EVALUATION OF RICE HUSK ASH STABILIZED SOIL IN OVIA LOCAL GOVERNMENT AREA, EDO STATE.

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ODIASE, Nosahare Gideon

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DEPARTMENT OF STRUCTURAL ENGINEERING

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A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.Eng) DEGREE IN THE DEPARTMENT OF STRUCTURAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

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CERTIFICATION

This is to certify that this work was carried out by **Odiase Nosahare Gideon**, Mat. No. **ENG1905272**, of the Department of Structural Engineering, Faculty of Engineering, University of Benin City. Edo State, Nigeria.

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ENGR. PROF. R.I. UMASABOR   **DATE**

Project Supervisor

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ENGR. PROF. R.I. UMASABOR   **DATE**

Head of Department

DEDICATION

This literary work is dedicated to God almighty, who has not only provided me life but also the strength, speed, Favour and his mercies to perform well academically thus far, not also neglecting his involvement especially for this area of study specifically this project and the outcome of it preeminently.

I also dedicate this work to my parents Mr. and Mrs. Odiase, my family and friends who has shown unwavering support and constant eagerness in help.

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ACRONYMS

AASHTO	-	American Association of State and Highway Transportation Officials
ASTM	-	American Society for Testing Materials
CBR	-	California Bearing Ratio
LL	-	Liquid limit
PL	-	Plastic limit
RHA	-	Rice husk Ash

ABSTRACT

Soil stabilization refers to the process of improving the engineering properties of soil through physical, chemical, or mechanical means to make it more suitable for construction purposes. In this study, the geotechnical properties of lateritic soil collected from the Ovia North East Local Government Area of Edo State were evaluated to determine the effect of rice husk ash (RHA) as a stabilizing agent. The study was prompted by observed pavement and foundation failures within the study area, which were attributed to the poor strength and instability of the underlying lateritic soils.

Rice husk ash, an agricultural waste generated from the combustion of rice husks, was utilized in this research to promote sustainable waste management while improving soil performance. The soil samples were mixed with varying proportions of RHA at 2%, 4%, 6%, 8%, and 10% by dry weight of soil. Laboratory tests including sieve analysis, specific gravity, Atterberg limits, compaction, and California Bearing Ratio (CBR) tests were conducted to evaluate the impact of RHA on the soil's mechanical and index properties.

Results showed that the inclusion of RHA led to improvements in the maximum dry density (MDD) and optimum moisture content (OMC), with noticeable increases in CBR values compared to the untreated samples. However, the results also indicated that RHA alone exhibits limited potential as a stabilizing material at higher percentages. The optimum performance was recorded at 5% RHA content, which provided the best balance between strength and workability. Therefore, the use of 5% RHA is recommended for field stabilization of lateritic soils intended for pavement sub-base construction. Furthermore, to achieve better pozzolanic activity, it is advised that RHA used for stabilization be calcined at a controlled temperature range of 600°C to 700°C, as supported by Alabi et al. (2015)

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

In the Precambrian times, Nigeria consisted of uplifted continental landmass made up of basement sediments (kogbe, 2005). This resulted in the formation of lateritic soils which are of relatively good quality for road construction works and other civil engineering works. However, the characteristics of native soils often fail to meet the demands of certain structures. In such situations, enhancing the soil's properties becomes a practical and effective solution. (Hasan,2007.) When physical properties of soil are improved, it is named modification, and stabilization when a significant level of long-term strength gain and durability are developed. Modification can produce important strength improvement (Leo, 2016). The United States Department of Agriculture (USDA) estimated that the world rice production in 2019/2020 would be 499.31 million metric tons. In 2018/2019, this figure was 499.37 million metric tons (World agricultural production, 2020). Rice husk is an agricultural waste obtained from milling of rice. About 108 million tons of rice husk is generated annually in the world. In Nigeria, about 2.0 million tons of rice is produced annually (Oyetola, 2006). To minimize the large amount of waste generated, rice husks are often burned either in open piles or used as fuel in furnaces for activities such as rice drying and power generation. During combustion, the organic components and moisture in the husk are volatilized, leaving behind about 20% of the original mass as rice husk ash (RHA). If all global rice husks were incinerated, approximately 20 million tons of RHA would be produced annually. Utilizing this byproduct offers an environmentally beneficial alternative to disposal.

The color of RHA varies from light gray to black, depending on factors such as the source of the husk, incineration method, duration, and burning temperature. Several approaches have been explored for its proper management through commercial applications. Typically, rice husk is burned in a controlled furnace or incinerator at temperatures ranging from 600°C to 800°C in laboratory settings. After combustion, the ash is cooled either rapidly or gradually.

RHA possesses a very fine texture, with an average particle size between 5 and 10μm (Sensale, 2010), making it suitable for use as a soil additive or replacement material in experimental studies. several works with RHA have shown that it has interesting potentials of improving the engineering properties of soils for the purpose of sub-grade. The RHA contains around 90% silica and shows excellent pozzolanic properties due to its high surface area, high amorphous nature, and compatibility with cement-concrete (Al-Kutti et al., 2019)

Thus, this work focused on investigating the actual effect of RHA on some geotechnical index properties of lateritic soil which are relevant for evaluating the performance of sub grade soil.

1.2 Statement of the Problem

Laterite soils are a common type of soil found in tropical and subtropical regions, characterized by their high iron and aluminum oxide content.

These soils often exhibit challenging geotechnical properties, such as high plasticity, low bearing capacity, and susceptibility to volume changes. One potential solution to improve the engineering behavior of laterite soils is the use of rice husk ash (RHA), a waste material generated from the burning of rice husk. The method of stabilizing serve majorly as a means of recycling rice husk as it's uses are very limited, It doesn't serve as consumables for farm animals or any industrial purpose hence it is used to reduce the amount of husk dump pollutants in the environment.

Traditional soil stabilization methods such as use of lime and cement can also be expensive and sometimes environmentally damaging (Ingles & Metcalf, 1972) Rice husk ash is an economical method

1.3 Aim and Objectives

To evaluate the effect of rice husk ash (RHA) as a stabilizing agent on the geotechnical properties of lateritic soil obtained from Ovia North East Local Government Area, Edo State.

The primary objectives are;

i. To investigate the effect of incorporating varying percentages of rice husk ash on the geotechnical index properties of a laterite soil.

ii. To determine the optimal Rice Husk ash content that can improve the engineering characteristics of the laterite soil.

1.4 Scope of Study

The scopes of this study includes;

i. Collection of laterite soil samples from a local site.

ii. Preparation of RHA samples by burning rice husks in a controlled environment.

iii. Mixing of laterite soil with varying percentages of RHA (0%,2%,4%,6%,8% and 10%)

iv. Determination of the geotechnical index properties Laboratory tests for determining the effect of the admixture on the geotechnical properties inherent in the soil sample.

v. Specific gravity

vi. Sieve analysis

vii. Atterberg limit

viii. Compaction

ix. CBR (California Bearing Ratio)/ Triaxial

x. Analysis of the data to determine the optimal percentage of RHA that can be added to laterite soil to achieve the desired engineering properties.

1.5 Justification of study

The use of rice husk ash (RHA) as a soil stabilizer for laterite soil has a promising approach to improve the engineering properties of a particular problematic soil type in areas such as Edo state environs. The use of RHA as a soil stabilizer has several benefits, including:

The recycling of rice husk as a valuable resource is an important consideration in this study. Rice husk is a significant agricultural waste product, and its disposal can pose environmental and health hazards. By utilizing RHA as a soil stabilizer, this study aims to contribute to the sustainable management of rice husk waste and reduce the environmental impact of its disposal.

i. **Varieties of options:** With this experiment we can truly know the amount of percentage of RHA that can improve the strength, stability, and durability of laterite soil, making for more stabilizing and soil admixture options.

ii. **Environmental benefits:** Recycling rice husk as RHA reduces the amount of waste sent to landfills and water bodies minimizing the environmental impact of its disposal.

iii. **Cost-effectiveness:** RHA is a readily available and inexpensive material, making it a cost-effective alternative to traditional soil stabilizers.

iv. **Data Accumulation:** The study will also evaluate the optimal percentage of RHA that can be added to laterite soil to achieve the desired engineering properties.

v. **Contribute to the development of new technologies in the geotechnical scope of study:** This study would contribute to the development of new technologies and other materials for soil stabilization, which have not really been commonly explored before now. The significance of this study lies in its potential to Improve construction projects by improving the engineering properties of laterite soil, this study would then contribute to the development of more stable and durable construction projects in tropical regions. Promote sustainable waste management, by recycling rice husk as RHA, this study can also cause for a trial of other waste substance in the environment and their effect on soil properties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil in construction.

Stabilized soil can be applied in various civil engineering projects such as highway construction, geotechnical structures, and building developments. Improving the engineering properties and characteristics of soil is one of the most cost-effective approaches in construction. Moreover, several famous ancient structures were built using stabilized soils, including the Egyptian Pyramids (Giulieri, 2017), the Great Wall of China, the Alhambra Palace in Granada, and the Great Mosque of Djenné. When compared with other conventional construction materials, stabilized soil is considered an economical and sustainable option, materials like cement, lime, and bitumen have been employed to enhance the engineering properties of problematic soils, improving characteristics such as strength, durability, and resistance to environmental factors. While these materials have been effective, growing concerns about their environmental impact, sustainability, and cost have led researchers to explore alternative, eco-friendly stabilizers. One such alternative that has gained attention in recent years is the use of agricultural waste products, with Rice husk ash emerging as a particularly promising solution.

2.2 Types of Soil

Soils are generally categorized based on particle size and composition. Common types include sand, silt, clay, and loamy. Laterite, a clayey soil abundant in iron and aluminum oxides, is typically found in tropical regions and is formed through intense weathering. Lateritic soils are known for their high moisture content and specific gravity, ranging from 2.40 to 2.78, which affects their compressibility and suitability for engineer.

2.3 Properties of Soil

Key properties of soil relevant to geotechnical engineering include:

i. Moisture content for laterite, moisture content varies seasonally, typically ranging from 17% to 25%, which impacts soil plasticity and behavior under load

ii. Atterberg Limits; Lateritic soils tend to have a high liquid limit (up to 60%) and plasticity index (up to 30%), indicating varying degrees of plasticity depending on the location.

iii. Specific gravity Indicates the soil's density compared to water, with lateritic soils having a specific gravity between 2.55 and 2.78 【12†source】

2.4 Engineering Classifications of Soil

Soils are classified for engineering purposes based on their ability to support loads and retain stability:

1. California Bearing Ratio (CBR): Laterite soils have relatively low CBR values (17.32% in unstabilized form), making them unsuitable for direct use in subgrade construction without stabilization

2. Compaction characteristics: Maximum dry density (MDD) and optimum moisture content (OMC) values are critical in determining how a soil will behave under load, with laterite showing MDD between 1.51 mg/m³ and 1.76 mg/m³

2.4.1 Unified Soil Classification System

The Unified Soil Classification System (USCS) classifies soils based on their particle size distribution and plasticity. Lateritic soils, being fine-grained, typically fall into the CL (low plasticity clay) or CH (high plasticity clay) categories. Their fine particles and plastic nature require careful treatment to ensure they are stable under engineering conditions.

The AASHTO classification system (American Association of State Highway and Transportation Officials) is a widely used method for categorizing soils, particularly for transportation projects. It classifies soils into seven main groups, ranging from A -1 to A-7, based on grain size distribution and plasticity characteristics like Atterberg limits. These characteristics help assess the suitability of the soil for road construction and its behavior under load and moisture conditions.

i. Group A-1 soils are coarse-grained materials such as gravel and sands, which typically have excellent drainage and stability, making them highly suitable for
ii. subgrade and base layers in road construction.
iii. Groups A-2 and A-3 also cover coarse-grained soils but with slightly more fines (clay or silt content). A-2 soils are intermediate in quality between A-1 and the poorer groups.
iv. Groups A-4 through A-7 include fine-grained soils, which tend to have higher plasticity and less favorable engineering properties. These soils, especially those in A-6 and A-7 groups, contain significant amounts of clay, leading to poor drainage and potentially problematic behavior under load, especially when wet.

