“STABILIZATION OF MOHALI SOIL USING RHA AND LIME SLUDGE ”

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Mr. Chandra Pal Gautam
(Assistant Professor)

By

***Akanksha Guleria* (131659)**
***Srishti Thakur* (131673)**

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

CERTIFICATE

Candidate's Declaration

We hereby declare that the work presented in this report entitled **" Stabilization of Mohali soil using RHA and Lime Sludge"** in fulfilment of the requirements for the award of the degree of **Bachelor of Technology** submitted in the department of Civil Engineering**,** Jaypee University of Information Technology , Waknaghat is an authentic record of our own work carried out over a period from August 2016 to April 2017 under the supervision of**Mr. Chandra Pal Gautam**, Assistant Professor, Department Of Civil Engineering.

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

Srishti Thakur, 131673 Akanksha Guleria, 131659

This is to certify that the above statement made by the candidates is true to the best of my knowledge.

Dr. Ashok Kumar Gupta	Mr. Chandra Pal Gautam	External Examiner
Professor & Head of Department	Assistant Professor	
Civil Engineering Department	Civil Engineering Department	
JUIT Waknaghat	JUIT Waknaghat	

ACKNOWLEDGEMENT

It is our proud privilege and duty to acknowledge the kind of help and guidance received from several people in preparation of this report. It would not have been possible to prepare this report in this form without their valuable help, cooperation and guidance.

We owe our profound gratitude to our project supervisor Mr. Chandra Pal Gautam, who took keen interest and guided us all along in our project work titled — "STABILIZATION OF MOHALI SOIL USING RHA AND LIME SLUDGE" till the completion of our project by providing all the necessary information for developing the project. The project development helped us in research and we got to know a lot of new things in our domain. We are really thankful to him.

ABSTRACT

Construction of pavements and other civil engineering structures on available piece of land containing some percentage of clay minerals is highly risky on geotechnical grounds because of poor strength properties of the clayey soil. Avoiding the use of that piece of land is not always possible economically. This brings in the need for soil treatment to improve the engineering properties of soil. In practise admixtures with fly ash, lime and rice husk ash are used frequently to stabilize soils and improve their strength properties. This project involves the use of two waste materials Rice Husk Ash (RHA) and Lime Sludge containing lime which acts as a binder. These two undergo reactions to form complexes that fill in the spaces, changing the structure of soil and hence reduce the shrink or swell characteristics and plasticity thereby increasing the strength of soil. RHA and Lime sludge are waste materials available in huge quantities, making the construction processes economical. The purpose of this project is to find the optimum ratio of the two to maximise the strength of soil. In this study, RHA (8%,10%,12%,15% by wt. of dry clay) and Lime sludge(5%,10%,15% by wt. of dry clay) were mixed with soil in various proportions to find out the relative strength gained in terms of unconfined compression. It was found that strength of soil increases by increasing the content of RHA and Lime sludge.

Contents

LIST OF TABLES

LIST OF FIGURES

List of abbreviations

CBR- California Bearing Ratio
OMC- Optimum Moisture Content
MDD-Maximum dry density
RHA- Rice husk ash
UCS-Unconfined Compressive Strength

CHAPTER 1

1.1 INTRODUCTION

Soil stabilisation refers to alteration of soil to improve its physical properties. It can increase the shear strength and/or control the shrink or swell characteristics of soil. In this way, it improves the load bearing capacity of a sub-grade to support pavements and foundation. The objective of this project is to improve the properties of Mohali soil (expansive clayey soil) to increase its suitability for road construction activities by adding RHA and Lime Sludge, which are waste materials. Both of these are hazardous for the environment. They are produced in lump sum as industrial-by-product and their disposal is a matter of concern in India. Effects of RHA and Lime Sludge on Proctor's density, Atterberg limits and unconfined Compressive strength are to be determined. In this project, without additives soil is tested for plasticity index, unconfined compressive strength and optimum moisture content.

