

**GEOTECHNICAL EVALUATION OF BAMBOO ASH ON THE CALIFORNIA
BEARING RATIO CHARACTERISTICS OF CLAY SOIL**

BY

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PLAGIARISM

This work “**GEOTECHNICAL EVALUATION OF BAMBOO ASH ON THE C.B.R CHARACTERISTICS OF CLAY SOIL**”, by **EGHIANRUWA, Osahenrhun**, with matriculation number **ENG1810676** of the department of civil engineering, faculty of engineering, University of Benin, Edo state, Nigeria has **PASSED** the **PLAGIARISM TEST**.

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CERTIFICATION

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DEDICATION

This project is dedicated to God Almighty, the giver of life, who gave me the wisdom, knowledge, and understanding to carry out this work and his grace upon me in successfully completing my Bachelors of Engineering Programme.

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ABSTRACT

Clay soils at many construction sites often exhibit low strength and high plasticity, making them unsuitable for supporting heavy structural loads without proper stabilization. This study aimed to investigate the potential of bamboo ash (BA) as an environmentally friendly and cost-effective soil stabilizer to improve the engineering performance of clay soils. The research specifically examined how varying BA contents (5%, 10%, 15%, and 20% by dry weight) affect the geotechnical properties and California Bearing Ratio (CBR) characteristics of clay soils, with the goal of addressing the problem of weak subgrade performance in road and foundation construction.

The materials used were locally sourced clay soil and bamboo ash produced from the controlled burning of bamboo plants. Laboratory testing was carried out on both untreated and BA-treated soils. The experimental program included soil classification tests—specific gravity, particle size distribution, and Atterberg Limits—compaction tests to determine Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), and CBR tests to evaluate load-bearing capacity. The natural clay was classified as A-4 and A-5 according to the AASHTO system, while BA was used as the stabilizing additive in different proportions.

Results indicated that untreated clay soils exhibited low CBR values. The addition of BA improved both MDD and CBR, with the highest performance observed at 15% BA content. Beyond this level (20%), both MDD and CBR values declined, and Atterberg Limit results showed an overall increase in plasticity with higher BA content. The findings demonstrate that BA has significant potential as a sustainable soil stabilizer, particularly at the 15% level, for improving clay soil strength and bearing capacity. However, the reduction in performance at higher contents and the rise in plasticity highlight the need for further microstructural analysis and field trials to develop practical guidelines for its use in construction projects.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

A natural soil material with fine grains that contains clay minerals, such as kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$), is called clay (Olive et al., 1989). While natural clays display a range of colors from impurities, such as a reddish or brownish color from minute amounts of iron oxide, pure clay minerals are typically white or light-colored (Klein & Hurlbut, 1993; Nesse, 2000).

Clays can be fired to harden them, but they lose their fluidity when wet. Clay is the oldest known ceramic material (Guggenheim & Martin, 1995; Science Learning Hub, 2010; Breuer 2012). Particle sizes in silts, or fine-grained soils without clay minerals, are often bigger than in clays. Loam refers to mixtures of sand, silt, and less than 40% clay. A significant problem in civil engineering is soils with large concentrations of swelling clays, or expansive clay minerals that easily expand in volume when they absorb water (Olive et al. 1989).

Clays generally have low strength, making them less suitable for supporting heavy structures (Ubanni, 2024). They exhibit high compressibility, meaning they can undergo significant volume changes under load. Clays have high plasticity, allowing them to deform without cracking (Ural, 2018). They have low permeability, which means they retain water well but have poor drainage.

Highway engineering is a branch of civil engineering that focuses on the planning, design, construction, operation, and maintenance of roads, highways, streets, bridges, and tunnels.

Modern highway engineering began in the late 19th to early 20th century, with significant advancements post-World War II. Key Competencies includes geometric design of roads, pavement design, traffic engineering, and construction management. High-quality road networks are crucial for the transportation of people and goods, impacting the economy positively (Rogers

and Martin, 2002). Modern Approaches: Emphasizes a mechanistic-empirical approach to design, considering current and future traffic demands.

Some soils, especially clays, can undergo volume changes due to moisture content variations, affecting pavement performance(AASHTO, 2007). Clay soils are used as subgrade material, although they often require stabilization to improve their performance under traffic loads. The use of bamboo ash, especially bamboo leaf ash, as an additional cementitious ingredient is becoming more popular. The following are some salient points: Bamboo has a high silica content, which allows it to partially substitute cement in concrete. The ash has a high silica content and other qualities that make it pozzolanic, improving the durability and strength of concrete. Recycling waste and lowering the carbon footprint of cement production are two benefits of using bamboo ash in construction (Akinlabi et al., 2017; Cavalho and Velasco, 2021).

1.2 Statement of the problem

Owing to their special characteristics, clay soils pose a number of difficulties for roadway engineers. They are highly plastic, meaning they can withstand large deformations without splitting. However, this same property often coincides with poor load-bearing capacity. Clay soils frequently have a low California Bearing Ratio (CBR), usually between 1% and 5%, indicating that they cannot support heavy loads effectively. This characteristic also makes them sensitive to moisture changes, causing them to swell when wet and shrink when dry (Amakye, 2022). Such volume changes can lead to significant movement in pavement foundations.

When clay soils expand and contract due to moisture fluctuations, the pavement structure may suffer from cracks, uneven surfaces, and other forms of structural distress. They are also difficult to compact, particularly when wet, and proper compaction is critical for developing a strong foundation for pavements. In addition, clay soils are highly attracted to water, which can increase

their moisture content and reduce durability. This often results in higher maintenance costs and early pavement deterioration (Geotechnologies, 2024).

Poor highway subgrades, such as those formed from clay soils, can lead to severe pavement performance issues. Weak subgrades may cause structural failures including alligator cracking, rutting, and potholes, compromising the pavement's integrity. Inadequate drainage can result in water infiltration, further weakening the pavement layers. Subgrade settlement and insufficient compaction can also cause depressions, uneven surfaces, and long-term instability. Ultimately, these conditions require frequent repairs and maintenance, increasing lifecycle costs and reducing the overall service life of road infrastructure.

1.3 Aim and Objectives

This experimental study aims at comparing the index properties of a problematic clay soil and a stabilized clay soil using Bamboo ash as admixture.

The objectives are;

- i. To compare the engineering properties of a stabilized clay soil such as compaction and optimum moisture content with those of its index properties.
- ii. To compare the suitability of the admixture as the percentage increases, i.e. (5%, 10%, 15% and 20%).
- iii. To compare the California bearing ratio (C.B.R) of the un-stabilized soil to the stabilized soil as the percentage increases, i.e. (5%, 10%, 15% and 20%).

1.4 Scope of the study

In this experimental study, California bearing ratio (C.B.R), optimum moisture content (OMC), and Atterberg limit tests was be conducted for a problematic clay soil samples and bamboo ash

stabilized clay soil samples. Soil samples was be collected from a nearby construction site to the Geotechnical engineering laboratory.

California Bearing Ratio (CBR) test was used to evaluate the strength of laterite and grinded bamboo clay soil samples. Experimental procedures for the CBR test involve; Soil samples preparation, compaction, soaking, penetration tests at 2.5mm, 5mm and CBR values calculation for laterite and bamboo ash clay soil samples at 5%, 10%, 15% and 20% for 9 stabilized and un-stabilized clay soil samples.

Optimum moisture content test was performed to determine the moisture content at which soil samples reaches their maximum dry density, ensuring the samples are compacted to its best possible. Test procedures were involved; Soil samples Preparation, Moisture Content Adjustment, Compaction, trimming and weighing, moisture Content determination and moisture content calculations:

The Specific Gravity test on soil samples was be essential for determining the density of soil particles relative to the density of water. Testing procedures were involved, but not limited to: Soil samples preparation, weighing, de-airing, filling and weighing, temperature measurement, specific gravity calculations.

Numerical analysis of results was be based on the effects of proportional addition of bamboo ash to clay soil samples on its California Bearing Ratio, Moisture content and Specific gravity as compared to those of the problematic clay soil samples.

1.5 Justification of the study

Clay soils are widely encountered in construction projects, particularly in roadworks and foundation engineering, but their high plasticity, low shear strength, and poor load-bearing capacity make them unsuitable for direct use as subgrade material. Conventional soil

stabilization methods often rely on cement, lime, or other industrial additives, which can be costly and have environmental impacts due to high energy consumption and carbon emissions during production. There is a growing need for alternative, sustainable materials that can improve soil performance while reducing environmental footprints and overall construction costs. Bamboo ash (BA), a by-product of bamboo combustion, offers potential as such an alternative. Bamboo is abundant in many tropical regions, including Nigeria, and its ash is often disposed of as waste, contributing to environmental pollution. Utilizing BA for soil stabilization not only provides a cost-effective solution but also supports waste recycling and sustainable construction practices. However, limited studies have explored its effect on the geotechnical properties of clay soils, particularly in terms of California Bearing Ratio (CBR) performance, which is crucial for assessing subgrade suitability in pavement design.

This study is justified by the need to fill this knowledge gap and provide empirical data on the viability of BA as a soil stabilizer. By systematically examining its impact on Atterberg Limits, compaction characteristics, and CBR values, this research will offer practical insights for engineers and policymakers seeking to adopt environmentally friendly stabilization methods. The findings have the potential to promote resource efficiency, reduce construction costs, and contribute to sustainable infrastructure development in regions where clay soils and bamboo residues are prevalent.

CHAPTER TWO

LITERATURE REVIEW

2.1 Bamboo ash clay soil literature review

Particularly in clay soils, bamboo ash has been investigated as a sustainable material for soil stabilization. Following are some salient ideas from the literature: Because of its high silica content, bamboo leaf ash (BLA) is a potential supplemental cementitious material (SCM). Research has indicated that BLA can decrease the plasticity index¹ of lateritic soils while increasing their shear strength and California bearing ratio (Kabdiyono et al., 2024). As an environmentally friendly substitute for conventional cement, bamboo ashes are used. They meet sustainability standards by giving soil and concrete the required mechanical and physical qualities. The ideal range of percentages to replace cement in concrete with bamboo ash is 8% to 12% (Cavalho and Velasco, 2021). Research on lime-bamboo ash stabilized subgrade soils indicates that the resilient modulus (Mr) improves with the addition of bamboo ash (Chijioke and Nwonu, 2019). These results demonstrate the potential of bamboo ash to improve the geotechnical properties of clay soils, making it a valuable material for sustainable construction practices. The high silica content in bamboo leaf ash contributes to its effectiveness in soil stabilization. However, the chemical composition can vary based on environmental and biological factors (Cavalho and Velasco, 2021).

2.2 Highway Pavement

A vital part of the road infrastructure, highway pavement is made to give moving traffic a smooth, long-lasting surface. There are basically two types of pavement forms in highway engineering, namely; Rigid and Flexible pavement.

2.2.1 Flexible pavement

Composed of a base layer, a subbase layer, and an asphaltic surface layer. When traffic loads are applied to flexible pavements, the load is distributed over a larger area of the subgrade. They can also be made to meet different traffic loads and are quicker and easier to repair (Nehme and Jean, 2017).



Typical cross section of a flexible pavement

Figure 2.1. Flexible pavement layers (Source : Mishra, 2024)

The typical cross-section of a flexible pavement, designed in accordance with AASHTO pavement design standards, particularly the *AASHTO Guide for Design of Pavement Structures (1993)* and the *AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG)*. Flexible pavements are multilayer systems in which traffic loads are transferred gradually from the surface layer to the natural subgrade through successive layers of decreasing strength and stiffness. At the top of the pavement structure is the surface course (25–50 mm), which serves as the wearing course and provides a smooth, skid-resistant riding surface for traffic. It is typically constructed of asphalt concrete and is designed to resist traffic abrasion, weathering, and surface deformation. According to the *AASHTO Guide for Design of Pavement Structures (1993)*, the surface course also contributes to load distribution and protects the underlying layers from water

infiltration. A seal coat may be applied on the surface to waterproof the pavement and improve skid resistance, while a tack coat is applied between asphalt layers to ensure proper bonding and composite action, as recommended in AASHTO construction and material practice guidelines referenced within the design guide.

Beneath the surface course is the binder course (50–100 mm), which consists of a coarser asphalt mixture designed primarily for structural strength rather than surface performance. Its main function, as outlined in the *AASHTO 1993 Guide* and reinforced in the *AASHTO MEPDG*, is to distribute traffic loads from the surface course to the base course while reducing shear stresses and fatigue cracking within the asphalt layers.

The base course (100–300 mm) lies below the asphalt layers and plays a major structural role in flexible pavement design. It distributes loads over a wider area, reduces stresses transmitted to the subbase and subgrade, and contributes significantly to the overall structural number used in AASHTO pavement design. According to *AASHTO (1993)*, base courses may consist of crushed stone, crushed gravel, or stabilized materials, provided they meet specified strength and durability requirements. The *AASHTO MEPDG* further emphasizes the role of the base course in controlling permanent deformation and improving pavement performance under repeated loading.

Below the base course is the subbase course (100–300 mm), which is provided when additional structural support, improved drainage, frost protection, or separation between the base and subgrade is required. The *AASHTO Guide for Design of Pavement Structures (1993)* states that the subbase course improves load distribution, minimizes pumping of fines, and protects the subgrade from excessive stresses, especially in areas with weak or moisture-sensitive soils. The *AASHTO MEPDG* incorporates subbase properties into its environmental and foundation analysis.

The compacted subgrade (150–300 mm) represents the upper portion of the natural soil that has been prepared and compacted to specified density and moisture conditions. Its function is to provide a stable foundation for the entire pavement system. In AASHTO pavement design, the subgrade is characterized primarily by its strength parameter—such as the California Bearing Ratio (CBR) in the 1993 Guide or the resilient modulus (M_r) in the MEPDG. Proper compaction and moisture control of the subgrade are emphasized in both AASHTO documents to ensure long-term pavement performance.

Finally, the natural subgrade is the in-situ soil beneath the compacted layer and forms the ultimate support for the pavement structure. According to *AASHTO T 307*, the resilient modulus of the subgrade soil is a key input parameter in mechanistic-empirical design, as adopted in the *AASHTO MEPDG*. The behavior of this layer significantly influences pavement thickness design, rutting potential, and overall service life.

In summary, the flexible pavement cross-section shown in the image aligns with the layered pavement system described in the *AASHTO Guide for Design of Pavement Structures (1993)* and the *AASHTO Mechanistic-Empirical Pavement Design Guide*. Each layer—from the surface course to the natural subgrade—has a clearly defined function under AASHTO codes, ensuring adequate load distribution, durability, and serviceability throughout the pavement’s design life.

2.2.2 Rigid pavement

Consist of a single layer of base or subgrade that has been prepared and covered with Portland cement concrete (PCC). They also last longer and require less maintenance, although repairs can be more involved and costly. In comparison to flexible pavements, rigid pavements have a higher flexural strength and disperse loads over a smaller area (Solaimanian, 2024).

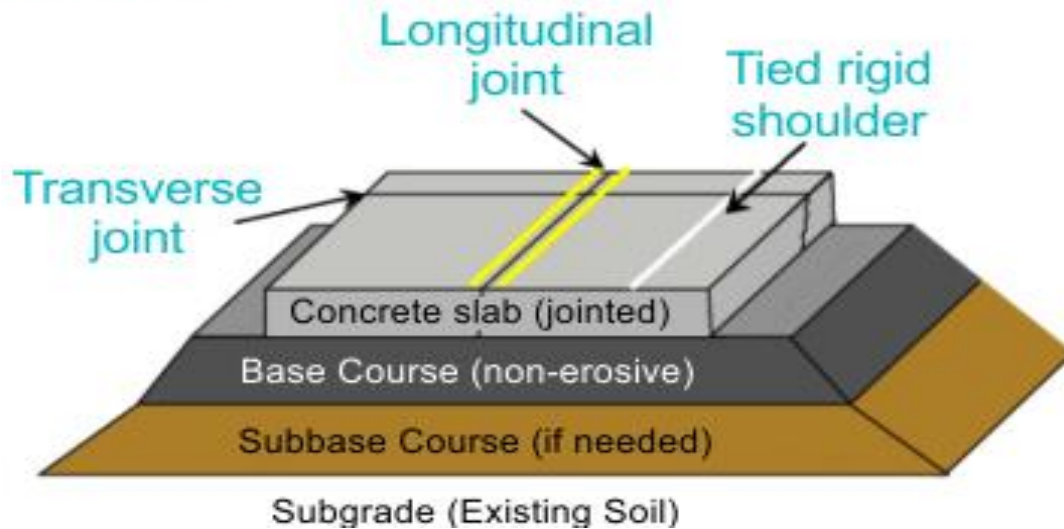


Figure 2.2. Rigid pavement layers (Source : Mishra, 2024)

The figure illustrates a Jointed Plain Concrete Pavement (JPCP) system, which is widely used in highway and rigid pavement design. A JPCP consists of concrete slabs divided by joints that control cracking and accommodate movements caused by temperature variation, moisture changes, and traffic loading, while transferring loads efficiently to the underlying layers in accordance with AASHTO pavement design principles.

The longitudinal joint is provided to separate adjacent traffic lanes and to control cracking caused by temperature changes and drying shrinkage of the concrete slab. Structurally, this joint prevents random longitudinal cracking and improves load transfer between adjacent slabs, thereby enhancing pavement performance and durability. The design and functional requirements of longitudinal joints are addressed in the *AASHTO Guide for Design of Pavement Structures (1993), Chapter III on Rigid Pavement Design*, as well as in the *AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG), Volume 2*, which covers rigid pavement design procedures.

The transverse joint is introduced to control cracking in the transverse direction that results from thermal expansion and contraction of the concrete slab. These joints are typically spaced between

4 and 6 meters, depending on slab thickness, concrete properties, traffic loading, and prevailing climatic conditions. Guidance on transverse joint spacing and performance is provided in the *AASHTO Guide for Design of Pavement Structures (1993)*, Section 3.4.6, and in Chapter 6 of the *AASHTO MEPDG*, which focuses on jointed concrete pavements.

The tied rigid shoulder provides additional lateral support to the main pavement slab and plays a critical role in reducing edge stresses and faulting at the slab edge. Steel tie bars are used to connect the shoulder to the main slab, preventing separation while still allowing the pavement to act monolithically; however, these tie bars do not permit expansion. The design and performance of tied rigid shoulders are discussed in the *AASHTO Guide for Design of Pavement Structures (1993)* under rigid pavement drainage and shoulder design, as well as in the *AASHTO MEPDG* section addressing shoulder–pavement interaction.

The jointed concrete slab is the primary load-carrying layer of the pavement system. It distributes wheel loads over a wide area, thereby reducing stresses transmitted to the underlying layers. This slab is typically constructed using Portland Cement Concrete (PCC). Structural design considerations for the concrete slab are detailed in the *AASHTO Guide for Design of Pavement Structures (1993)* under rigid pavement structural design, while material characterization and performance modeling of PCC are addressed in the *AASHTO MEPDG*.

Beneath the concrete slab lies the base course, which is required to be non-erosive. Its main functions are to provide uniform support to the slab and to prevent pumping and erosion that may occur under repeated traffic loading, particularly in the presence of moisture. Common base materials include cement-treated base, lean concrete, or asphalt-treated base. Design guidance for base courses in rigid pavements is contained in Chapter III of the *AASHTO Guide for Design of*

Pavement Structures (1993) and in the *AASHTO MEPDG* requirements for base layers in rigid pavement systems.

The subbase course, where required, serves to improve drainage, protect the subgrade, and enhance resistance to frost action. It is particularly necessary in areas with weak, highly plastic, or moisture-sensitive soils. The selection and design of subbase layers are discussed in the *AASHTO Guide for Design of Pavement Structures (1993)* under subbase design, and in the *AASHTO MEPDG* within the environmental and foundation analysis framework.

At the bottom of the pavement system is the subgrade, which consists of the existing soil and forms the final foundation supporting the entire pavement structure. The most important parameter used to characterize the subgrade is the resilient modulus (M_r), which reflects the soil's elastic response under repeated loading. Procedures for determining resilient modulus are specified in *AASHTO T 307: Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials*, while subgrade characterization and modeling are further addressed in the *AASHTO MEPDG*.

2.3 Highway pavement structure

In a normal roadway pavement, the following layers are present:

2.3.1 Surface Course

The top layer, which is often composed of concrete or asphalt, offers a smooth driving surface and is resistant to deterioration (Lees, 2021).

2.3.2 Base course

An additional layer of material that helps with drainage and load distribution, usually consisting of crushed stones or gravels.

2.3.3 Subbase Course

An extra layer that can be added to assist drainage and further distributed loads (Lees, 2021).

2.3.4 Subgrade Course

The upgraded material or natural soil that serves as the pavements structure base.

2.3.5 Highway pavement design considerations

1. Traffic Load

The thickness and materials used in pavement design are influenced by the anticipated volume and weight of traffic (Constro, 2021).

2. Climate

The performance and longevity of pavements can be impacted by changes in temperature, precipitation, and freeze-thaw cycles.

3. Soil Conditions

When choosing the right pavement design, the subgrade soil's characteristics, such as its moisture content and carrying ability, are very important to consider.

2.4 Highway maintenance and rehabilitation

Included are preventive maintenance, which comprises filling in fractures and giving surfaces treatments to prolong the life of the pavement, and rehabilitation, which entails more involved repairs including rebuilding damaged areas or replacing the current pavement with new material (Tikkanen, 2024).

2.5 Highway subgrade

The basic layer of material upon which the pavement structure is constructed is known as the highway subgrade. It is essential to the pavement's lifespan and general performance.

Highway subgrades are important for the following reasons:

i. Function

By supporting the loads transferred from the surface layers, the subgrade supports the pavement structure.

It needs to be study and robust enough to avoid deforming too much when there is a lot of traffic (AASHTO, 2007).

ii. Materials

Improved materials, rock, or natural soil can make up subgrades.

The performance of the pavement is greatly impacted by the subgrade material's quality (Koche, 2024).

c) Preparation

The subgrade must be properly prepared, compaction is one way to improve the stability and loadbearing capacity of the material.

Sometimes stabilization with substances like cement, asphalt, or lime is required to improve its properties (AASHTO, 2007).

iii. Difficulties

Moisture content can have an impact on subgrades and cause volume variations in some soils, including clay.

This may result in problems including shrinking and swelling that compromise the integrity of the pavement.

iv. Improvement Techniques

There are a number of techniques that can be employed to strengthen a weak natural subgrade, including: removal and replacement, better quality fill is used to replace subgrade material that is of lower quality.

v. Stabilization

Increasing stiffness and lowering swelling by adding binders, such as cement or lime.

vi. Extra Base Layers

Adding more base layers to improve load distribution

2.5 Clay soil

Natural soil material with fine grains that contains clay minerals (hydrous aluminum phyllosilicates, such as kaolinite and $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) is called clay (Olive et al., 1969). Natural clays exhibit a range of colors due to impurities, such as a reddish or brownish color from trace amounts of iron oxide, however the majority of pure clay minerals are white or light in color (Nesse, 2000). Approximately half to two-thirds of the world's population live or work in buildings made with clay, often baked into brick, as an essential part of its load-bearing structure.

One of the biggest problems in civil engineering is soils that contain a lot of swelling clays, also known as expansive clay. These clay minerals easily expand in volume as they absorb water.

Most often, silicate-bearing rocks weather chemically over time to produce clay minerals. Hydrothermal activity can also produce them locally. (Foley, 1999) Low amounts of carbonic acid, dissolved in rainfall or produced by plant roots, cause acid hydrolysis, which is primarily responsible for chemical weathering. The acid releases silica and other metal ions by breaking the bonds that hold aluminum and oxygen together (as a gel of orthosilicic acid).

2.5.1 Types of clay soil

Based on their mineral makeup and characteristics, clay soils can be divided into a number of categories. These are a few of the primary kinds:

i. Kaolinite

The clay mineral has a low shrinkswell capacity and does not expand. It frequently used as a filter in paint and paper, as well as in pottery.

Has a high shrinkswell capacity, which allows it to expand and contract dramatically in response to variations in moisture content

ii. Montmorillonite (smectite)

Has a high shrinkswell capacity, which allows it to expand and contract dramatically in response to variations in moisture content. It is frequently utilized as a sealer in landfills and in drilling muds (Olive et al., 1969).

iii. Illite

Often found in marine shales, this clay mineral has a moderate shrink-swell capacity. It is employed in the manufacturing of tiles and bricks.

iv. Chlorite

Frequently occurring in metamorphic rocks, this kind of clay has a moderate shrink-swell capacity. It is used in the production of ceramics and as a filler in paints.

v. Vermiculite

This clay mineral has a high shrink-swell capacity and is often used in horticulture as a soil conditioner.

vi. Talc

This is a non-expanding clay mineral with a very low shrink-swell capacity. It is used in the production of talcum powder and as a filler in paints and plastics.

vii. Pyrophyllite

This clay mineral has a low shrink-swell capacity and is used in the production of ceramics and as a filler in paints and plastics.

2.6 Soil classification

The Unified Soil Classification System (USCS) is a widely used method for classifying soils based on their texture and grain size. This system is particularly useful in engineering and geology.

Major Soil Divisions:

1. Coarse-Grained Soils: More than 50% of the soil particles are larger than 0.075 mm.

Gravel (G): Particles larger than 4.75 mm.

- i. GW: Well-graded gravel
- ii. GP: Poorly graded gravel
- iii. GM: Silty gravel
- iv. GC: Clayey gravel

Sand (S): Particles between 0.075 mm and 4.75 mm.

- i. SW: Well-graded sand
- ii. SP: Poorly graded sand
- iii. SM: Silty sand
- iv. SC: Clayey sand

2. Fine-Grained Soils: More than 50% of the soil particles are smaller than 0.075 mm (Robert, 2013).

Silt (M): Particles between 0.002 mm and 0.075 mm.

- i. ML: Low plasticity silt
- ii. MH: High plasticity silt

Clay (C): Particles smaller than 0.002 mm.

- i. CL: Low plasticity clay

- ii. CH: High plasticity clay

3. Organic Soils (O): Soils containing a significant amount of organic material.

- i. OL: Organic silt
- ii. OH: Organic clay

4. Highly Organic Soils (PT): Peat and other highly organic soils.

Classification Criteria

Grain Size Distribution determines whether the soil is coarse-grained or fine-grained, while Plasticity index is usually assessed using the Atterberg limits to determine the soil's plasticity characteristics.