The system uses Atterberg limits to further refine classification within each group, identifying the transition points between the solid, plastic, and liquid states of the soil. For example, A-6 soils are clays with high plasticity, while A-4 soils are silts with lower plasticity. These limits help predict how soils will perform in varying moisture conditions, an important factor for road design and construction.

2.4.2 The AASHTO classification system

This is commonly used in civil engineering, particularly in the U.S., to ensure that appropriate materials are selected for infrastructure projects based on their mechanical properties and long-term behavior under environmental and load conditions.

2.4.3 Laterite Soil and Its Properties

Laterite is characterized by:

i. High iron and aluminum content, which gives it strength but also makes it vulnerable to weathering.

ii. Low CBR and high plasticity, indicating the need for stabilization when used in construction projects Laterite soil, which is abundant in tropical and subtropical regions, is heavily influenced by intense weathering processes that result in high concentrations of iron and aluminum oxides. The soil is widely used in construction due to its significant bearing capacity and other advantageous properties, but its specific characteristics can vary depending on local environmental factors.

2.5 Properties of Laterite Soil:

1. **Geotechnical Characteristics**

Laterite soil is recognized for its high compressive strength and is often used in road construction and as a material for foundations. Research shows that the unconfined compressive strength (UCS) can range from approximately 184.5 kn/m^2 in raw states, depending on moisture content and local mineral composition (Raheem & Adesanya,2015)

2. **Plasticity and Permeability**

The plasticity index, a key measure in determining the soil's workability and shrinks well behavior, typically ranges from low to moderate. The permeability of laterite soils is relatively low, with values such as 9.46×10^{-3} cm/s reported in various regions. This low permeability makes it a good material for foundations, as it restricts water flow through the soil matrix, helping to stabilize structures built on it.

3. **Chemical Composition**

Laterite soil is rich in iron oxides (Fe_2O_3), aluminum oxides (Al_2O_3), and silica (SiO_2), which contribute to its reddish coloration and stability. Studies show that lateritic soil often has a combined percentage of silica, alumina, and iron oxide ranging from about 70% to 90%, making it a highly cementitious material when stabilized with pozzolanic additives like rice husk ash (RHA) and bagasse ash (BA), commonly used for soil improvement.

4. **Use in Stabilization**

Given its high iron and aluminum oxide content, laterite soil has been widely researched for stabilization techniques using materials such as lime, cement, and agricultural byproducts. Stabilization improves both its load-bearing capacity and its resistance to erosion.

In conclusion, laterite soil, with its unique combination of high strength, low permeability, and rich mineral content, is a valuable material in geotechnical engineering. However, due to its variability across regions, local testing and modifications (e.g., through stabilization techniques) are often necessary to fully optimize its use in construction projects. For further details, the studies conducted in recent years, including those focusing on its properties and stabilization methods, provide a rich source of data. In summary, lateritic soil exhibits significant variability in terms of plasticity and strength, necessitating proper classification and potential stabilization. For engineering applications, systems like AASHTO and USCS help in determining its suitability for construction, especially in roadworks or as a foundation material.

2.6 Stabilization of Laterite Soil with Rice Husk Ash

The use of rice husk ash (RHA) as a stabilizer for laterite soil has been a subject of increasing interest in recent years. RHA is a byproduct of rice husk combustion and is rich in silica. It has been shown to improve the geotechnical properties of various types of soil, including laterite.

2.6.1 Proposed Effects of Rice Husk Ash on Laterite Soil

The proposed effects of RHA on laterite soil include:

Increased strength: RHA can increase the shear strength of laterite soil by forming a pozzolanic reaction with the calcium hydroxide present in the soil. This reaction results in the formation of cementitious compounds that bind the soil particles together.

Reduced permeability: RHA can reduce the permeability of laterite soil by filling the voids between the soil particles. This can help to improve the drainage characteristics of the soil and prevent seepage.

Improved durability: RHA can improve the durability of laterite soil by making it more resistant to weathering and erosion.

Reduced cost: RHA is a low-cost material that can be obtained from local sources. This can make it a more economical option for stabilizing laterite soil compared to other additives.

2.7 Previous Related work

The enhancement of soil properties through the incorporation of rice husk ash (RHA) has been widely investigated in different studies. For this purpose, four sandy soil samples obtained from various regions of Uruguay, together with four residual RHA samples (RHAU) collected from conventional furnaces, were examined. RHA produced under controlled laboratory conditions with regulated temperature and duration (RHAC) was also studied. The analyses showed that all RHAU samples appeared black in color, signifying high-carbon char with varying amounts of unburned husk. Among these, the RHA generated from a power-generation furnace (RHAG) exhibited the finest texture and the least quantity of unburned husk residues.

The X-ray diffraction (XRD) results of the ash obtained from rice husk combustion in the conventional furnace of the Arrozur Mill (RHAA) revealed peaks of cristobalite—a high-temperature crystalline form of silica—alongside carbon formed from partial organic crystallization. The organic matter content in the RHAU samples ranged from high to very high, exceeding the level generally considered suitable for soil stabilization. RHAG showed the lowest loss on ignition, followed by RHAA, while the higher values in other samples were attributed to unburned husk remnants. Since the ash type most suitable for pozzolanic reactivity is amorphous with low organic content rather than crystalline, the studied RHAU samples can be classified as low to moderately reactive materials.

Previous research on using Rice Husk Ash (RHA) to stabilize lateritic soil has shown promising results.

Here's a summary of findings from studies using varying percentages of RHA:

Musa Alhassan also conducted a study on the potentials of RHA for soil stabilization, using 2-12% RHA to stabilize lateritic soil. The research saw a general deduction in MDD and an increase in OMC with increasing RHA content. The peak UCS values were recorded between 6-8% RHA, showing some potential for using RHA for strength improvement of A-7-6 lateritic soil.

Examined study shows the impact of Rice Husk Ash (RHA) based-geopolymer on some geotechnical properties of selected tropical soils. The soil samples were stabilized with alkali activated RHA varying from 3 -15% (in 3% increment). The Liquid Limit (LL) and Plasticity Index (PI) of the stabilized soils decreased, while the CBR and UCS increased. The chemical analysis of rice husk ash reveals significant concentrations of silica, potassium, iron, calcium, magnesium, and aluminum. Several studies have shown that both rice husk powder and rice husk ash contain a significant amount of silicon oxide (SiO_2), which contributes to their strong pozzolanic characteristics. Compressive strength tests conducted on cement-stabilized bricks incorporating these materials demonstrated a rapid improvement in strength — increasing from 0.76 to 3.38 kN/m² for rice husk ash and from 0.76 to 3.76 kN/m² for rice husk powder.

The findings therefore indicate that rice husk powder and ash are effective stabilizing agents for lateritic soils. Overall, the compressive strength of the samples was observed to rise consistently with an increase in the proportion of the stabilizers used.

CHAPTER THREE

METHODOLOGY

3.1 Study area

This study was carried out in Block of Flats, University of Benin Ovia North East Edo State. Rusty red soil sample was collected from different boreholes at different location of the area and transported to the Geotechnical Laboratory, Department of Civil Engineering, University of Benin where the laboratory test and analysis were carried out.

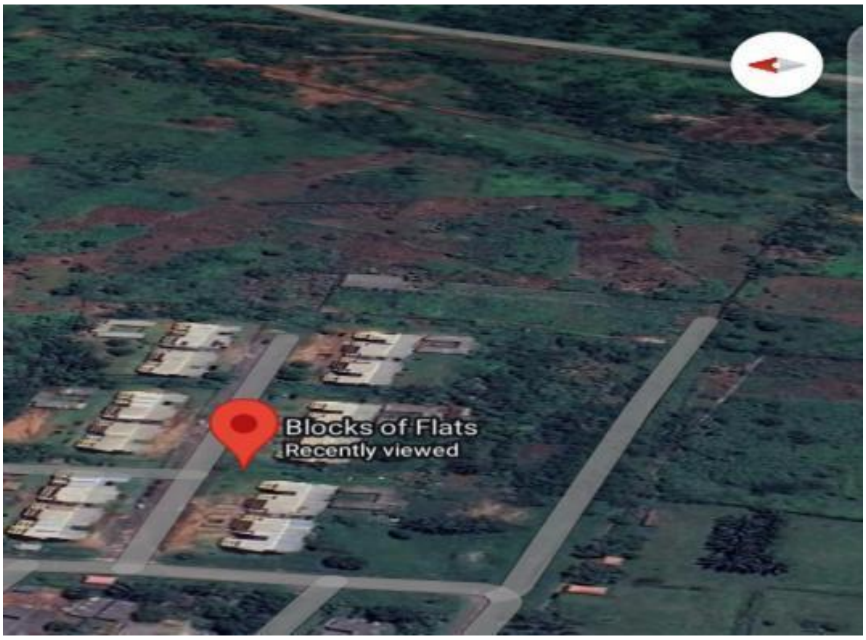

Figure 3.1: (Google map depiction of site position-Blocks of flat, Uniben 2024)

3.2 Materials

3.2.1 Soil Sample Collection and Preparation

At the depths of 1m samples from were collected from Two different pits on the study area by means of the manual hand auger accessed from the geotechnical laboratory of the civil engineering department of the University. The samples were then bagged and labelled as BH1, BH2 respectively. They were there after transported to the laboratory in vehicle.

The samples were spread on different locations within the laboratory with their tag numbers placed on them respectively and were air-dried for a period of four days. The reason for this long drying period was due to the damp weather observed during this period which made the soil to retain great moisture content from the site. The samples were not oven-dried since other properties of the soil apart from the moisture content were also required. After the drying period, the samples were sieved through sieve size 4.75mm to remove the debris and other contaminants obtained alongside the samples from the site and then transported to the different machine locations in the laboratory for the experimental tests.

Two sets of samples were made for each test. The first set was made of 100% of distilled water while the second set is made of concentrated percentage of the admixture (KOH). The aim was to compare the results obtained and to make comparison between them so as to ascertain the effect of the admixture on the geotechnical properties of the soil sample. All the tests were carried out in accordance with the British Standard (BS 1377, 2000).

3.2.2 Rice husk ash Preparation

The rice husk ash was prepared by collecting rice husks from a local rice mill. The husks were then dried in the sun to remove moisture content. After drying, they were burned in a furnace to produce ash combusted in a muffle furnace at a temperature range of 500°C to 700°C, ensuring the complete incineration of organic. The cooled ash was sieved to obtain a fine particle size. The sieved RHA was then stored in a dry, airtight container until it was used for the stabilization experiments.

3.3 Experimental Design

The experimental design involved the testing of soil samples with varying percentages of RHA to determine the optimum RHA content for stabilization. RHA was added at increments of 2%, 4%, 6%, 8%, and 10% by weight of the dry soil. Also, with a control sample of untreated soil for comparison the main stages of the experimental design included:

1. Control Sample Testing: Initial geotechnical properties, such as Atterberg limits, sieve analysis, specific gravity, compaction characteristics, and shear strength of the untreated soil, were established to serve as a benchmark.
2. Soil-RHA Mixture Preparation: Soil samples were thoroughly mixed with the varying percentages of RHA to ensure a homogeneous blend. Dry mixing was followed by the addition of water at optimum moisture content levels.

3.4 Laboratory Testing Procedures

Several laboratory tests were carried out to assess the effects of RHA on the soil properties. These tests include the as Atterberg limits, sieve analysis, specific gravity, compaction characteristics, and shear strength, and durability test.

3.4.1 Specific Gravity Test

To determine the ratio of the mass of unit volume of the soil sample to the mass of the same volume of gas-free distilled water at a given temperature. As specified in BS 1377-1:1990. This test is used to calculate the unit weight of the soil

Apparatus

i. 50ml density bottles with stoppers ii.