Soil is the basic foundation for all engineering structures. It is responsible to bear loads without failure. Clayey soil possesses poor strength characteristics and can pose a serious threat to structures constructed on them due to their property of differential settlement. It leads to severe damages in structures like light building, pavements, retaining walls, and linings etc. founded on the expansive soils. Clayey soil may swell and shrink due to alteration in water content. This is due to the presence of minerals like montmorillonite, Kaolinite, Illite. These minerals make the soil active. It is not always possible to avoid clayey soil in sites, so the best possible way to tackle with it is their stabilisation. Stabilisation can be achieved by mixing either pozzolanic materials like RHA, Ground Granulated Blast Furnace Slag, etc or chemicals like Lime, Calcium Chloride,etc.Soil stabilization is defined as a process in which soil is improved and made more stable improving its bearing capacity, increasing soil strength, and durability under changing moisture and stress conditions. Any discarded or abandoned materials which are solid in state and stay at the place where they have been scrapped are called as solid wastes. They are divided into four groups according to the source of their generation

i) Industrial solid wastes (Fly ash, Blast furnace slag, Red mud, Copper slag etc.)

ii) Agricultural solid wastes (Rice husk, Bagasse, Ground nut shell etc.)

iii) Domestic solid wastes (Incinerator ash, Waste tire etc.)

iv) Mineral solid wastes (Quarry dust, Marble dust etc.) .

Use of solid wastes to improve and enhance the engineering properties of expansive soils is one of the different techniques to make them acceptable for construction purposes.

This project is focused on investigating the effects and optimum ratio of RHA and Lime Sludge on some geotechnical properties of soil. RHA and Lime Sludge both are waste materials produced in huge amount and cause a threat to environment.

The weight of Rice Husk Ash (RHA) is about 25% by weight of rice husk when burnt in boilers. Rice husk works as a fuel in the rice mills to foster steam for the parboiling process. It consists of 75% organic volatile matter and 25% of the weight of this husk is turn to ash during the firing process, is known as rice husk ash (RHA). This RHA has around 85%-90% silica

Chemical stabilization brought the use of technique and that is to add a binder to the soil so as to upgrade the geotechnical potential of land like the mechanical and chemical properties of soil.Lime sludge is an inert material which is composed of calcium carbonate, is the byproduct of process of softening of hard water for utilizing it as drinking water .

Project's concern is to improve the properties of soil to make it suitable for use as subgrade. To find the effects of RHA and Lime Sludge on the properties of soil following tests were performed: Atterberg Limits, Optimum moisture content and Unconfined Compression test. Additives have both short-term and long-term effects on the properties of soil. Flocculation and agglomeration of soil particles on the surface of soil by ion exchanges are some of the short term effects they have on the soil. It improves the workability of soil and helps reducing the shrinking, plastic and swell properties of soil. Also, the improvement of compactive properties of soils is the result of long-term effect of chemical stabilization.

CHAPTER 2

LITERATURE REVIEW

2.1 “Soil stabilization with fly ash and rice husk ash (RHA)”

The objective of this paper is to improve the quality of expansive clayey soil as a construction material by using fly ash and rice husk ash which are waste materials.RHA and fly ash were mixed with the remolded clayey soil in different proportions. In order to examine the importance of the study, the cost comparison was made for the preparation of the sub base of a highway project with and without the mineral admixture stabilizations.

RHA with 90.2% silica content and that passes through 150 microns was used along with Type C fly ash. The test methods that were performed are Light weight Compaction Test, Unconfined Compression Test,Califoria Bearing Test and consolidation test.From compaction test it was found out that the optimum moisture content of soil is 20% with maximum dry density equal to 15.5kn/m3.The rest of the tests were performed by adding water equal to OMC.