2.7 Index properties of clay soil

Index properties of clay soil are essential for understanding its behavior and characteristics. Here are some key index properties:

- i. Water Content: The amount of water present in the soil, which affects its consistency and compaction (Molenaar, 2015).
- ii. Specific Gravity: The ratio of the density of soil particles to the density of water.
- iii. Consistency: The soil's ability to resist deformation, which depends on its water content.
- iv. Plasticity Index (PI): The range of water content over which the soil remains plastic. It is the difference between the liquid limit (LL) and the plastic limit (PL).
- v. Liquid Limit (LL): The water content at which the soil changes from a plastic to a liquid state.
- vi. Plastic Limit (PL): The water content at which the soil changes from a semi-solid to a plastic state.

- vii. Shrinkage Limit (SL): The water content at which the soil changes from a solid to a semi-solid state.
- viii. Flow Index (If): Measures the plasticity of soils.
- ix. Cation Exchange Capacity (CEC): The soil's ability to exchange cations, which affects its fertility.
- x. Swelling Behavior: The soil's tendency to expand when wet and shrink when dry.
- xi. Permeability: The soil's ability to transmit water.
- xii. These properties help in classifying and identifying the soil for engineering and construction purposes.

2.8 Engineering properties of clay soil

The engineering properties of clay soil are crucial for understanding its behavior and suitability for construction and other applications. Here are some key engineering properties (Carter and Bentley, 2016):

- i. Shear Strength: The resistance of clay soil to shear stress. It is influenced by factors such as water content, density, and the presence of organic matter.
- ii. Compressibility: The tendency of clay soil to decrease in volume under load. High compressibility can lead to settlement issues in structures built on clay soil.
- iii. Permeability: The ability of clay soil to transmit water. Clay soils typically have low permeability, which can lead to poor drainage and waterlogging.
- iv. Plasticity: The ability of clay soil to undergo deformation without cracking or breaking. This property is measured using the Atterberg limits (liquid limit, plastic limit, and shrinkage limit).

- v. Swelling and Shrinkage: The tendency of clay soil to expand when wet and contract when dry. This behavior can cause significant movement in structures built on clay soil.
- vi. Cohesion: The internal bonding of soil particles. Clay soils have high cohesion, which contributes to their shear strength.
- vii. Density: The mass of soil per unit volume. The density of clay soil affects its strength and compressibility.
- viii. Cation Exchange Capacity (CEC): The ability of clay soil to exchange cations with the surrounding environment. This property affects the soil's fertility and its interaction with pollutants.
- ix. These properties are essential for designing foundations, embankments, and other structures involving clay soil.

2.9 Review of past works

(Bamboo leaf Ash) BLA was employed in a 2010 study in Nigeria as a soil stabilizing material (Kabdiyono et al., 2024). For the purpose of building highways, the study looked into the stabilizing qualities of BLA in lateritic soils. The BLA was added by weight at 2, 4, 6, 8, and 10% combination using three soil samples. According to the findings, BLA considerably raised the CBR value, increased the shear strength characteristics, and decreased the plastic index value of the soil.

2011 saw the completion of a related experiment in response to the study (Kabdiyono et al., 2024). The purpose of the study was to find out how bamboo fly ash, together with lime addition, affected laterite soil during a highway construction project. In order to ascertain BLA's value as an extra stabilizer for lime, the study attempted to reduce the price of the soil stabilizing substance. Three samples were taken in Ile-Ife, Nigeria, at various points. Preliminary tests

including moisture content, specific gravity, Atterberg limits, and grain size analysis were carried out in the study. The study also included technical factors including three-axis ground sensation, California Bearing Ratio (CBR), and compression. The percentages of lime and BLA combination that produced the best stability were 2, 4, and 6%. The use of more lime and BLA as a soil stabilizer results in higher strength and undrained CBR values.

Another study conducted in the Makurdi region in 2012 employed cement and BLA as the binding material for roads (Kabdiyono et al., 2024).

Using a cement-BLA mixture and the dry weight of the soil, stabilization was carried out. ratios in the mixture were between 2% and 14%, while the ratios of pure BLA were between 4% and 20%. Soil classification, compaction, consistency, CBR, and the unconfined compression test (UCS) were performed on the samples. According to test results, adding 14% of BLA was, in comparison to other BLA mixtures, reduce the plasticity index by 34.7%, enhance the maximum dry volume value (MDD), increase the optimal moisture content (OMC) by 18.6%, and obtain the maximum soaking CBR value. According to the study's findings, it is advised to add BLA to sedimentary soil in the range of 14% to 20% in order to enhance the base material when building curve pavements.

BLA was used to stabilize the shale at a rate of 4–20% of the soil's dry weight. To find out how BLA affected the soil, examinations for both technical and exponential properties were carried out. In comparison to earlier mixing results, the results indicated a 25% decrease in IP and a 39.4% decrease in strength. It was recommended that more stabilizers, such as cement or lime, be added in order to achieve the desired result after the study's conclusion that the BLA rate was below the lower limit of the road construction strength requirement.

The ideal moisture content ranges from 12.5% to 17.5%, while the dry solidities range from 16.3 kN/m³ to 17.45 kN/m³. The MDD dramatically increased at 6% cement_BLA combination and progressively decreased at 4% cement_BLA mixture when the stabilizers were introduced. Conversely, as the ratio of cement_BLA combination grows, the OMC of the soil does as well. For the three samples, the CBR values improved marginally, from 2.36% to 9.61%, on average when using 8% cement+BLA combinations.

The effect of BLA addition on the values of the plasticity index was investigated in 2015. The amount of BLA added to the soil varies from 0% to 10%. The study's findings demonstrated that when the amount of BLA increases, the stabilized soil's PI values fall. A study conducted that same year assessed the efficacy of fly ash, rice husk ash, and BLA obtained from individual industrial wastes as soil stabilizers for clayey areas. The study found that the dry density, unconfined compressive strength, and CBR all rose with a 15% addition of the three materials. Conversely, the soil's three strengths diminished when the stabilizer addition approached 20% of the soil weight (Kabdiyono et al., 2024).

A laboratory investigation with BLA content for laterite soils ranging from 2 to 8% was carried out in 2018. For the constant BLA of 5%, extra lime was administered between 2.5% and 10% during the research. Four distinct blends were produced using the laterite:BLA:lime ratio 1 (20:1:0.5), 2 (20:1:1), and plus Combination 4 (20:1:2). The mixtures underwent tests for water absorption, compressive strength, UCS, and CBR. The soil's CBR values rose to 34% and 49% in soaked and unsoaked situations, respectively, bringing the laterite soil up to par with the subgrade soils' minimal needs. Free compression tests (UCT) were used that same year to assess the deviator stress and shear strength of BLA-gray clay-cement samples (Kabdiyono et al., 2024).

A study performed in 2021 examined the various BLA percentages with laterite soils of 0%, 2%, 4%, 6%, and 8% (Kabdiyono et al., 2024). The findings indicated that a decrease in the Atterberg limits, an increase in maximum dry density (MDD) values, and a decrease in optimum moisture content (OMC) values was follow an increase in BLA content. The CBR values for the soaked CBR rise to 6% of the BLA combination then fall to 8% of the BLA mixture. The study's overall conclusion was that adding more BLA to the soil stabilizer was boost its compressive strength while slowing down the hydration process.

The final investigation in this work was conducted in 2023 and examined the geotechnical characteristics of soil mixtures treated with BLA that contained bentonite and mixed laterite (Kabdiyono et al., 2024).

The research encompassed sodium bentonite added to the laterite soil in increments of 5%, 10%, 15%, and 20% based on the soil's weight. Next, BLA was added to the mixture in increasing weights of 4%, 8%, 12%, and 16%. In general, the treated soil's UCS value rises by as much as 141.29 kN/m², while its plasticity index falls by as much as 10.94%. The bentonite-laterite mixture's soil strength increased as a result of BLA.

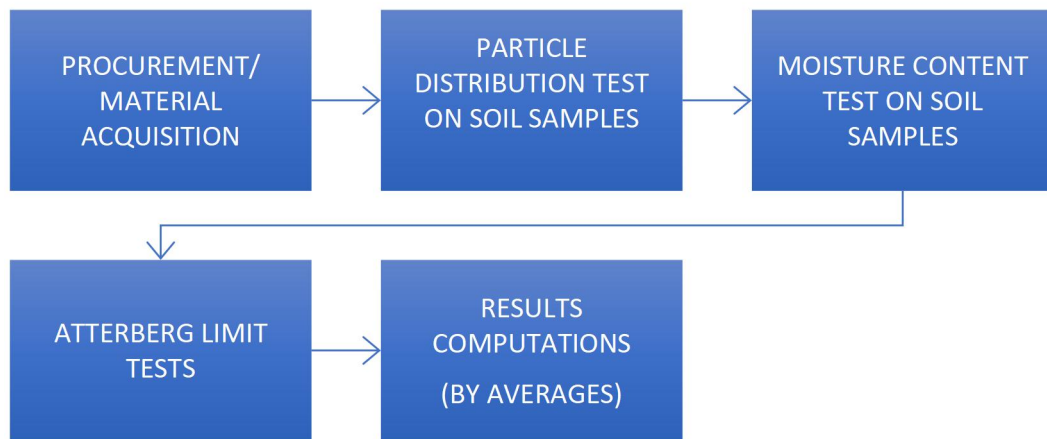
It is evident from the thorough literature assessment that 2021 saw the greatest volume of BLA research undertaken. In order to comprehend BLA's behavior as SCM at the period, a variety of soil types and additives were examined alongside it.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Methodology

The sequential proceedings of this experimental study are given below in flow chart form.



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Figure 3.1. Experimental Procedures Flow Chart *Source: (Author,2025)*

3.1 Procurement of Clay soil samples

Problematic clay soil samples of measurable volume were to be used in this experiment and was obtained from a nearby construction site in dry state.

3.1.1 Particle size distribution test

The particle size distribution (PSD) test, commonly known as sieve analysis, is a method used to determine the distribution of particle sizes in a granular material.

Equipment's Needed

- i. **Set of standard sieves (with different mesh sizes):** A collection of sieves with specified opening sizes used to separate soil or aggregate particles based on their sizes during sieve analysis.



Figure 3.2. Set of standard sieves (with different mesh sizes) *Source: (Goggle, 2025)*

- ii. **Sieve shaker:** A mechanical device that vibrates or shakes a stack of sieves to ensure efficient and uniform separation of particles by size.



Figure 3.3. Sieve shaker *Source: (Goggle, 2025)*

- iii. **Balance sensitive to 0.01 g:** A precision weighing scale used to accurately measure small masses of soil or aggregate samples in laboratory tests.

iv. **Brush:**

A soft tool used to gently clean sieve openings and transfer fine particles without damaging the sieve mesh.



Figure 3.4. Brush *Source: (Goggle, 2025)*

- v. **Sample of the material to be tested:** A representative portion of clay sample taken from a larger mass for laboratory testing to determine its properties.



Figure 3.5. Clay sample *Source: (Goggle, 2025)*

- vi. **Pan and cover:** The pan collects particles passing the smallest sieve, while the cover prevents material loss during sieving operations.



Figure 3.6. Pan and Oven *Source: (Goggle, 2025)*

Procedure

1. Clay soil samples preparation:

- i. Dry the sample in an oven at 105°C to 110°C to remove moisture.
- ii. Weigh the dried sample accurately (W1).

2. Stacking Sieves:

- i. Arrange the sieves in descending order of mesh size, with the largest mesh on top.
- ii. Place the pan at the bottom to collect the finest particles.

3. Sieving:

- i. Pour the dried sample into the top sieve.
- ii. Cover the stack and place it on the sieve shaker.
- iii. Shake the stack for a specified period (usually 10-15 minutes)

4. Weighing:

- i. After shaking, carefully remove each sieve and weigh the amount of material retained on each sieve (W2, W3, etc.).
- ii. Weigh the material collected in the pan.

5. Calculations:

a. Calculate the percentage of the total sample retained on each sieve:

ii.
$$\% \text{ Retained} = \frac{\text{Sample weight}}{\text{Sample weight on sieve}} \times 100 \quad \dots \text{Equation 3.1}$$

a. Calculate the cumulative percentage retained and the cumulative percentage passing for each sieve.

6. Plotting:

i. Plot the cumulative percentage passing against the sieve sizes on a semi-logarithmic graph to obtain the particle size distribution curve.

7. Interpretation

The particle size distribution curve helps in understanding the gradation of the material.

It is crucial for applications in construction, where particle size affects strength.

Equipment Needed

i. **Proctor mold (standard or modified):** A cylindrical steel mold of known volume used to compact soil in layers for determining its maximum dry density and optimum moisture content.



Figure 3.7. Standard proctor mold *Source: (Goggle, 2025)*

ii. **Rammer (standard: 2.5 kg, modified: 4.5 kg):** A handheld compaction hammer used to apply controlled energy to the soil inside the mold during compaction.



Figure 3.8. Rammer *Source: (Goggle, 2025)*

- iii. **Balance sensitive to 0.01 g:** A precise weighing instrument used to measure soil



samples and moisture cans accurately.

Figure 3.9. Sensitive Balance *Source: (Goggle, 2025)*

- iv. **Oven:** A laboratory heating device used to dry soil samples at a controlled temperature to determine moisture content.



Figure 3.10. Oven *Source: (Goggle, 2025)*

- v. **Mixing tools (spatula, mixing pan):** Tools used to thoroughly mix soil with water to achieve uniform moisture distribution before compaction.



Figure 3.11. Mixing tools (spatula, mixing pan) *Source: (Goggle, 2025)*

- vi. **Graduated cylinder:** A calibrated glass or plastic container used to accurately measure the volume of water added to the soil.



Figure 3.12. Graduated cylinder *Source: (Goggle, 2025)*

- vii. **Moisture cans:** Small metal containers with lids used to hold soil samples for moisture content determination.



Figure 3.13. Moisture cans *Source: (Goggle, 2025)*

- viii. **Straightedge:** A flat metal tool used to level off excess soil from the top of the mold to ensure a smooth and even surface.



Figure 3.14. Straightedge *Source: (Goggle, 2025)*

- ix. **Sieve (No. 4 or 4.75 mm):** A sieve used to remove oversized particles from the soil sample before conducting the compaction test.



Figure 3.15. Sieve (No. 4 or 4.75 mm) *Source: (Goggle, 2025)*

Procedure

1. Preparation:

- i. Sieve the soil sample through a No. 4 sieve.
- ii. Weigh approximately 3 kg of soil for the standard Proctor test or 5 kg for the modified Proctor test.

2. Moisture Content Adjustment:

- i. Add water to the soil sample to bring it to a moisture content below the expected OMC.
- ii. Mix thoroughly to ensure uniform distribution of moisture.

3. Compaction:

- i. Place the soil in the Proctor mold in three layers (standard) or five layers (modified).
- ii. Compact each layer with 25 blows (standard) or 56 blows (modified) using the rammer.
- iii. Ensure the blows are evenly distributed over the surface of each layer.

4. Trimming and Weighing:

- i. After compacting the final layer, trim the soil level with the top of the mold using a straightedge.
- ii. Weigh the mold with the compacted soil (W1).

Calculations:

- i. Calculate the wet density of the compacted soil using the formula:

$$\text{Wet Density} = \frac{\text{Volume of soil mold}}{\text{Weight of compacted soil}} \quad \text{.....Equation 3.1}$$

- ii. Plot the dry density versus moisture content to find the OMC and maximum dry density.

3.1.2 Atterberg limits test

Determining the critical water contents in fine-grained soils requires the use of the Atterberg Limits Tests. These tests aid in predicting how the clay soil samples will behave under various moisture circumstances and classifying them according to their flexibility. The three main Atterberg limits—the Liquid Limit (LL), Plastic Limit (PL), and Shrinkage Limit (SL)—have the following protocols.

3.1.2.1 Liquid limit test

The liquid limit test is used to find the moisture content at which soil transitions from a plastic limit to a liquid condition. It helps in the classification of soil and also to forecast how it will behave under various moisture circumstances, this test is essential to geotechnical engineering.

The test for the liquid limit aids in: Soil Classification: if falls under the Atterberg limits, which are used to categorize soils with the fine grains (Sanjay, 2021).

Equipment needed

They include, The Casagrande's Liquid Limit Device, Grooving tools, Oven, Evaporating Dish or Glass Sheet, Spatula, 425 Micron IS Sieve, Weighing Balance and Wash Bottle.

i. **Casagrande's Liquid Limit Device:** A mechanical device used to determine the liquid limit of soil by measuring the moisture content at which soil flows under standard impacts.

iii. **Oven:** A thermostatically controlled heating unit used to dry soil samples at a constant temperature (usually 105–110 °C) for moisture content determination.

iv. **Evaporating Dish or Glass Sheet:** A flat or shallow container used for mixing soil with water and allowing partial evaporation during Atterberg limit tests.

v. **Spatula:** A flat metal tool used for mixing soil with water, transferring soil samples, and smoothing soil surfaces during testing.

vi. **425 Micron IS Sieve:** A standard Indian Standard (IS) sieve used to separate fine-grained soil particles for Atterberg limits and other soil tests.

vii. **Weighing Balance:** A precision instrument used to accurately measure the mass



of soil samples, moisture cans, and other laboratory materials.

Figure 3.16. Liquid limit Equipment

Procedures

- i. Loosen the screws and use a gauge or grooving tool to get the cup's drop in the liquid limit device down to 1 cm.
- ii. After adjusting, tighten the screws, use a 425 micron IS sieve to filter 120g of air-dried soil.
- iii. In a glass plate or evaporating dish, thoroughly mix the soil with distilled water until a homogenous paste forms.
- iv. Stir for fifteen to thirty minutes.
- v. Give the paste enough time to grow in a humid environment up to 24 hours for some clay kinds.
- vi. Take some of the mature paste and give it a good remix. Using a spatula or straight edge, level it to a minimum depth of 1 cm after placing it in the device's cup.
- vii. Make a groove in the soil paste with the grooving tool.
- viii. Count the number of blows needed to close the groove across a 12-mm length while rotating the liquid limit device's crank at a pace of two revolutions per second.
- ix. To get consistent results, run the test several times, usually three or four times. Sanjay, (2021).

3.1.2.2 Plastic limit test

The plastic limit test is used to find the moisture content at which soil transitions from a plastic to a semi-solid condition. The Atterberg limits, which are used to categorize fine-grained soils and forecast how they will behave under various moisture circumstances, include this test (Sanjay, 2021).

Procedures

- i. Before passing the soil sample through a 425-micron filter, let it air dry.
- ii. To get a consistent paste, combine the soil with distilled water.
- iii. To create a uniformly sized thread, take a bit of the dirt paste and roll it between your fingers and a glass plate.
- iv. Keep rolling the soil thread until it has a 3 mm diameter.
- v. The soil is at its plastic limit if the thread breaks apart before it reaches this diameter. To get consistent results, run the test several times.

3.1.2.3 Shrinkage limit test

The moisture content at which soil changes from a semi-solid to a solid state without additional volume reduction is ascertained in a laboratory setting using the shrinkage limit test. The Atterberg limits, which are used to categorize fine-grained soils and forecast how they will behave under various moisture circumstances, include this test. Analyzing the possible volume change of soil after drying is known as volume change analysis, and it is essential for earthwork and foundation projects (Sanjay, 2021).

Procedures

- i. Preparing the Soil: Let the soil sample air dry before sifting it through a 425-micron screen.
- ii. To get a consistent paste, combine the soil with distilled water.
- iii. Level off the soil paste after placing it in a shrinking dish.
- iv. Put the dirt in an oven set at 105°C until its weight stays consistent.
- v. Use the mercury displacement method or other appropriate methods to determine the volume of the dried soil.
- vi. Weigh the dried soil sample to determine its weight.

Calculations;

$$\text{Shrinkage Limit(\%)} = \frac{(\text{Weight of wet soil} - \text{Weight of dry soil})}{(\text{Weight of dry soil})} \times 100 \quad \text{.. Equation 3.2}$$

3.2 Material requirements

A combination of earth materials and mechanical equipment was needed in this experimental study. Materials to be used will be obtained from remnants of nearby construction sites or procured (based on means of availability), while tools and equipment available at the

geotechnical laboratory (Highway section) of the civil engineering laboratory. These materials will be procured through volumetric estimation based on apparatus sizes and samples number. Materials to be used are; Laterite soil, Clay soil, Bamboo, and water.

1. Water

Tap water will be used for mixing all soil types and samples. The physical analysis of the water demonstrates that it is pure, devoid of contaminants, and suitable for consumption as advised by the standard. BS EN 1008 (2002).

2. Clay soil

River sand clay soil was be obtained from a nearby construction site. To lessen the moisture content, it will be allowed to air dry for 3 days. Along with being devoid of loam, silt, and organic matter, conforming to BS EN 12620 (2008) standards for cleanliness and sharpness.



Figure 3.17. Clay soil materials *Source: (Wikipedia, 2025)*

3. Bamboo Ash

Bamboo columns of variable sizes will be procured and incinerated to nearly powdered form, dried and stored till at room temperature.



Figure 3.18. Grinded Bamboo ash *Source: (Wikipedia, 2025)*

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The results of the various laboratory test are presented here as tables and figures.

4.1 Laboratory results of control tests

A control test was conducted on the soil sample without any percentage of Bamboo Ash to it to serve as a baseline for observing the behavior of Bamboo Ash (BAMBOO ASH).

4.1.1 Specific Gravity Test

The specific gravity test was conducted on the soil sample to determine the ratio of the unit weight of the soil to the unit weight of water. A summary of the results is presented in Table 4.1, with the detailed laboratory test sheet available in the appendix.

Table 4.1: Specific Gravity Result of the Soil

Sample ID	Specific Gravity (GS)
BH1	2.39
BH2	2.47
BH3	3.00

From Table 7 above, the specific gravity of sample BH1, BH2 and BH3 are 2.39, 2.47 and 3.0, respectively, with an average of 2.62. According to Federal Ministry of Works and Housing (1997) specification, a good lateritic soil should have a specific gravity that ranges from 2.5 to 2.75. The value obtained for BH3 fall within the specification, while those obtained in BH1, and BH2 fall below the specification, thus making it unsuitable for use for construction purposes.

4.1.2 Particle Size Distribution of the Soil

The sieve analysis result obtained shows the percentage of different grain sizes present in the soil sample. In the table below only selected sieve sizes are shown t and fine grain of the soil presented in Table 4.3 below. The complete sieve analysis, showing all the various grain sizes, is

provided in the appendix.

Table 4.2 Sieve Analysis Test result of the Soil

Sample ID	% Passing selected sieve sizes			Consistency Limit	
	2mm	0.425	0.075	LL	PI
BH1	99.94	79.23	48.65	28.22	7.83
BH2	99.79	70.13	36.57	26.53	6.87
BH3	99.31	71.38	37.244	28.91	7.93

Table 4.3. Nigeria Standard for Classification (Federal Ministry of Works and Housing, 1997)

General Classification	General Materials (35% or less passing 0.075 mm)							Silt-clay materials (more than 35% passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing 2.00 mm (No10) 0.425 mm (No40) 0.725 mm (No200)	50max 30max 15max	50max 25max	51min 10max	35max	35max	35max	35max	36min	36min	36min	36min
Characteristics of fraction passing Liquid limit Plastic Index	6max		N.P	40max 10max	41min 10max	40max 11min	41min 11min	40max 10max	41min 10max	40max 11min	40min 11min
Usual types of significant Constituent material	Stone fragment Gravel and sand		Fine Sand	Silty or clayey Gravel and sand				Silty soils		Clayey soils	
General rating	Excellent to Good							Fair to poor			

The sieve analysis results of the soil samples are presented in Table 1. The results show that 48.65%, 36.57%, and 37.24% of the soil samples from BH1, BH2, and BH3, respectively, passed through sieve No. 200 (75 microns). This indicates that the studied soils can be classified as silty-clayey sand. According to the Federal Ministry of Works and Housing (F.M.W&H) clause 6201, for a soil to be suitable as subgrade fill or base material, the percentage by weight passing the No. 200 sieve should not exceed 35%. Therefore, the results indicate that the lateritic material is unsuitable for use as subgrade or base fill, as the percentage passing sieve No. 200 exceeds the recommended limit.

4.1.3 Atterberg Limit

The Atterberg limit test was conducted to determine the consistency of the soil s. A summary of the results is displayed in Table 4.3, while a detailed analysis of the Atterberg limit test, is provided in the appendix

Table 4.4 Atterberg Limit Test Result of the Soil

Sample ID	Liquid limit (LL) %	Plastic limit (PL) %	PLASTICITY INDEX %
BH1	29.65	19.63	8.94
BH2	26.07	19.55	6.52
BH3	29.50	21.23	7.67

According to the Federal Ministry of Works and Housing (1997), liquid limits of 80% maximum are recommended for road works for subgrade and 35% maximum for base materials. It also recommends a plastic index of 55% maximum for sub grade and 12% maximum for base materials. All the results fall within below specification, making the soil samples unsuitable for used for construction purposes.

4.1.4 California Bearing Ratio Test

The CBR test involves finding the soaked and unsoaked CBR value of the soil and the results are presented in table 4.6 below.

Table 4.5. California Bearing Ratio Result of the Soil

S/N	Sample ID	Pressure Layer	Unsoaked		Soaked	
			2.5mm	5.0mm	2.5mm	5.0mm
1	BH1	Bottom	11.48	10.25	.3.13	2.46
2		Top	13.13	11.34	2.15	3.56
3	BH2	Bottom	8.84	9.32	5.12	4.06
4		Top	6.44	5.43	2.07	2.47
5	BH3	Bottom	10.41	9.809	2.23	2.08
6		Top	11.15	10.25	2.808	2.9

Table 4.6. Nigeria Standard for Classification (Federal Ministry of Works and Housing, 1997)

Location	1	2	3	4	5	6	7	8	9	10
Sample	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
LL ($\leq 35\%$)	34.5 Pass	36.6 Fail	33.5 Pass	23.5 Pass	22.5 Pass	35.5 Fail	34.5 Pass	49.6 Fail	34.5 Pass	41.4 Fail
P.I ($\leq 12\%$) comment	13.5 Fail	12.1 Pass	11.5 Pass	9.5 Pass	8.7 Pass	12.5 Fail	11.3 Pass	21.6 Fail	13.5 Fail	19.43 Fail
C.B.R soaked for subbase ($\geq 30\%$)	11.0 Fail	40.0 Pass	18.0 Fail	64.90 Pass	72.70 Pass	36.0 Pass	54 Pass	5.1 Fail	9.0 Fail	7.7 Fail
C.B.R unsoaked Base course ($\geq 80\%$)	32.0 Fail	ND	30.0 Fail	77.5 Pass	83.8 Pass	48.0 Fail	ND	ND	40.0 Fail	ND
Overall Rating	Sub-base	Sub-base	Sub-base	Base	Base	Sub-base	Sub-base	Poor	Poor	Poor

ND: not determined

As shown in Table 9, the California bearing ratio values show that CBR for the unsoaked soil samples ranges between 5.43 % and 13.3%. The California bearing ratio ranges from 2.07 to 5.12% for the soaked soil samples. From the results, the soil can be used as subgrade or earth fill but cannot be used as a base course as it will require stabilization for founding stable structures. This is because the Federal Ministry of Works and Housing Specification for Roads recommends that the CBR values (unsoaked) for sub-grade and base courses should not be less than 10% and 80%, respectively.