Sensitive weighing balance of 0.01g accuracy

Figure 3.2: Specific gravity equipment (source: reddit/geotech 2018)

Required Measurements

i. Weight of the density bottle (w1)

ii. Weight of bottle + soil sample (w2)

iii. Weight of bottle + soil sample + water (3)

iv. Weight of bottle + water (4)

Procedure

i. The density bottle was cleaned and air-dried for about five minutes.

ii. The bottle with its stopper was weighed and the weight recorded as 1

iii. The bottle was filled to the half of its capacity with the dry soil sample with its stopper, weighed and the weight recorded as 2.

iv. Water was added into the sample in the soil till it was about half filled.

v. The sample was mixed thoroughly with glass rod to remove any entrapped air.

vi. Water was continuously added while stirring the sample until it flushed with the graduated mark using the stopper.

vii. The outer surface of the bottle was dried using the water handkerchief, weighed and the weight recorded as 3.

viii. The bottle was then emptied and refilled with water to the graduated mark.

ix. The outer surface of the bottle was dried using the water handkerchief, weighed and the weight recorded as 4

3.4.2 Atterberg Limits

The Atterberg limits were determined using the Casagrande cup method, as specified in BS 1377-1:1990. These tests are important for predicting the soil's behavior under different moisture conditions.

Atterberg limits test was conducted to determine the liquid limit (LL), plastic limit (PL), and plasticity index (PI) of both untreated and GSA-stabilized soil in accordance with ASTM D4318.

Liquid Limit (LL): Determined using the Casagrande method, which measures the moisture content at which the soil transitions from a plastic state to a liquid state.

Apparatus

i. Liquid Limit device and glove
ii. Weighing balance (0.01g sensitivity)
iii. Drying oven
iv. Moisture cans
v. Spatula vi. Large glass plate for mixing the sample
vi. Sieve No 425
vii. vii. Squeeze bottle filled with distilled water
viii. viii. Mortal and Pastel

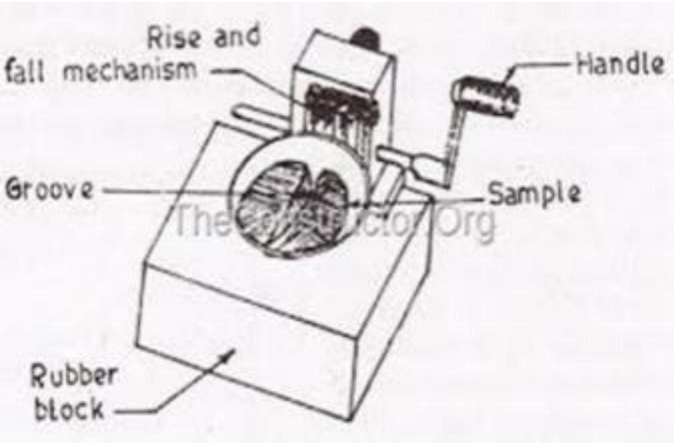

Figure 3.3: Casagrande Device (Source: indiamart 2011)

Required Measurements

i. Weights of the moisture cans
ii. Weights of the representative sample passing through 425 micro standard sieves

iii. Weight of the moisture can plus soil

iv. Weight of moisture can plus the dry soil sample

Procedures

i. The soil sample to be tested was air dried.

ii. A representative sample was obtained, ground in the porcelain mortal and Rubber tipped pastel and then sieved through 425 standard micro sieves.

iii. The sieved sample was placed on a large glass tray with an amount of water added and mixed to paste.

iv. The paste was placed in the cup of a casagrande device.

v. A groove was drawn with the grooving tool through the sample along the symmetrical axis of the cup at the point of contact.

vi. The crank was turned at a rate of about two revolutions per seconds while counting the blows necessary to close the drawn groove in the soil.

vii. The sample in the cup was removed and remixed after adding water.

viii. Steps (iii) to (v) were repeated until the number of blows required to close the gap was observed to be steady.

Plastic Limit (PL): Determined by rolling small soil samples into threads to a diameter of 3mm, the moisture content at which the soil crumbles represent the plastic limit.

Apparatus

i. Large glass plate

ii. Moisture can

iii. Weighing balance (0.01g sensitivity)

iv. Spatula

v. Drying oven

vi. Squeeze bottle filled with distilled water

Required measurements

i. Weight of the moisture can.

ii. Weight of moisture can plus the oven dried soil sample.

Procedure

i. The soil sieved sample used for the liquid limit test was used.

ii. The soil sampled was mixed with little water using hands and divided into smaller parts.

iii. The soil part is placed on the glass plate and rolled using sufficient pressure on the thread of uniform diameter using about 80 to 90 rolling strokes per minute.

iv. The soil was observed to crack, just as it reached a diameter of about 3mm, the soil moisture content assumed to be at the plastic limit was put on the soil thread, weighed and covered immediately. The sample was then oven dried for 24 hours, thereafter, the moisture content was determined.

v. Step (i) to (v) were repeated for the second specimen.

3.4.3 Sieve Analysis

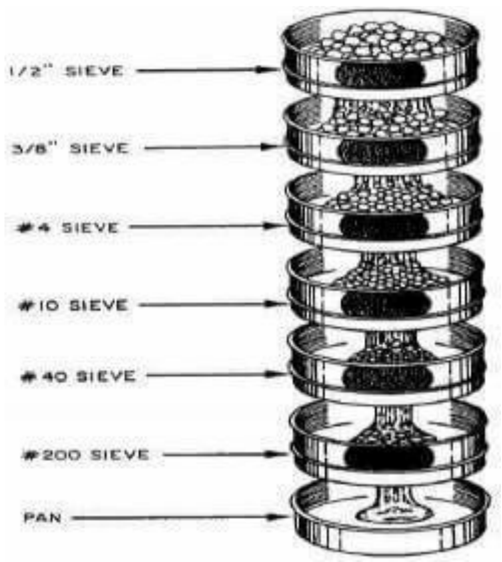

Figure 3.4: sieve analysis material

Procedure

i. Sample Preparation: A representative sample of the material is collected, ensuring it's dry and of a known weight.

ii. Stacking Sieves: A set of sieves with decreasing mesh sizes is arranged in a stack, with the largest mesh on top and the smallest at the bottom.

iii. Weighing the Sample: The total weight of the sample is measured before sieving.

iv. iv. Sieving Process: The sample is placed in the top sieve, and the sieve stack is shaken mechanically for a specified period to allow particles to separate based on size.

v. Weighing Retained Material: After sieving, material retained on each sieve is carefully weighed.

3.4.4 Compaction Test

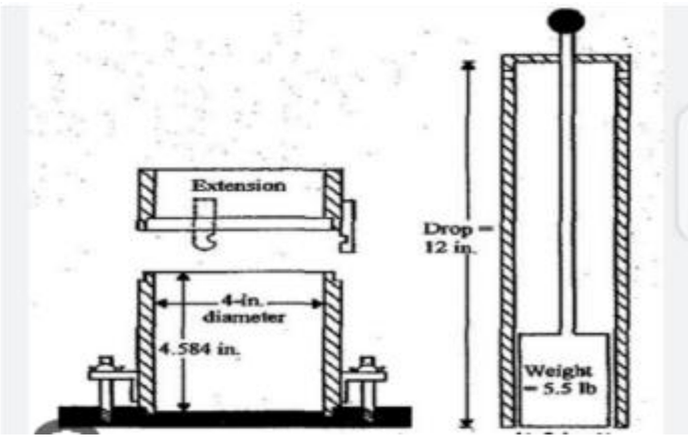

Figure 3.5: Compaction Equipment and Accessories to determine the relationship between water and soil sample as it is being compacted at a specific comparative effort.

Apparatus

i. Compaction mould (100mm diameter and 125mm height) with a 50mm high extension collar

ii. Weighing balance (0.01g sensitivity)

iii. 4.5kg Compaction rammer iv. 4.75mm sieve (ASTM)

iv. Moisture cans

v. Steel straight edge

vi. Large mixing pan

vii. Dry oven

viii. Scoop

ix. Mould oil

Required measurements

i. Weight of the empty mould

ii. Weight of the compaction mould with compacted soil

iii. Weight of empty can iv. Weight of the moisture can with wet sample

iv. Weight ofthe moisture can with dry sample

Procedure

The test procedures were carried out in three phases. They include

i. The sample preparation phase

ii. The mould preparation phase

iii. The compaction phases

Sample Preparation

The soil was sieved through sieve number 47.5mm (ASTM) and obtained 3kg of the sample. This 3kg sample was then poured on the large mixing pan for proper missing with 6% of water content. It was then thoroughly mixed to obtain a uniform mixture of the sample.

The shells were first air-dried to eliminate excess moisture and then combusted in a muffle furnace at a temperature range of 500°C to 700°C, ensuring the complete incineration of organic materials. The ash obtained was finely ground using a ball mill to enhance its reactivity. The GSA was sieved through a 75-micron sieve to achieve a uniform particle size distribution, suitable for soil stabilization purposes.

Mould Preparation

The mould was fixed to the base plate and weighed without the collar, the weight was recorded as w1, then, the collar was attached to the mould and lightly oiled.

Procedure

i. The weight of the mould was recorded

ii. The soil sample was thoroughly mixed to obtain a uniform mixture.

iii. The sample was then divided into approximately equal three parts.

iv. The first part of the soil sample was filled into the mould in three layers given 25 blows of the rammer on each layer.

v. The extension collar was then removed, the excess soil was trimmed off with the straight edge to flush with the top of the mould.

vi. The mould with the compacted soil was weighed without the collar and the weight was recorded as w2.

vii. The sample was extruded from the mould and broken down with the representative sample taken from the middle for the moisture content test. viii. Steps (i) to (vii) were repeated until the weight of the compacted soil with the mould fell.

viii. The weight of the representative sample with the moisture can was also determined for each compaction.

ix. The steps were repeated for the different points of sample collection pits andall the obtained data recorded accordingly.

x. The representative samples in the moisture cans were taken to the oven and were oven dried at 100^{o}C for 24 hours.

3.4.5. Tri-axial Test

Tri-axial test is a crucial method for assessing the strength of soil. The triaxial test is a common laboratory testing method used to measure the mechanical properties of soils under controlled stress conditions. It is widely used in geotechnical engineering to determine soil strength and its deformation characteristics.

Apparatus

i. Tri-axial machine

ii. Scoop

iii. Receiving pan

iv. iv. Sieve 475mm

v. Measuring cylinder

vi. Compaction mould and Rammer (4.5kg)

vii. Weighing balance (0.01 sensitivity)

viii. Extruder

ix. U-2 x. U-4

x. Moisture cans xii. Receiver

xi. Cell membrane xiv. Knife

xii. Membrane suction stretcher

xiii. Straight edge xvii. Proving ring

xiv. Load frame (50KN)

xv. Load and ring dial gauge

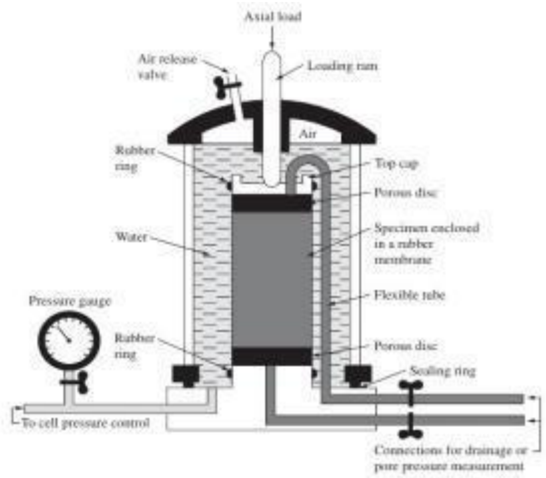

Figure 3.6: Tri-axial machine (source: EIE instrument)

Required measurement

a. Weight of extruded sample

Procedure

i. The soil sample was taken using the scoop and sieved using the 475mm sieve.

ii. From the sieved soil sample 2kg was weighed.

iii. The water content to be added was determined from the OMC (optimum moisture content) from the compaction done.

iv. The water content was added to the soil and thoroughly mixed.

v. The mixed sample was shared into three parts vi. Each part was introduced into the comaction mould with 25 blows per layer for the three layer.

vi. Three U-2 was inserted into the compaction mould and tapped.

vii. The mould was carefully dismember to access the U-2.

viii. The U-2 were removed and taken to the extruder.

ix. The soil sample was collected from the U-2 from the extruder to U-4.

x. The U-4 was taken with receiver to a flat surface.

xi. Using fingers the soil sample was pushed into the receiver and the soil was cut on both end of the receiver with a knife.

xii. The weight of the sample collected from the receiver was taken.

xiii. On the tri-axial machine Place the soil specimen between two porous stones (top and bottom) and wrap it in a thin rubber membrane to prevent water infiltration from the surrounding fluid in the cell.

xiv. The sample is placed inside the tri-axial cell, and a confining pressure (σ_3) is applied by filling the cell with water.

xv. The axial load was applied using the loading frame at a controlled rate. During this stage, the soil sample was subjected to increased vertical stress while the confining pressure remains constant.

xvi. The stress and strain from the gauge are recorded.

xvii. The test continues until the sample fails.