When the RHA was increased from 0-12%,unconfined compressive stress increased from 660-1300kPa.further increase in fly ash decreased UCS which indicated that the optimum value of fly ash is 25%.similarly it was concluded that the optimum value of RHA is 12%.Fly ash is pozzolanic in nature and when it is mixed with clay,pozzzolanic reactions take place along with cation exchange, carbonation and cementation which leads to agglomeration in large size particles. This leads to an increase in compressive strength and reduction in the swelling of clay. The swelling reduces because sodium ions in the soil get replaced by calcium ions in fly ash.

RHA was not use as the only admixture because low cohesion makes RHA a poor cushioning and construction material. but after it was stabilized with fly ash and cured for 28 days, construction properties of the soil were improved.

In order to examine the importance of this study, a cost comparison was made for the preparation of the sub base of a highway project with and without the presence of admixtures. For this purpose , an eight lane heavy duty highway for a design period of 20 years was considered as per AASHTO design procedures. A sub base of 13 inch thickness was eliminated by treated soil. The savings in cost per mile over control group were calculated and the results were good but there were some challenges as well in the form of bad weather conditions and dust issues.

2.2 “Stability of clay soil using rice husk ash and stone dust”

The objective of this study is the improvement in stability of soil for the good building construction in civil engineering and observes a right concentration mixture of the additional components rice husk ash and stone dust making the foundation process cheap and comfortable economically.

The procedure under this study included the analysis of standard proctor test (light compaction) and unconfined compressive strength(UCS) under various proportions of stone dust and RHA.

It was observed that the optimum moisture content of the untreated sample was 25.5% and the maximum dry density was 1.73 . the maximum strength gained by the sample was at strain of 0.0438. which was the result of mixing 10% stone dust with 20% RHA. Then the next step was to check if it was economically suitable or not. The study concluded that the cost of experiment is totally based on the ease of availability of the admixtures. If stone dust and RHA were available at nearby locations at a cheaper rate, then it is suitable but if not, then it is better that we try other alternatives as well.

2.3 "A study of paper mill lime sludge for stabilization of village road sub base"

The aim of the study is to investigate the possibility of use of paper mill waste for stabilization of village road sub-base.the soil was collected from three different sites of Assam and their physical properties were determined in the laboratory. In a developing country like India, soil stabilization methods using local available materials have considerable scope in reducing the construction cost of roads. But the stabilization technique should be simple, lowest, labor intensive and decentralized. The properties investigated were particle size distribution, Atterberg limits (liquid limit, plastic limit and plasticity index), compaction properties (optimum moisture content and maximum dry density), California bearing ratio value and swelling properties (free swell index and differential free swell index).After these tests were completed on untreated soil the soil is e then mixed with paper mill lime sludge collected from Jagiroad Paper Mill, Jagiroad, Assam, India in different proportions and the physical properties of treated soils were determined.

The results from the particle size analysis depicted that all the soil samples were fine grained (clays) and the lime mud was clayey sands (>12% fines).the lime sludge contains an appreciable amount of sands(84.90%) which provides proper drainage in the road sub base. Addition of lime sludge lowered the liquid limit raised the plastic limit and thus reduced the plasticity index of the soil. This rendered the clayey soil friable, easy to be pulverized and helped reduce the shrinkage. The results showed that the optimum moisture content increases and maximum dry density decreases with increase in lime mud in all types of soil .The increase may be due to consumption of more water by lime and the decrease in maximum dry density may be due to increase in OMC. For 1%addition of lime sludge, the increase in CBR came out to be 19.76%.

It is evident from the study that CBR value of clayey soils increases with addition of paper mill lime mud in all types of sludge. The percentage of increase depends on the type of soil. Lime sludge of NPM may be used for stabilization of village road sub-base. The village roads which get deformed and muddy during rainy season could be stabilized and maintained by using lime mud waste.

