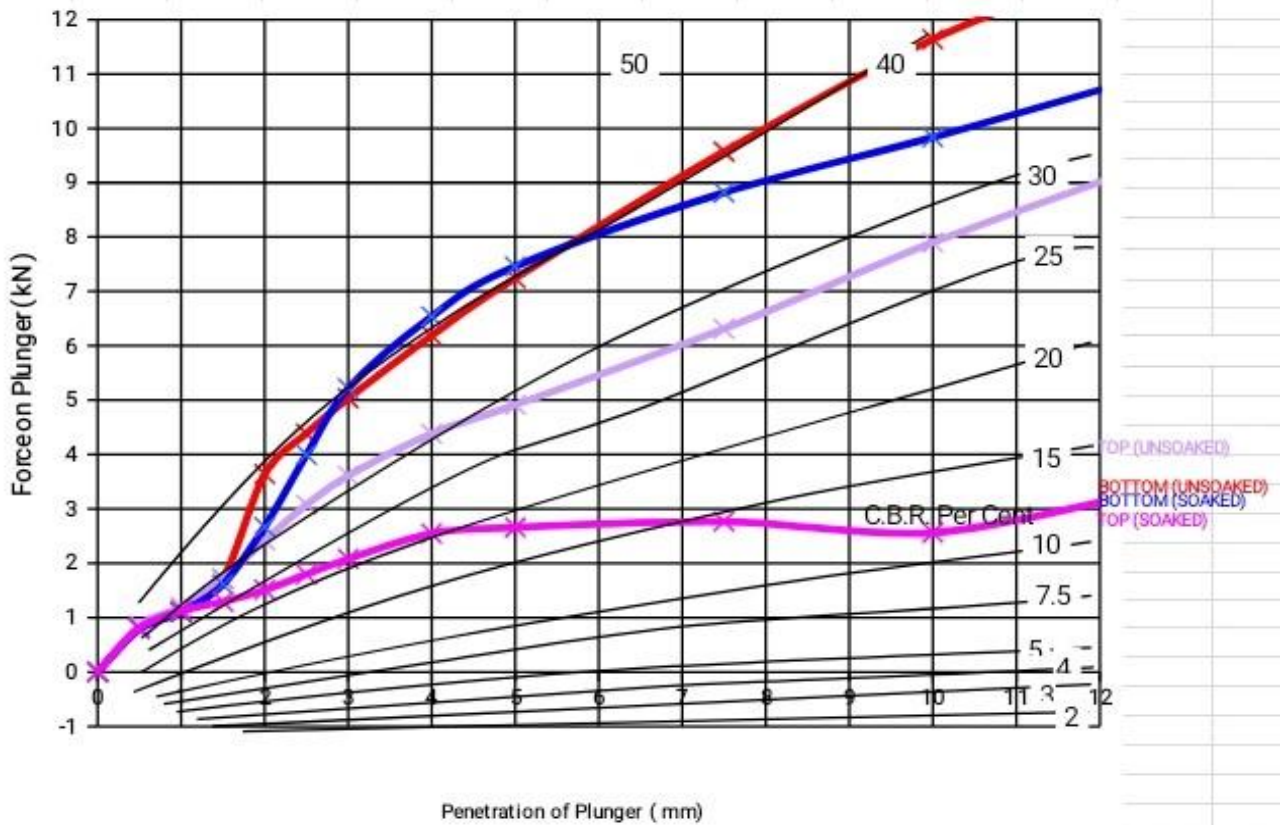


Figure 4.2.3 Force on plunger versus penetration of plunger (mm) subgrade P1R3

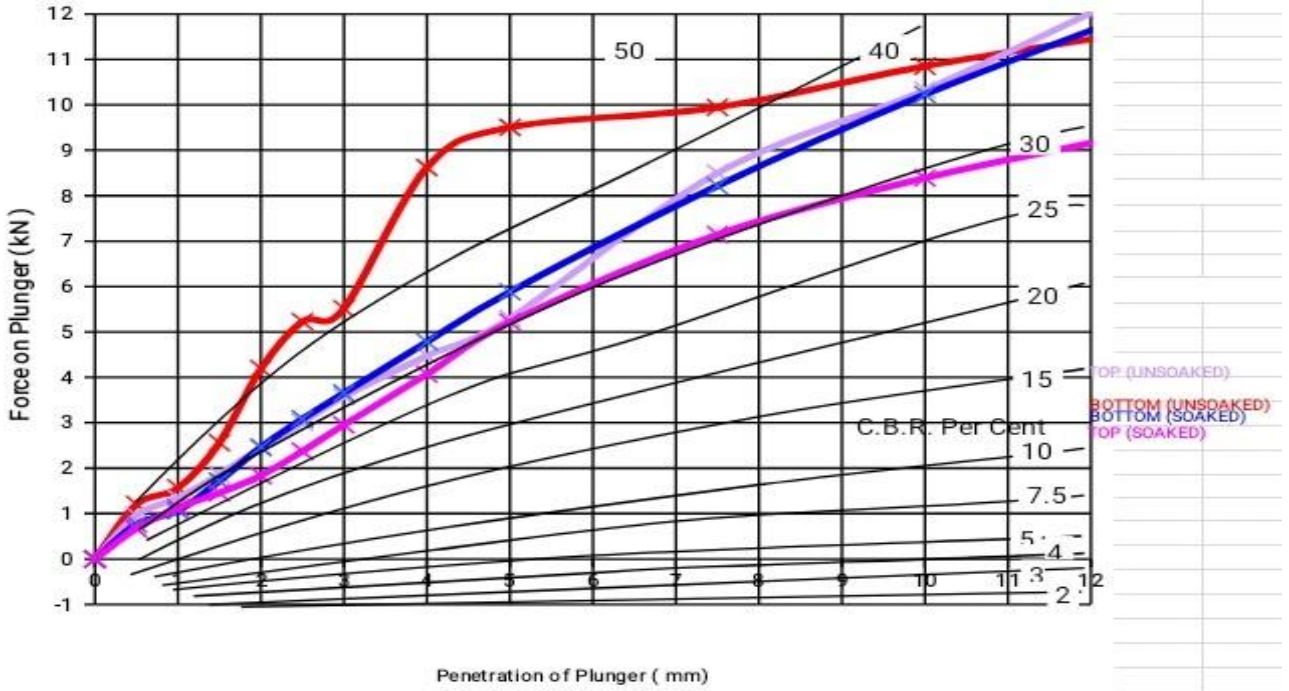


Figure 4.2.4 Force on plunger versus penetration of plunger (mm) subgrade P1R4

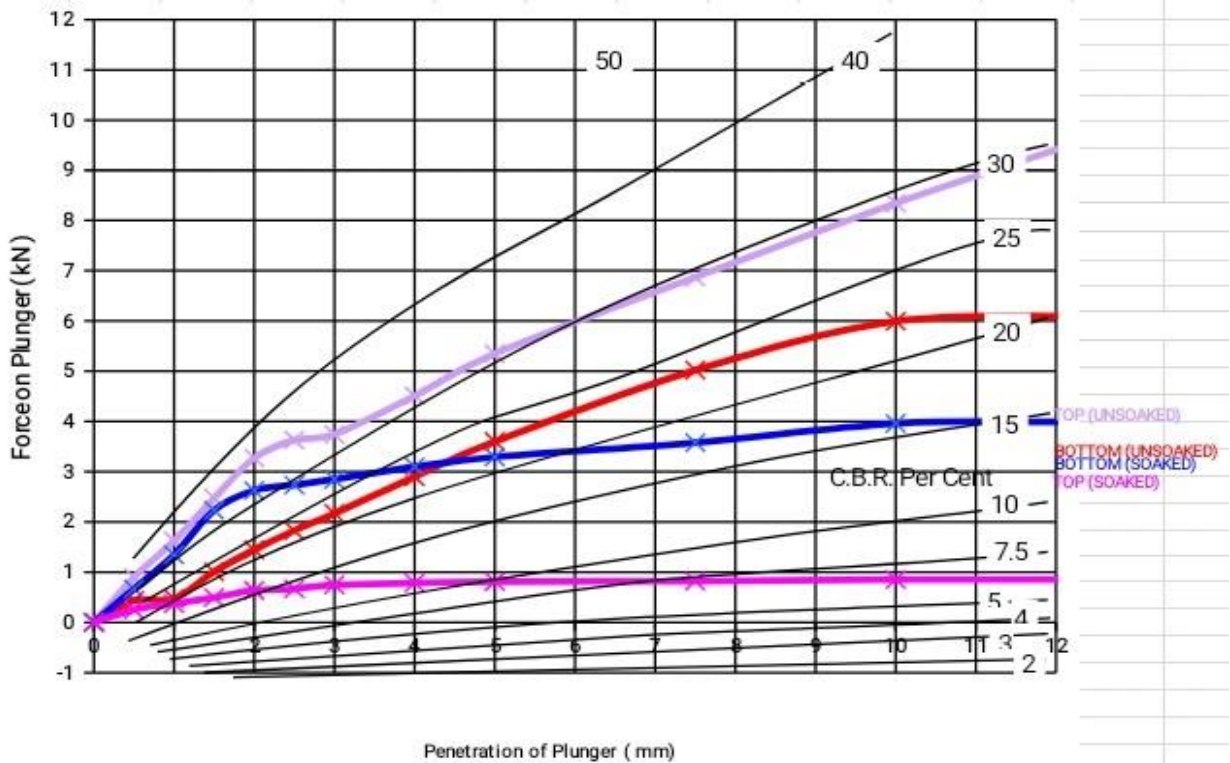


Figure 4.2.5 Force on plunger versus penetration of plunger (mm) subgrade P2R1

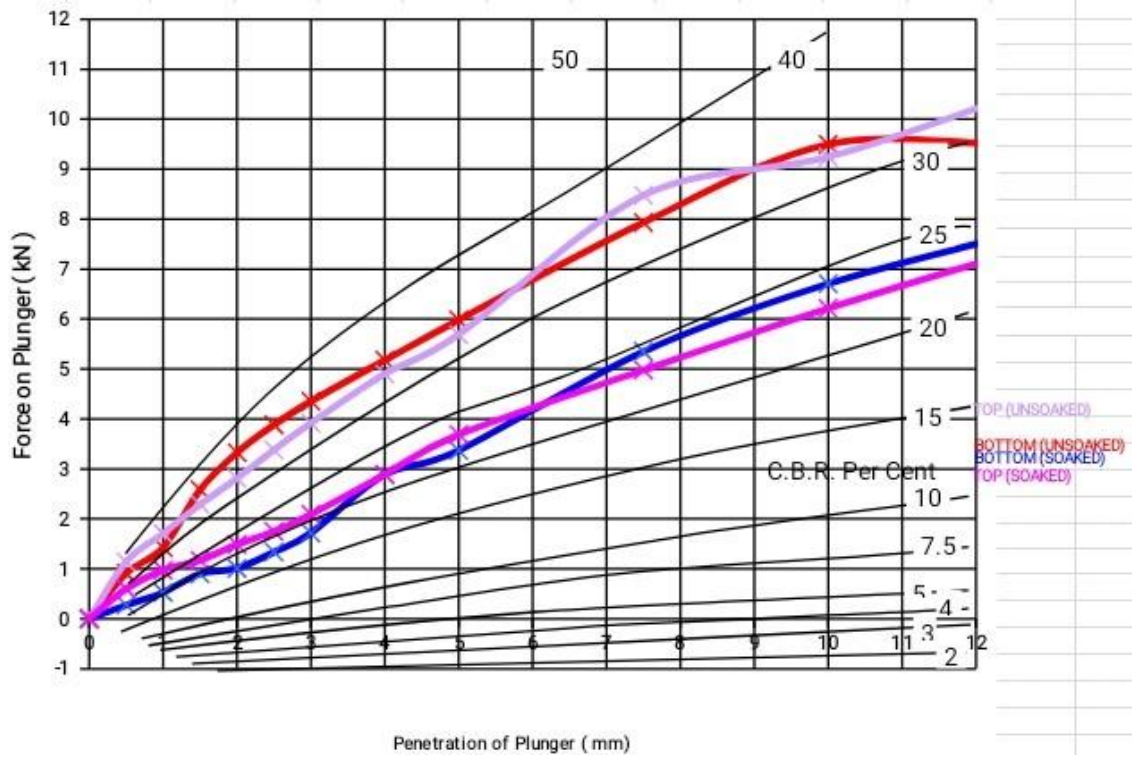


Figure 4.2.6 Force on plunger versus penetration of plunger (mm) subgrade P2R2

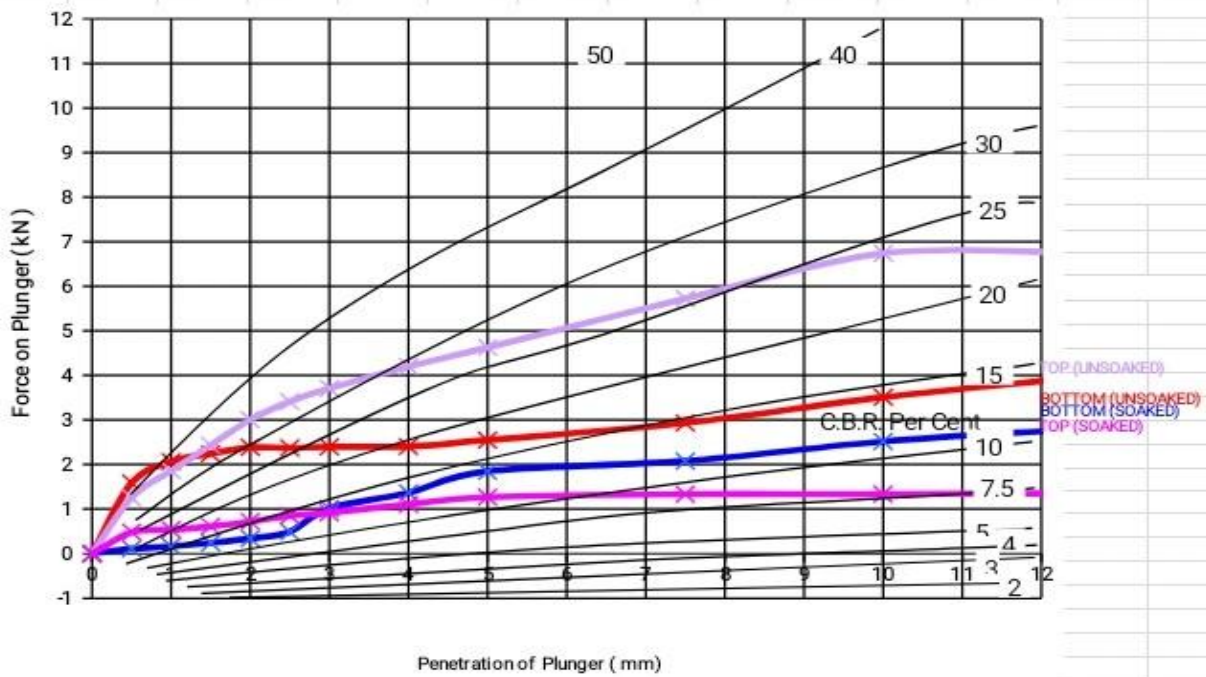


Figure 4.2.7 Force on plunger versus penetration of plunger (mm) subgrade P2R3

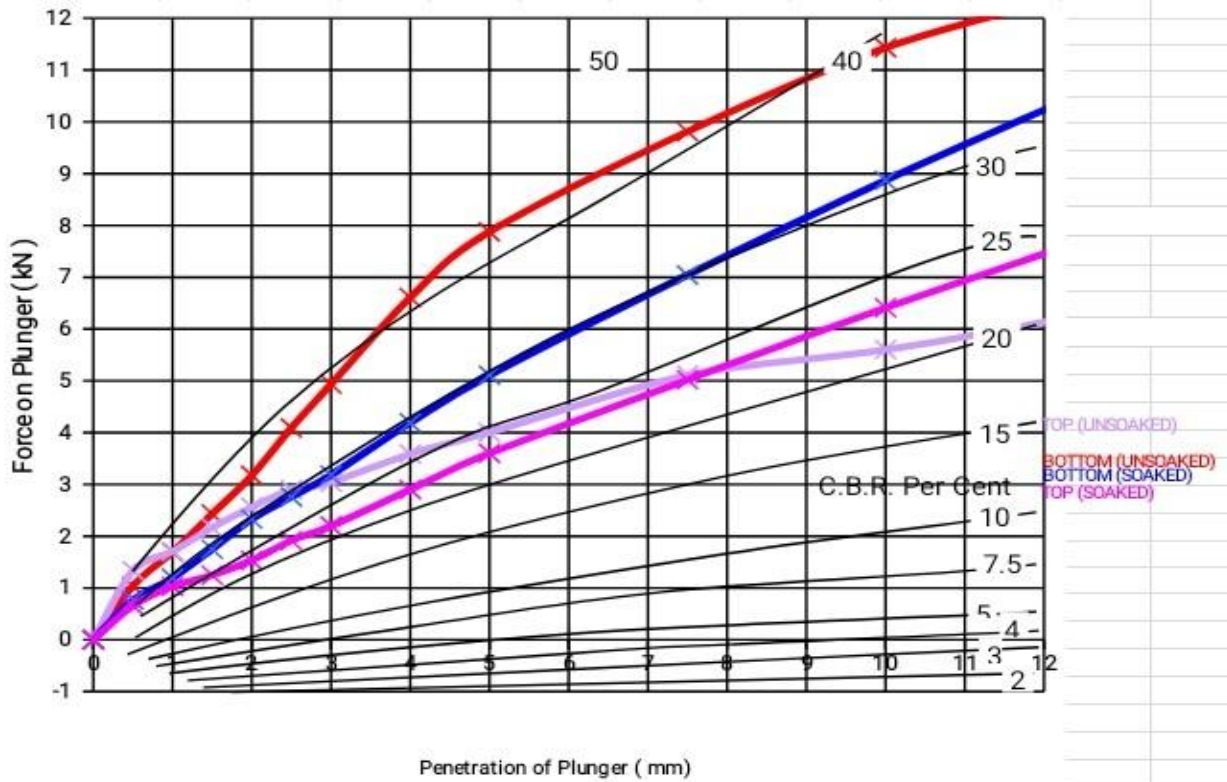


Figure 4.2.8 Force on plunger versus penetration of plunger (mm) subgrade P2R4

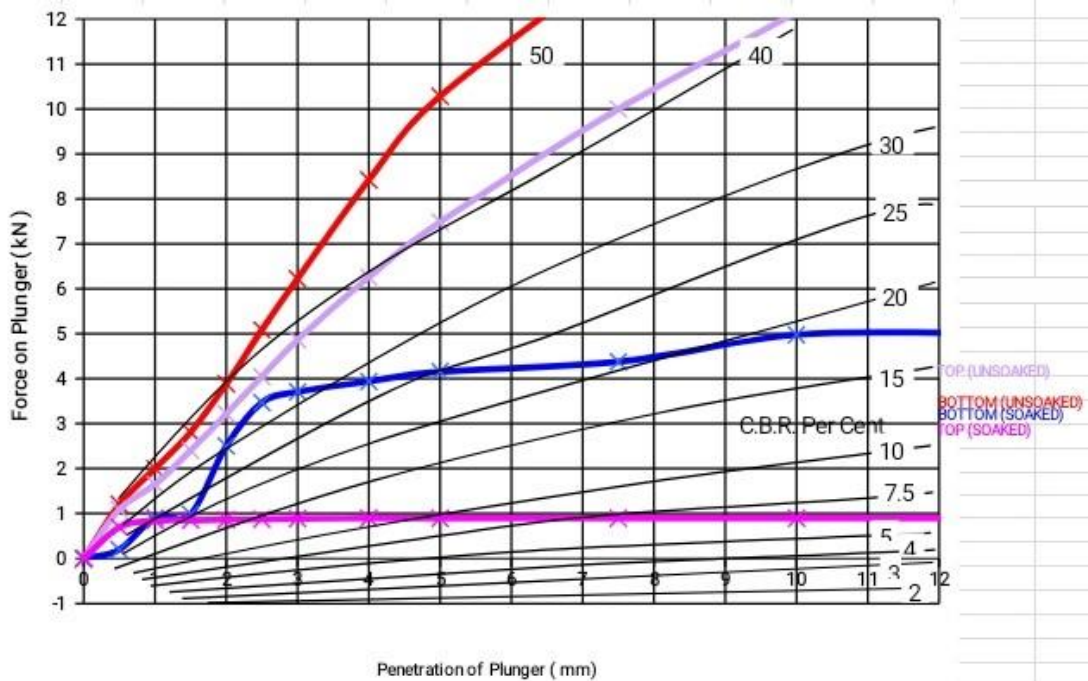


Figure 4.2.9 Force on plunger versus penetration of plunger (mm) subgrade P2R5