CHAPTER FOUR

RESULTS AND DISCUSSION

The test parameters as stated in chapter three were investigated to achieve the objectives of this study. The parameters include the Specific gravity, Sieve analysis, Atterberg limits, Compaction, California bearing ratio (CBR) values of the soil samples and the effect of a plastic powder stabilization on the soil geotechnical properties.

4.1 The Classification of the Soil Based on its Index and Engineering Properties

The soil index properties investigated in this study were the natural moisture content, specific gravity, particle size distribution, liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, and California Bearing Ratio.

Values.

Table 4.1: summary of the physical testing of the sample

S/N	Sample ID	Characteristic	Value	Remarks
1	BH1	Natural moisture content	9.52	Indicating soils is relatively dry
2		Specific gravity	2.42	Contain coarse material granular grain soil
3		Particle size distribution %Passing BS Sieve N0 200 (0.075)	31.98%	AASHTO class A-6
4		Atterberg Limits: Liquid Limit Plastic Limit Plasticity index	 26.27% 15.65% 10.62%	Moderate plasticity silt soil
5		Compaction: Maximum Dry Density Optimum Moisture Content	 1.92 10.5%	Silt soil
		MDD,OMC @2% MDD,OMC @4% MDD,OMC @6% MDD, OMC @8% MDD,OMC @10%	1.88 11.8% 1.83 13.2% 1.78 14.7% 1.72 16.0% 1.67 17.5%	The MDD gradually Decreases with the input of RHA as the OMC is increased.
6		California Bearing Ratio Least Unsoaked CBR Value Least Soaked CBR Value	 7.598 2.137	The soil is not a good subgrade material for design pavement.
		Total	5.27%	Requires stabilization
7	**BH2**	Natural moisture content	12.08%	Indicating soils with moderate wetness, good workability
8		Specific gravity	2.44	Contain coarse material granular grain soil
9		Particle size distribution %Passing BS Sieve N0 200 (0.075)	41.31%	AASHTO class A-6
10		Atterberg Limits: Liquid Limit Plastic Limit Plasticity index	 27.01% 16.07% 10.94%	Moderate plasticity silt soil
11		**Compaction:** Maximum Dry Density Optimum-Moisture- content Control (@0%)	 1.88 11.6%	Silt sand soil
		MDD,OMC @ 2%. MDD,OMC @4% MDD,OMC @6% MDD,OMC. @8% MDD,OMC @10%	1.85 12.5% 1.80 14.0% 1.75 15.5% 1.70 17.0% 1.65 18.5	MDD gradually Decreases with the input of RHA as the OMC is increased.
12		**California Bearing Ratio** Unsoaked CBR value **Soaked CBR Value**	 7.514 3.174	The soil is not a subgrade material for design pavement.
		Total	5.34%	stabilization or improvement methods may be required to enhance its load-bearing capacity for use in road construction.

Table 4.2: CBR Test Results – Soil with Rice Husk Ash Additives

RHA (%)	Unsoaked CBR (mean)	Unsoaked CBR (std, ±)	Soaked CBR (mean)	Soaked CBR (std, ±)
0	7.514	0.376	3.174	0.222
2	8.867	0.532	3.967	0.317
4	10.069	0.705	4.761	0.476
6	11.271	0.902	5.713	0.686
8	10.895	0.981	5.396	0.701
10	10.369	1.037	4.92	0.689

Remark: The results indicate that the addition of Rice Husk Ash (RHA) significantly improves the California Bearing Ratio (CBR) of the soil up to an optimum level of approximately 6% RHA content, beyond which the CBR values begin to decrease slightly. This trend suggests that moderate RHA replacement enhances soil strength due to pozzolanic reactions and improved particle bonding. However, excessive RHA may lead to increased voids or incomplete reactions, reducing load-bearing efficiency. Overall, the RHA-treated soil demonstrates improved performance compared to the untreated sample, making it suitable for subgrade improvement and light pavement applications.

Table 4.3: Sample Laboratory Readings Leading to CBR Values

RHA (%)	Penetration (mm)	Load (kN)	CBR (%)
0	2.5	0.42	7.514
2	2.5	0.5	8.869
4	2.5	0.57	10.071
6	2.5	0.64	11.271
8	2.5	0.62	10.894
10	2.5	0.59	10.37

4.1.1 Natural moisture content Test

The natural moisture content test was conducted on the soil sample to determine the amount of water content present in the soil when it was extracted. Moisture content is the ratio of weight of water contained in the pore space of the soil to the weight of dry soil, expressed in percentage. The natural moisture content is calculated using the equation 4.1 with summary of results provided in table 4.1

Moisture content

Where: W.t of water added to soil = (Wt. of wet soil + container) / (Wt. of dry soil + container) × 10%

Wt. of dry soil = (Wt. of dry soil + container) - (Wt. of container)

BH1, with a moisture content of 9.52%, falls between the dry and moderately wet, indicating it is relatively dry but still contains some moisture. BH2, at 12.08%, is moderately wet, meaning it has a more noticeable level of moisture. Overall, BH2 is moderately moist, while BH1 is on the drier side but not excessively so.

4.1.2 Specific Gravity Test

The specific gravity of the soil was conducted to determine the reaction of the density of the soil to the density of water. (density = unit weight) BH1 and BH2 have lower specific gravity values than the typical range for pure clay (2.60–2.75) but still fit within the range for clayey soils with more coarse grains or less dense mineral composition. This suggests that these samples contain a mix of coarse material (sand, gravel) or organic matter, which lowers the overall specific gravity.

4.1.3 Sieve Analysis

The sieve analysis results for BH1 and BH2classify the soils as fine, medium, and coarse sand, respectively. This analysis determines the percentage of individual grain diameters ranging from 75 mm to 0.075 mm, with selected sizes representing coarse, medium, and fine grains, as shown in the table 4.1

Table 4.4 Sieve Analysis Test result of the Soil

Sample ID	% Passing selected sieve sizes			Consistency Limit		AASHTO
	2mm	**0.425**	**0.075**	**LL**	**PI**	
BH1	99.19	78.72	31.98	26.27	10.62	A-6
BH2	99.87	84.21	41.21	27.01	10.94	A-6

Both BH1 and BH2 fall under the A-6 classification in the AASHTO system, which indicates clayey soils with moderate plasticity. The high percentage passing the 2mm and 0.425mm sieves and the liquid limits shows that both soils are primarily fine-grained materials (likely silts or clays) with moderate plasticity. The PI values has moderate plasticity, classifying them as A-6, which indicates that the soils may have some workability but are still somewhat cohesive and able to retain moisture.

4.1.4 Atterberg Limit

The Atterberg limit test was performed to evaluate the consistency of the soil sample. A summary of the results is presented in Table 4.4. The liquid limit was determined at a moisture content of 25 blows, while the plastic limit and plasticity index were calculated using the equation provided below

P.L = Average of the moisture content from plastic limit test

$$P.I = L.L - P.L \qquad (4.3)$$

Moisture content =

Where:

W.t of water added to soil = (Wt. of wet soil + container) - (Wt. of dry soil + container)

Wt. of dry soil = (Wt. of dry soil + container) - (Wt. of container)

Table 4.5: Atterberg Limit Test Result of the Soil

Sample ID	PLASTICITY INDEX %
BH1	10.62
BH2	10.94

Both BH1 and BH2 have liquid limits greater than 25%, which classifies them as clayey soils with moderate plasticity according to the A-6 category in the AASHTO system. The plasticity index for both soils falls within the 10-20% range which is moderately plastic clayey soil.

4.1.4 Compaction

A typical range for MDD in the AASHTO classification system is between 1.6 g/cm³ to 2.0 g/cm³ and OMC around 10% to 20% for most soils. Both BH1 and BH2 values fall within the typical range for MDD and OMC according to the AASHTO system. This value conforms to the classification of the soil as Silty sand.

California Bearing Ratio Test

The California bearing ratio (CBR) test is a penetration test carried out to evaluate the mechanical strength of subgrade beneath a pavement. The CBR test involved the determination of the soaked and unsoaked CBR value at the bottom and top layer of the soil as seen in below

The Highway Design Manual, federal Ministry of Works and Housing Specifications of soil characteristics for flexible pavement specifies a minimum value of 10%, 30% and 80% for subgrade, subbase and base course materials respectively.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study has been able to access the tests results show that the soil passing the 0.075mm sieve ranges from 4.43% - 15.99% for all the samples. The liquid limit ranges from 22.26% - 57.3l%. The soil is majorly composed of sand with very few having trace amounts of clay and silt. Majority are A-3 soils while others are A-1-b, A-2-4 and A-2-6 soils. The compaction test shows that the Maximum Dry Density for all BH1 & BH2 ranges from 1.88g/cm3 – 1.92g/cm3 respectively. The input of rice husk ash reduces it to 1.6 & 1.7 while the Optimum moisture content ranges from 11.2% - 10.8% and then increases by 17.4 & respectively. The California Bearing Ratio of the soil is improved up to an optimum level of approximately 6% RHA content.

5.2 Recommendation

Rice Husk Ash would honestly work out well with other stabilizers like Cement or Lime: Given that the study indicates limited potential for using RHA alone for soil improvement it is recommended to combine RHA with cement or lime. This combination can facilitate the formation of secondary cementitious compounds, enhancing soil stabilization. The ideal amount for practical applications is soil stabilized with 10% RHA content and 2% cement for the greatest boost in strength

2. Further Research: Additional research should explore the long-term performance and durability of RHA-stabilized soils under various environmental conditions.

Consider locally available materials: The use of locally available Rice Husk Ash (RHA) in the construction industry in order to reduce the volume of waste that must be disposed of to the environment, causing environmental contamination run.