2.4 “Models and Optimization of rice husk ash-clay soil stabilization”

Soil stabilization has been found to be very effective in incresing the bearing capacity of weak soils for construction purposes. The stabilizing agent, ought to provide a cheaper alternative to other possible processes for cost efficiency. With the rapid industrialization efforts around the globe, a large quantity of waste materials are generated and there has not been adequate mechanism for recycling and re-use of such wastes to reduce the consequent environmental problems and hazardous situations created as a result. The objective of the soil is to upgrade the expansive soils from Eke Obinagu,Ugwuaji in Enugu State and Egbede in Abia State Nigeria.

In road construction, there is aneed to use high quality sub grade materials to affect a substantial reduction in the thickness of pavement, thereby reducing the overall cost of production. However it is important to maintain the them to ensure their long life. A study on strength characteristics of clay soil stabilized with lime and the ash was conducted and the unconfined compressive strength and soaked CBR (California Bearing Ratio) tests for different combinations of the stabilizing agents showed that 4% lime is very close to the optimal value either as sole additive or with any other secondary additive, from the view point of optimum efficiency. When the sample was untreated, the CBR value was 5% but after the treatment the CBR value rose to 17.5%.The soil was mixed with this ash, remolded and tested to examine the effect on the OMC (optimum moisture content) and the CBR (California Bearing Ratio). The characterization of the soils was done in accordance with BS1377 and 1990b, with respect to their engineering properties which include OMC, MDD, Soaked CBR, Liquid Limit, Classification and Sieve Analysis. The rice husk was burnt and prepared in a cylindrical incinerator to form the ash. There was an increase in the OMC values from 15% to 33%.The major challenge now is to develop mathematical models that will encourage wider and easier application of soil improvement techniques.

2.5 “Soil stabilization using lime”

The main objective of this study is to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability by the adding lime to the soil . Unstable soils can create many problems for pavements or structures, Therefore techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil.

If we use quicklime, it immediately hydrates (i.e. chemically combines with water) and releases heat. Soil is dried, because water present in the soil participates in this reaction, and because the heat generated can evaporate additional moisture. The hydrated lime produced by these initial reactions will subsequently react with clay particles .they reduce the soil’s moisture holding capacity and subsequently produce additional drying. If we use hydrated lime or slurry, drying occurs only through the chemical changes in the soil that reduces its capacity to hold water and thus increases its stability. After initial mixing, the calcium ions (Ca^{++}) from hydrated lime migrate to the surface of the clay particles and displace water and other ions. The soil becomes friable and granular, making it easier to work and compact. At this stage the Plasticity Index of the soil decreases drastically, as does its tendency to swell and shrink. The soil suddenly switches from being plastic (yielding and sticky) to being crumbly (stiff and grainy)

Limitation of the need for embankment materials brought in from outside and the elimination of their transporting costs. Reduction of transport movements in the immediate vicinity of the construction site. Machines can move about with far greater ease. There are no delays due to weather conditions leading to improved productivity. As a result, the overall construction duration and costs can be dramatically reduced. Moreover the structures have a longer service life (embankments, capping layers) and are cheaper to maintain.

Lime is used as an excellent soil stabilizing materials for highly active soils which undergo through frequent expansion and shrinkage. Lime acts immediately and improves various property of soil such as carrying capacity of soil, resistance to shrinkage during moist conditions, reduction in plasticity index, increase in CBR value and subsequent increase in the compression resistance with the increase in time. The reaction is very quick and stabilization of soil starts within few hours.

2.6 "Experimental study on the use of lime for construction: An Example for Sustainability"

This study investigates a sustainable development strategy from beneficial utilization of lime. Drinking water treatment plants annually produce significant economic burden to daily operations. This experimental program is implemented to address the technical issues related to application of lime in the construction of soil embankment where it is used to stabilize the soil.