### 4.3 Soil physical properties

Sand fraction ranges from 710g/kg to 830g/kg with a mean of 770g/kg, P1R3 having the lowest of the fraction and P2R4 having the highest fraction. Silt ranges from 40 g/kg to 120g/kg with a mean of 93.3g/kg, P1R4 having the lowest of the fraction and P1R1, P2R1, and P2R2 having the highest fraction. The texture of the following sampling sites are as follows; P1R2, P1R3, P1R4, P2R1, P2R2, P2R3 are sandy loamy(SL) soil. P1R1, and P2R4 are loamy sandy(LS) soil. P2R5 is sandy clay soil. The soft soils have low infiltration and high runoff because of their low porosity and high cohesion. Ramous *et al.* (2000) reported that the silt is the most sensitive particles to erosion because of their size and it can cause to increase soil compaction and decrease infiltration which consequently the runoff increases. pH value ranges from 4.62 to 6.16 with a mean of 5.3. Electrical conductivity (EC) ranges from 66.80 $\mu$ S/cm to 263 $\mu$ S/cm with a mean of 111.5 $\mu$ S/cm, with the highest (263.0 $\mu$ S/cm). Organic carbon ranges from 2.34g/kg to 15.28g/kg with a mean of 6.9g/kg, the highest organic carbon was recorded in P2R4. Manganese ranges from 2.35g/kg to 26.34g/kg with a mean of 11.9g/kg, the highest Manganese was recorded in P2R4. Total nitrogen ranges from 0.10g/kg to 1.08g/kg with a mean of 0.5g/kg, the highest total Nitrogen was recorded in P2R4. Available phosphorus ranges from 3.13mg/kg to 58.35mg/kg with a mean of 13.8g/kg, the highest available phosphorus was recorded in P2R4. Calcium ranges from 0.60cmol/kg to 1.48cmol/kg with a mean of 1.2cmol/kg. magnesium ranges from 0.13cmol/kg to 0.51cmol/kg with a mean of 0.3cmol/kg. Sodium ranges from 0.00cmol/kg to 0.26cmol/kg with a mean of 0.1cmol/kg. Potassium ranges from 0.02cmol/kg to 0.11cmol/kg with a mean of 0.05cmol/kg.