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APPENDIX


Rice Husk after Burning


Rice Husk before Burning

CONTROL

NATURAL MOISTURE CONTENT RESULT

DETERMINATION OF MOISTURE CONTENT OF SOIL PARTICLES

(STANDARD LABORATORY METHOD)

DATE: LOCATION: **BLOCK OF FLAT**

S/N	LOCATION	DEPTH	CN	WWS+WC	WDS+WC	WC	WDS	WM	MC	AMC
1	**BH1**	**1m**	O.3	99.49	92.64	16.77	75.87	6.85	9.03	9.62
			O.29	97.68	90.14	16.31	73.83	7.54	10.21	
4	**BH2**	**1m**	PLU	95.28	87.12	17.77	69.35	8.16	11.77	12.09
			RT5	91.23	83.05	17.11	65.94	8.18	12.41	

WC = M1

WWS+WC = M2

WDS+WC = M3

WDS = Weight of dry soil (M3-M1)

WM = Weight of moisture (M2-M3)

MC = Moisture Content ((M2-M3)/(M3-M1))*100

AMC = Average moisture content (MC/2)

SPECIFIC GRAVITY RESULT

S/N	LOCATION	DEPTH (m)	BN	B+W	B+S+W	B+S			B	Ad. W	WWAS	WS	WO WDS
1	**BH 1**	1.0	MA	73.47	88.59	44.27	18.59	54.88	44.32	25.68	10.56	**Gs**	**AGs**
1	**BH 1**	1.0	HF	76.64	90.64	46.88	22.88	53.76	43.76	24.00	10.00	2.43	2.42
7	**BH 2**	1.0	DI	76.14	89.78	48.27	24.61	51.53	41.51	23.66	10.02	2.40	
7	**BH 2**	1.0	R	75.81	92.35	49.00	21.56	54.25	43.35	27.44	10.90	2.36	2.44
												2.52	

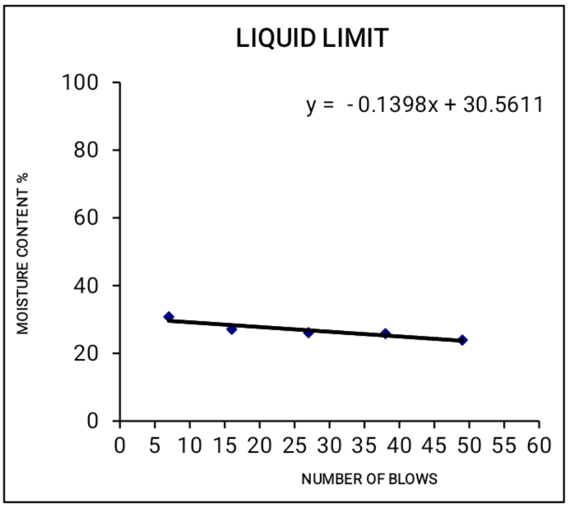
PARTICLE SIZE DISTRIBUTION RESULT

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	0.67	99.33	99.33
10	2	0.14	99.19	99.19
14	1.18	1.24	97.95	97.95
25	0.6	13.7	84.25	84.25
36	0.425	5.53	78.72	78.72
52	0.3	8.51	70.21	70.21
72	0.212	25.62	44.59	44.59
100	0.15	5.37	39.22	39.22
200	0.075	7.24	31.98	31.98

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	0.13	99.87	99.87
10	2	0	99.87	99.87
14	1.18	0.96	98.91	98.91
25	0.6	10.82	88.09	88.09
36	0.425	3.88	84.21	84.21
52	0.3	7.61	76.6	76.6
72	0.212	28.28	48.32	48.32
100	0.15	0.12	48.2	48.2
200	0.075	6.99	41.21	41.21

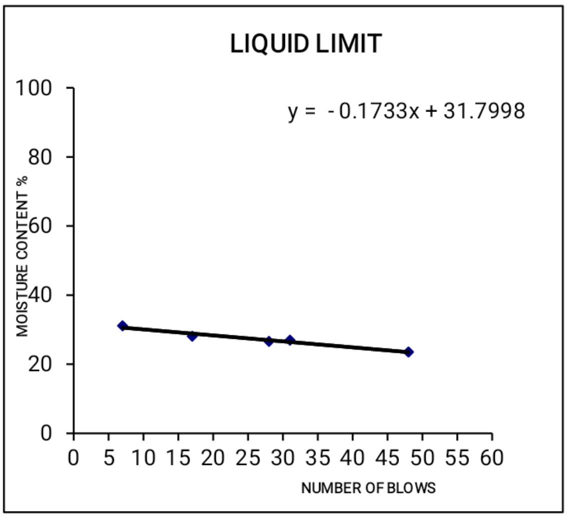
ATTERBERG RESULT

Type of Test	LL	LL	LL	LL	LL
No. of Blows/shrinkage %	48.00	31.00	28.00	17.00	7.00
Container No.	GM1	GAN	AK4	SVD	O.21
Wt of wet soil & container (g)	34.80	36.10	38.00	40.50	50.80
Wt of dried soil & container (g)	32.80	33.00	35.10	36.20	44.30
Wt of container (g)	24.30	21.50	24.20	20.90	23.40
Wt of dry soil (Wd) (g)	8.50	11.50	10.90	15.30	20.90
Wt of moisture (Wm) (g)	2.00	3.10	2.90	4.30	6.50
Moisture contain 100 (Wm/Wd)	23.53	26.96	26.61	28.10	31.10
Type of Test	PL	PL	PL		
No. of Blows/shrinkage %					
Container No.	2M	O.12	LUP		
Wt of wet soil & container (g)	28.50	27.00	26.80		
Wt of dried soil & container (g)	28.00	26.70	26.50		
Wt of container (g)	24.83	24.90	24.60		
Wt of dry soil (Wd) (g)	3.18	1.80	1.90		
Wt of moisture (Wm) (g)	0.50	0.30	0.30		
Moisture contain 100 (Wm/Wd)	15.75	16.67	15.79		



Type of Test	LL	LL	LL	LL	LL
No. of Blows/shrinkage %	49.00	38.00	27.00	16.00	7.00
Container No.	O.3	HAT	LP	GM1	PO2
Wt of wet soil & container (g)	41.00	42.30	37.70	40.90	44.70
Wt of dried soil & container (g)	37.20	38.30	34.70	36.70	39.50
Wt of container (g)	21.30	22.80	23.20	21.20	22.60
Wt of dry soil (Wd) (g)	15.90	15.50	11.50	15.50	16.90
Wt of moisture (Wm) (g)	3.80	4.00	3.00	4.20	5.20
Moisture contain 100 (Wm/Wd)	23.90	25.81	26.09	27.10	30.77

Type of Test	**PL**	**PL**	**PL**		
No. of Blows/shrinkage %					
Container No.	T11	V17	I10		
Wt of wet soil & container (g)	28.50	28.80	28.10		
Wt of dried soil & container (g)	28.00	28.10	27.30		
Wt of container (g)	24.83	23.40	22.40		
Wt of dry soil (Wd) (g)	3.18	4.70	4.90		
Wt of moisture (Wm) (g)	0.50	0.70	0.80		
Moisture contain 100 (Wm/Wd)	15.75	14.89	16.33		



LABORATORY COMPACTION TEST SHEET

BLOCK OF FLAT Sample ID: **BH 1, CONTROL** Depth: **1m** :Location

% MDD: **1.9g/cm^3** OMC: **11.2… 02/02/2025**:Date

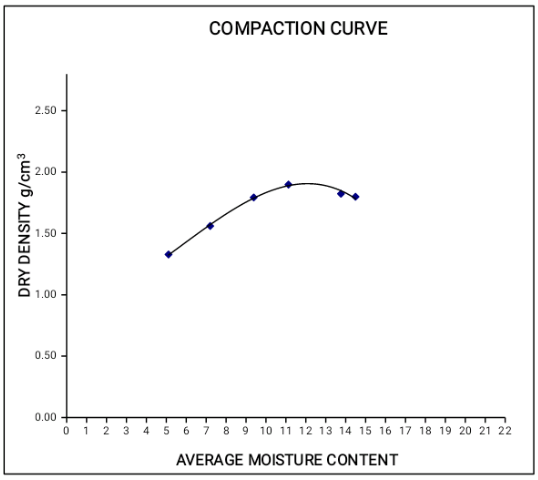
Wt. of mould & wet Soil (W2) g	*5943.00*		*6205.00*		*6477.00*		*6617.00*		*6584.00*		*6570.00*	
Wt. of mould (W1) g	*4625.00*		*4625.00*		*4625.00*		*4625.00*		*4625.00*		*4625.00*	
Wt. of wet soil (W2-W1) g	*1318.00*		*1580.00*		*1852.00*		*1992.00*		*1959.00*		*1945.00*	
Bulk Density (Pb) (W2-W1)/x g/cm^3	*1.40*		*1.67*		*1.96*		*2.11*		*2.08*		*2.06*	
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3												
Container No.	*GE*	*VI6*	*SE*	*VI3*	*AD*	*A*	*O.19*	*AAA*	*EIS*	*O.5*	*VI5*	*VT*
Wt. of wet soil & container (g)	31.20	39.60	48.70	42.30	48.00	54.70	70.70	58.30	57.80	71.80	58.10	65.10
Wt. of Dry soil & container (g)	30.80	38.60	47.20	40.80	46.20	51.70	65.90	54.80	53.10	66.10	53.60	59.70
Wt. of Container (g)	21.80	21.30	24.60	21.50	25.90	21.40	23.50	22.80	20.30	22.90	21.80	23.30
Wt. of dry soil (Wd) g	9.00	17.30	22.60	19.30	20.30	30.30	42.40	32.00	32.80	43.20	31.80	36.40
Wt. of Moisture (Wm) g	0.40	1.00	1.50	1.50	1.80	3.00	4.80	3.50	4.70	5.70	4.50	5.40
Moistur Content 100(Wm/Wd) %	4.44	5.78	6.64	7.77	8.87	9.90	11.32	10.94	14.33	13.19	14.15	14.84
Average Moisture Content (m) %	*5.11*		*7.20*		*9.38*		*11.13*		*13.76*		*14.49*	
Dry Density = Pb/1+ (m/100) (g/cm^3)	*1.33*		*1.56*		*1.79*		*1.90*		*1.82*		*1.80*	
C.B.R (mseen of top & bottom) %												

LABORATORY COMPACTION TEST SHEET

BLOCK OF FLAT Sample ID: **BH 2, CONTROL** Depth: **1m** :Locatior

% MDD: **1.88g/cm^3** OMC: **10.6… 02/02/2025**:Date

Wt. of mould & wet Soil (W2) g	*6036.00*		*6188.00*		*6418.00*		*6593.00*		*6561.00*		*6540.00*	
Wt. of mould (W1) g	*4625.00*		*4625.00*		*4625.00*		*4625.00*		*4625.00*		*4625.00*	
Wt. of wet soil (W2 -W1) g	*1411.00*		*1563.00*		*1793.00*		*1968.00*		*1936.00*		*1915.00*	
Bulk Density (Pb) (W2-W1)/x g/cm^3	*1.49*		*1.66*		*1.90*		*2.08*		*2.05*		*2.03*	
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3												
Container No.	*R1*	*LF*	*2T*	*IX*	*LOV*	*2E*	*BY*	*TIU*	*NTA*	*DO4*	*B*	*VLG*
Wt. of wet soil & container (g)	*41.50*	*57.20*	*61.80*	*47.90*	*54.90*	*57.20*	*60.20*	*66.80*	*70.90*	*77.50*	*60.40*	*57.20*
Wt. of Dry soil & container (g)	*40.40*	*55.50*	*59.10*	*46.00*	*51.80*	*54.10*	*56.20*	*62.30*	*65.20*	*71.80*	*55.40*	*52.50*
Wt. of Container (g)	*21.40*	*23.20*	*24.50*	*21.60*	*21.30*	*23.10*	*21.50*	*23.00*	*23.40*	*28.50*	*21.50*	*22.10*
Wt. of dry soil (Wd) g	*19.00*	*32.30*	*34.60*	*24.40*	*30.50*	*31.00*	*34.70*	*39.30*	*41.80*	*43.30*	*33.90*	*30.40*
Wt. of Moisture (Wm) g	*1.10*	*1.70*	*2.70*	*1.90*	*3.10*	*3.10*	*4.00*	*4.50*	*5.70*	*5.70*	*5.00*	*4.70*
Moistur Content 100(Wm/Wd) %	*5.79*	*5.26*	*7.80*	*7.79*	*10.16*	*10.00*	*11.53*	*11.45*	*13.64*	*13.16*	*14.75*	*15.46*
Average Moisture Content (m) %	*5.53*		*7.80*		*10.08*		*11.49*		*13.40*		*15.10*	
Dry Density = Pb/1+ (m/100) (g/cm^3)	*1.42*		*1.54*		*1.75*		*1.87*		*1.83*		*1.77*	
C.B.R. (mseen of top & bottom) %												