Lime sludge samples were collected from the lagoon of Massillon water plant. It looks like a paste with a high natural water content (over 90% on the gravimetric basis). Both chemical and mineral analyses were conducted on the collected lime sludge sample using an Energy-Dispersive X-ray spectroscopy (EDX) equipped with Scanning Electron Microscopy (SEM) probe. Prior to the test, lime sludge was first dried in an oven. EDX measures the existence and concentration of different elements in a sample .The chemical content of each constituent (e.g. CaO, MgO) is derived from the measured percentage. However we didn't get to know of the exact quantities of $CaCO_3$ and CaO and for that we needed to do further tests. The optimum lime content for soil stabilization was determined by the use of ASTM D6276 (ASTM) .according to this standard , the optimum value of lime content is the minimum lime content that can produce a pH of12. As an alternative method to determine the optimal lime sludge content, unconfined compressive strength tests were conducted on soil mixed with different concentration of dry lime sludge. If we achieve a compressive strength greater than 345kpa, it significantly reduces the potential for settlement in deep fills. Unconfined compressive strength tests were conducted on lime sludge treated soil specimens to study the effect of dry/wet mix method on soil strength and find the optimum soil-lime sludge ratio.

Additions of lime sludge increased the soil deformation modulus and reduced the plastic behaviors. There was no effect of dry or wet samples in the strength of the soil.if we consider the economic factors associated with drying lime sludge, lime sludge can be introduced in the slurry format via the procedure of wet mix. The existing testing data demonstrated the positive effects of lime sludge treatment in improving the soil mechanical performance properties as well as improving the durability under freeze-thaw cycles. Continue refinement of mix design and performance evaluation could provide a way to effectively utilize lime sludge as an economic and sustainable development strategy.

2.7 "Beneficial utilization of lime sludge for sub grade stabilization: A pilot investigation"

The main purpose of this study was to determine the feasibility of using lime sludge as sub grade stabilization. The study was focused on the feasibility of using lime sludge as a substitute of regular lime used in road construction, design issues such as, method of lime sludge introduction, the optimum content of lime sludge and the long term performance etc. Soil stabilization has performance and economic benefits in providing pavement with rugged base .the experimental studies were conducted on five types os soils including low plastic clay soil and high plastic clay soil. the experimental testing included the measurement of soil index properties ,characteristics of lime sludge, testing for pH values of lime sludge and stabilized soil, testing for unconfined compressive strength of soil and stabilized soil, microstructure testing.

According to the test results, it was concluded that the addition of lime sludge doesn't significantly affect the strength of low plastic soils but it significantly does increase the strength of the high plastic soil. The percentage in the reduction of soil strength due to freezing-thawing is typically lower for soils with introduction of lime sludge. Also the soil specimens treated with lime sludge typically show higher unconfined compressive strength than untreated soil specimens .

2.8 OBJECTIVES

- The main objective of this project is the stabilization of clayey soil.
- Addition of RHA and Lime Sludge.
- Perform Atterberg Limits, Compaction Test and Unconfined Compression Test on soil first in its natural state and then with different percentage of additives.
- To study the changes in various characteristics of soil on varying percentage of RHA and Lime Sludge added to the soil. For the same, graphs are plotted for all percentages of RHA and Lime Sludge.
- To find an optimum ratio of RHA and Lime Sludge for which the soil gains its maximum strength.

CHAPTER 3

METHODOLOGY

3.1 MATERIALS USED

3.1.1. SOIL:

The soil used for this experiment is collected from a region in Mohali.

Properties of soil play a crucial role in selection of the land for construction purposes. Their properties may need to be altered by mixing additives. The properties of soil used are listed in Table 3.1.

Properties	**Value**
Specific Gravity	2.632
Liquid Limit	37.0%
Plastic Limit	16.96%
OMC	17.0%
MDD	1.715g/cc
Plasticity Index	20.04%

TABLE 3.1: Properties of Soil

FIGURE 3.1: Soil

3.1.2. RICE HUSK ASH:

RHA is collected from KGR Agro Fusions Pvt. Ltd., Ludhiana. The RHA was ground and sieved through 0.075mm sieve before use. The properties of RHA are given in Table 2.