4.2 Effect of Bamboo Ash on the Geotechnical Properties of the Soil

Bamboo Ash was added to the soil percentages of 5%, 10%, 15%, and 20% to improve the quality of the soil.

4.2.1 Atterberg Limits

BAMBOO ASH was added to 200g of clay soil in proportions of 5%, 10%, 15%, and 20%, and. The liquid limit, plastic limit, and plasticity index of the BAMBOO ASH-stabilized soil were compared to those of the untreated clay soil and are presented in Tables 4.8 below. A detailed analysis of the experiment can be found in the appendix.

Table 4.7. Atterberg Limits Values of BAMBOO ASH Stabilized Soil (BH1)

S/N	Percentage of Stabilizer (%)	Atterberg Limit Tests		
		L.L (%)	P.L (%)	P.I (%)
1	0	28.65	19.68	8.94
2	5	30.85	22.52	8.44

3	10	33.45	23.55	9.64
4	15	35.71	23.92	11.81
5	20	38.31	24.88	13.48

As shown in Table 4.8, adding BAMBOO ASH to the soil sample increased the liquid limit (L.L) from 28.65% at 0% to 38.31% at 20% BAMBOO ASH. Similarly, the plastic limit (P.L) and plasticity index (P.I) increased from 19.68% and 8.94% at 0% to 24.88% and 13.48% at 20%

Table 4.8. Atterberg Limits Values of BAMBOO ASH Stabilized Soil (BH2)

S/N	Percentage of Stabilizer (%)	Atterberg Limit Tests		
		L.L (%)	P.L (%)	P.I (%)
1	0	26.53	19.66	6.87
2	2	30.24	22.34	7.91
3	4	36.36	23.54	12.82
4	6	40.26	27.07	13.19
5	8	43.23	28.93	14.30
6	10	39.42	25.46	13.96

As seen in Table 4.9, the addition of BAMBOO ASH to the soil sample increased the liquid limit (L.L) from 26.53% at 0% to 43.23% at 8% BAMBOO ASH. However, at 10% BAMBOO ASH, the L.L significantly decreased to 39.42%. Similarly, the plastic limit (P.L) and plasticity index (P.I) increased from 19.66% and 6.87% at 0% to 28.93% and 14.30% at 8% BAMBOO ASH, respectively, but decreased to 25.46% and 13.96% at 10% BAMBOO ASH.

Table 4.9. Atterberg Limits Values of BAMBOO ASH Stabilized Soil (BH3)

S/N	Percentage of Stabilizer (%)	Atterberg Limit Tests		
		L.L (%)	P.L (%)	P.I (%)
1	0	29.50	21.23	7.67
2	2	30.59	22.40	8.41
3	10	36.08	24.15	12.93

4	15	37.05	24.60	13.46
5	20	42.25	28.40	14.48

As shown in Table 4.10, adding BAMBOO ASH to the soil sample increased the liquid limit (L.L) from 28.91% at 0% to 42.25% at 20% BAMBOO ASH. to 41.34%. Similarly, the plastic limit plasticity index (P.I) increased from 21.23% and 7.67% at 0% to 28.40% and 14.48% at 20% BAMBOO ASH, respectively,

4.2.2 Compaction

A summary of the result obtain proctor compaction test results is provided in Table 4.4, while a thorough analysis of the compaction test is available in the appendix.

Table 4.10. Compaction Test Result

Sample ID	MDD g/cm^3	OMC %
BH1	1.77	9.4
BH2	1.72	14.2
BH3	1.62	13.8

Table 4.11. Nigeria Standard for Classification (Federal Ministry of Works and Housing, 1997)

Sample No	M.D.D(g/CM3)	O.M.C(%)	Group symbol	Description
L1	2.05	12.11	SM-SC	Sandysilt clay mix with slightly plastic fines
L2	2.059	13.2	SM-SC	Sandysilt clay mix with slightly plastic fines
L3	2.18	7.81	SC	Siltyclay mix with slightly plastic fines
L4	2.33	6.30	SC	Siltyclay mix with slightly plastic fines
L5	2.35	6.50	SC	Siltyclay mix with slightly plastic fines
L6	2.11	9.05	SC	Siltyclay mix with slightly plastic fines
L7	2.076	10.8	SM-SC	Sandysilt clay mix with slightly plastic fines
L8	1.785	14.3	SM	Silty soils, poorly graded sandysilt mix
L9	2.19	9.5	SM-SC	Sandysilt clay mix with slightly plastic fines
L10	1.805	14.4	SM	Silty soils, poorly graded sandysilt mix

BAMBOO ASH was added to 3000g of soil sample in percentage of 5%, 10%, 15%, and 20% to each of the three soil samples. The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were compared with the control sample, The results of this experiment are presented in table below, with a detailed analysis provided in the appendix.

Table 4.12. Compaction Values of BAMBOO ASH Stabilized Soil (BH1)

S/N	Percentage of stabilizer (%)	MDD g/cm^3	OMC (%)
1	0	1.77	9.4
2	5	1.81	11.8
3	10	1.82	11.2
4	15	1.84	12.6
5	20	1.66	8.2

It is observed from table 4.11 above, addition of the Bamboo Ash to the soil sample increased the MDD from $1.77 g/cm^3$ at 0% to $1.84g/cm^3$ at 15% Bamboo Ash addition. At 20% addition a significant reduction in the MDD to $1.66g/cm^3$ is observed. Similarly, the OMC value increased from 9.4% at 0% to 11.8% at 5% Bamboo Ash addition, at 10% Bamboo Ash addition the value of the OMC reduced to 11.2%. which increases to 12.6% on 15% Bamboo Ash addition and further drops to 8.2% at 20% Bamboo Ash addition

Table 4.13. Compaction Values of BAMBOO ASH Stabilized Soil (BH2)

S/N	Percentage of stabilizer (%)	MDD g/cm^3	OMC (%)
1	0	1.72	14.2
2	5	1.74	15.2
3	10	2.68	15.6
4	15	2.73	16.1
5	20	1.71	15.4

From table 4.12 above, addition of the Bamboo Ash to the soil sample increased the MDD from $1.72 g/cm^3$ at 0% to $2.73 g/cm^3$ at 15% Bamboo Ash addition but at 20% Bamboo Ash addition there was a significant reduction in the MDD to $1.71g/cm^3$. Similarly, addition of Bamboo Ash to the soil sample increased the OMC from 14.2. % at 0% Bamboo Ash addition to 16.1% at 15% Bamboo Ash Addition, but at 20% there was a significant reduction in the OMC to 15.4%

Table 4.14. Compaction Values of BAMBOO ASH Stabilized Soil (BH3)

S/N	Percentage of stabilizer (%)	MDD g/cm^3	OMC (%)
1	0	1.62	13.8

2	5	1.76	14.1
3	10	1.77	14.6
4	15	2.05	15.8
5	20	1.78	15.4

From table 4.13 above, it is observed that the addition of the Bamboo Ash to the soil sample increased the MDD from 1.62 g/cm^3 at 0% to 2.04 g/cm^3 at 15% Bamboo Ash addition but at 20% Bamboo Ash addition there was a significant reduction in the MDD to 1.78 g/cm^3 . Similarly, addition of Bamboo Ash to the soil sample increased the OMC from 13.8% at 0% Bamboo Ash addition to 15.8% at 15% Bamboo Ash addition, but at 20% BAMBOO ASH addition there was a significant reduction in the OMC vale to 15.4%.

4.2.3 California Bearing Ratio

BAMBOO ASH was added to 5000g of soil sample in proportions of 5%, 10%, 15%, and 20% t. The results of this experiment are presented in Tables below, with a detailed analysis provided in the appendix.

Table 4.15. CBR values of BAMBOO ASH stabilized soil (BH1)

1	0	10.25	2.14
2	5	11.52	3.51
3	10	12.55	5.37
4	15	18.85	7.59
5	20	14.03	4.77

From table 4.14 above, it is observed that addition of the Bamboo Ash to the soil sample increased the Unsoaked CBR value from 10.25 at 0% to 18.85 at 15% Bamboo Ash addition, but at 20% addition there was a significant reduction in the CBR to 14.03%. Similarly, addition of Bamboo Ash to the soil sample increased the Soaked CBR value from 1.14% at 0% BAMBOO ASH addition to 7.59% at 15% Bamboo Ash addition, but there a reduction in the soaked CBR value to 4.71% at 10% Bamboo Ash addition.

Table 4.16. CBR Values of BAMBOO ASH Stabilized Soil (BH2)

S/N	Percentage of stabilizer (%)	Unsoaked (%)	Soaked (%)
1	0	5.42	2.06
2	5	9.04	3.06
3	10	10.25	4.32
4	15	16.76	6.36
5	20	7.64	5.61

As observed from table 4.15 above, addition of the Bamboo Ash to the soil sample increased the Unsoaked CBR value from 5.42 at 0% 16.60 at 15% Bamboo Ash addition, but at 20% Bamboo Ash addition the CBR value reduced to 7.64%. Similarly, addition of BAMBOO ASH to the soil sample increased the Soaked CBR value from 2.05% at 0% BAMBOO ASH addition to 6.36% at 15% Bamboo Ash addition, but there was a reduction in the CBR value to 5.61% at 20% Bamboo Ash addition.

Table 4.17. CBR Values of BAMBOO ASH Stabilized Soil (BH3)

S/N	Percentage of stabilizer (%)	Unsoaked (%)	Soaked (%)
1	0	9.81	2.08
2	5	11.51	3.95
3	10	12.27	4.79
4	15	17.51	7.95
5	20	13.96	4.77

As observed from table 4.15 above, addition of the BAMBOO ASH to the soil sample increased the Unsoaked CBR value from 9.81 at 0% 17.51 at 15% BAMBOO ASH addition, but at 20% BAMBOO ASH addition the CBR value reduced to 13.98%. Similarly, addition of BAMBOO ASH to the soil sample increased the Soaked CBR value from 2.8% at 0% BAMBOO ASH addition to 7.95% at 15% BAMBOO ASH addition, but at 20% BAMBOO ASH addition the CBR value reduced to 4.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the experimental results it can be concluded of the soil stabilization, an 15% Bamboo Ash stabilized soil increases the CBR value of BH1, BH2 and BH3 from 2.14% 7.59%, 2.06% to 6.36%, and 2.08% to 7.75% respectively indicating that the the addition of bamboo ash to the tested soils generally improved both compaction characteristics and California Bearing Ratio (CBR) values, indicating enhanced load-bearing capacity. However, this improvement was observed up to a certain percentage of bamboo ash addition (approximately 15%), beyond which both Maximum Dry Density (MDD) and CBR decreased. Furthermore, the addition of bamboo ash also led to an increase in the Atterberg Limits (Liquid Limit, Plastic Limit, and Plasticity Index), suggesting a potential increase in soil plasticity. These findings highlight the importance of determining the optimal bamboo ash content for soil stabilization, as exceeding this optimum can lead to diminished improvements and potentially adverse effects on other soil properties It can be conclude also that the stabilized soil is a suitable subgrade material to be used for design pavement and Bamboo Ash can be used to improve the strength properties of clay soils

5.2 Recommendation

1. Bamboo Ash can be applied as a suitable admixture to improve the Strength properties of a Clay soil.
2. The results strongly suggest an optimal bamboo ash content of around 15% for improving both compaction and CBR. Further research should focus on refining this optimal percentage and exploring the mechanisms behind the observed increases
3. Further research is recommended to explore the long-term performance, mechanisms of improvement, and soil-specific optimization of bamboo ash stabilization,

REFERENCES

- AASHTO, (2007). Standard Specifications for Transportation Materials and Methods of Sampling and Testing. Available at: <https://pavementinteractive.org/>. Accessed on September, 2024.
- Aboluwarin, O. *et al.*, (2017). Investigating the effect of bamboo trunk ash blended cement in engineering properties of mortar. International Journal of Science and Research, Raipur, Índia, v. 6, n. 7, p. 2037-2040. Disponível em: <https://doi.org/10.21275/art20175631>.
- Abu Bakar, B. H.; Ramadhansyah, P. J.; Megat Azmi, M. J (2020). Effect of rice husk ash fineness on the chemical and physical properties of concrete. Magazine of Concrete Research, Londres, Reino Unido, v. 63, n. 5, p. 313-320,
- Ademola, S. A.; Buari, T. A. Behaviour 2020. of bamboo leaf ash blended cement concrete in sulphates environment. IOSR Journal of Engineering, Gurugram, Índia, v. 4, n. 6,
- Akinlabi, E.T., Anane-Fenin, K., Akwada, D.R. (2017). Properties of Bamboo. In: Bamboo. Springer, Cham. https://doi.org/10.1007/978-3-319-56808-9_3.
- Altun, F.; Aktaş, B 2013. Investigation of reinforced concrete beams behavior of steel fiber added lightweight concrete. Construction and Building Materials, v. 38, p. 575-581,
- American Society For Testing And Materials 2019.. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete. Astm C618-19
- Amin, M. N. *et al.*, 2020. Pozzolanic potential and mechanical performance of wheat straw ash incorporated sustainable concrete. Sustainability, Basel, Suíça, v. 11, n. 2, p. 1-20, 2019. Disponível em: <https://doi.org/10.3390/su11020519>.

- Arvaniti, E. C. *et al.*, 2020. Physical characterization methods for supplementary cementitious materials. *Materials and Structures/Materiaux et Constructions*, Lonres, Reino Unido, v. 48, p. 3675-3686, 2015. Disponível em: <https://doi.org/10.1617/s11527-014-0430-4>.
- ASTM Standard D2487, 2000. "Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)," ASTM International, West Conshohocken, PA, 2000, DOI: 10.1520/D2487-00, www.astm.org.
- Breuer, Stephen (July 2012). "[The chemistry of pottery](#)" (PDF). *Education in Chemistry*: 17–20. [Archived](#) (PDF) from the original on 9 October 2022. Retrieved 8 December 2020.
- Constro F.,(2021).Structural layers and types of highway pavements. Available at: <https://constrofacilitator.com/>. Accessed on September 18, 2024.
- Cordeiro, G. C.; Sales, C. P 2015 . Pozzolanic activity of elephant grass ash and its influence on the mechanical properties of concrete. *Cement and Concrete Composites*, Amsterdan, Países Baixos, v. 55, p. 331-336,. Disponível em:
- Cordeiro, G. C.; Toledo Filho, R. D.; Fairbairn, E. M. R 2009. Effect of calcination temperature on the pozzolanic activity of sugar cane bagasse ash. *Construction and Building Materials*, Amsterdan, Países Baixos, v. 23, n. 10, p. 3301-3303.
- Damineli, B. L.; Pilleggi, R. G.; John, V. M 2017. Influence of packing and dispersion of particles on the cement content of concretes. v. 10, n. 5, p. 998-1024,
- Damtoft, J. S. *et al.* 2008. Sustainable development and climate change initiatives. *Cement and Concrete Research*, Amsterdan, Países Baixos, v. 38, n. 2, p. 115-127,. Disponível em: <https://doi.org/10.1016/j.cemconres.2007.09.008>. Acesso em: 17 aug. 2020.

- David, N. L.; Hassan, L. K. 2018. Physical and mechanical properties of cement mortar using lime and bamboo-ash as partial replacements. *Malaysian Journal of Civil Engineering*, Johor Bahru, Malásia, v. 30, n. 2, p. 254-268,. Acesso em: 17 aug. 2020.
- Day, Robert W. (2013). [Geotechnical engineer's portable handbook : with the 2012 international building code](#) (2nd ed.). New York: McGraw-Hill. [ISBN 978-0-07-178971-4](#). [OCLC 837179787,D 2487 – 06: Standard Practice for Classification of Soils for Engineering Purposes \(Unified Soil Classification System\)](#) (PDF) (Technical report). [ASTM International](#). 2006.
- Dhengare, S. *et al.* (2020). Fineness effect of sugarcane bagasse ash, rice husk ash, and fly ash on strength of concrete. *International Research Journal of Engineering and Technology*, Hyderabad, Índia, v. 6, n. 2, p. 121-126, 2019.
- Dhinakaran, G.; Chandana, G. H. 2016. Compressive strength and durability of bamboo leaf ash concrete. *Jordan Journal of Civil Engineering*, Irbid, Jordânia, v. 10, n. 3, p. 279289,
- Duchesne, J. 2020. Alternative supplementary cementitious materials for sustainable concrete structures: a review on characterization and properties. *Waste and Biomass Valorization*, n. 0123456789, 2020. Disponível em: <https://doi.org/10.1007/s12649-020-01068-4>. Acesso em: 17 aug.
- Dwivedi, V. N. *et al* 2006. A new pozzolanic material for cement industry: bamboo leaf ash. *International Journal of Physical Sciences*, v. 1, n. 3, p. 106-111,
- Frias, M. *et al* 2012. Characterization and properties of blended cement matrices containing activated bamboo leaf wastes. *Cement and Concrete Composites*, Amsterdan, Países Baixos, v. 34, n. 9, p. 1019-1023, Disponível em:

GeoTech , (2024). Soil Properties and Classification in Geotechnical Engineering. Available at:
<http://www.thegeotech.com/> Accessed on September,2024.

Guggenheim, Stephen; Martin, R. T. 2018. "Definition of clay and clay mineral: Journal report of the AIPEA nomenclature and CMS nomenclature committees", *Clays and Clay Minerals*, 43 (2):256, [Bibcode:1995CCM...43..255G](#), [doi:10.1346/CCMN.1995.0430213](#), [S2CID 129312753](#).guide for evaluation of alternative supplementary cementitious materials (ASCM) for use in concrete. West Conshohocken, EUA: ASTM International,

Habeeb, G. A.; Mahmud, H. B 2010. Study on properties of rice husk ash and its use as cement replacement material. *Materials Research*, v. 13, n. 2, p. 185-190,

Heiri, O.; Lotter, A. F.; Lemcke, G 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Journal of Paleolimnology*, v. 25, p. 101-110,

Helander, M. *et al* 2013. Endophytic fungi and silica content of different bamboo species in giant panda diet. *Symbiosis*, v. 61, n. 1, p. 13-22.

Ikeagwuani, C. C. *et al* 2019. Potential of bamboo stem ash as supplementary cementitious material in concrete production. *International Journal of Engineering Research & Technology*, v. 8, n. 08, p. 75-80.

Ikeagwuani, C.C., Nwonu, D.C. (2019). Resilient Modulus of Lime-Bamboo Ash Stabilized Subgrade Soil with Different Compactive Energy. *Geotech Geol Eng* 37, 3557–3565).
<https://doi.org/10.1007/s10706-019-00849-6>.

- Ikumapayi, C. M 2017. Crystal and microstructure analysis of Pozzolanic properties of bamboo leaf ash and locust beans pod ash blended cement concrete. *Journal of Applied Sciences and Environmental Management*, v. 20, n. 4, p. 943.
- Jaya, R. P. *et al* 2013. Properties of mortar containing rice husk ash at different temperature and exposed to aggressive environment. *Advanced Materials Research*, v. 620, p. 87–93, <https://doi.org/10.4028/www.scientific.net/AMR.620.87>. Acesso em: 17 aug. 2020.
- Kabdiyono, E. A., Soepandji, B. S., Handika, N., Wulandari, S., & Sagitaningrum, F. H. (2024). Potential of Bamboo Leaf Ash for Soil Stabilization - Literature Review. *IOP Conference Series: Earth and Environmental Science*, 1324(1).
- Klein, Cornelis; Hurlbut, Cornelius S. Jr. (1993). *Manual of mineralogy : (after James D. Dana) (21st ed.)*. New York: Wiley. [ISBN 047157452X](https://doi.org/10.1002/9781118133131).
- Koche, (2024). What Is Road Subgrade in Construction and Why Is It Important?. Available at : <https://constructowiki.com/>. Accessed on September 20, 2024.
- Kolawole, J. T.; Olusola, K. O.; ATA, O 2015. Strength of bamboo leaf ash and pulverized burnt clay waste blended cement concrete. *IOSR Journal of Mechanical and Civil Engineering Ver. II*, v. 12, n. 6, p. 36-42,. Disponível em: <https://doi.org/10.9790/1684-12623642>. Acesso em: 17 aug. 2020.
- Lees, (2021). *Road Construction: Pavement Types, Methods, and Designs*. Available at: <https://www.tensarinternational.com/resources/articles/>. Accessed on September 18, 2024.
- Lian, C.; Zhuge, Y.; Beecham, S 2011. The relationship between porosity and strength for porous concrete. *Construction and Building Materials, Amsterdam, Países Baixos*, v. 25, n. 11, p.

- 4294-4298, Disponível em: <https://doi.org/10.1016/j.conbuildmat.2011.05.005>. Acesso em: 17 aug. 2020.
- Libre, N. A. et al., 2011. Mechanical properties of hybrid fiber reinforced lightweight aggregate concrete made with natural pumice. *Construction and Building Materials*, Amsterdam, Países Baixos, v. 25, n. 5, p. 2458-2464,
- Luhar, S.; Cheng, T. W.; Luhar, I 2019. Incorporation of natural waste from agricultural and aquacultural farming as supplementary materials with green concrete: a review. *Composites Part B: Engineering*, Amsterdam, Países Baixos, v. 175, n. March, p. 107076,
- Ma, J. F.; Takahashi, E 2002. *Soil, fertilizer, and plant silicon research in Japan*. 1. ed. Amsterdam, Países Baixos: Elsevier Science B.V., 2
- Nehme, Jean (14 July 2017). "[About Long-Term Pavement Performance](#)". [Federal Highway Administration](#). Retrieved 22 October 2017.
- Nesse, William D. (2000). *Introduction to mineralogy*. New York: Oxford University Press. [ISBN 9780195106916](#).
- Olive, W.W.; Chleborad, A.F.; Frahme, C.W.; Shlocker, Julius; Schneider, R.R.; Schuster, R.L. (1989). "[Swelling Clays Map of the Conterminous United States](#)". U.S. Geological Survey Miscellaneous Investigations Series Map. I-1940. Retrieved 8 December 2020.
- Rogers and Martin (2002). *Highway engineering*. Oxford, UK: Blackwell Science. [ISBN 978-0-632-05993-5](#).
- Science Learning Hub (2016). "[What is clay](#)". [University of Waikato](#). [Archived](#) from the original on 3 January 2016. Retrieved 10 January 2016.

Solaimanian, (2024).What are roads made of? A pavement materials engineer explains the science behind the asphalt you drive on. Available at: <https://theconversation.com/>. Accessed on September 18, 2024.

Tikkanen, (2024). Pavements in civil engineering. Available at: <https://www.britannica.com>. Accessed on September 18, 2024.;

Ubanni, (2024). Soil classification and engineering properties of soil. Available at: [Soil Classification and Typical Engineering Properties of Soils - Structville/](#) Accessed on September,2024.

Ural, (2018). The Importance of Clay in Geotechnical Engineering. Available at: <https://www.intechopen.com/chapters/60931/> Accessed on September,2024.

APPENDIX

SPECIFIC GRAVITY OF SOIL PARTICLES LABORATORY TEST RESULT SHEET (Standard Laboratory Method)

S/N	Sampling Location	DEPTH (m)	BN	B+W	B+S+W	B+S	B	Ad. W	WWAS	WS	WOWDS	Gs	AGs
1	BH1	1.0	EV	77.32	90.20	47.12	25.03	52.29	43.08	22.09	9.21	2.40	2.39
			BI	75.71	88.80	45.08	22.51	53.20	43.72	22.57	9.48	2.38	
2	BH1	1.0	H27	76.08	90.08	47.45	23.58	52.50	42.63	23.87	9.87	2.42	2.47
			VVV	74.82	85.21	40.19	22.94	51.88	45.02	17.25	6.86	2.51	
3	BH3	1.0	RT2	74.67	87.93	42.05	23.78	50.89	45.88	18.27	5.01	3.65	3.00
			RT1	75.07	86.19	40.62	21.23	53.84	45.57	19.39	8.27	2.34	

B+W = Wt. of Bottle + Water (full) W4
B+S+W = Wt. of Bottle + Soil+ Water W3
B+S = Wt. of Bottle + Soil W2
B = Wt. of Bottle W1
Ad.W = Wt. of Added Water (full) (W4-W1)
WWAS = Wt. of Water added to Soil (W3-W2)
WS = Wt. of Soil (W2-W1)
WOWDS = Wt. of Water Displaced by Soil (W4-W1)-(W3-W2) = W
GS = Specific Gravity (W2-W1)/W

PARTICLE SIZE DISTRIBUTION LABORATORY TEST RESULT SHEET (SIEVE ANALYSIS METHOD)

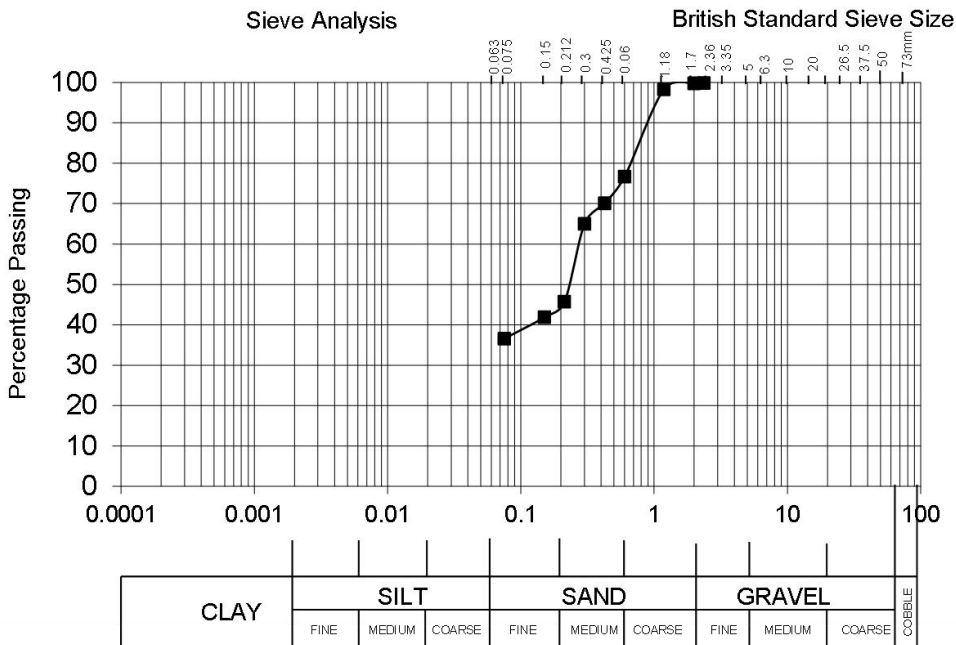
LOCATION: UNIBEN, .