**Table 1: Soil Physical properties**

S/N	Sample	Sand	Silt	Clay	Tex.	pH(1:2)	EC	Org. C	Org. M	Total N	Avail. P	Ca	Mg	Na	K	EA	ECEC	%BS
	Name	g/kg	g/kg	g/kg		H <sub>2</sub> O	μS/cm	g/kg	g/kg	g/kg	mg/kg	.....cmol/kg.....						
1	<b>P1R1</b>	810	120	70	LS	6.16	155.70	11.29	19.46	0.80	19.47	1.48	0.37	0.09	0.04	0.06	2.03	97.05
2	<b>P1R2</b>	790	100	110	SL	5.46	100.90	6.03	10.40	0.43	8.34	1.04	0.26	0.17	0.07	0.10	1.65	93.93
3	<b>P1R3</b>	710	100	190	SL	5.88	71.20	2.34	4.03	0.17	4.66	1.48	0.37	0.17	0.04	0.08	2.14	96.26
4	<b>P1R4</b>	770	40	190	SL	5.11	78.10	1.36	2.35	0.10	6.83	0.88	0.22	0.09	0.05	0.15	1.39	89.22
5	<b>P2R1</b>	770	120	110	SL	5.11	113.10	13.82	23.82	0.98	5.18	1.34	0.33	0.09	0.04	0.17	1.97	91.36