Properties	**Value**
Silica content	89%
Loss on Ignition	5.81
Specific Gravity	2.11

TABLE 3.2: RHA

FIGURE 3.2: Rice Husk Ash

3.1.3 LIME SLUDGE:

Lime sludge /mud is a byproduct relatively free of any contaminants produced from sugar, paper, calcium carbide industries. Approximately 4.5 million tons of sludge in total is generated annually from these industries. Lime is mostly used to change the engineering properties of fine-grained soils.

3.2 TESTING OF SOIL

Soil was collected from the site and its engineering properties are studied by conducting following experiments. To check the effects of RHA and Lime Sludge on clayey soil following tests are again performed on soil after mixing additives in various proportions.

3.2.1 MOISTURE CONTENT

Preparation of sample

After receiving the soil sample, it is dried in oven at a temperature of 105 to 115°C for a period of 16 t o24 hrs.

Procedure ("IS: 2720 (Part II) – 1973")

- The soil sample was placed in three different containers.
- Three samples weighed (W1) on the electric weighing machine.
- Then the container was filled with wet soil were weighed and there weights were taken(W2)
- Then the three samples were placed in an oven for drying for 24 hours at 110C.
- After complete drying of the samples they were again weighed (W3).
- From the difference between the two weights (W1-W2), natural water content present in the given soil sample was determined.
- Using (W3-W1) the weight of dry soil was calculated.
- Using formula w =(W2-W3)/(W3-W1),the moisture content of sample was calculated.
- The mean of the water content of the three water sample gives the required water content in soil sample.

Precautions

- Avoid the loss of sample while transferring it to the pan.
- Inaccuracies in weighing.
- Maintain a temperature of oven from 105 to 115°C.

3.2.2 PARTICLE SIZE ANALYSIS

(A) DRY SIEVE ANALYSIS

Preparation of sample

Soil sample was collected, weighed are dried in oven at 105 to 115°C for a period of 16 to 24 hrs. Lumps of soil were then broken to their original size.

Procedure (“IS-2720-PART-4-1985”)

- 1500 gm of clayey soil was taken.
- This quantity of soil was passed through a set of sieves arranged according to their sizes with the largest sieve size at the top and smallest at the bottom.
- The size of the sieves were 4.75 mm,2.36 mm,1.18 mm.0.6 mm,425 micron,300 micron,150 micron and75 micron.
- A receiver was kept at the bottom and a lid was placed at the topmost sieve of the stack.
- The whole stack was placed inside the mechanical sieve shaker and was shaked for 10 minutes.
- The amount of soil retained on each sieve was weighed.
- % retained on each sieve =(weight of soil on that sieve/total weight of soil taken)*100
- Cumulative % of soil retained was calculated by the formula,
  =sum of %retained on all sieves of larger sizes and the % retained on that particular sieve
- The percentage of the total weight passing through each sieve =100-%cumulative retained.

Precautions

- Care must be taken to remove the particles stuck in sieves of various sizes.
- Examine the sieve for any breaks in the screen and discard it in case of any breaks in the main body.
- Minimize the loss of sample while transferring the sample to sieves.

(B) WET SIEVE ANALYSIS (HYDROMETER ANALYSIS)

For clayey soil because of the presence of finer particles, wet sieve analysis by hydrometer method is performed. The hydrometer contains a scale that gives the value of specific gravity. It is based on the Archimedes' principle. The lower the density of the substance, the farther the hydrometer sinks.

Preparation of sample

Lumps of soil are broken to fine particles. 50g of clayey soil was taken in the 75 micron sieve. The sample was washed under the tap water, the clay content and water is collected in tub below the sieve. The soil particles in the tub were allowed to settle down for 24 hours and the settled particles were oven dried for 24 hours at 105°C.