SAMPLE ID : BH1 (CONTROL)

DEPTH: 1.0m

TEST TYPE: WET SIEVE

SIEVE NO.	APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3		75			
2 1/2					
2		50			
1 1/2		37.5			
1		26.5			
3/4		20			
1/2		14			
3/8		10			
1/4		6.3			
3/16		5			
1/8		3.35			100
7		2.36		0.14	99.86
10		2		0.07	99.79
14		1.18		1.52	98.27
25		0.6		21.56	76.71
36		0.425		6.58	70.13
52		0.3		5.15	64.98
72		0.212		19.28	45.7
100		0.15		3.83	41.87
200		0.075		5.3	36.57



PARTICLE SIZE DISTRIBUTION LABORATORY TEST RESULT SHEET (SIEVE ANALYSIS METHOD)

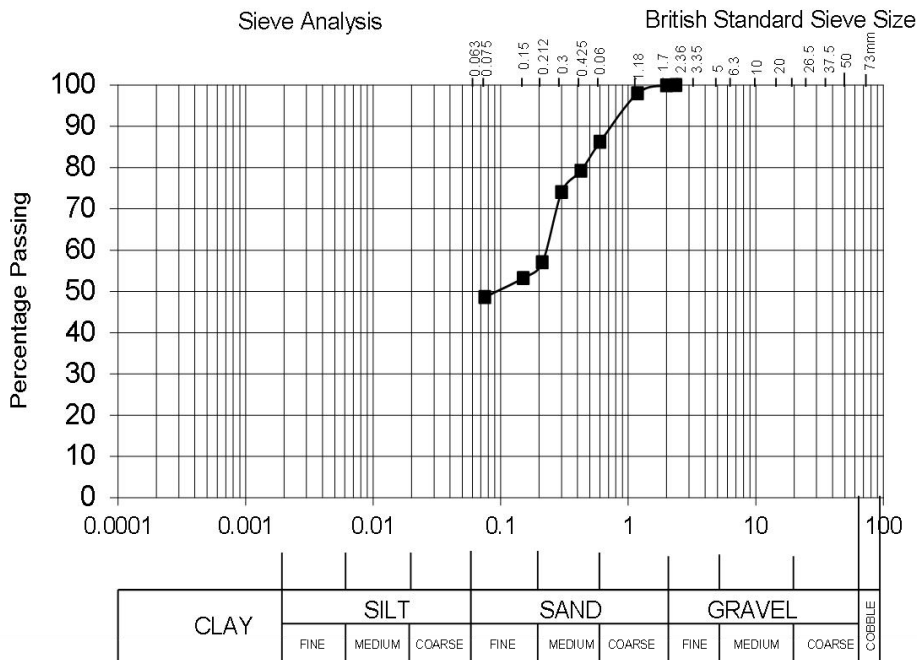
LOCATION: UNIBEN, .

SAMPLE ID : BH2 (CONTROL)

DEPTH: 1.0m

TEST TYPE: WET SIEVE

SIEVE NO.	APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3		75			
2 ½					
2		50			
1 ½		37.5			
1		26.5			
¾		20			
½		14			
⅜		10			
¼		6.3			
3/16		5			
⅛		3.35		100	
7		2.36	0.01	99.99	99.99
10		2	0.05	99.94	99.94
14		1.18	1.94	98	98
25		0.6	11.78	86.22	86.22
36		0.425	6.99	79.23	79.23
52		0.3	5.15	74.08	74.08
72		0.212	17.05	57.03	57.03
100		0.15	3.79	53.24	53.24
200		0.075	4.61	48.63	48.63



PARTICLE SIZE DISTRIBUTION LABORATORY TEST RESULT SHEET (SIEVE ANALYSIS METHOD)

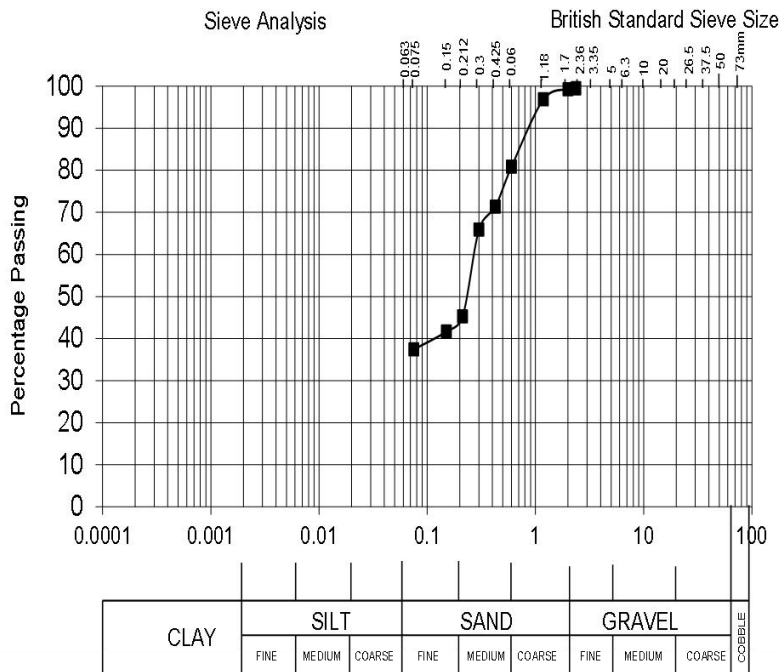
LOCATION: UNIBEN, .

SAMPLE ID : BH3 (CONTROL)

DEPTH: 1.0m

TEST TYPE: WET SIEVE

SIEVE NO.	APPROX IMPERIAL EQUIV (inches)	BRITISH STANDARD SIEVE SIZES (mm)	RETAINED IN gm	PASSING IN gm	PASSING IN (%)
3		75			
2 ½					
2		50			
1 ½		37.5			
1		26.5			
¾		20			
½		14			
⅜		10			
¼		6.3			
3/16		5			
⅛		3.35		100	
7		2.36	0.52	99.48	99.48
10		2	0.17	99.31	99.31
14		1.18	2.43	96.88	96.88
25		0.6	15.99	80.89	80.89
36		0.425	9.51	71.38	71.38
52		0.3	5.43	65.95	65.95
72		0.212	20.64	45.31	45.31
100		0.15	3.65	41.66	41.66
200		0.075	4.22	37.44	37.44



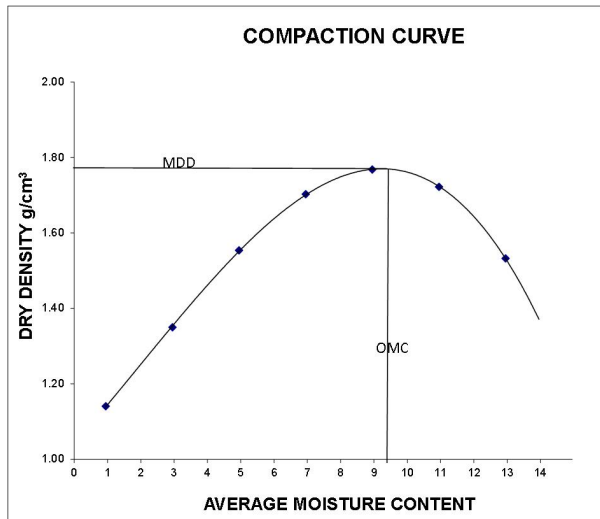
LABORATORY COMPACTION TEST SHEET

Sample ID: BH 1, 5% Depth: 1m

MDD: 1.77g/cm³ OMC: 9.4%

Mould weight: 4550g

Wt. of mould & wet Soil (W2) g	5692.00	5920.00	6160.00	6335.00	6440.00	6419.00	6260.00							
Wt. of mould (W1) g	4565.00	4565.00	4565.00	4565.00	4565.00	4565.00	4565.00							
Wt. of wet soil (W2-W1) g	1127.00	1355.00	1595.00	1770.00	1875.00	1854.00	1695.00							
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.19	1.44	1.69	1.88	1.99	1.96	1.80							
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³														
Container No.	MI	XXX	0.21	0.4	MO2	HUT	OK	A1	PA7	PA5	MIT	HY	TR	VA
Wt. of wet soil & container (g)	34.40	34.41	43.10	47.85	40.69	52.79	46.75	48.92	55.50	53.75	63.19	57.28	80.00	79.50
Wt. of Dry soil & container (g)	33.85	33.50	41.42	46.22	38.78	50.00	44.15	45.98	51.23	49.80	57.50	51.92	70.83	72.56
Wt. of Container (g)	17.95	17.78	17.25	17.60	17.00	17.92	17.97	17.41	17.38	17.01	15.52	15.00	24.50	24.65
Wt. of dry soil (Wd) g	15.90	15.72	24.17	28.62	21.78	32.08	26.18	28.57	33.85	32.79	41.98	36.92	46.33	47.91
Wt. of Moisture (Wm) g	0.55	0.91	1.68	1.63	1.91	2.79	2.60	2.94	4.27	3.95	5.69	5.36	9.17	6.94
Moistur Content 100(Wm/Wd) %	3.46	5.79	6.95	5.70	8.77	8.70	9.93	10.29	12.61	12.05	13.55	14.52	19.79	14.49
Average Moisture Content (m) %	4.62	6.32	8.73	10.11	12.33	14.04	17.14							
Dry Density = Pb/1+(m/100) (g/cm ³)	1.14	1.35	1.55	1.70	1.77	1.72	1.53							
C.B.R. (mseen of top & bottom) %														



LABORATORY COMPACTION TEST SHEET

Sample ID: BH 1, 5%

Depth: 1m

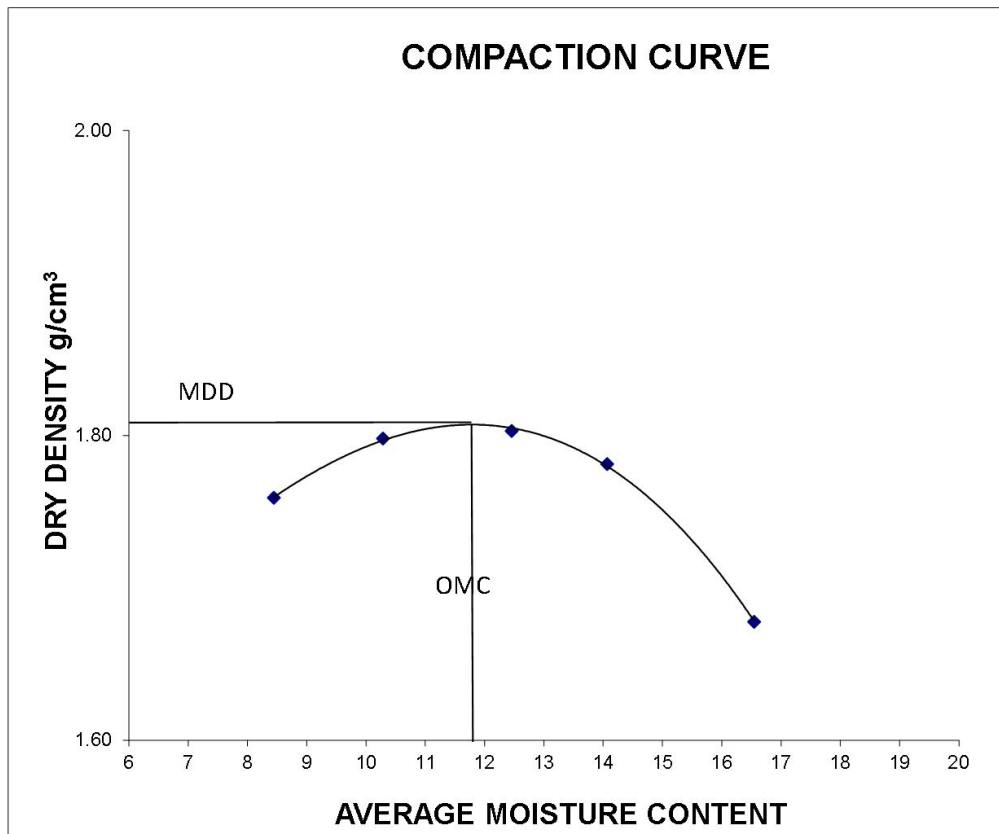
...

MDD: 1.81g/cm³

OMC: 11.8%

Mould weight: 46230g

Wt. of mould & wet Soil (W2) g	6424.00	6495.00	6537.00	6541.00	6469.00							
Wt. of mould (W1) g	4623.00	4623.00	4623.00	4623.00	4623.00							
Wt. of wet soil (W2-W1) g	1801.00	1872.00	1914.00	1918.00	1846.00							
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.91	1.98	2.03	2.03	1.96							
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3												
Container No.	PA6	GAG	HOM	22	HUT	MYM	FG	G7	PA8	MV		
Wt. of wet soil & container (g)	32.42	33.97	42.70	38.85	41.81	51.95	58.71	51.91	58.86	58.28		
Wt. of Dry soil & container (g)	31.35	32.52	40.41	36.79	39.10	48.41	52.75	48.40	52.40	52.89		
Wt. of Container (g)	17.51	16.69	17.40	17.40	18.19	18.79	17.52	17.10	17.60	15.80		
Wt. of dry soil (Wd) g	13.84	15.83	23.01	19.39	20.91	29.62	35.23	31.30	34.80	37.09		
Wt. of Moisture (Wm) g	1.07	1.45	2.29	2.06	2.71	3.54	5.96	3.51	6.46	5.39		
Moistur Content 100(Wm/Wd) %	7.73	9.16	9.95	10.62	12.96	11.95	16.92	11.21	18.56	14.53		
Average Moisture Content (m) %	8.45		10.29		12.46		14.07		16.55			
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.76		1.80		1.80		1.78		1.68			
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

Sample ID: BH1, 10%

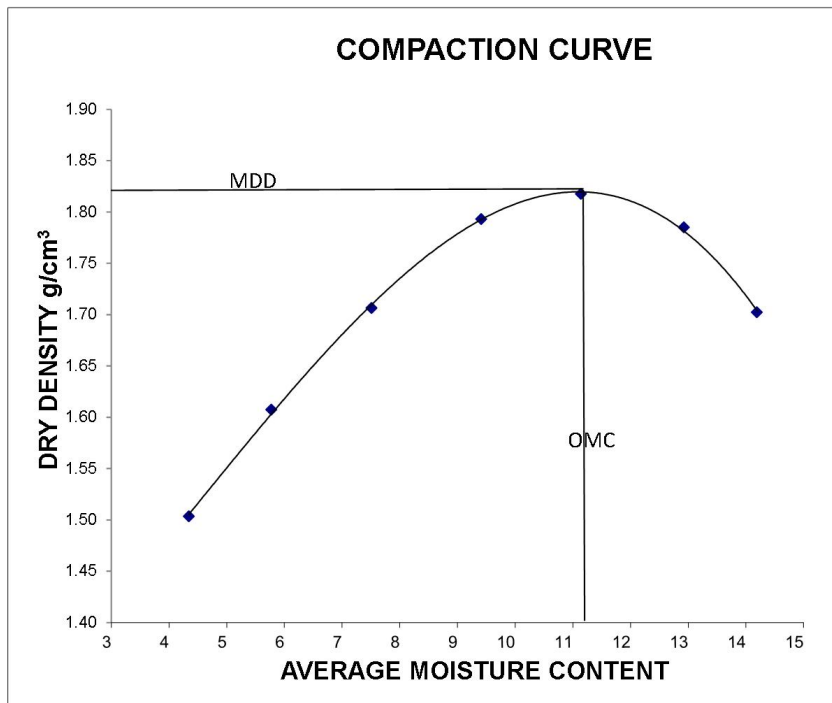
Depth:.. 1m

MDD: 1.82g/cm³

OPT.MC:11.2%

Mould.....4623g .

Wt. of mould & wet Soil (W2) g	6104.00	6228.00	6355.00	6475.00	6530.00	6526.00	6458.00							
Wt. of mould (W1) g	4623.00	4623.00	4623.00	4623.00	4623.00	4623.00	4623.00							
Wt. of wet soil (W2-W1) g	1481.00	1605.00	1732.00	1852.00	1907.00	1903.00	1835.00							
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.57	1.70	1.83	1.96	2.02	2.02	1.94							
MOISTURE CONTENT DETERMINATIONS for B. S. Mould, X = 944cm ³														
Container No.	MTT	YZ	XYZ	TAT	KIL	MU	ILL	0.11	OTA	F12	M24	PA3	FAR	0.II
Wt. of wet soil & container (g)	43.01	41.10	50.85	49.65	41.92	47.21	44.86	38.34	44.92	46.98	51.90	53.30	40.69	44.20
Wt. of Dry soil & container (g)	42.10	40.00	49.50	47.45	40.15	45.22	42.37	36.70	42.58	43.58	47.58	49.02	36.92	41.20
Wt. of Container (g)	18.26	17.41	17.50	17.43	17.72	17.29	17.63	17.98	17.31	17.46	14.97	15.05	14.25	15.66
Wt. of dry soil (Wd) g	23.84	22.59	32.00	30.02	22.43	27.93	24.74	18.72	25.27	26.12	32.61	33.97	22.67	25.54
Wt. of Moisture (Wm) g	0.91	1.10	1.35	2.20	1.77	1.99	2.49	1.64	2.34	3.40	4.32	4.28	3.77	3.00
Moistur Content 100(Wm/Wd) %	3.82	4.87	4.22	7.33	7.89	7.12	10.06	8.76	9.26	13.02	13.25	12.60	16.63	11.75
Average Moisture Content (m) %	4.34		5.77		7.51		9.41		11.14		12.92		14.19	
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.50	1.61	1.71	1.79	1.82	1.79	1.70							
C.B.R. (mseen of top & bottom) %														



LABORATORY COMPACTION TEST SHEET

Sample ID: **BH1, 15%**

Depth:.. **1m**

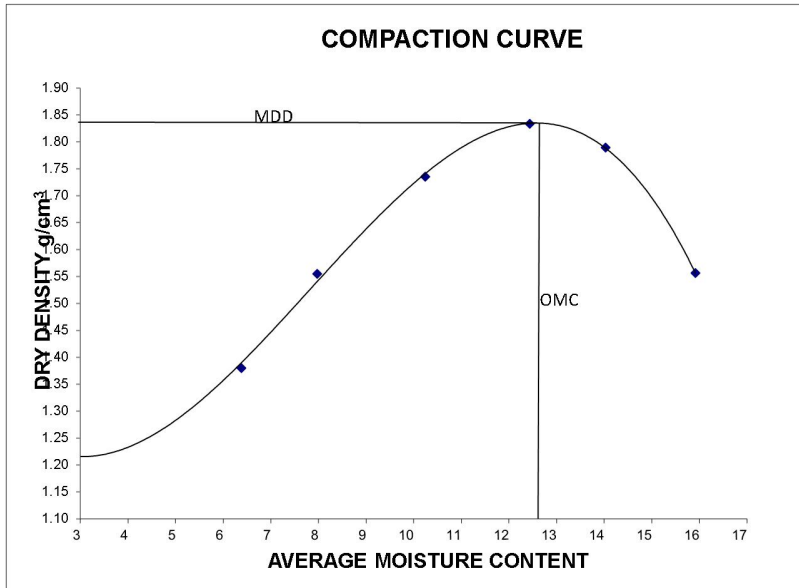
MDD: **1.84g/cm³**

OPT.MC: **12.6%**

Mould Weight.....4566g

0.35

Wt. of mould & wet Soil (W2) g	5748.00	5952.00	6151.00	6372.00	6512.00	6492.00	6269.00							
Wt. of mould (W1) g	4566.00	4566.00	4566.00	4566.00	4566.00	4566.00	4566.00							
Wt. of wet soil (W2-W1) g	1182.00	1386.00	1585.00	1806.00	1946.00	1926.00	1703.00							
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.25	1.47	1.68	1.91	2.06	2.04	1.80							
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³														
Container No.	UL	MP4	MAL	TA7	V12	PA4	MLU	B4	YT	JA81	0.21	0.36	0.13	HUR
Wt. of wet soil & container (g)	40.70	43.71	47.40	37.40	55.40	54.21	66.83	64.39	61.54	60.05	63.69	64.50	63.79	65.60
Wt. of Dry soil & container (g)	40.40	42.70	45.09	36.57	52.39	51.66	62.35	59.97	56.30	55.40	58.19	58.59	56.92	59.49
Wt. of Container (g)	17.01	18.14	17.60	17.55	17.00	17.40	17.91	17.47	14.71	17.52	17.89	17.57	17.26	17.38
Wt. of dry soil (Wd) g	23.39	24.56	27.49	19.02	35.39	34.26	44.44	42.50	41.59	37.88	40.30	41.02	39.66	42.11
Wt. of Moisture (Wm) g	0.30	1.01	2.31	0.83	3.01	2.55	4.48	4.42	5.24	4.65	5.50	5.91	6.87	6.11
Moistur Content 100(Wm/Wd) %	1.28	4.11	8.40	4.36	8.51	7.44	10.08	10.40	12.60	12.28	13.65	14.41	17.32	14.51
Average Moisture Content (m) %	2.70		6.38		7.97		10.24		12.44		14.03		15.92	
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.22	1.38	1.56		1.74	1.83	1.79	1.56						
C.B.R. (mseen of top & bottom) %														



LABORATORY COMPACTION TEST SHEET

Sample ID: **BH 1, 20%**

Depth:.. **1.0m**

MDD: **1.663g/cm³**

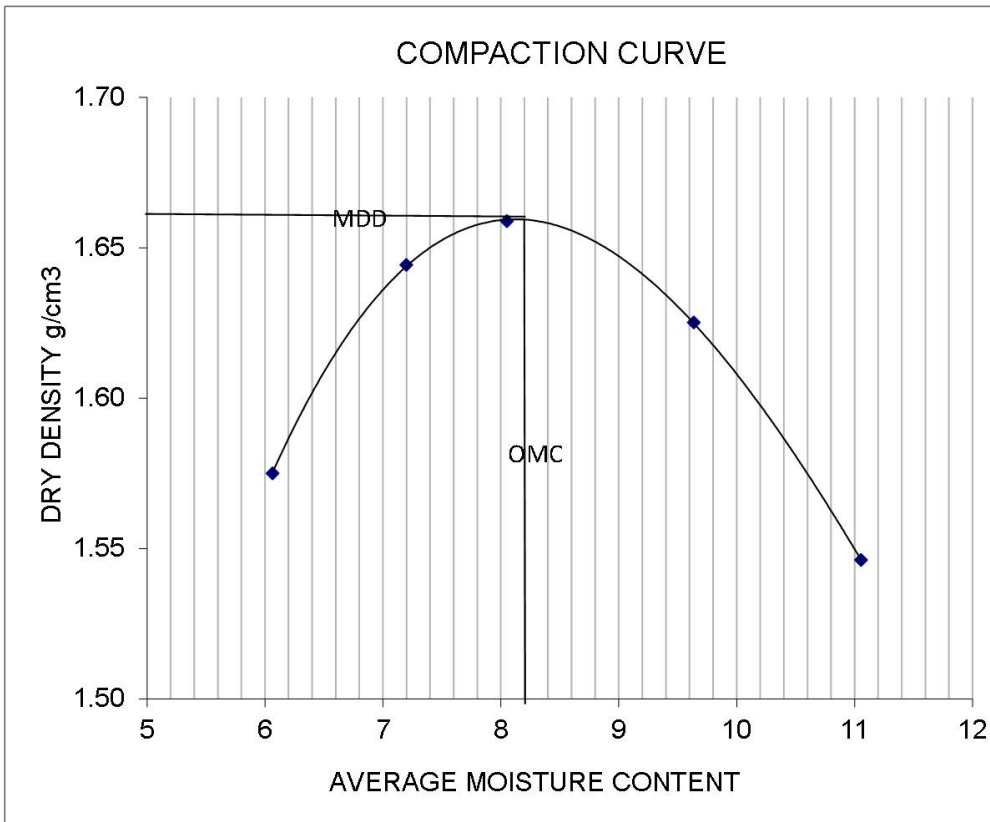
OPT.MC: **8.2%**

Mould.....**4621g**

Wt. of mould & wet Soil (W2) g	6200.00	6287.00	6315.00	6305.00	6244.00
Wt. of mould (W1) g	4623.00	4623.00	4623.00	4623.00	4623.00
Wt. of wet soil (W2-W1) g	1577.00	1664.00	1692.00	1682.00	1621.00
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.67	1.76	1.79	1.78	1.72