CALIFORNIA BEARING RATIO RESULT

CALIFONIA BEARING RATIO TEST

SAMPLE NO	*BH1 1m*	
DESCRIPTION	*BLOCK OF FLAT*	*DATE:18-02-2025*
NOTES O	*CONTR*	
SOIL	*OL*	

TEST ONBOTTOM (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*	*3.00*	*23*	*33*	*65*	*91*	*117*	*150*	*167*	*245*	*323*	*355*
Ditto corrected												
Load (KN)	*0*	*0.03281*	*0.25158*	*0.36096*	*0.71098*	*0.99537*	*1.27976*	*1.64072*	*1.82667*	*2.67985*	*3.53302*	*3.88304*
C.B.R %												

TEST ONTOP (UNSOAKED) ***SURCHARGE***

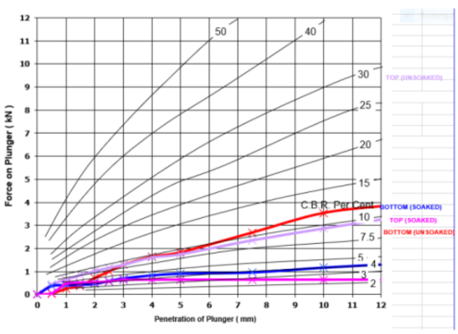
Penetration (mm)	*0.00*	*0.50*	*1.00*	*1.50*	*2.00*	*2.50*	*3.00*	*4.00*	*5.00*	*7.50*	*10.00*	*12.50*
Load Indicator	*0*	*40.00*	*59*	*77*	*93*	*106*	*118*	*147*	*160*	*215*	*262*	*306*
Ditto corrected												
Load (KN)	*0*	*0.43753*	*0.64535*	*0.84224*	*1.01725*	*1.15944*	*1.2907*	*1.60791*	*1.7501*	*2.3517*	*2.8658*	*3.34707*
C.B.R %												

TEST ONBOTTOM (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*	*34.00*	*37*	*39*	*42*	*54*	*64*	*76*	*83*	*88*	*107*	*122*
Ditto corrected												
Load (KN)	*0*	*0.3719*	*0.40471*	*0.42659*	*0.4594*	*0.59066*	*0.70004*	*0.8313*	*0.90787*	*0.96256*	*1.17038*	*1.33445*
C.B.R %												

TEST ONTOP (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*	*42*	*46*	*48*	*51*	*57*	*58*	*58*			
Ditto corrected												



CALIFONIA BEARING RATIO TEST

SAMPLE NO **BH2 1m**

DESCRIPTION **BLOCK OF FLAT** *DATE: 18-02-2025*

NOTES O **contr**

SOIL **ol**

TEST ONBOTTOM (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	37.00	61	75	86	92	106	130	159	237	324	375
Ditto corrected												
Load (KN)	0	0.40471	0.66723	0.82036	0.94068	1.00631	1.15944	1.42196	1.73917	2.59234	3.54396	4.10181
C.B. R. %												

TEST ONTOP (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	77	99	120	128	160	201	237	283	338	392
Ditto corrected												
Load (KN)	0	0.54691	0.84224	1.08288	1.31258	1.40008	1.7501	2.19857	2.59234	3.0955	3.69709	4.28775
C.B. R. %												

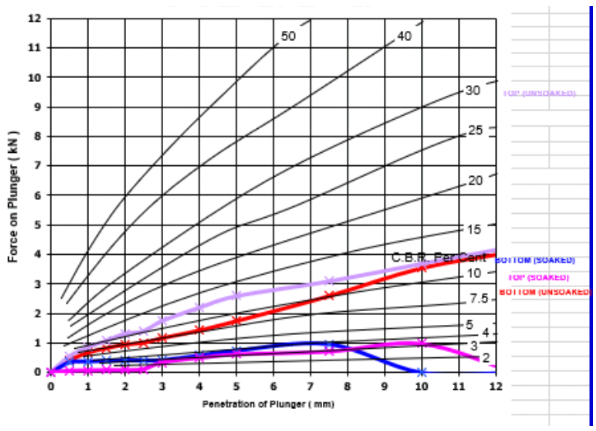
TEST ONBOTTOM (SOAKED) ***SURCHARGE***

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	32.00	35	37	38	38	39	53	68	88		
Ditto corrected												
Load (KN)	0	0.35002	0.38284	0.40471	0.41565	0.41565	0.42659	0.57972	0.74379	0.96256	0	0
C.B. R. %												

TEST ONTOP (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	6	7	7	10	31	45	56	65	89	
Ditto corrected												
Load (KN)	0	0.05469	0.06563	0.07657	0.07657	0.10938	0.33908	0.49222	0.61254	0.71098	0.9735	0
C.B. R. %												

	UNSOAKED		***SOAKED***	
	2.5mm	5.0mm	2.5mm	5.0mm



COMPACTION

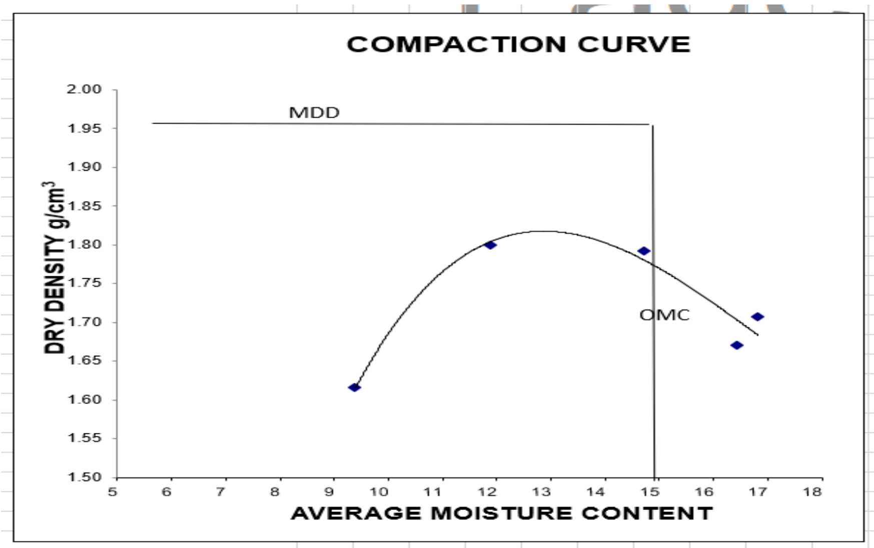
BH1 2%

Wt. of mould & wet Soil (W2) g	6246.00	6379.00	6710.00	6707.00	6523.00
Wt. of mould (W1) g	4662.00	4662.00	4662.00	4662.00	4662.00
Wt. of wet soil (W2-W1) g	1584.00	1717.00	2048.00	2045.00	1861.00
Bulk Density (Pb) (W2-W1)/x g/cm3	1.68	1.82	2.17	2.17	1.97

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

Container No.	ACD	JAS	RTS	KEI	MT	O.33	AS	JAC	AE2	DE2
Wt. of wet soil & container (g)	55.70	57.70	72.50	75.10	86.00	78.10	81.70	83.10	85.60	88.80
Wt. of Dry soil & container (g)	53.50	55.10	68.40	70.90	79.70	72.40	74.20	75.80	76.20	80.20
Wt. of Container (g)	21.40	23.00	23.40	23.60	23.10	23.00	24.10	23.10	22.70	20.90
Wt. of dry soil (Wd) g	32.10	32.10	45.00	47.30	56.60	49.40	50.10	52.70	53.50	59.30
Wt. of Moisture (Wm) g	2.20	2.60	4.10	4.20	6.30	5.70	7.50	7.30	9.40	8.60
Moistur Content 100(Wm/Wd) %	6.85	8.10	9.11	8.88	11.13	11.54	14.97	13.85	17.57	14.50
Average Moisture Content (m) %	7.48		9.00		11.33		14.41		16.04	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.56		1.67		1.95		1.89		1.70	

C.B.R. (mseen of top & bottom) %					



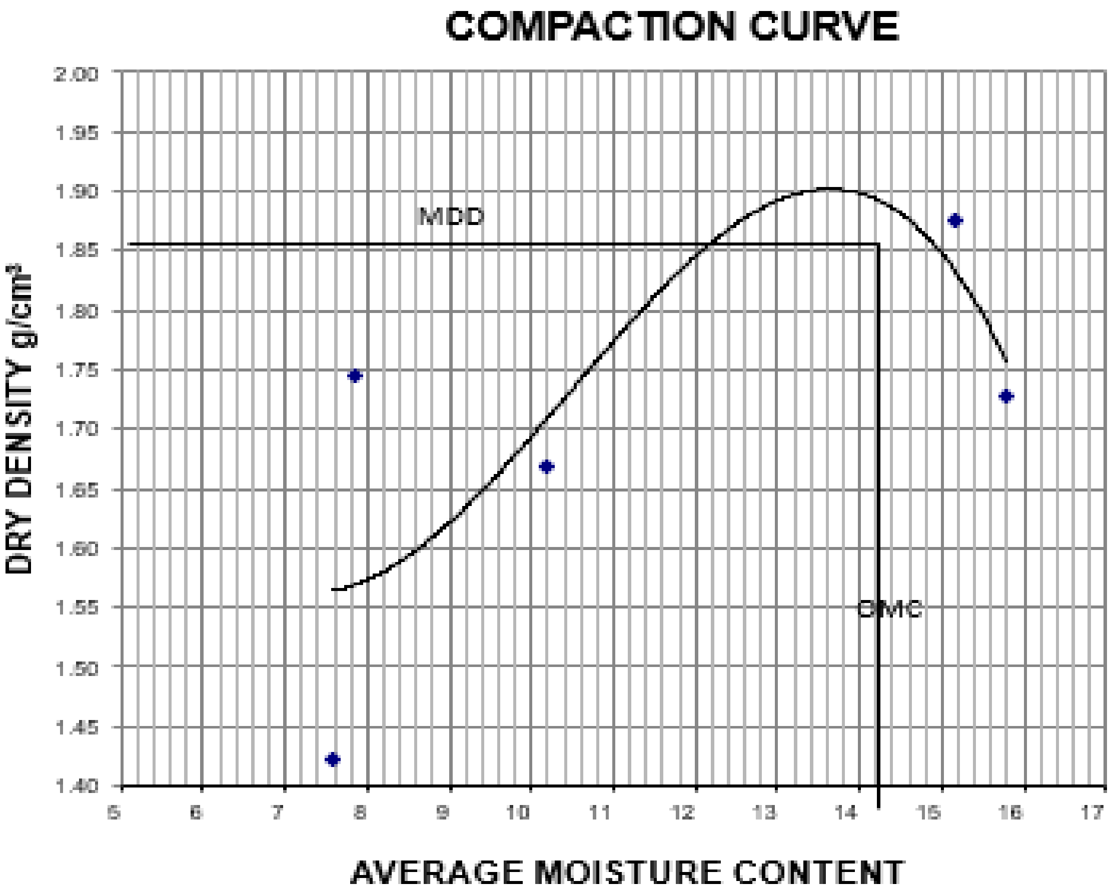
4%

Wt. of mould & wet Soil (W2) g	6105.00	6397.00	6700.00	6549.00	6438.00
Wt. of mould (W1) g	4662.00	4662.00	4662.00	4662.00	4662.00
Wt. of wet soil (W2-W1) g	1443.00	1735.00	2038.00	1887.00	1776.00
Bulk Density (Pb) (W2-W1)/x g/cm3	1.53	1.84	2.16	2.00	1.88