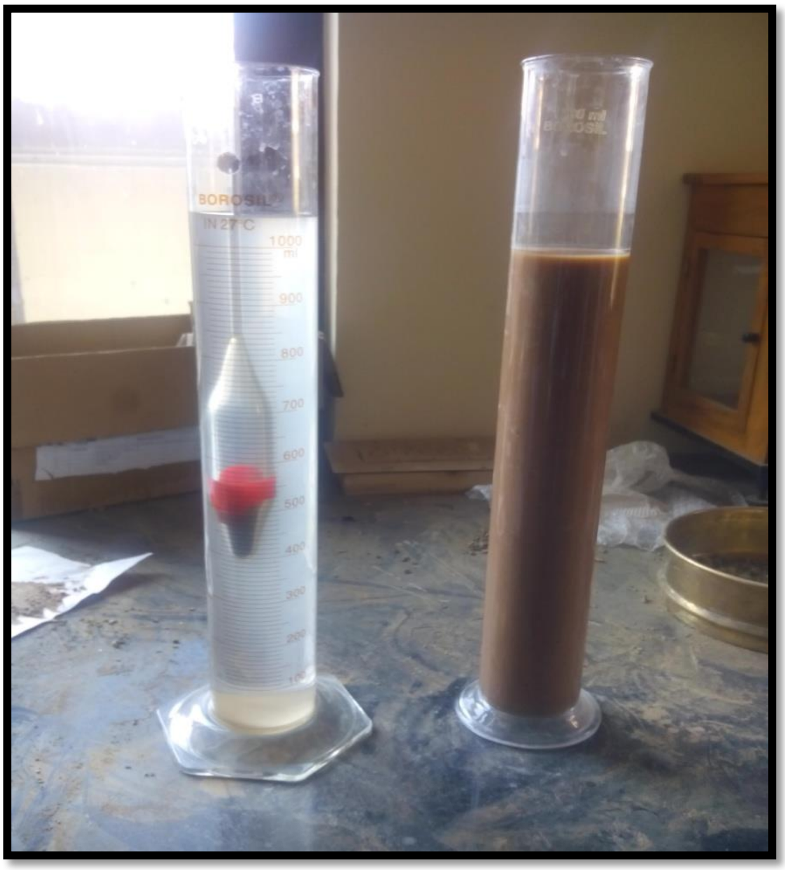


FIGURE 3.3: Hydrometer Analysis

Procedure ("IS: 2720 (Part 4) – 1985 (Reaffirmed-2006)")

- The portion passing through 75 micron sieve was substantial, so a wet sieve analysis using hydrometer was carried out.
- The oven dried sample collected on 75 micron sieve was weighed.

- From the difference between the two weights, the clay content present in the soil sample was determined.
- To this 50 gm of soil, 90 ml of distilled water and 10 ml of dispersing solution was added.
- The above formed mixture (soil + water + dispersing solution) was transferred to the cup of mechanical stirrer.
- The mixture was operated for about 10 minutes.
- Meanwhile the clean hydrometer was kept in 1000cc jar filled with distilled water and 100 cc dispersing agent solutions.
- After completion of stirring, the mixture was poured into the 1000cc jar and enough water was added to bring level to 1000cc mark.
- The suspension in the jar was thoroughly mixed.
- After thoroughly mixing, the jar was placed on the table and the hydrometer was inserted.
- The stop watch was simultaneously started.
- Values were taken by reading the top of the meniscus at 0.5, 1, 2 and 4 minutes.
- After 4 minutes reading the hydrometer was removed, cleaned by placing in another second jar which contained distilled water and dispersing solution.
- Further readings at 8, 15, 30 minutes and 1,2,4,8 and 24 hours after the start of the test was taken.
- For determining the correction, the top and bottom of the meniscus formed on the stem of the hydrometer when it is floating in the second jar containing the distilled water and dispersing agent was taken.

Precautions

- Make sure the jar is clean before pouring the solution.
- Avoid the formation of bubbles by gently mixing the solution.
- Make sure the apparatus is at room temperature else don’t forget to make temperature corrections.