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm³

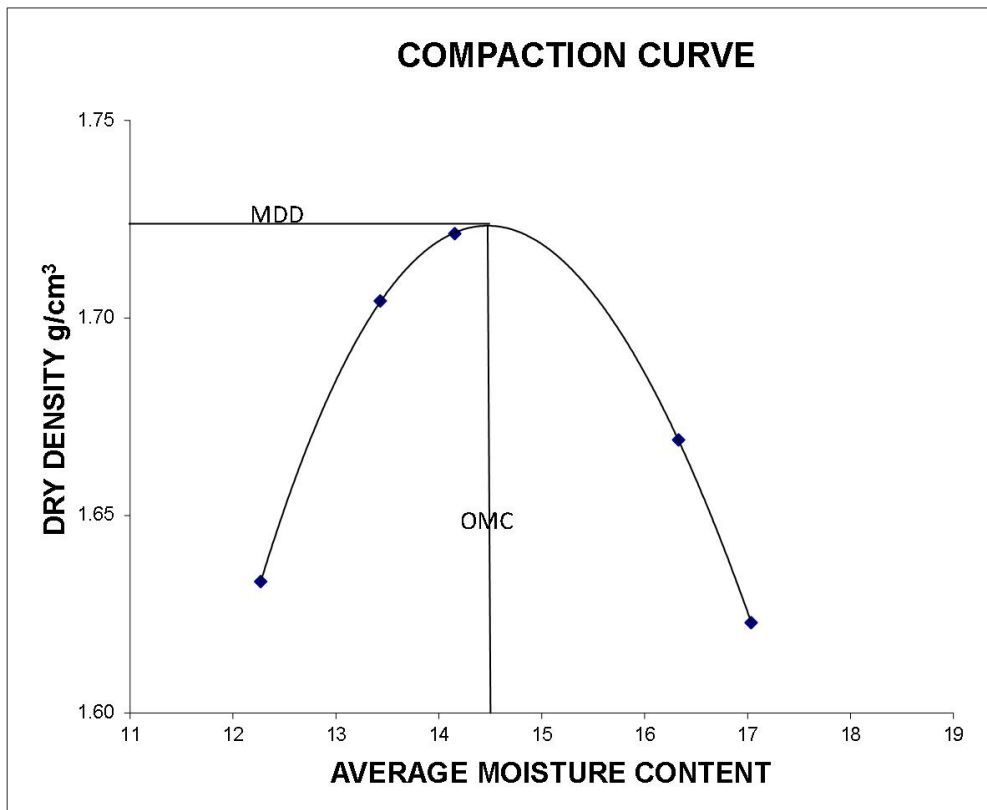
Container No.	MIL	0.30	0.68	LOP	LU.P	LMP	MAT	B12	B15	UP
Wt. of wet soil & container (g)	44.91	34.65	41.12	45.10	32.39	41.18	44.22	45.42	44.18	37.48
Wt. of Dry soil & container (g)	43.05	33.77	39.37	43.55	31.27	39.47	41.80	43.00	41.17	35.85
Wt. of Container (g)	17.00	16.12	18.01	18.57	17.60	17.85	17.42	17.10	17.31	18.68
Wt. of dry soil (Wd) g	26.05	17.65	21.36	24.98	13.67	21.62	24.38	25.90	23.86	17.17
Wt. of Moisture (Wm) g	1.86	0.88	1.75	1.55	1.12	1.71	2.42	2.42	3.01	1.63
Moistur Content 100(Wm/Wd) %	7.14	4.99	8.19	6.20	8.19	7.91	9.93	9.34	12.62	9.49
Average Moisture Content (m) %	6.06		7.20		8.05		9.63		11.05	
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.58		1.64		1.66		1.63		1.55	
C.B.R. (mseen of top & bottom) %										



LABORATORY COMPACTION TEST SHEET

Sample ID: **BH 2 Control** Depth:.. **1.0m**
 ...
 MDD: **1.723g/cm³** OPT.MC: **14.2%**
 Mould Wieght..... **3367.g**

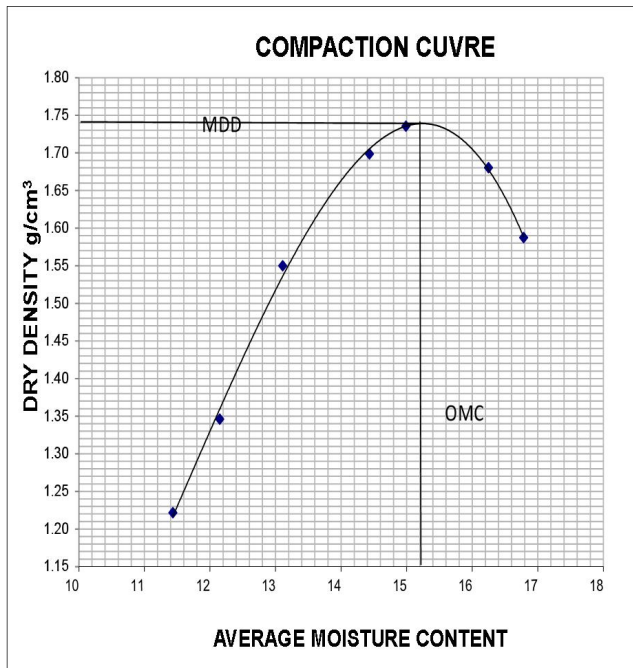
Wt. of mould & wet Soil (W2) g	5098.00	5192.00	5222.00	5200.00	5160.00					
Wt. of mould (W1) g	3367.00	3367.00	3367.00	3367.00	3367.00					
Wt. of wet soil (W2-W1) g	1731.00	1825.00	1855.00	1833.00	1793.00					
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.83	1.93	1.97	1.94	1.90					
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³										
Container No.	PA4	IE	0.11	PA8	PA6	LTP	A14	MUM	WOW	LP
Wt. of wet soil & container (g)	43.50	41.05	50.14	35.42	42.38	45.71	44.92	60.77	52.84	51.73
Wt. of Dry soil & container (g)	40.75	38.31	46.13	33.33	39.19	42.31	41.02	54.98	47.68	46.73
Wt. of Container (g)	17.33	16.90	17.29	17.20	17.40	17.44	17.79	18.49	17.77	17.00
Wt. of dry soil (Wd) g	23.42	21.41	28.84	16.13	21.79	24.87	23.23	36.49	29.91	29.73
Wt. of Moisture (Wm) g	2.75	2.74	4.01	2.09	3.19	3.40	3.90	5.79	5.16	5.00
Moistur Content 100(Wm/Wd) %	11.74	12.80	13.90	12.96	14.64	13.67	16.79	15.87	17.25	16.82
Average Moisture Content (m) %	12.27		13.43		14.16		16.33		17.03	
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.63	1.70	1.72	1.67	1.62					
C.B.R. (mseen of top & bottom) %										



LABORATORY COMPACTION TEST SHEET

Sample ID: BH2, 5% Depth:.. 1m
MDD: 1.74g/cm³ OPT.MC: 15.2%
Mould.....3365g

Wt. of mould & wet Soil (W2) g	4650.00	4790.00	5020.00	5200.00	5249.00	5209.00	5115.00							
Wt. of mould (W1) g	3365.00	3365.00	3365.00	3365.00	3365.00	3365.00	3365.00							
Wt. of wet soil (W2-W1) g	1285.00	1425.00	1655.00	1835.00	1884.00	1844.00	1750.00							
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.36	1.51	1.75	1.94	2.00	1.95	1.85							
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³														
Container No.	VOV	MIM	PA5	MWB	A10	A16	0.17	0.26	JKL	MAN	PA5	OMI	LOP	WUW
Wt. of wet soil & container (g)	33.93	40.94	37.12	45.21	54.23	46.76	48.01	45.11	37.21	41.80	49.84	52.97	43.51	41.79
Wt. of Dry soil & container (g)	31.79	39.09	34.57	42.45	50.00	43.39	44.20	41.65	34.65	38.49	45.58	47.77	39.85	38.25
Wt. of Container (g)	16.70	17.79	14.98	17.98	18.09	17.39	17.20	18.20	16.91	17.20	17.71	17.55	17.45	17.70
Wt. of dry soil (Wd) g	15.09	21.30	19.59	24.47	31.91	26.00	27.00	23.45	17.74	21.29	27.87	30.22	22.40	20.55
Wt. of Moisture (Wm) g	2.14	1.85	2.55	2.76	4.23	3.37	3.81	3.46	2.56	3.31	4.26	5.20	3.66	3.54
Moistur Content 100(Wm/Wd) %	14.18	8.69	13.02	11.28	13.26	12.96	14.11	14.75	14.43	15.55	15.29	17.21	16.34	17.23
Average Moisture Content (m) %	11.43	12.15	13.11	14.43	14.99	16.25	16.78							
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.22	1.35	1.55	1.70	1.74	1.68	1.59							
C.B.R. (mseen of top & bottom) %														



LABORATORY COMPACTION TEST SHEET

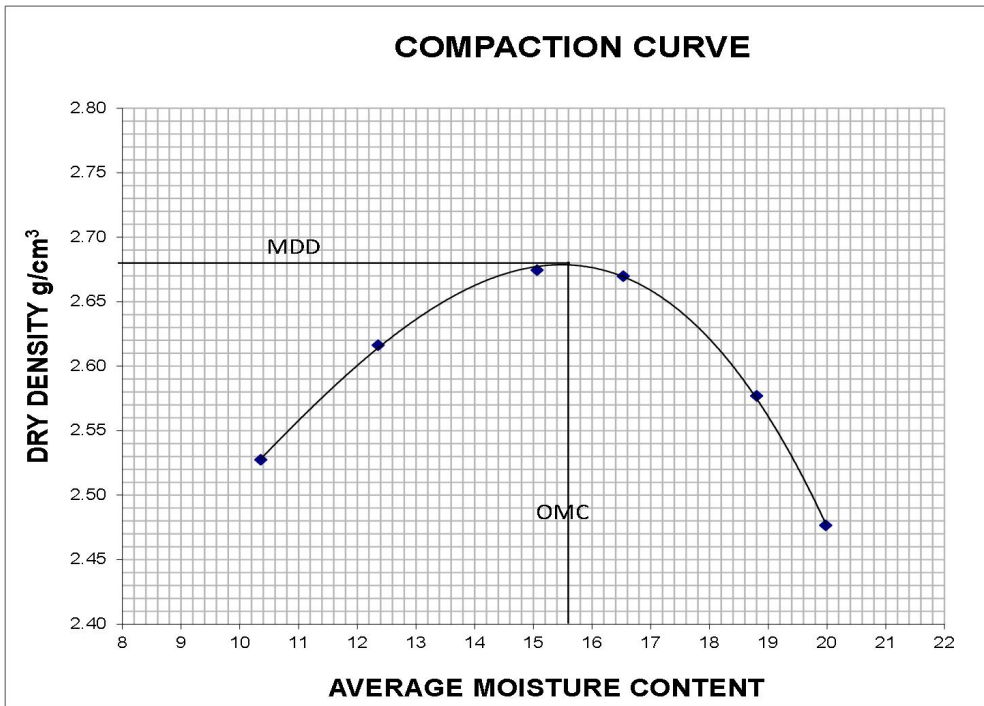
Sample ID: **BH 2, 10%**

Depth: **1m**

MDD: **2.68g/cm³**

OMC: **15.6%**

Wt. of mould & wet Soil (W2) g	5998.00	6140.00	6270.00	6302.00	6255.00	6170.00						
Wt. of mould (W1) g	3365.00	3365.00	3365.00	3365.00	3365.00	3365.00						
Wt. of wet soil (W2-W1) g	2633.00	2775.00	2905.00	2937.00	2890.00	2805.00						
Bulk Density (Pb) (W2-W1)/x g/cm ³	2.79	2.94	3.08	3.11	3.06	2.97						
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm³												
Container No.	RT2	PLZ	MLU	T2	O11	MUT	HUT	WBB	DAM	PA80	808	
Wt. of wet soil & container (g)	34.00	29.64	51.22	44.31	56.12	49.35	44.56	51.89	41.31	48.98	52.40	45.98
Wt. of Dry soil & container (g)	32.40	28.58	47.45	41.25	51.00	45.29	41.00	46.98	37.40	44.19	46.58	41.52
Wt. of Container (g)	17.56	17.91	17.51	16.00	18.00	17.50	18.50	18.50	16.81	18.45	18.61	18.23
Wt. of dry soil (Wd) g	14.84	10.67	29.94	25.25	33.00	27.79	22.50	28.48	20.59	25.74	27.97	23.29
Wt. of Moisture (Wm) g	1.60	1.06	3.77	3.06	5.12	4.06	3.56	4.91	3.91	4.79	5.82	4.46
Moistur Content 100(Wm/Wd) %	10.78	9.93	12.59	12.12	15.52	14.61	15.82	17.24	18.99	18.61	20.81	19.15
Average Moisture Content (m) %	10.36	12.36	15.06	16.53	18.80	19.98						
Dry Density = Pb/1+ (m/100) (g/cm ³)	2.53	2.62	2.67	2.67	2.58	2.48						
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

Sample ID: BH 2, 15%

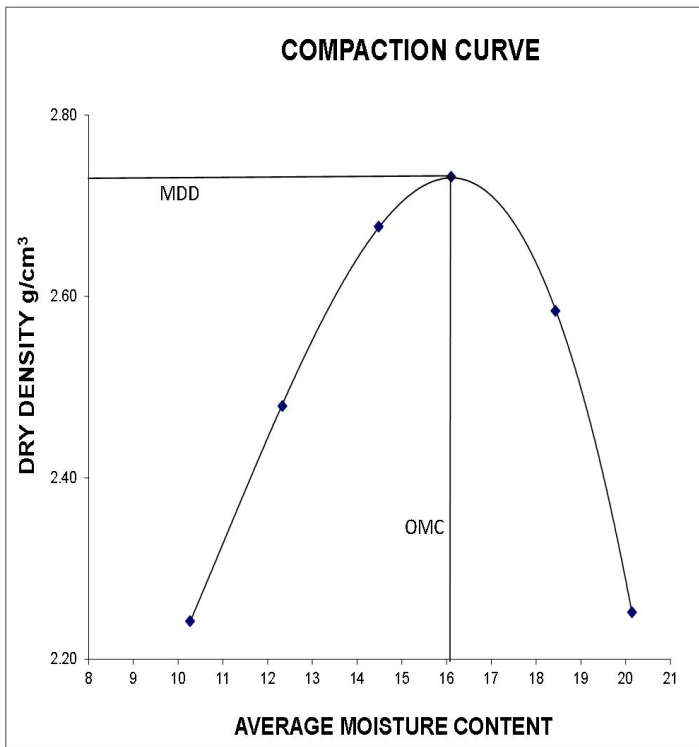
Depth: 1.0m

MDD: 2.73g/cm³

OMC: 16.1%

Mould weight: 3365g

Wt. of mould & wet Soil (W2) g	5699.00	5994.00	6258.00	6359.00	6254.00	5919.00						
Wt. of mould (W1) g	3365.00	3365.00	3365.00	3365.00	3365.00	3365.00						
Wt. of wet soil (W2-W1) g	2334.00	2629.00	2893.00	2994.00	2889.00	2554.00						
Bulk Density (Pb) (W2-W1)/x g/cm ³	2.47	2.78	3.06	3.17	3.06	2.71						
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³												
Container No.	TT1	TT2	RT5	MUM	WOW	PA8	MAT	PA6	MB	FOG	PAM	LS
Wt. of wet soil & container (g)	34.01	29.62	51.17	44.32	55.79	49.38	44.42	51.98	41.12	49.01	52.39	46.07
Wt. of Dry soil & container (g)	32.41	28.58	47.49	41.20	50.99	45.37	41.00	47.10	37.37	44.21	46.58	41.51
Wt. of Container (g)	17.58	17.91	17.52	16.00	18.00	17.54	18.50	18.39	16.84	18.39	18.60	18.15
Wt. of dry soil (Wd) g	14.83	10.67	29.97	25.20	32.99	27.83	22.50	28.71	20.53	25.82	27.98	23.36
Wt. of Moisture (Wm) g	1.60	1.04	3.68	3.12	4.80	4.01	3.42	4.88	3.75	4.80	5.81	4.56
Moistur Content 100(Wm/Wd) %	10.79	9.75	12.28	12.38	14.55	14.41	15.20	17.00	18.27	18.59	20.76	19.52
Average Moisture Content (m) %	10.27		12.33		14.48		16.10		18.43		20.14	
Dry Density = Pb/1+ (m/100) (g/cm ³)	2.24		2.48		2.68		2.73		2.58		2.25	
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

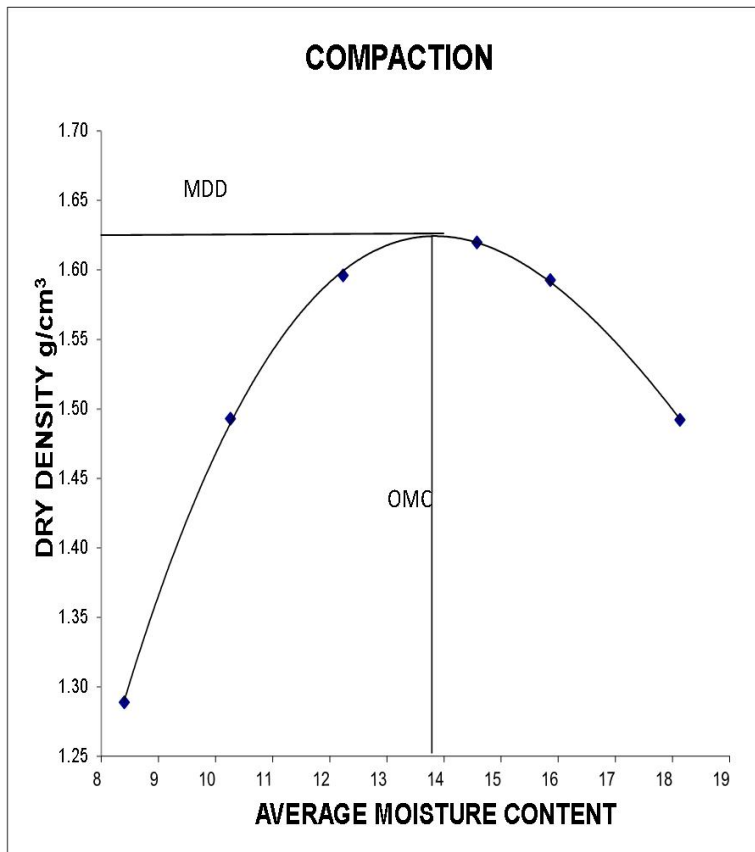
Sample ID: **BH3, Control** Depth: **1m**

MDD: **1.62g/cm³** OPT.MC: **13.8%**

Mould: **4558g**

Wt. of mould & wet Soil (W2) g	5877.00	6112.00	6249.00	6310.00	6300.00	6222.00
Wt. of mould (W1) g	4558.00	4558.00	4558.00	4558.00	4558.00	4558.00
Wt. of wet soil (W2-W1) g	1319.00	1554.00	1691.00	1752.00	1742.00	1664.00
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.40	1.65	1.79	1.86	1.85	1.76

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm ³												
Container No.	MOB	MOM	LO	LU.P	MIM	V10	V16	KIL	LT	RA8	MG	LOP
Wt. of wet soil & container (g)	46.10	47.77	55.59	63.61	57.41	60.67	53.67	56.11	71.38	66.59	70.49	65.98
Wt. of Dry soil & container (g)	44.00	45.36	52.12	59.14	53.01	56.01	49.00	51.09	64.02	59.89	62.29	58.44
Wt. of Container (g)	18.71	17.00	16.62	17.55	17.45	17.48	15.71	17.89	18.00	17.28	16.89	17.00
Wt. of dry soil (Wd) g	25.29	28.36	35.50	41.59	35.56	38.53	33.29	33.20	46.02	42.61	45.40	41.44
Wt. of Moisture (Wm) g	2.10	2.41	3.47	4.47	4.40	4.66	4.67	5.02	7.36	6.70	8.20	7.54
Moistur Content 100(Wm/Wd) %	8.30	8.50	9.77	10.75	12.37	12.09	14.03	15.12	15.99	15.72	18.06	18.19
Average Moisture Content (m) %	8.40	10.26	12.23	14.57	15.86	18.13						
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.29	1.49	1.60	1.62	1.59	1.49						
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

Sample ID: BH2, 20% Depth:.. 1.0m

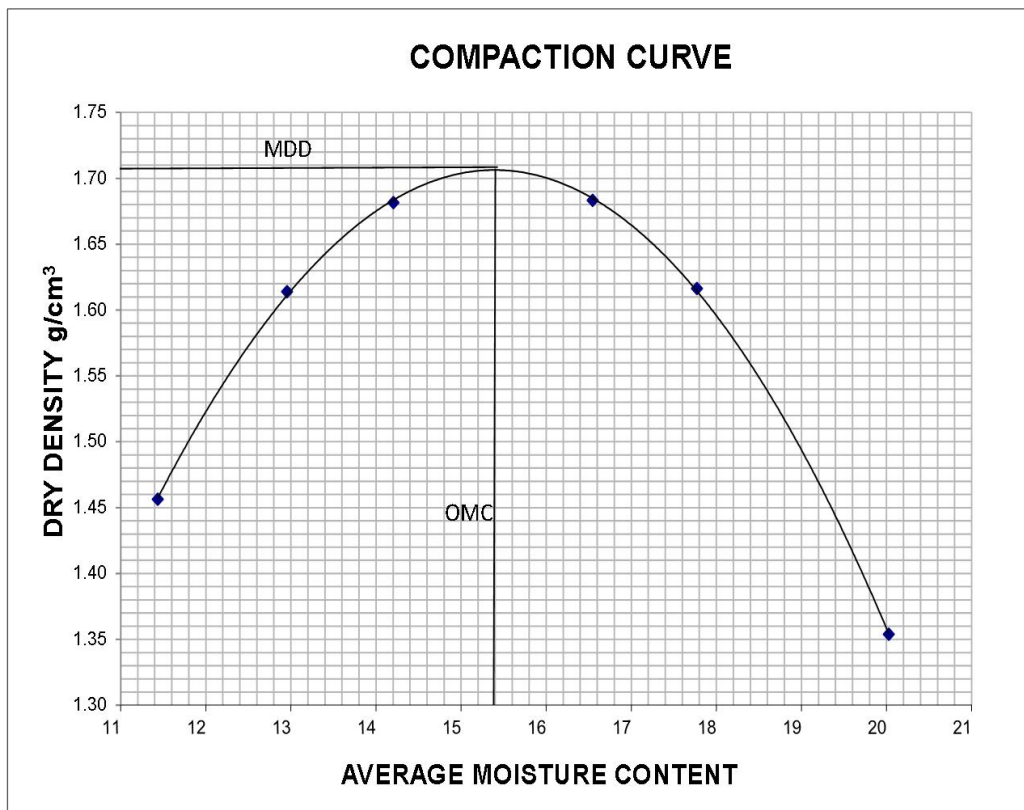
MDD: 1.71g/cm³ OPT.MC: 15.4%

Mould Weigh :3365g

Wt. of mould & wet Soil (W2) g	4898.00	5087.00	5179.00	5218.00	5163.00	4900.00
Wt. of mould (W1) g	3366.00	3366.00	3366.00	3366.00	3366.00	3366.00
Wt. of wet soil (W2-W1) g	1532.00	1721.00	1813.00	1852.00	1797.00	1534.00
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.62	1.82	1.92	1.96	1.90	1.63

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm³

Container No.	MP4	MUM	NON	T8	UL	C80	VT	T4	T7	A	O80	B12
Wt. of wet soil & container (g)	31.09	33.27	39.62	46.05	39.61	51.00	59.00	56.19	48.89	42.69	44.12	42.61
Wt. of Dry soil & container (g)	29.30	32.23	36.83	43.02	36.91	46.89	54.09	49.69	44.39	38.73	40.19	38.00
Wt. of Container (g)	17.42	18.90	17.27	17.00	17.39	18.70	17.10	16.89	17.17	17.90	17.23	17.90
Wt. of dry soil (Wd) g	11.88	13.33	19.56	26.02	19.52	28.19	36.99	32.80	27.22	20.83	22.96	20.10
Wt. of Moisture (Wm) g	1.79	1.04	2.79	3.03	2.70	4.11	4.91	6.50	4.50	3.96	3.93	4.61
Moistur Content 100(Wm/Wd) %	15.07	7.80	14.26	11.64	13.83	14.58	13.27	19.82	16.53	19.01	17.12	22.94
Average Moisture Content (m) %	11.43		12.95		14.21		16.55		17.77		20.03	
Dry Density = Pb/1+(m/100) (g/cm ³)	1.46		1.61		1.68		1.68		1.62		1.35	
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

SampleID: **BH3, 5%**

Depth: **1.0m**

MDD: **1.76g/cm³**

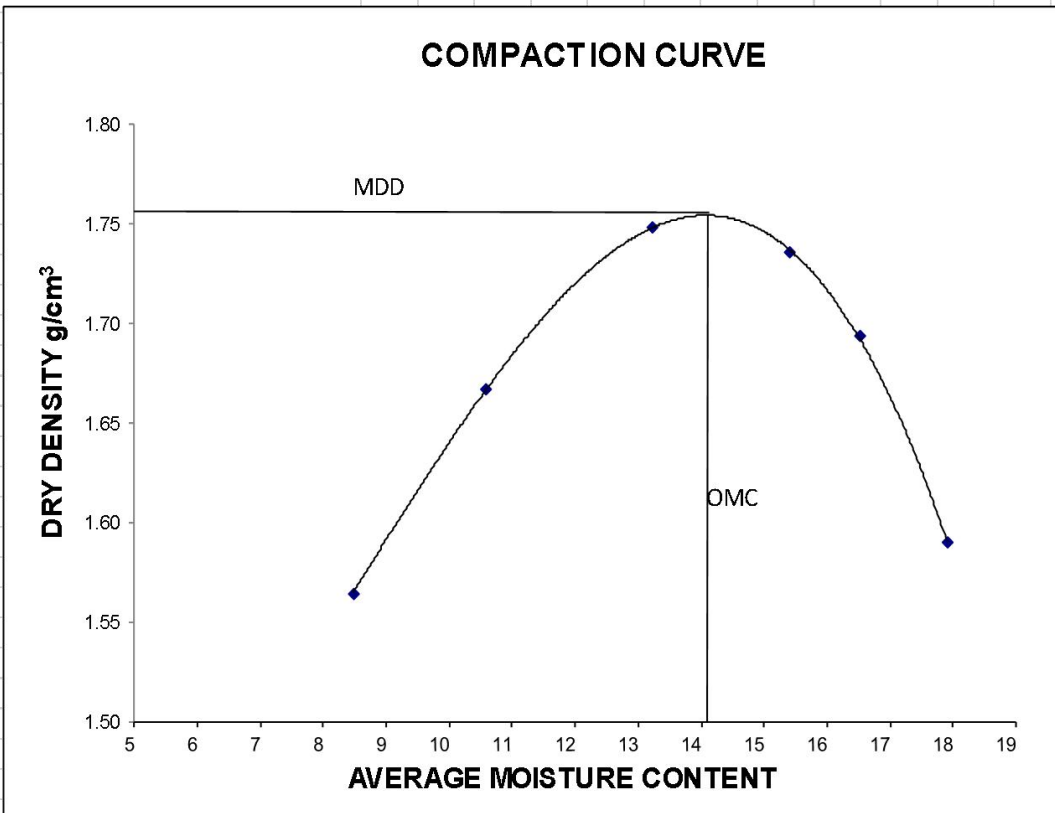
OPT.MC: **14.1%**

Mould Weight: **3358g.**

Wt. of mould & wet Soil (W2) g	4960.00	5098.00	5226.00	5249.00	5221.00	5128.00
Wt. of mould (W1) g	3358.00	3358.00	3358.00	3358.00	3358.00	3358.00
Wt. of wet soil (W2-W1) g	1602.00	1740.00	1868.00	1891.00	1863.00	1770.00
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.70	1.84	1.98	2.00	1.97	1.88

MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm³

Container No.	MA	LP	LOP	MA	TA12	KL	V15	V19	LS	MK	MOM	DE2
Wt. of wet soil & container (g)	47.29	39.62	36.78	40.91	49.00	30.09	51.10	50.62	51.32	42.26	44.09	55.25
Wt. of Dry soil & container (g)	44.77	37.85	35.34	38.24	44.91	28.48	46.04	46.99	47.09	37.29	39.29	50.81
Wt. of Container (g)	14.00	17.61	18.59	16.99	17.42	14.54	18.35	18.00	17.00	11.10	17.45	18.72
Wt. of dry soil (Wd) g	30.77	20.24	16.75	21.25	27.49	13.94	27.69	28.99	30.09	26.19	21.84	32.09
Wt. of Moisture (Wm) g	2.52	1.77	1.44	2.67	4.09	1.61	5.06	3.63	4.23	4.97	4.80	4.44
Moistur Content 100(Wm/Wd) %	8.19	8.75	8.60	12.56	14.88	11.55	18.27	12.52	14.06	18.98	21.98	13.84
Average Moisture Content (m) %	8.47		10.58		13.21		15.40		16.52		17.91	
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.56		1.67		1.75		1.74		1.69		1.59	
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

Sample ID: **BH 3, 10%**

Depth: **1.0m**

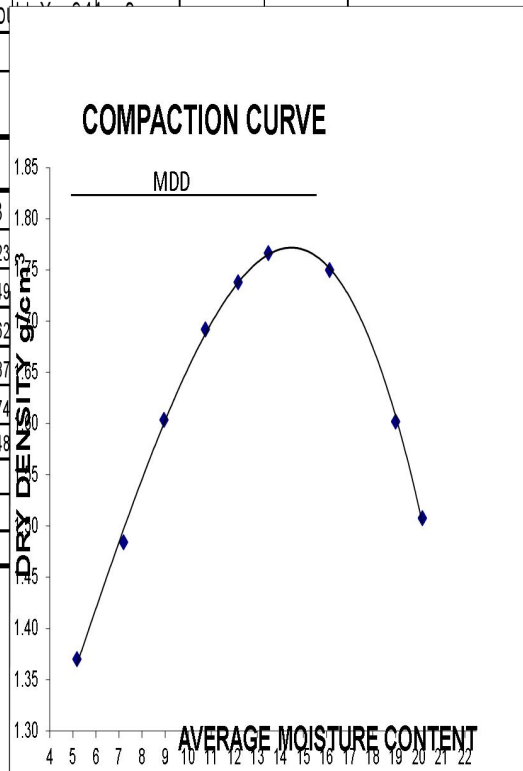
MDD: **1.77g/cm³**

OPT.MC: **14.6%**

B.S. / C.B.R. Mould: **3358g**

Wt. of mould & wet Soil (W2) g	1.45	1.58	1.74	1.87	1.94	2.00	2.02	1.90	1.80
Wt. of mould (W1) g	MOISTURE CONTENT DETERMINATIONS for B.S. Mo								
Wt. of wet soil (W2-W1) g									
Bulk Density (Pb) (W2-W1)/x g/cm ³									

Container No.	0.18	OMI	V12	M12	HTY	V12	TA4	MI2	TA5	V13
Wt. of wet soil & container (g)	47.51	49.00	50.10	41.31	48.74	33.79	37.53	35.58	44.69	45.23
Wt. of Dry soil & container (g)	46.05	47.69	47.49	40.19	45.21	33.09	34.65	34.68	40.79	43.49
Wt. of Container (g)	16.52	16.68	17.00	17.00	17.29	16.68	15.89	17.77	17.65	16.62
Wt. of dry soil (Wd) g	29.53	29.68	30.49	23.19	27.92	16.41	18.98	16.91	23.14	26.87
Wt. of Moisture (Wm) g	1.46	1.31	2.61	1.12	3.53	0.70	2.88	0.90	3.90	1.74
Moistur Content 100(Wm/Wd) %	4.94	4.41	8.56	4.83	12.64	4.27	15.17	5.32	16.85	6.48
Average Moisture Content (m) %										
Dry Density = Pb/1+ (m/100) (g/cm ³)										
C.B.R. (mseen of top & bottom) %										



LABORATORY COMPACTION TEST SHEET

Sample ID: BH 3, 15%

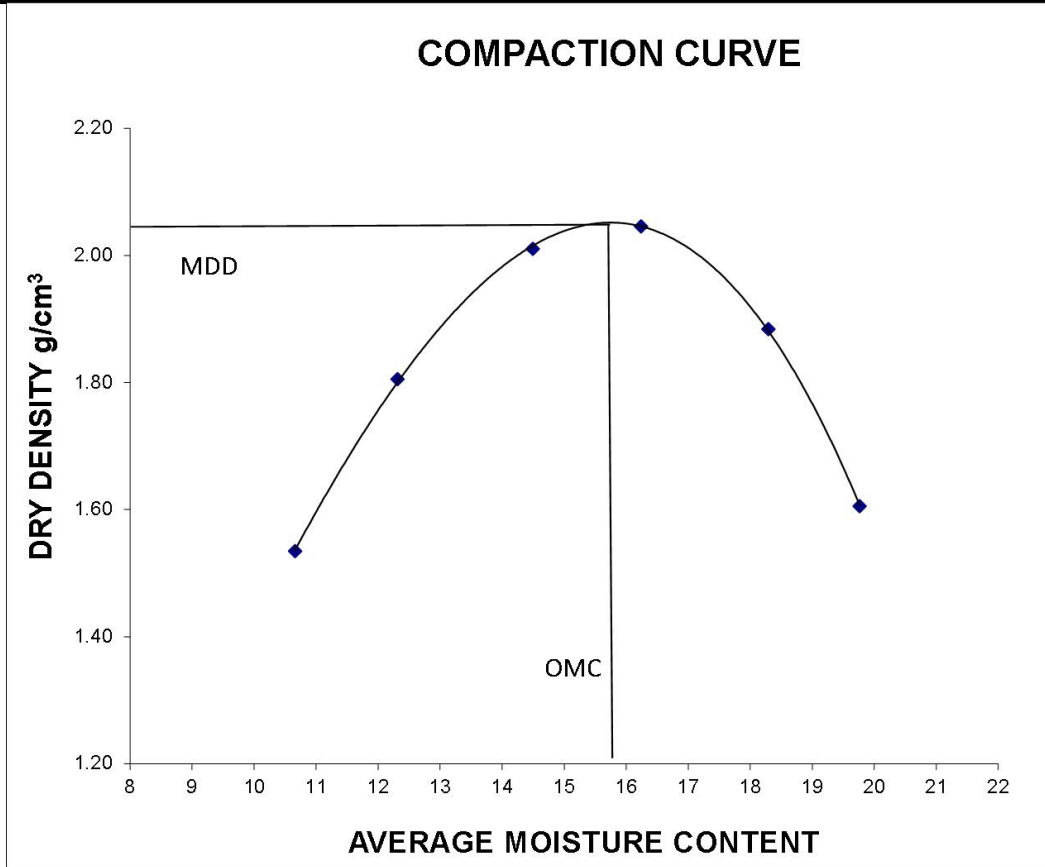
Depth: 1m

MDD: 2.05g/cm³

OMC: 15.8%

Mould weight: 3665g

Wt. of mould & wet Soil (W2) g	4968.00	5279.00	5538.00	5610.00	5469.00	5180.00						
Wt. of mould (W1) g	3365.00	3365.00	3365.00	3365.00	3365.00	3365.00						
Wt. of wet soil (W2-W1) g	1603.00	1914.00	2173.00	2245.00	2104.00	1815.00						
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.70	2.03	2.30	2.38	2.23	1.92						
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm³												
Container No.	MA8	MRT	TA8	MVP	MRT	MNO	LP	GHY	OZH	HP	TA5	LOP
Wt. of wet soil & container (g)	34.00	29.72	51.21	44.32	55.78	49.39	44.43	51.88	41.15	48.98	52.39	45.99
Wt. of Dry soil & container (g)	32.34	28.64	47.43	41.28	50.98	45.37	41.00	46.97	37.41	44.22	46.58	41.57
Wt. of Container (g)	17.59	17.91	17.43	16.00	17.98	17.53	18.49	18.49	16.82	18.38	18.52	18.09
Wt. of dry soil (Wd) g	14.75	10.73	30.00	25.28	33.00	27.84	22.51	28.48	20.59	25.84	28.06	23.48
Wt. of Moisture (Wm) g	1.66	1.08	3.78	3.04	4.80	4.02	3.43	4.91	3.74	4.76	5.81	4.42
Moistur Content 100(Wm/Wd) %	11.25	10.07	12.60	12.03	14.55	14.44	15.24	17.24	18.16	18.42	20.71	18.82
Average Moisture Content (m) %	10.66	12.31	12.31	14.49	16.24	18.29	19.77					
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.53	1.81	2.01	2.05	1.88	1.61						
C.B.R. (mseen of top & bottom) %												



LABORATORY COMPACTION TEST SHEET

Sample ID: **BH3,20%**

Depth:.. **1.0m**

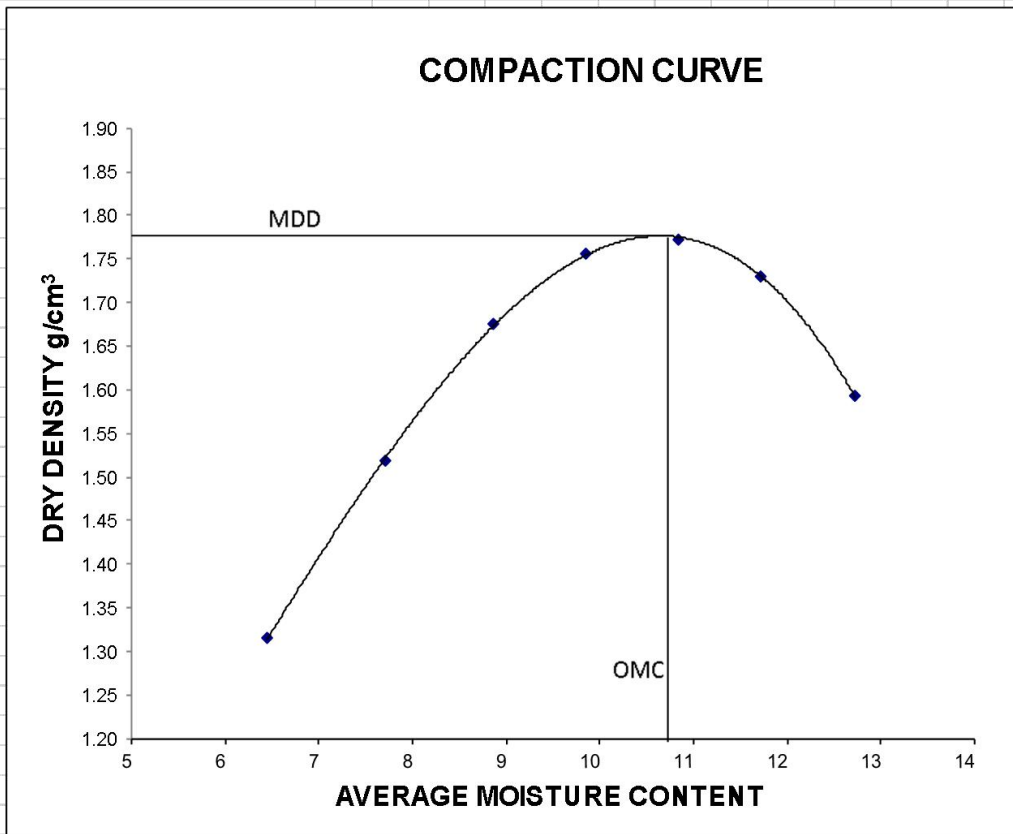
MDD: **1.78g/cm³**

OPT.MC: **10.7%**

Mould..... **3356g**

Wt. of mould & wet Soil (W2) g	4678.00	4900.00	5079.00	5177.00	5210.00	5181.00	5051.00
Wt. of mould (W1) g	3356.00	3356.00	3356.00	3356.00	3356.00	3356.00	3356.00
Wt. of wet soil (W2-W1) g	1322.00	1544.00	1723.00	1821.00	1854.00	1825.00	1695.00
Bulk Density (Pb) (W2-W1)/x g/cm ³	1.40	1.64	1.83	1.93	1.96	1.93	1.80

MOISTURE CONTENT DETERMINATIONS														for B.S. Mould, X = 944cm ³	
Container No.	NUT	MOY	PA7	RT2	MLK	ALP	OZX	MO	O.31	JP	V10	LOP	V11	0.28	
Wt. of wet soil & container (g)	30.91	33.42	32.88	38.09	39.88	33.47	37.50	41.73	49.71	45.03	48.21	37.96	49.14	50.09	
Wt. of Dry soil & container (g)	29.87	32.51	31.65	36.63	39.25	31.34	35.70	39.42	46.32	42.64	45.07	35.43	44.72	47.29	
Wt. of Container (g)	15.99	15.68	17.47	15.00	17.49	16.98	17.56	15.77	17.56	18.42	16.93	14.82	17.45	16.97	
Wt. of dry soil (Wd) g	13.88	16.83	14.18	21.63	21.76	14.36	18.14	23.65	28.76	24.22	28.14	20.61	27.27	30.32	
Wt. of Moisture (Wm) g	1.04	0.91	1.23	1.46	0.63	2.13	1.80	2.31	3.39	2.39	3.14	2.53	4.42	2.80	
Moistur Content 100(Wm/Wd) %	7.49	5.41	8.67	6.75	2.90	14.83	9.92	9.77	11.79	9.87	11.16	12.28	16.21	9.23	
Average Moisture Content (m) %	6.45		7.71		8.86		9.85		10.83		11.72		12.72		
Dry Density = Pb/1+ (m/100) (g/cm ³)	1.32	1.52	1.68	1.76	1.77	1.73	1.59								
C. B. R. (mseen of top & bottom) %															



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH1, Control Depth: 1m

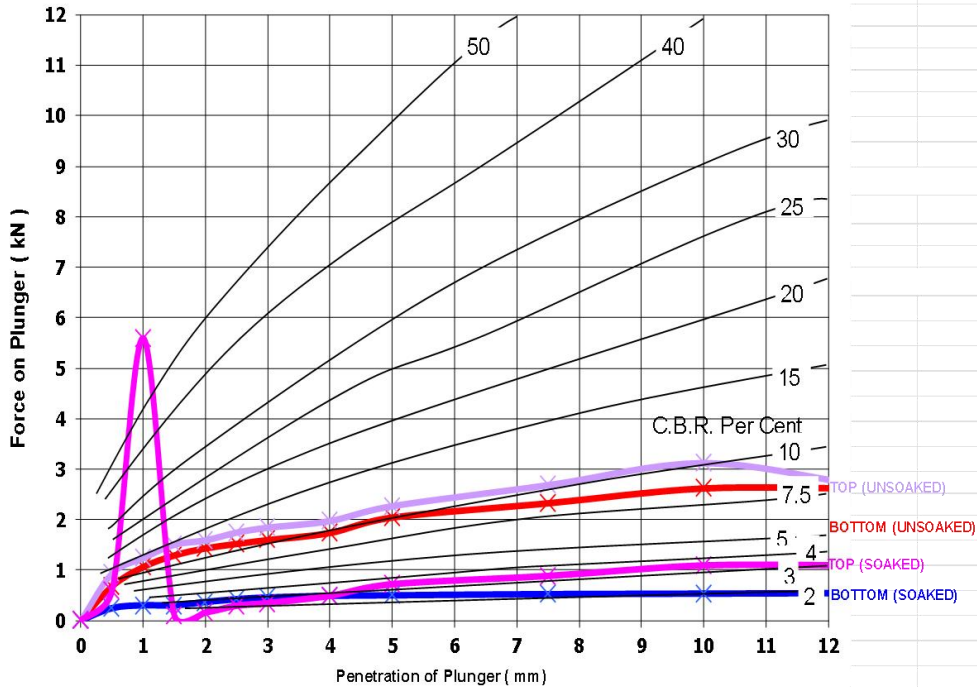
	TEST ON BOTTOM (UNSOAKED)								SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	62.00	97.00	118.00	131.00	139.00	146.00	159.00	187.00	213.00	240.00	240.00
Ditto corrected												
Load (KN)	0	0.67817	1.061	1.2907	1.4329	1.5204	1.59697	1.73917	2.04543	2.32983	2.62516	2.62516
C. B. R. %												

	TEST ON TOP (UNSOAKED)								SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	85.00	113.00	137.00	145.00	159.00	168.00	180.00	207.00	245.00	285.00	246.00
Ditto corrected												
Load (KN)	0	0.92974	1.23601	1.49853	1.58603	1.73917	1.83761	1.96887	2.2642	2.67985	3.11737	2.69078
C. B. R. %												

	TEST ON BOTTOM (SOAKED)								SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	22.00	27.00	27.00	33.00	38.00	41.00	44.00	45.00	47.00	48.00	49.00
Ditto corrected												
Load (KN)	0	0.24064	0.29533	0.29533	0.36096	0.41565	0.44846	0.48128	0.49222	0.51409	0.52503	0.53597
C. B. R. %												

	TEST ON TOP (SOAKED)								SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	54.00	510.00	9.00	14.00	26.00	31.00	44.00	65.00	80.00	99.00	99.00
Ditto corrected												
Load (KN)	0	0.59066	5.57846	0.09844	0.15313	0.28439	0.33908	0.48128	0.71098	0.87505	1.08288	1.08288
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	11.479	10.248	3.138	2.466
TOP	13.131	11.344	2.147	3.562



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH1, 5%

Depth: 1m

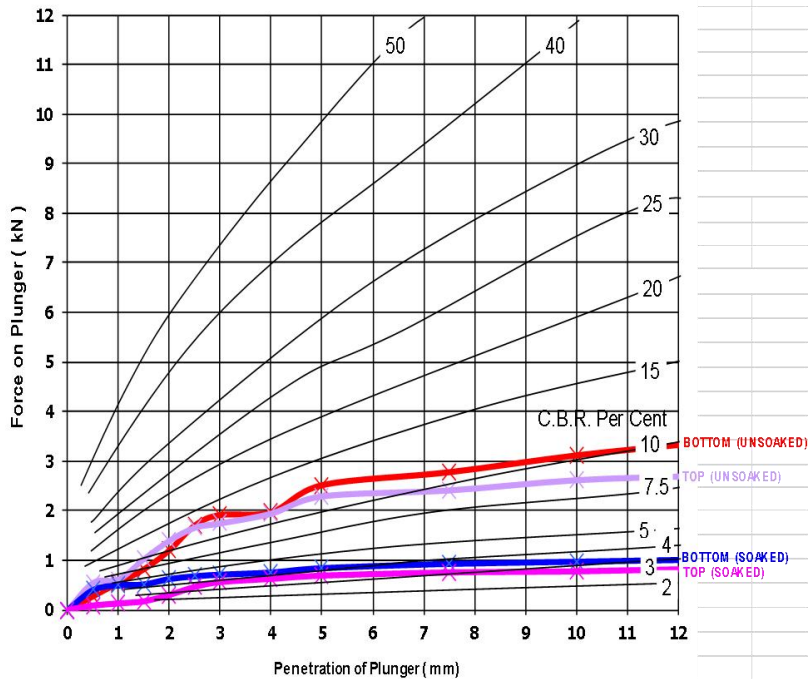
TEST ON BOTTOM (UNSOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	25.00	50.00	75.00	110.00	156.00	175.00	180.00	230.00	254.00	285.00	309.00
Ditto corrected												
Load (kN)	0	0.27345	0.54691	0.82036	1.2032	1.70635	1.91418	1.96867	2.51577	2.77829	3.11737	3.37989
C. B. R. %												

TEST ON TOP (UNSOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	50.00	56.00	94.00	128.00	152.00	160.00	178.00	210.00	221.00	240.00	248.00
Ditto corrected												
Load (kN)	0	0.54691	0.61254	1.02819	1.40008	1.6626	1.7501	1.94699	2.29701	2.41733	2.62516	2.71266
C. B. R. %												

TEST ON BOTTOM (SOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	37.00	45.00	47.00	57.00	62.00	65.00	69.00	77.00	85.00	89.00	93.00
Ditto corrected												
Load (kN)	0	0.40471	0.49222	0.51409	0.62347	0.67817	0.71098	0.75473	0.84224	0.92974	0.9735	1.01725
C. B. R. %												

TEST ON TOP (SOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	8.00	12.00	16.00	26.00	43.00	52.00	58.00	64.00	70.00	72.00	77.00
Ditto corrected												
Load (kN)	0	0.08751	0.13126	0.17501	0.30627	0.47034	0.56878	0.63441	0.70004	0.78567	0.78755	0.84224
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	12.883	12.604	5.120	4.220
TOP	12.553	11.508	3.551	3.507



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH1, 10%** Depth: **1m**

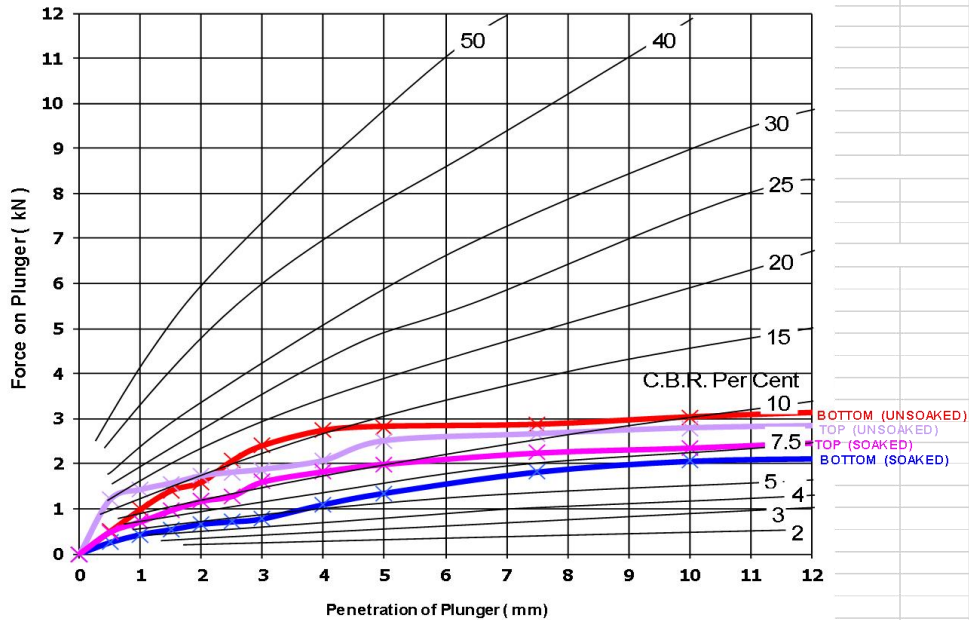
TEST ON BOTTOM (UNSOAKED)								SURCHARGE				
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	45.00	90.00	128.00	145.00	188.00	219.00	250.00	258.00	262.00	277.00	288.00
Ditto corrected												
Load (KN)	0	0.49222	0.98443	1.40008	1.58603	2.05637	2.39545	2.73454	2.82204	2.8658	3.02987	3.15019
C. B. R. %												

TEST ON TOP (UNSOAKED)								SURCHARGE				
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	110.00	130.00	143.00	158.00	165.00	171.00	189.00	229.00	243.00	255.00	260.00
Ditto corrected												
Load (KN)	0	1.2032	1.42196	1.56416	1.72823	1.80479	1.87042	2.06731	2.50484	2.65797	2.78923	2.84392
C. B. R. %												

TEST ON BOTTOM (SOAKED)								SURCHARGE				
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	23.00	39.00	49.00	60.00	65.00	71.00	100.00	123.00	166.00	188.00	194.00
Ditto corrected												
Load (KN)	0	0.25158	0.42659	0.53597	0.65629	0.71098	0.77661	1.09382	1.34539	1.81573	2.05637	2.122
C. B. R. %												

TEST ON TOP (SOAKED)								SURCHARGE				
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	44.00	65.00	88.00	107.00	117.00	146.00	167.00	182.00	205.00	215.00	228.00
Ditto corrected												
Load (KN)	0	0.48128	0.71098	0.96256	1.17038	1.27976	1.59697	1.82667	1.99074	2.24232	2.3517	2.4939
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	15.526	14.138	5.368	6.740
TOP	13.626	12.549	9.662	9.974