6	<b>P2R2</b>	770	120	110	SL	4.91	66.80	3.50	6.04	0.25	6.22	0.54	0.13	0.00	0.02	0.50	1.19	58.10
7	<b>P2R3</b>	750	100	150	SL	4.62	81.30	5.64	9.73	0.40	12.10	0.60	0.15	0.09	0.04	0.77	1.64	53.15
8	<b>P2R4</b>	830	80	90	LS	5.25	263.00	15.28	26.34	1.08	58.35	2.04	0.51	0.26	0.11	0.08	3.00	97.33
9	<b>P2R5</b>	730	60	210	SCL	4.97	73.00	2.84	4.89	0.24	3.13	1.12	0.28	0.01	0.05	0.62	2.08	70.16

## **CHAPTER FIVE**

### **RECOMMENDATION AND CONCLUSION**

#### **5.1 RECOMMENDATION**

Based on the investigations of the study, the following recommendations are proffered;

- a. It is recommended that laboratory tests 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.
- b. Resident engineers and contractors should always work in strict adherence to code of ethics of engineering profession so as to achieve or maintain best practices.

#### **5.2 CONCLUSION**

Geotechnical properties of subgrade soil obtained along Warri-Sapele Road, South-South, Nigeria, have been examined. The result showed that the studied soil samples conform to the requirements for subgrade soil as recommended in the Federal Ministry of Works and Housing Specification on Roads and Bridges, volume II, 1997 (revised edition), except P2R3 which does not meet up with the requirement. However, subgrade material present at P2R3 should be stabilized to meet the standard requirement before being used. These valuable data obtained from the geotechnical analysis can be useful for civil engineers in designing and constructing the Sapele-Warri Road, South-South, Nigeria, for maximum durability and efficiency. A confirmatory engineering test is recommended to be carried out before embarking on any road construction.

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