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

Container No.	FN	O.4 O	PA7	R2	RT2	AIO	O24	OV	O.31	LBP
Wt. of wet soil & container (g)	75.00	77.60	83.40	79.70	94.10	92.00	74.00	89.40	81.70	86.30
Wt. of Dry soil & container (g)	71.20	73.80	77.70	74.40	85.70	82.60	66.80	80.30	73.50	86.30
Wt. of Container (g)	23.00	21.40	21.20	23.00	26.20	24.60	21.50	22.20	21.40	18.42
Wt. of dry soil (Wd) g	48.20	52.40	56.50	51.40	59.50	58.00	45.30	58.10	52.10	67.88
Wt. of Moisture (Wm) g	3.80	3.80	5.70	5.30	8.40	9.40	7.20	9.10	8.20	0.00

Moistur Content 100(Wm/Wd) %	7.88	7.25	10.09	10.31	14.12	16.21	15.89	15.66	15.74	0.00
Average Moisture Content (m) %	7.57		10.20		15.16		15.78		7.87	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.42		1.67		1.87		1.73		1.74	
C.B.R. (mseen of top & bottom) %										



6%

Wt. of mould & wet Soil (W2) g	6154.00	6364.00	6513.00	6551.00	6527.00	6475.00
Wt. of mould (W1) g	4662.00	4662.00	4662.00	4662.00	4662.00	4662.00
Wt. of wet soil (W2-W1) g	1492.00	1702.00	1851.00	1889.00	1865.00	1813.00
Bulk Density (Pb) (W2-W1)/x g/cm3	1.58	1.80	1.96	2.00	1.98	1.92

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

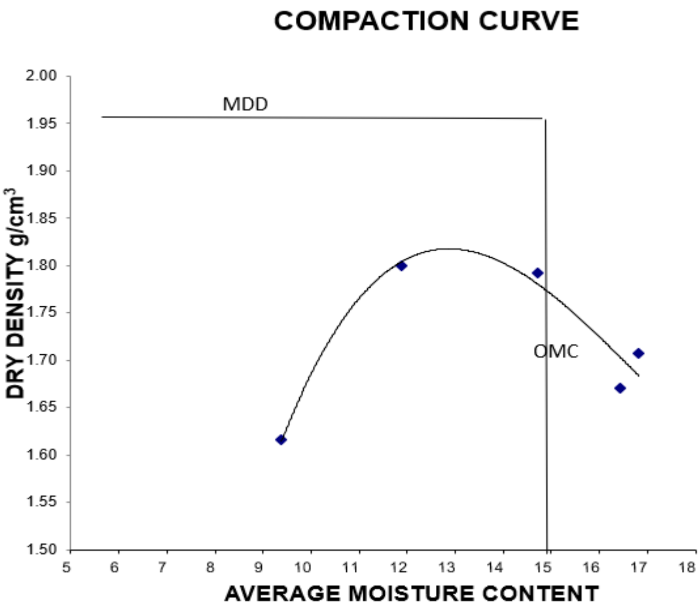
Container No.	OAT	OZI	OZ2	TA8	O.33	JA8	TA3	8O2	OGA	FF	KO	RXD
Wt. of wet soil & container (g)	73.90	75.80	89.60	95.50	95.20	88.70	83.20	90.00	99.00	98.90	80.10	83.00
Wt. of Dry soil & container (g)	70.20	71.90	83.20	89.80	87.20	80.60	75.50	81.30	87.20	87.60	71.50	74.40
Wt. of Container (g)	23.50	20.80	21.40	24.50	24.50	20.90	23.50	24.90	21.60	24.50	21.90	22.20
Wt. of dry soil (Wd) g	46.70	51.10	61.80	65.30	62.70	59.70	52.00	56.40	65.60	63.10	49.60	52.20
Wt. of Moisture (Wm) g	3.70	3.90	6.40	5.70	8.00	8.10	7.70	8.70	11.80	11.30	8.60	8.60
Moistur Content 100(Wm/Wd) %	7.92	7.63	10.36	8.73	12.76	13.57	14.81	15.43	17.99	17.91	17.34	16.48
Average Moisture Content (m) %	7.78		9.54		13.16		15.12		17.95		16.91	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.47		1.65		1.73		1.74		1.68		1.64	
C.B.R. (mseen of top & bottom) %												

BH2

2%

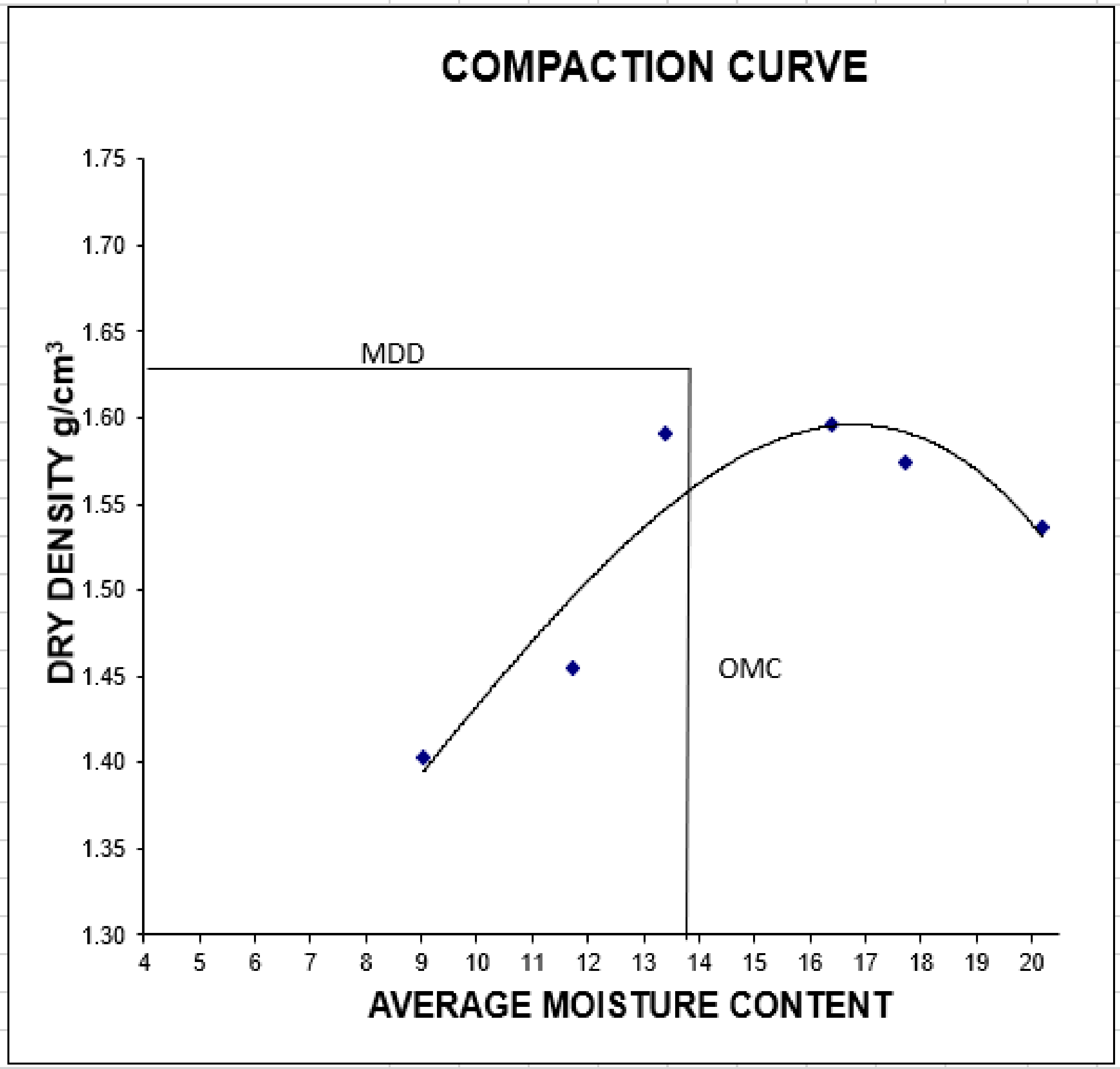
Wt. of mould & wet Soil (W2) g	6330.00	6563.00	6603.00	6544.00	6498.00
Wt. of mould (W1) g	4662.00	4662.00	4662.00	4662.00	4662.00
Wt. of wet soil (W2-W1) g	1668.00	1901.00	1941.00	1882.00	1836.00

Bulk Density (Pb) (W2-W1)/x g/cm3	1.77		2.01		2.06		1.99		1.94	
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3										
Container No.	ACD	JAS	C4	ESH	RTS	KEI	MT	O.33	AS	JAC
Wt. of wet soil & container (g)	62.20	63.00	70.50	74.40	86.90	78.20	83.80	75.40	81.30	75.50
Wt. of Dry soil & container (g)	58.70	59.50	65.40	68.70	78.90	70.80	75.20	67.90	72.90	68.10
Wt. of Container (g)	21.80	21.80	21.30	22.00	23.60	21.40	24.30	23.10	23.40	21.60
Wt. of dry soil (Wd) g	36.90	37.70	44.10	46.70	55.30	49.40	50.90	44.80	49.50	46.50
Wt. of Moisture (Wm) g	3.50	3.50	5.10	5.70	8.00	7.40	8.60	7.50	8.40	7.40
Moistur Content 100(Wm/Wd) %	9.49	9.28	11.56	12.21	14.47	14.98	16.90	16.74	16.97	15.91
Average Moisture Content (m) %	9.38		11.89		14.72		16.82		16.44	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.62		1.80		1.79		1.71		1.67	
C.B.R. (mseen of top & bottom) %										