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH1, 15%

Depth: 1m

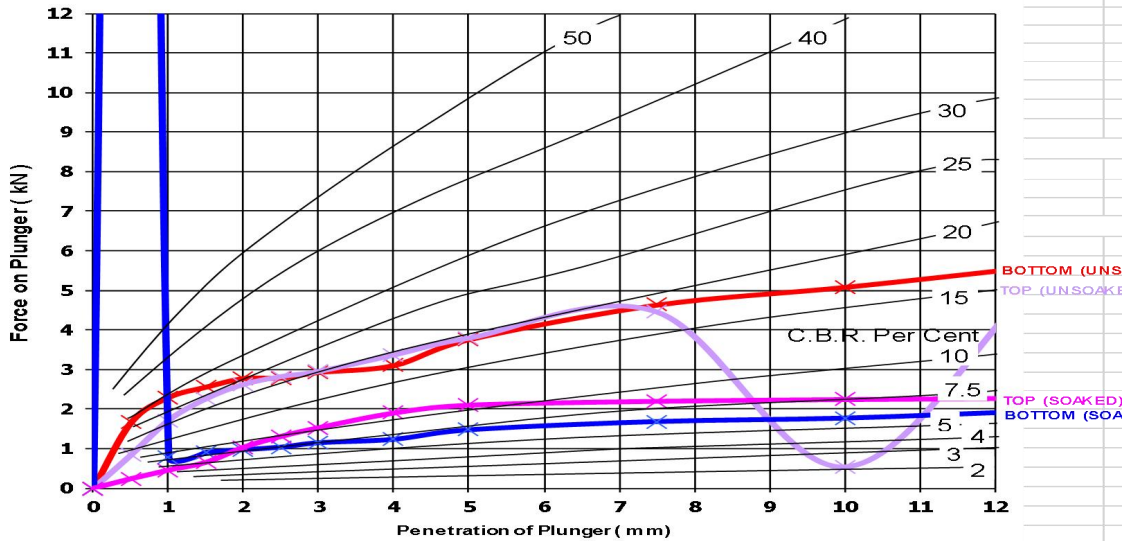
TEST ON BOTTOM (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	152.00	210.00	234.00	254.00	255.00	268.00	284.00	344.00	424.00	465.00	512.00
Ditto corrected												
Load (KN)	0	1.6626	2.29701	2.55953	2.77829	2.78923	2.93142	3.10643	3.76272	4.63778	5.08624	5.60033
C. B. R. %												

TEST ON TOP (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	77.00	157.00	207.00	240.00	258.00	270.00	308.00	347.00	407.00	49.00	466.00
Ditto corrected												
Load (KN)	0	0.84224	1.71729	2.2642	2.62516	2.82204	2.9533	3.36895	3.79554	4.45183	0.53597	5.09718
C. B. R. %												

TEST ON BOTTOM (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	5859.00	72.00	83.00	89.00	95.00	105.00	113.00	135.00	154.00	162.00	178.00
Ditto corrected												
Load (KN)	0	64.0866	0.78755	0.90787	0.9735	1.03912	1.14851	1.23601	1.47665	1.68448	1.77198	1.94699
C. B. R. %												

TEST ON TOP (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	22.00	42.00	60.00	95.00	120.00	140.00	174.00	192.00	201.00	205.00	208.00
Ditto corrected												
Load (KN)	0	0.24064	0.4594	0.65629	1.03912	1.31258	1.53134	1.90324	2.10012	2.19857	2.24232	2.27514
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	21.059	18.851	7.845	7.398
TOP	21.306	19.016	9.910	10.522



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH1, 20%**

Depth: **1m**

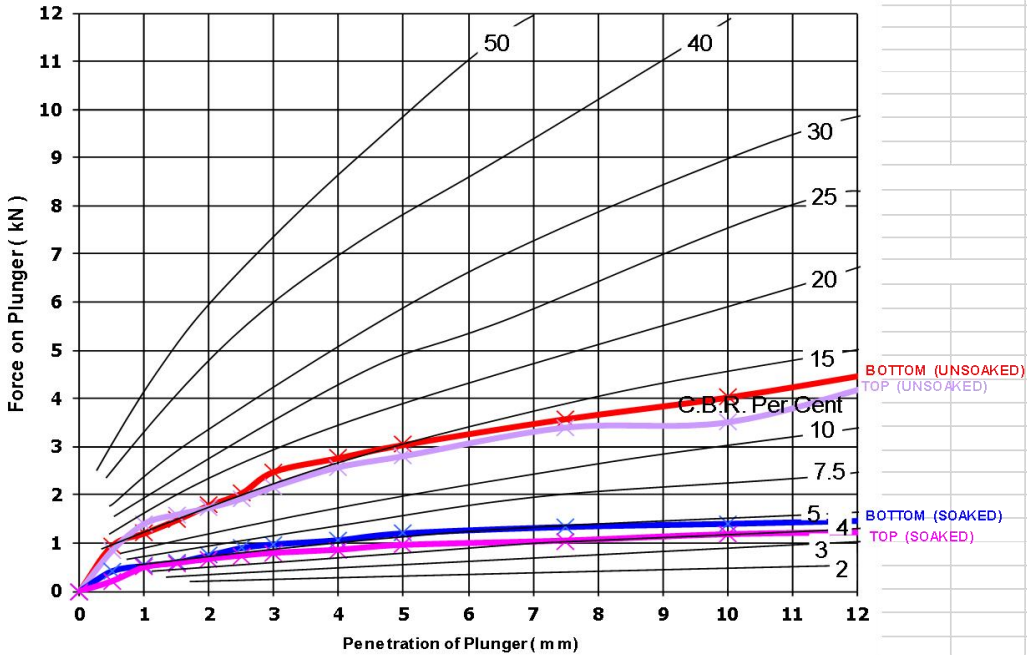
TEST ON BOTTOM (UNSOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	86.00	110.00	135.00	163.00	186.00	227.00	253.00	278.00	327.00	368.00	419.00
Ditto corrected												
Load (KN)	0	0.94068	1.2032	1.47665	1.78292	2.0345	2.48296	2.76735	3.04081	3.57678	4.02524	4.58308
C. B. R. %												

TEST ON TOP (UNSOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	77.00	128.00	145.00	158.00	175.00	198.00	235.00	256.00	310.00	320.00	398.00
Ditto corrected												
Load (KN)	0	0.84224	1.40008	1.58603	1.72823	1.91418	2.16575	2.57047	2.80017	3.39083	3.50021	4.35338
C. B. R. %												

TEST ON BOTTOM (SOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	39.00	48.00	55.00	68.00	82.00	89.00	97.00	110.00	122.00	129.00	135.00
Ditto corrected												
Load (KN)	0	0.41565	0.52503	0.6016	0.74379	0.89693	0.9735	1.061	1.2032	1.33445	1.40008	1.47665
C. B. R. %												

TEST ON TOP (SOAKED)											SURCHARGE	
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	19.00	45.00	53.00	61.00	67.00	72.00	78.00	87.00	95.00	107.00	111.00
Ditto corrected												
Load (KN)	0	0.20782	0.49222	0.57972	0.66723	0.73286	0.78755	0.85318	0.95162	1.03912	1.17038	1.21413
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	15.360	15.234	6.772	6.028
TOP	14.452	14.029	5.533	4.768



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH2 Control

Depth: 1m

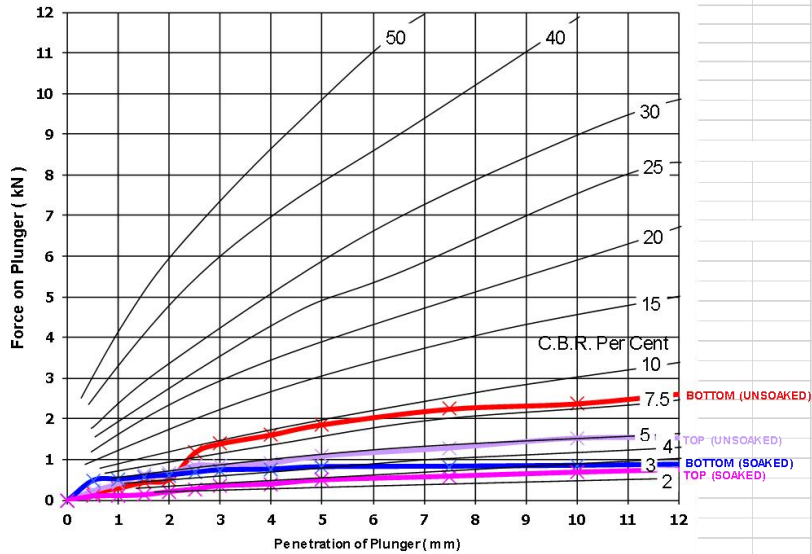
TEST ON BOTTOM (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	16.00	27.00	40.00	47.00	107.00	127.00	147.00	170.00	205.00	217.00	245.00
Ditto corrected												
Load (kN)	0	0.17501	0.29533	0.43753	0.51409	1.17038	1.38915	1.60791	1.85949	2.24232	2.37358	2.67985
C. B. R. %												

TEST ON TOP (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	21.00	37.00	57.00	60.00	78.00	78.00	83.00	99.00	117.00	139.00	139.00
Ditto corrected												
Load (kN)	0	0.2297	0.40471	0.62347	0.65629	0.85318	0.85318	0.90787	1.08288	1.27976	1.5204	1.5204
C. B. R. %												

TEST ON BOTTOM (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	44.00	47.00	52.00	56.00	62.00	67.00	69.00	74.00	75.00	77.00	80.00
Ditto corrected												
Load (kN)	0	0.48128	0.51409	0.56878	0.61254	0.67817	0.73286	0.75473	0.80942	0.82036	0.84224	0.87505
C. B. R. %												

TEST ON TOP (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	9.00	10.00	12.00	19.00	25.00	32.00	36.00	45.00	53.00	62.00	69.00
Ditto corrected												
Load (kN)	0	0.09844	0.10938	0.13126	0.20782	0.27345	0.35002	0.39377	0.49222	0.57972	0.67817	0.75473
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	8.836	9.316	5.120	4.055
TOP	6.441	5.425	2.065	2.466



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH2 5%**

Depth: **1m**

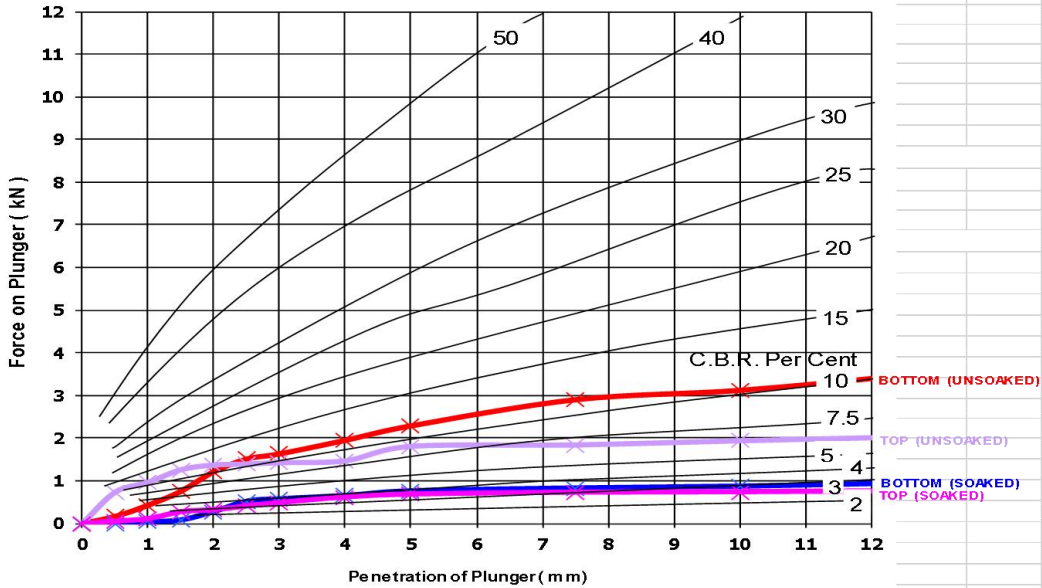
TEST ON BOTTOM (UNSOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	15.00	39.00	69.00	111.00	138.00	149.00	178.00	209.00	265.00	285.00	317.00		
Ditto corrected														
Load (KN)	0	0.16407	0.42659	0.75473	1.21413	1.50946	1.62978	1.94699	2.28607	2.89861	3.11737	3.46739		
C. B. R. %														

TEST ON TOP (UNSOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	67.00	88.00	115.00	125.00	127.00	130.00	134.00	165.00	168.00	177.00	185.00		
Ditto corrected														
Load (KN)	0	0.73286	0.96256	1.25789	1.36727	1.38915	1.42196	1.46571	1.80479	1.83761	1.93605	2.02356		
C. B. R. %														

TEST ON BOTTOM (SOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	0.00	3.00	7.00	25.00	47.00	52.00	59.00	69.00	75.00	79.00	86.00		
Ditto corrected														
Load (KN)	0	0	0.03281	0.07657	0.27345	0.51409	0.56878	0.64535	0.75473	0.82036	0.86411	0.94068		
C. B. R. %														

TEST ON TOP (SOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	5.00	10.00	25.00	29.00	37.00	44.00	56.00	62.00	66.00	67.00	69.00		
Ditto corrected														
Load (KN)	0	0.05469	0.10938	0.27345	0.31721	0.40471	0.48128	0.61254	0.67817	0.72192	0.73286	0.75473		
C. B. R. %														

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	11.396	11.453	3.881	3.781
TOP	10.488	9.042	3.056	3.398



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH2, 10%** Depth: **1m**

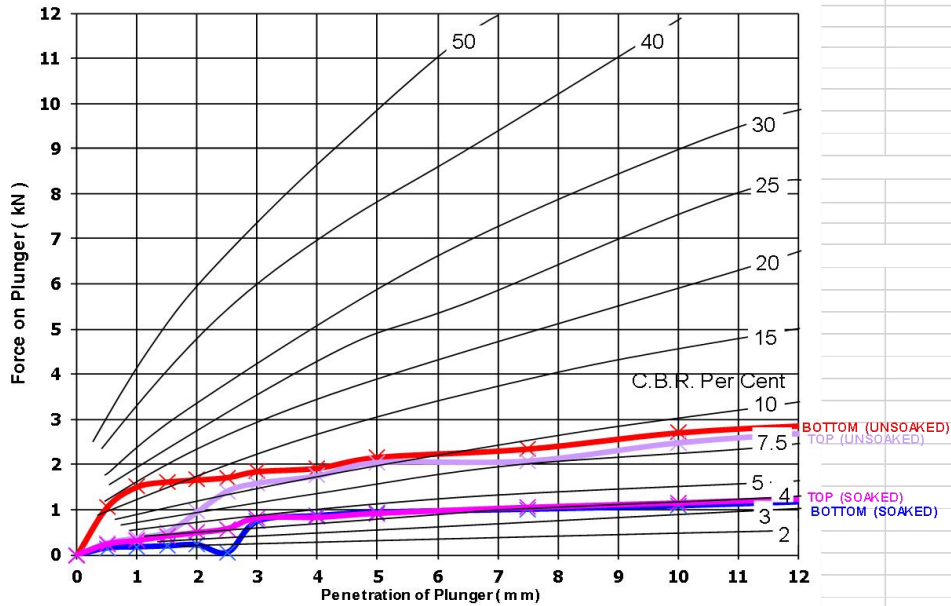
TEST ON BOTTOM (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	97.00	138.00	148.00	152.00	157.00	169.00	176.00	198.00	215.00	248.00	265.00
Ditto corrected												
Load (KN)	0	1.061	1.50946	1.61885	1.6626	1.71729	1.84855	1.92511	2.16575	2.3517	2.71266	2.89861
C. B. R. %												

TEST ON TOP (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	24.00	34.00	46.00	87.00	129.00	145.00	160.00	187.00	190.00	227.00	250.00
Ditto corrected												
Load (KN)	0	0.26252	0.3719	0.50315	0.95162	1.41102	1.58603	1.7501	2.04543	2.07825	2.48296	2.73454
C. B. R. %												

TEST ON BOTTOM (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	14.00	16.00	18.00	20.00	5.00	68.00	79.00	86.00	92.00	99.00	109.00
Ditto corrected												
Load (KN)	0	0.15313	0.17501	0.19689	0.21876	0.05469	0.74379	0.86411	0.94068	1.00631	1.08288	1.19226
C. B. R. %												

TEST ON TOP (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	22.00	29.00	38.00	45.00	53.00	75.00	76.00	84.00	96.00	105.00	115.00
Ditto corrected												
Load (KN)	0	0.24064	0.31721	0.41565	0.49222	0.57972	0.82036	0.8313	0.9188	1.05006	1.14851	1.25789
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	12.966	10.850	0.413	4.713
TOP	10.653	10.248	4.377	4.603



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH2, 15%**

Depth: **1m**

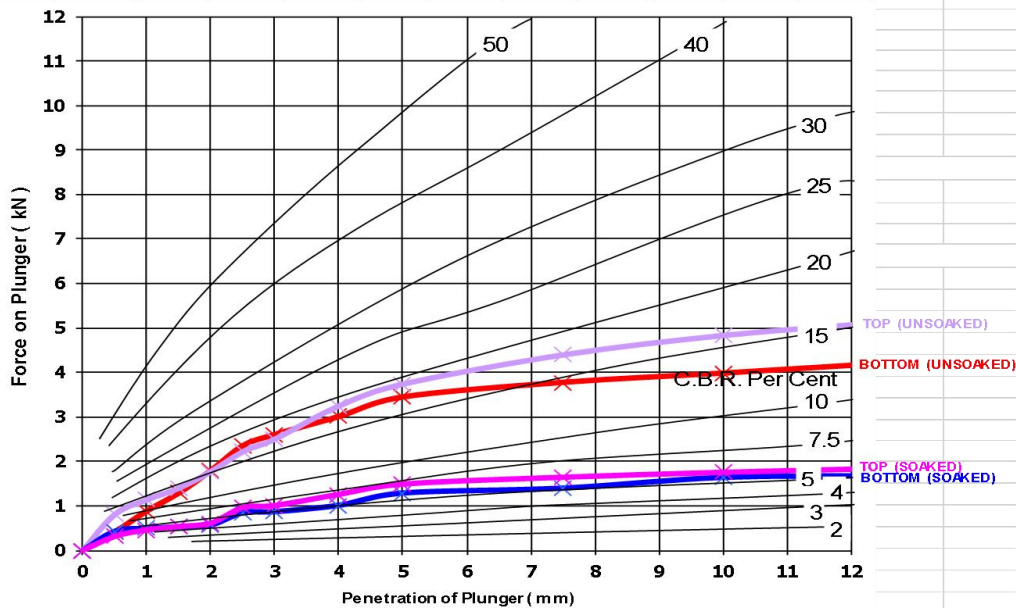
TEST ON BOTTOM (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	38.00	81.00	118.00	164.00	215.00	238.00	275.00	315.00	345.00	364.00	384.00		
Ditto corrected														
Load (KN)	0	0.41565	0.88599	1.2907	1.79386	2.3517	2.60328	3.00799	3.44552	3.77366	3.98149	4.20025		
C. B. R. %														

TEST ON TOP (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	74.00	104.00	128.00	162.00	203.00	229.00	297.00	342.00	402.00	442.00	469.00		
Ditto corrected														
Load (KN)	0	0.80942	1.13757	1.40008	1.77198	2.22044	2.50484	3.24863	3.74085	4.39714	4.83466	5.12999		
C. B. R. %														

TEST ON BOTTOM (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	39.00	45.00	48.00	52.00	77.00	79.00	92.00	117.00	127.00	149.00	152.00		
Ditto corrected														
Load (KN)	0	0.42659	0.49222	0.52503	0.56878	0.84224	0.86411	1.00631	1.27976	1.38915	1.62978	1.6626		
C. B. R. %														

TEST ON TOP (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	29.00	42.00	49.00	56.00	88.00	92.00	115.00	136.00	150.00	160.00	168.00		
Ditto corrected														
Load (KN)	0	0.31721	0.4594	0.53597	0.61254	0.96256	1.00631	1.25789	1.48759	1.64072	1.7501	1.83761		
C. B. R. %														

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	17.755	17.262	6.359	6.412
TOP	16.764	18.742	7.267	7.453



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH2, 20% Depth: 1m

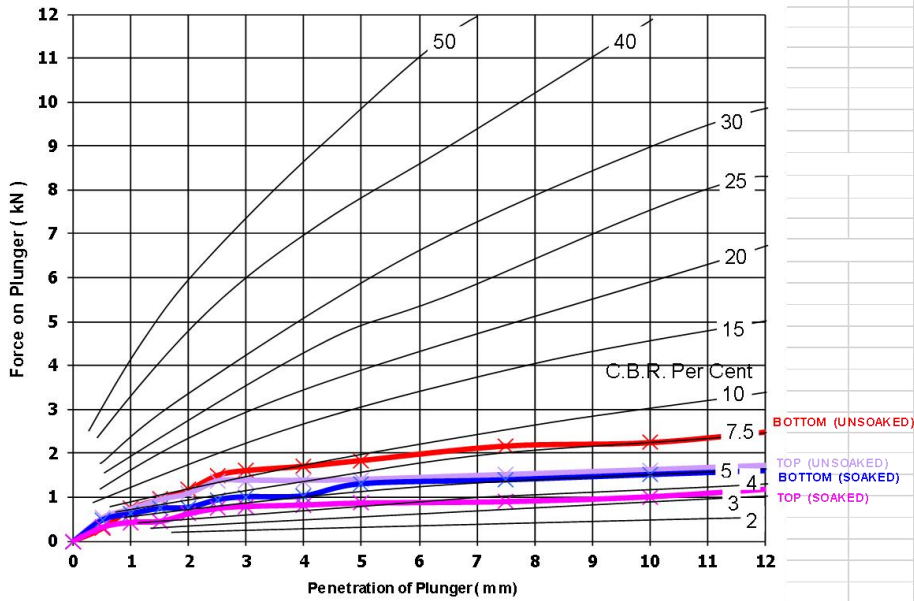
TEST ON BOTTOM (UNSOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	27.00	68.00	87.00	107.00	137.00	147.00	156.00	168.00	198.00	205.00	233.00
Ditto corrected												
Load (kN)	0	0.29533	0.74379	0.95162	1.17038	1.49853	1.60791	1.70635	1.83761	2.16575	2.24232	2.54859
C. B. R. %												

TEST ON TOP (UNSOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	48.00	67.00	86.00	99.00	125.00	126.00	126.00	128.00	138.00	148.00	159.00
Ditto corrected												
Load (kN)	0	0.52503	0.73286	0.94068	1.08288	1.36727	1.37821	1.37821	1.40008	1.50946	1.61885	1.73917
C. B. R. %												

TEST ON BOTTOM (SOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	44.00	57.00	68.00	70.00	86.00	92.00	94.00	119.00	127.00	138.00	148.00
Ditto corrected												
Load (kN)	0	0.48128	0.62347	0.74379	0.76567	0.94068	1.00631	1.02819	1.30164	1.38915	1.50946	1.61885
C. B. R. %												

TEST ON TOP (SOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	29.00	39.00	41.00	57.00	68.00	72.00	75.00	79.00	82.00	92.00	112.00
Ditto corrected												
Load (kN)	0	0.31721	0.42659	0.44846	0.62347	0.74379	0.78755	0.82036	0.86411	0.89693	1.00631	1.22507
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	11.314	9.206	7.102	6.521
TOP	10.323	7.014	5.616	4.329



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH3 Control**

Depth: **1m**

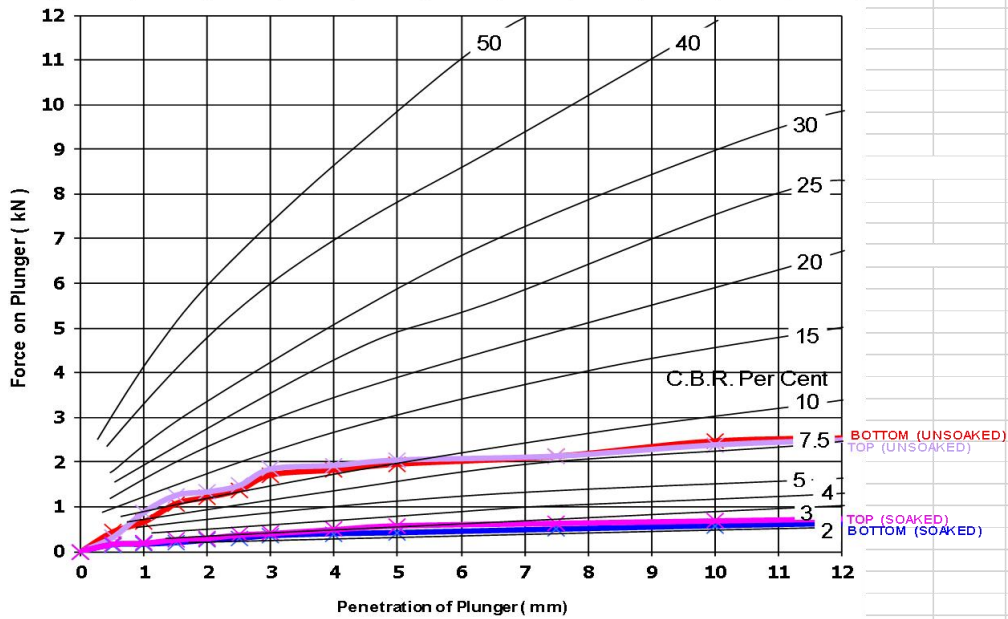
TEST ON BOTTOM (UNSOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	40.00	61.00	98.00	111.00	126.00	157.00	167.00	179.00	195.00	226.00	233.00		
Ditto corrected														
Load (KN)	0	0.43753	0.66723	1.07194	1.21413	1.37821	1.71729	1.82667	1.95793	2.13294	2.47202	2.54859		
C. B. R. %														

TEST ON TOP (UNSOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	29.00	81.00	115.00	122.00	135.00	169.00	176.00	187.00	195.00	218.00	230.00		
Ditto corrected														
Load (KN)	0	0.31721	0.88599	1.25789	1.33445	1.47665	1.84855	1.92511	2.04543	2.13294	2.38452	2.51577		
C. B. R. %														

TEST ON BOTTOM (SOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	14.00	15.00	18.00	23.00	27.00	32.00	36.00	38.00	45.00	52.00	58.00		
Ditto corrected														
Load (KN)	0	0.15313	0.16407	0.19689	0.25158	0.29533	0.35002	0.39377	0.41565	0.49222	0.56878	0.63441		
C. B. R. %														

TEST ON TOP (SOAKED)												SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	15.00	17.00	24.00	27.00	34.00	37.00	45.00	53.00	58.00	63.00	68.00		
Ditto corrected														
Load (KN)	0	0.16407	0.18595	0.26252	0.29533	0.3719	0.40471	0.49222	0.57972	0.63441	0.6891	0.74379		
C. B. R. %														

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	10.405	9.809	2.230	2.082
TOP	11.149	10.248	2.808	2.904



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH3 5%

Depth: 1m

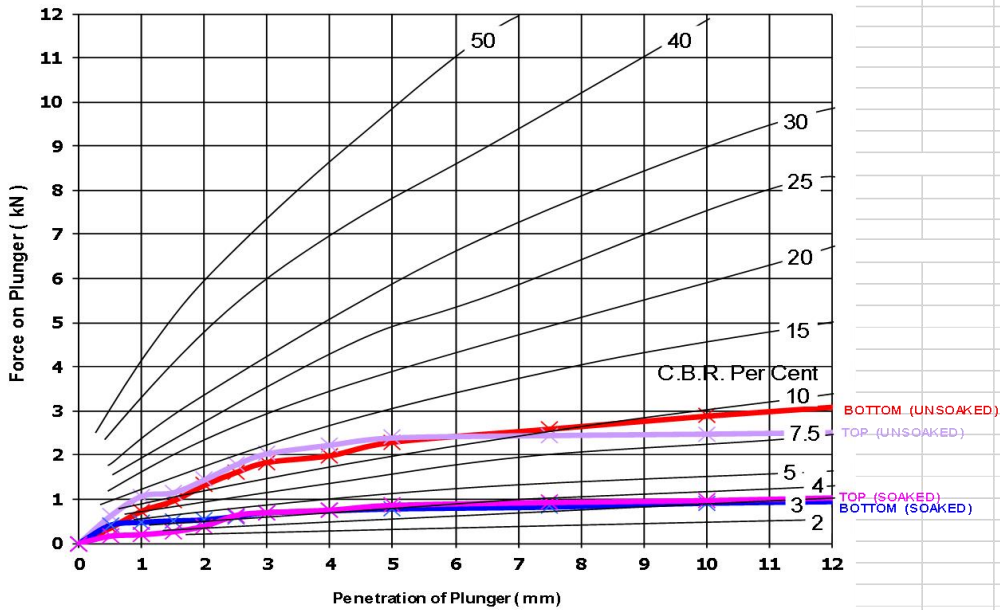
TEST ON BOTTOM (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	32.00	67.00	88.00	121.00	147.00	168.00	182.00	210.00	237.00	264.00	287.00
Ditto corrected												
Load (KN)	0	0.35002	0.73286	0.96256	1.32352	1.60791	1.83761	1.99074	2.29701	2.59234	2.88767	3.13925
C. B. R. %												

TEST ON TOP (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	57.00	98.00	105.00	132.00	163.00	186.00	204.00	219.00	224.00	227.00	231.00
Ditto corrected												
Load (KN)	0	0.62347	1.07194	1.14851	1.44384	1.78292	2.0345	2.23138	2.39545	2.45015	2.48296	2.52671
C. B. R. %												

TEST ON BOTTOM (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	38.00	44.00	47.00	49.00	56.00	64.00	68.00	72.00	76.00	84.00	88.00
Ditto corrected												
Load (KN)	0	0.41565	0.48128	0.51409	0.53597	0.61254	0.70004	0.74379	0.78755	0.8313	0.9188	0.96256
C. B. R. %												

TEST ON TOP (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	15.00	18.00	24.00	36.00	58.00	64.00	69.00	79.00	85.00	89.00	96.00
Ditto corrected												
Load (KN)	0	0.16407	0.19689	0.26252	0.39377	0.63441	0.70004	0.75473	0.86411	0.92974	0.9735	1.05006
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	12.140	11.508	4.625	3.946
TOP	13.461	12.001	4.790	4.329



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH3, 10%

Depth: 1m

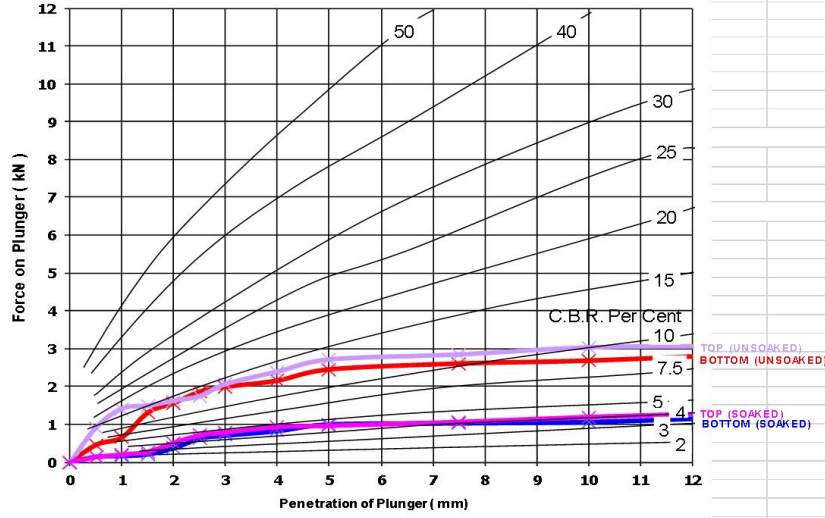
TEST ON BOTTOM (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	42.00	60.00	120.00	143.00	170.00	182.00	197.00	224.00	238.00	245.00	258.00		
Ditto corrected														
Load (kN)	0	0.4594	0.65629	1.31258	1.56416	1.85949	1.99074	2.15482	2.45015	2.60328	2.67985	2.82204		
C. B. R. %														

TEST ON TOP (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	84.00	129.00	136.00	148.00	159.00	188.00	218.00	247.00	259.00	276.00	279.00		
Ditto corrected														
Load (kN)	0	0.9188	1.41102	1.48759	1.61885	1.73917	2.05637	2.38452	2.70172	2.83298	3.01893	3.05174		
C. B. R. %														

TEST ON BOTTOM (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	13.00	15.00	19.00	34.00	58.00	65.00	76.00	92.00	95.00	98.00	108.00		
Ditto corrected														
Load (kN)	0	0.1422	0.16407	0.20782	0.3719	0.63441	0.71098	0.8313	1.00631	1.03912	1.07194	1.18132		
C. B. R. %														

TEST ON TOP (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	12.00	18.00	25.00	47.00	65.00	72.00	85.00	88.00	97.00	109.00	118.00		
Ditto corrected														
Load (kN)	0	0.13126	0.19689	0.27345	0.51409	0.71098	0.78755	0.92974	0.96256	1.061	1.19226	1.2907		
C. B. R. %														

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	14.039	12.275	4.790	5.042
TOP	13.131	13.536	5.368	4.822



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH3, 10%

Depth: 1m

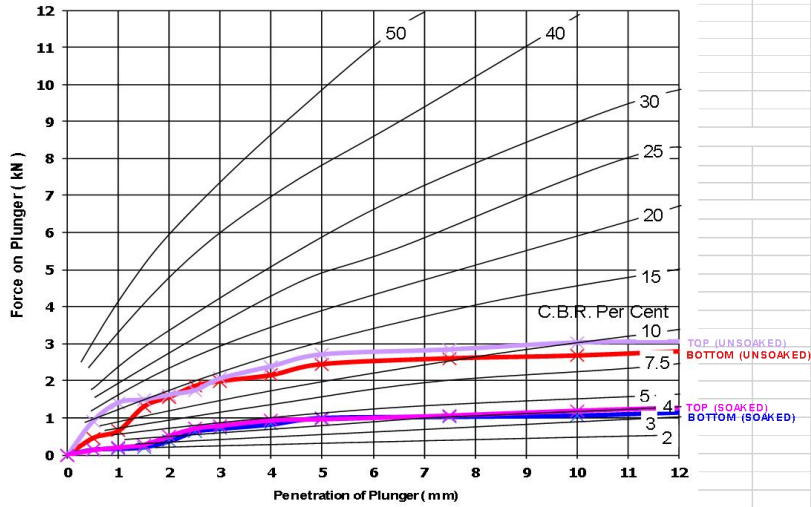
TEST ON BOTTOM (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	42.00	60.00	120.00	143.00	170.00	182.00	197.00	224.00	238.00	245.00	258.00
Ditto corrected												
Load (KN)	0	0.4594	0.65629	1.31258	1.56416	1.85949	1.99074	2.15482	2.45015	2.60328	2.67985	2.82204
C. B. R. %												

TEST ON TOP (UNSOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	84.00	129.00	136.00	148.00	159.00	188.00	218.00	247.00	259.00	276.00	279.00
Ditto corrected												
Load (KN)	0	0.9188	1.41102	1.48759	1.61885	1.73917	2.05637	2.38452	2.70172	2.83298	3.01893	3.05174
C. B. R. %												

TEST ON BOTTOM (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	13.00	15.00	19.00	34.00	58.00	65.00	76.00	92.00	95.00	98.00	108.00
Ditto corrected												
Load (KN)	0	0.1422	0.16407	0.20782	0.3719	0.63441	0.71098	0.8313	1.00631	1.03912	1.07194	1.18132
C. B. R. %												

TEST ON TOP (SOAKED)										SURCHARGE		
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	12.00	18.00	25.00	47.00	65.00	72.00	85.00	88.00	97.00	109.00	118.00
Ditto corrected												
Load (KN)	0	0.13126	0.19689	0.27345	0.51409	0.71098	0.78755	0.92974	0.96256	1.061	1.19226	1.2907
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	14.039	12.275	4.790	5.042
TOP	13.131	13.536	5.368	4.822



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: BH3, 15%

Depth: 1m

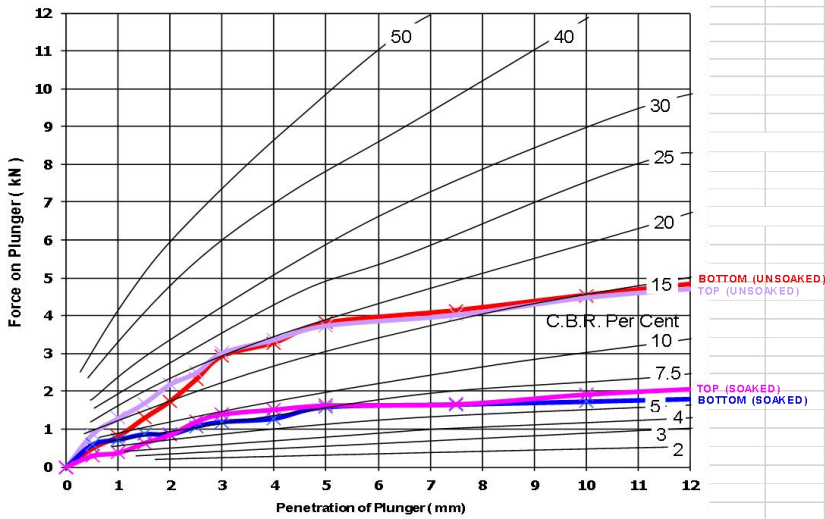
TEST ON BOTTOM (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	45.00	74.00	118.00	159.00	212.00	268.00	300.00	348.00	378.00	415.00	448.00		
Ditto corrected														
Load (kN)	0	0.49222	0.80942	1.2907	1.73917	2.31889	2.93142	3.28145	3.80648	4.13462	4.53933	4.90029		
C. B. R. %														

TEST ON TOP (UNSOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	79.00	118.00	154.00	200.00	228.00	276.00	308.00	342.00	368.00	410.00	436.00		
Ditto corrected														
Load (kN)	0	0.86411	1.2907	1.68448	2.18763	2.4939	3.01893	3.36895	3.74085	4.02524	4.48464	4.76903		
C. B. R. %														

TEST ON BOTTOM (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	54.00	66.00	79.00	79.00	98.00	109.00	117.00	145.00	151.00	158.00	166.00		
Ditto corrected														
Load (kN)	0	0.59066	0.72192	0.86411	0.86411	1.07194	1.19226	1.27976	1.58603	1.65166	1.72823	1.81573		
C. B. R. %														

TEST ON TOP (SOAKED)											SURCHARGE			
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50		
Load Indicator	0	27.00	34.00	58.00	78.00	110.00	128.00	139.00	149.00	152.00	176.00	192.00		
Ditto corrected														
Load (kN)	0	0.29533	0.3719	0.63441	0.85318	1.2032	1.40008	1.5204	1.62978	1.6626	1.92511	2.10012		
C. B. R. %														

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	17.508	19.070	8.093	7.946
TOP	18.829	18.742	9.084	8.165



LABORATORY CALIFORNIA BEARING RATIO TEST

Sample ID: **BH3, 20%**

Depth: **1m**

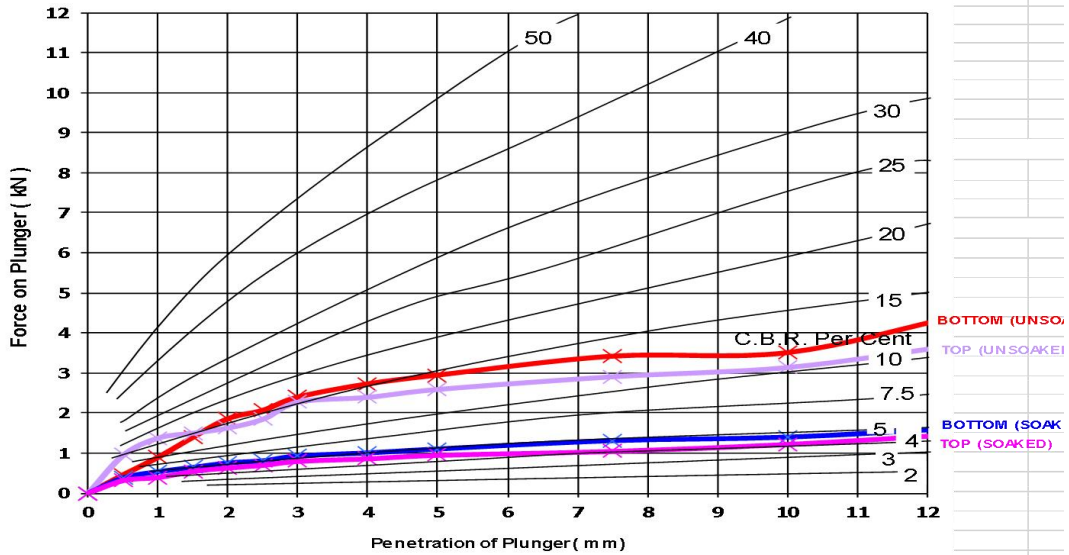
TEST ON BOTTOM (UNSOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	42.00	82.00	128.00	170.00	189.00	219.00	249.00	269.00	312.00	320.00	406.00
Ditto corrected												
Load (KN)	0	0.4594	0.89693	1.40008	1.85949	2.06731	2.39545	2.7236	2.94236	3.4127	3.50021	4.44089
C. B. R. %												

TEST ON TOP (UNSOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	87.00	126.00	137.00	149.00	169.00	208.00	219.00	237.00	266.00	287.00	340.00
Ditto corrected												
Load (KN)	0	0.95162	1.37821	1.49853	1.62978	1.84855	2.27514	2.39545	2.59234	2.90955	3.13925	3.71897
C. B. R. %												

TEST ON BOTTOM (SOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	35.00	49.00	59.00	69.00	74.00	85.00	92.00	101.00	120.00	128.00	149.00
Ditto corrected												
Load (KN)	0	0.38284	0.53597	0.64535	0.75473	0.80942	0.92974	1.00631	1.10475	1.31258	1.40008	1.62978
C. B. R. %												

TEST ON TOP (SOAKED)												
Penetration (mm)	0.00	0.50	1.00	1.50	2.00	2.50	3.00	4.00	5.00	7.50	10.00	12.50
Load Indicator	0	29.00	36.00	50.00	58.00	64.00	73.00	79.00	87.00	96.00	112.00	136.00
Ditto corrected												
Load (KN)	0	0.31721	0.39377	0.54691	0.63441	0.70004	0.79848	0.86411	0.95162	1.05006	1.22507	1.48759
C. B. R. %												

	UNSOAKED		SOAKED	
	2.5mm	5.0mm	2.5mm	5.0mm
BOTTOM	15.608	14.741	6.111	5.535
TOP	13.957	12.988	5.285	4.768

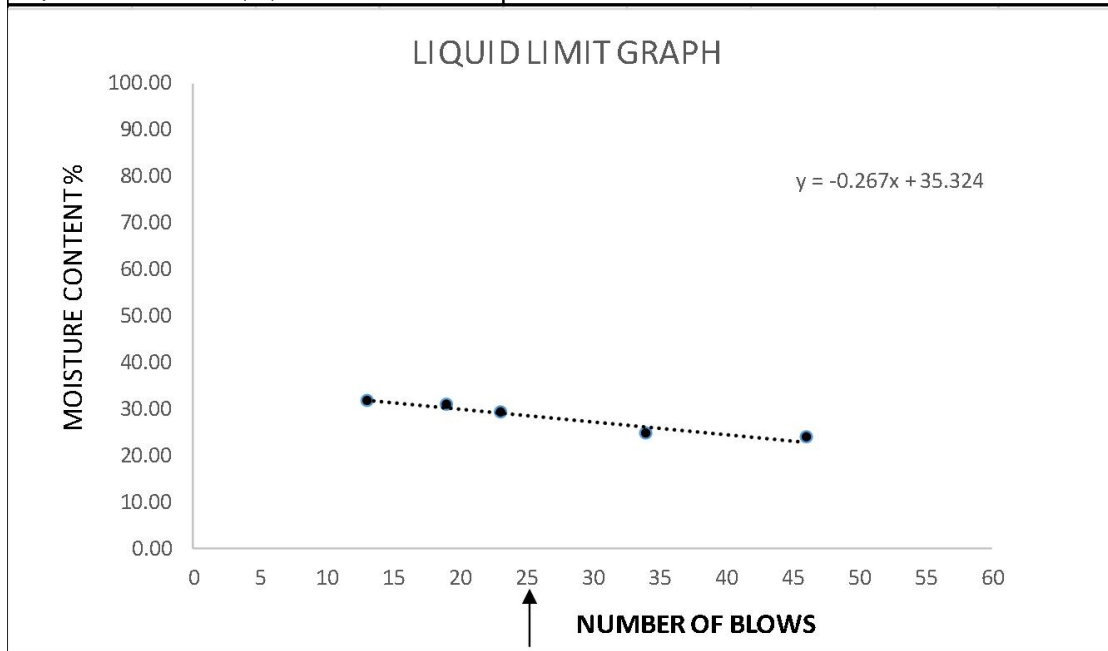


LABORATORY LIQUID AND PLASTIC LIMIT TEST SHEET

Sample ID: **BH1, CONTROL**

DEPTH: **1m**

LIQUID LIMIT TEST					
blows	46	34	23	19	13
can no	OZ	FR	OB	MI	DA
Wt. of wet soil & container (g) M1	68.22	71.43	62.2	51.35	72.68
wt. of dry soil & container (g) M2	58.56	59.89	51.69	43.12	59.72
wt. of container (g) M3	17.89	13.38	15.86	16.67	18.66
wt. of dry soil (Wd) g M4	40.67	46.51	35.83	26.45	41.06
wt. of moisture (Wm) g M5	9.66	11.54	10.51	8.23	12.96
moisture content (Wm/Wd) %	23.75	24.81	29.33	31.12	31.56
Liquid Limit Value (%)	28.57				



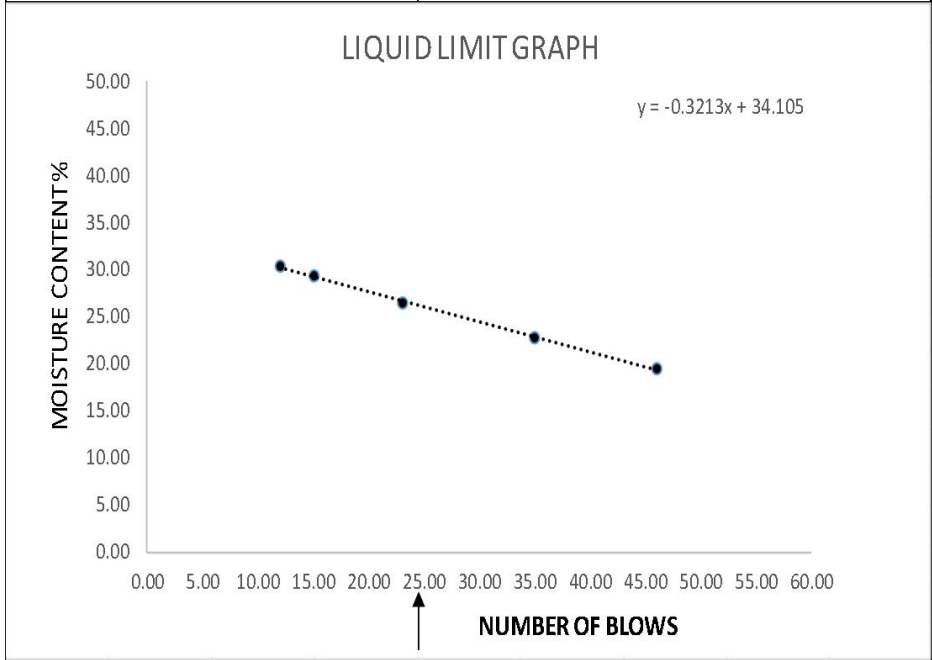
PLASTIC LIMIT TEST					
can no	OZ	FR	OB		
Wt. of wet soil & container (g) M1	30.78	29.65	29.25		
wt. of dry soil & container (g) M2	28.61	27.65	27.45		
wt. of container (g) M3	17.66	17.68	17.98		
wt. of dry soil (Wd) g M4	10.95	9.97	9.47		
wt. of moisture (Wm) g M5	2.17	2	1.8		
moisture content (Wm/Wd) %	19.82	20.06	19.01		
PLASTIC LIMIT	19.63				
PLASTIC INDEX	8.94				

LABORATORY LIQUID AND PLASTIC LIMIT TEST SHEET

Sample ID: **BH2, CONTROL**

DEPTH: **1m**

LIQUID LIMIT TEST					
blows	46.00	35.00	23.00	15.00	12.00
can no	MY	MUM	lt	1	mt
Wt. of wet soil & container (g) M1	32.59	38.19	49.44	53.33	51.60
wt. of dry soil & container (g) M2	30.09	34.42	42.91	45.30	43.92
wt. of container (g) M3	17.20	17.92	18.29	17.91	18.62
wt. of dry soil (Wd) g M4	12.89	16.50	24.62	27.39	25.30
wt. of moisture (Wm) g M5	2.50	3.77	6.53	8.03	7.68
moisture content (Wm/Wd) %	19.39	22.85	26.52	29.32	30.36
Liquid Limit Value (%)	26.07				



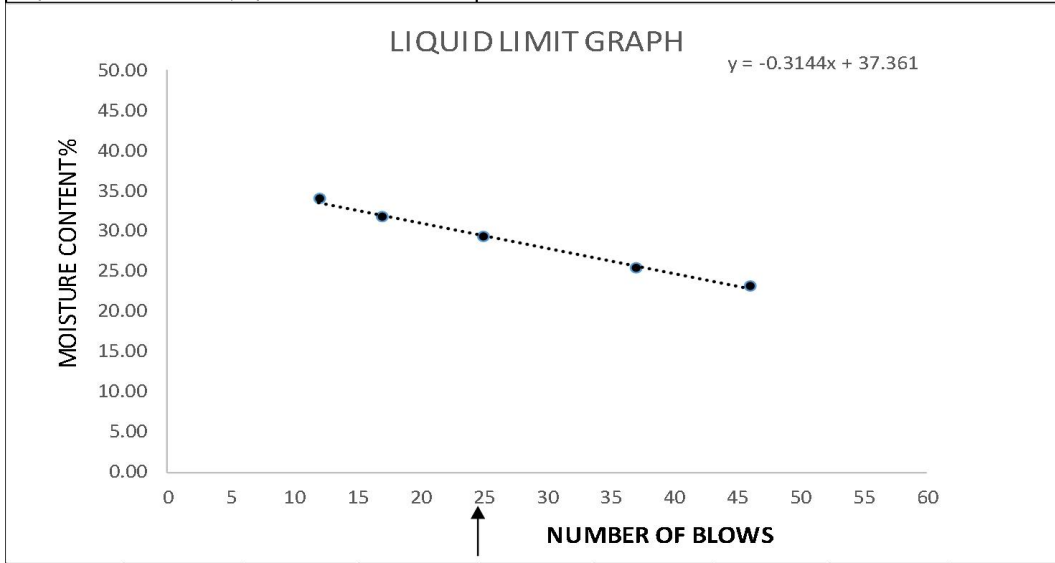
PLASTIC LIMIT TEST					
can no	MTY	LUV	MIT		
Wt. of wet soil & container (g) M1	29.34	26.91	29.49		
wt. of dry soil & container (g) M2	27.56	25.4	27.42		
wt. of container (g) M3	18.64	17.17	17.25		
wt. of dry soil (Wd) g M4	8.92	8.23	10.17		
wt. of moisture (Wm) g M5	1.78	1.51	2.07		
moisture content (Wm/Wd) %	19.96	18.35	20.35		
PLASTIC LIMIT				19.55	
PLASTIC INDEX				6.52	

LABORATORY LIQUID AND PLASTIC LIMIT TEST SHEET

Sample ID: **BH3, CONTROL**

DEPTH: **1m**

LIQUID LIMIT TEST					
blows	46	37	25	17	12
can no	XJ	BVN	ZD	O.31	XU
Wt. of wet soil & container (g) M1	30.52	33.85	46.30	52.95	54.97
wt. of dry soil & container (g) M2	28.29	30.80	39.77	44.45	45.74
wt. of container (g) M3	18.67	18.85	17.45	17.69	18.60
wt. of dry soil (Wd) g M4	9.62	11.95	22.32	26.76	27.14
wt. of moisture (Wm) g M5	2.23	3.05	6.53	8.50	9.23
moisture content (Wm/Wd) %	23.18	25.52	29.26	31.76	34.01
Liquid Limit Value (%)	28.91				



PLASTIC LIMIT TEST					
can no	KU	D2	O.31		
Wt. of wet soil & container (g) M1	27.45	27.5	29.26		
wt. of dry soil & container (g) M2	25.37	25.32	26.95		
wt. of container (g) M3	15.28	15.51	15.88		
wt. of dry soil (Wd) g M4	10.09	9.81	11.07		
wt. of moisture (Wm) g M5	2.08	2.18	2.31		
moisture content (Wm/Wd) %	20.61	22.22	20.87		
PLASTIC LIMIT	21.23				
PLASTIC INDEX	7.67				