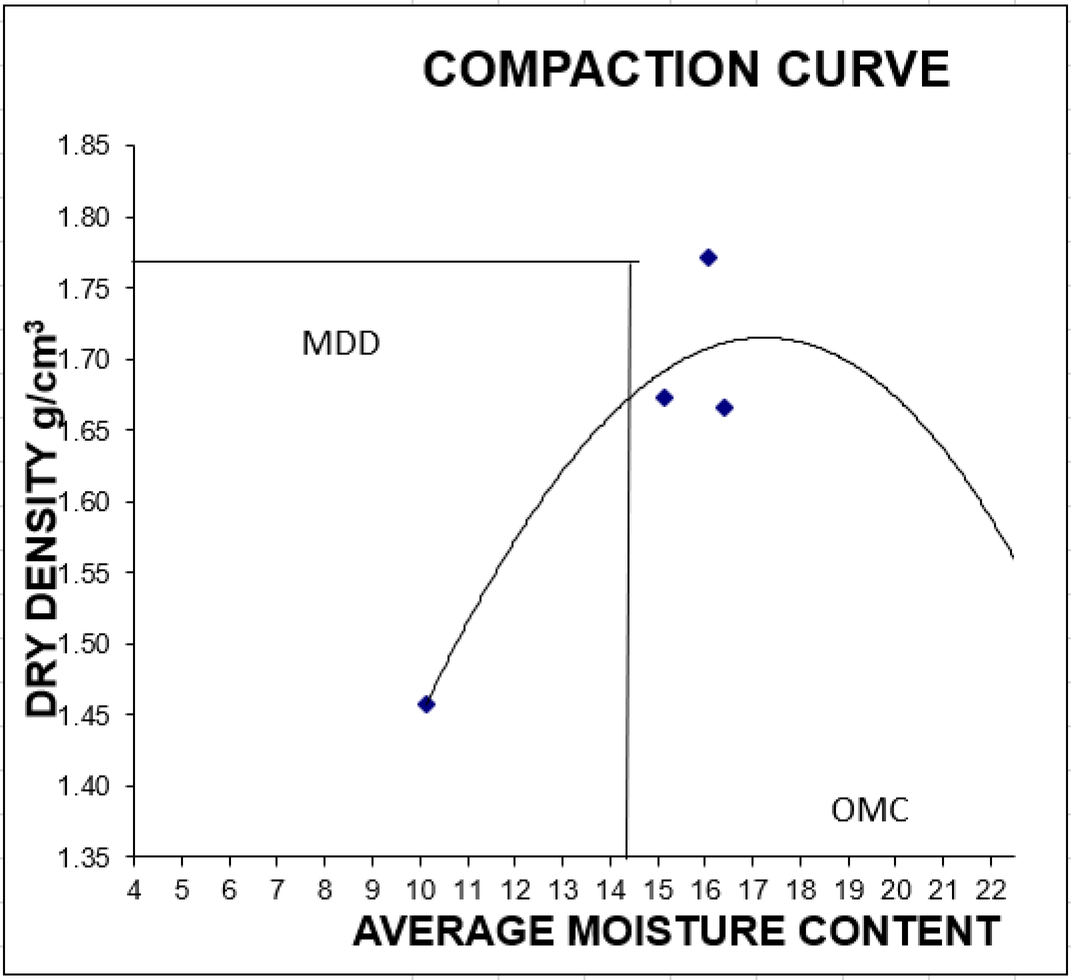
8%

Wt. of mould & wet Soil (W2) g	6178.00		6274.00		6450.00		6504.00		6499.00		6494.00	
Wt. of mould (W1) g	4662.00		4662.00		4662.00		4662.00		4662.00		4662.00	
Wt. of wet soil (W2-W1) g	1516.00		1612.00		1788.00		1842.00		1837.00		1832.00	
Bulk Density (Pb) (W2-W1)/x g/cm3	1.52		1.62		1.80		1.85		1.84		1.84	
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3												
Container No.	JABI	3OD	UK	CCO	VXX	O.41	ECB	TA6	B2	B3	RT4	P
Wt. of wet soil & container (g)	81.30	80.80	84.50	84.10	81.30	66.40	87.90	75.20	91.30	81.40	88.00	91.80
Wt. of Dry soil & container (g)	76.60	76.30	78.30	77.80	74.90	61.20	79.40	67.80	81.80	72.60	77.40	80.20
Wt. of Container (g)	21.70	23.30	23.50	21.40	24.30	21.60	25.40	21.60	24.80	23.20	23.50	21.40
Wt. of dry soil (Wd) g	54.90	53.00	54.80	56.40	50.60	39.60	54.00	46.20	57.00	49.40	53.90	58.80
Wt. of Moisture (Wm) g	4.70	4.50	6.20	6.30	6.40	5.20	8.50	7.40	9.50	8.80	10.60	11.60
Moistur Content 100(Wm/Wd) %	8.56	8.49	11.31	11.17	12.65	13.13	15.74	16.02	16.67	17.81	19.67	19.73
Average Moisture Content (m) %	8.53		11.24		12.89		15.88		17.24		19.70	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.40		1.46		1.59		1.60		1.57		1.54	
C.B.R. (mseen of top & bottom) %												


COMPACTION CURVE
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
DRY DENSITY g/cm3
MDD
OMC
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
AVERAGE MOISTURE CONTENT

10%

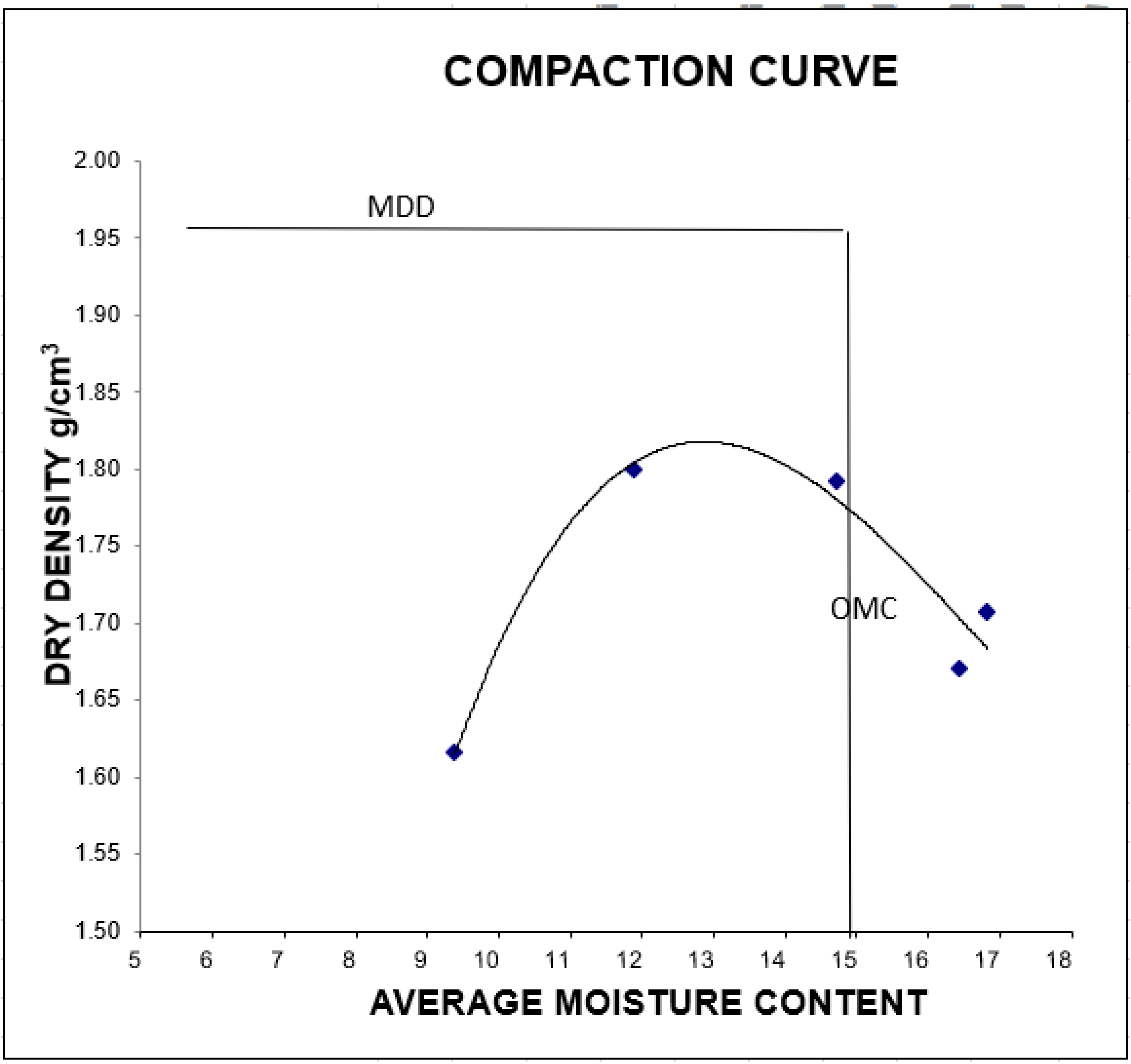
Wt. of mould & wet Soil (W2) g	6171.00		6473.00		6595.00		6484.00		6445.00	
Wt. of mould (W1) g	4662.00		4662.00		4662.00		4662.00		4662.00	
Wt. of wet soil (W2-W1) g	1509.00		1811.00		1933.00		1822.00		1783.00	
Bulk Density (Pb) (W2-W1)/x g/cm3	1.60		1.92		2.05		1.93		1.89	
MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3										
Container No.	O.39	OMI	V2	TA	RT7	V12	T3	O27	OZ6	O.34
Wt. of wet soil & container (g)	55.10	57.80	54.20	49.70	51.30	59.70	55.70	65.90	67.20	68.80
Wt. of Dry soil & container (g)	51.60	54.40	49.60	45.40	46.70	53.90	49.70	60.20	59.00	58.60
Wt. of Container (g)	17.30	16.90	16.80	17.30	16.90	16.90	17.10	17.70	17.30	17.50
Wt. of dry soil (Wd) g	34.30	37.50	32.80	28.10	29.80	37.00	32.60	42.50	41.70	41.10
Wt. of Moisture (Wm) g	3.50	3.40	4.60	4.30	4.60	5.80	6.00	5.70	8.20	10.20
Moistur Content 100(Wm/Wd) %	10.20	9.07	14.02	15.30	15.44	15.68	18.40	13.41	19.66	24.82
Average Moisture Content (m) %	9.64		14.66		15.56		15.91		22.24	
Dry Density = Pb/1+ (m/100) (g/cm3)	1.46		1.67		1.77		1.67		1.55	
C.B.R. (mseen of top & bottom) %										


COMPACTION CURVE
DRY DENSITY g/cm3
AVERAGE MOISTURE CONTENT
MDD
OMC
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

BH2

2%

<table>
<tr><td>Wt. of mould & wet Soil (W2) g</td><td colspan="2">6330.00</td><td colspan="2">6563.00</td><td colspan="2">6603.00</td><td colspan="2">6544.00</td><td colspan="2">6498.00</td></tr>
<tr><td>Wt. of mould (W1) g</td><td colspan="2">4662.00</td><td colspan="2">4662.00</td><td colspan="2">4662.00</td><td colspan="2">4662.00</td><td colspan="2">4662.00</td></tr>
<tr><td>Wt. of wet soil (W2-W1) g</td><td colspan="2">1668.00</td><td colspan="2">1901.00</td><td colspan="2">1941.00</td><td colspan="2">1882.00</td><td colspan="2">1836.00</td></tr>
<tr><td>Bulk Density (Pb) (W2-W1)/x g/cm3</td><td colspan="2">1.77</td><td colspan="2">2.01</td><td colspan="2">2.06</td><td colspan="2">1.99</td><td colspan="2">1.94</td></tr>
<tr><td colspan="11">MOISTURE CONTENT DETERMINATIONS for B.S. Mould, X = 944cm3</td></tr>
<tr><td>Container No.</td><td>ACD</td><td>JAS</td><td>C4</td><td>ESH</td><td>RTS</td><td>KEI</td><td>MT</td><td>O.33</td><td>AS</td><td>JAC</td></tr>
<tr><td>Wt. of wet soil & container (g)</td><td>62.20</td><td>63.00</td><td>70.50</td><td>74.40</td><td>86.90</td><td>78.20</td><td>83.80</td><td>75.40</td><td>81.30</td><td>75.50</td></tr>
<tr><td>Wt. of Dry soil & container (g)</td><td>58.70</td><td>59.50</td><td>65.40</td><td>68.70</td><td>78.90</td><td>70.80</td><td>75.20</td><td>67.90</td><td>72.90</td><td>68.10</td></tr>
<tr><td>Wt. of Container (g)</td><td>21.80</td><td>21.80</td><td>21.30</td><td>22.00</td><td>23.60</td><td>21.40</td><td>24.30</td><td>23.10</td><td>23.40</td><td>21.60</td></tr>
<tr><td>Wt. of dry soil (Wd) g</td><td>36.90</td><td>37.70</td><td>44.10</td><td>46.70</td><td>55.30</td><td>49.40</td><td>50.90</td><td>44.80</td><td>49.50</td><td>46.50</td></tr>
<tr><td>Wt. of Moisture (Wm) g</td><td>3.50</td><td>3.50</td><td>5.10</td><td>5.70</td><td>8.00</td><td>7.40</td><td>8.60</td><td>7.50</td><td>8.40</td><td>7.40</td></tr>
<tr><td>Moistur Content 100(Wm/Wd) %</td><td>9.49</td><td>9.28</td><td>11.56</td><td>12.21</td><td>14.47</td><td>14.98</td><td>16.90</td><td>16.74</td><td>16.97</td><td>15.91</td></tr>
<tr><td>Average Moisture Content (m) %</td><td colspan="2">9.38</td><td colspan="2">11.89</td><td colspan="2">14.72</td><td colspan="2">16.82</td><td colspan="2">16.44</td></tr>
<tr><td>Dry Density = Pb/1+ (m/100) (g/cm3)</td><td colspan="2">1.62</td><td colspan="2">1.80</td><td colspan="2">1.79</td><td colspan="2">1.71</td><td colspan="2">1.67</td></tr>
<tr><td>C.B.R. (mseen of top & bottom) %</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>


COMPACTION CURVE
MDD
OMC
DRY DENSITY g/cm3
AVERAGE MOISTURE CONTENT
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
5 6 7 8 9 10 11 12 13 14 15 16 17 18