3.2.3 SPECIFIC GRAVITY

Preparation of sample

After receiving the soil sample it is dried in oven at a room temperature of 105 to 115℃ for a period of 16 to 24 hrs.

Procedure ("IS: 2720 (Part III/Sec 1) – 1980")

- The given soil sample was passed through 2mm IS test sieve.
- From the passed soil 50gm of the soil was taken for the experiment.
- Distilled water was used to clean oven dried specific gravity bottle and was weighed (W1).
- Then 5-7gm of the soil sample is filled into the specific gravity bottle and is weighed (W2).
- Water was added into the specific gravity bottle containing 5-7gm of soil ,the water poured with constant shaking so no air voids are left , after filling the bottle completely with water it was weighed (W3).
- Again the empty sp gravity bottle is taken and was completely filled with distilled water and was weighed (W4).
- After performing the above mentioned steps , the specific gravity was determined by using the formula :
  $G = (W2-W1)/((W4-W1)-(W3-W2))$

Precautions

- Soil grains whose specific gravity is to be determined were taken completely dry.
- If on drying soil lumps are formed, they were broken to its original size.
- Inaccuracies in weighing and failure to completely eliminate the entrapped air.

3.2.4 ATTERBERG LIMITS

The physical properties of clays are considerably influenced by the amount of water present in them. Depending upon the water content, the following stages or states of consistency are used to define the consistency of a clay soil.

(A) LIQUID LIMIT

It is defined as the water content at which a groove cut in a pat of soil by a grooving tool of standard dimensions will flow together for a distance of 13 mm under the impact of 25 blows in a standard liquid limit device. It is determined by Casagrande apparatus.

FIGURE 3.4: Casagrande Apparatus

Preparation of sample

Take about 120 gm of soil sample passing through the 425 micron sieve. Mix it thoroughly with distilled water in the evaporating dish to form a uniform paste.

Procedure ("IS: 2720 (Part 5) – 1985")

- After the formation of uniform paste, a portion of paste was placed in the cup and was leveled so as to have maximum depth of about 10mm.
- A groove cut in the soil in the cup, using grooving tool.
- The handle was rotated at the rate of 2 revolutions per second and the number of blows necessary to close the groove for a distance of 13mm noted.
- 10gm of soil near the closed groove was taken to determine its water content.
- The same operation repeated by altering the water content of the soil.
- For four readings of moisture content range, blows are obtained.

- A graph plotted between no of blows, N on a logarithmic scale and water content ,w on the natural scale .
- From the graph the liquid limit was determined by reading the moisture content corresponding to 25 blows on the flow curve.

Precautions

- Groove in the soil should be closed by flow of soil not by slippage between soil and surface of cup.
- After mixing water with soil, leave it for some time to allow proper permeation of water through the soil.
- Soil used for performing the test should not be oven dried.

(B) PLASTIC LIMIT

It is defined as the water content at which a soil would just begin to crumble when rolled into a thread of approximately 3 mm diameter.

Preparation of sample

The given soil sample was mixed thoroughly with distilled water in an evaporating dish till the soil mass becomes plastic enough to be easily molded with fingers. Then the soil mass ball of about 8gm was formed.

Procedure ("IS: 2720 (Part 5) – 1985")

- The ball was then rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into the thread of uniform diameter throughout its length.
- The rolling was done till the thread is of 3mm diameter.
- The soil was then kneaded together to a uniform mass and rolled again.
- This process of alternate rolling and kneading was continued until the thread crumbled under the pressure required for rolling and the soil could no longer be rolled into a thread.
- At the point of crumble, the satisfactory end point was considered.
- After the formation of crumble the sample was weighed (W1).
- Then the sample was placed in the oven for drying for 24 hours at 105C.
- The dried sample was again weighed (W2).

- The difference between the two weights gave the moisture content.
- The same procedure performed for the three more samples.
- The required moisture content at plastic limit obtained from the mean of the four readings.

Precautions

- Soil used for sampling should not be oven dried prior to testing.
- Stop the crumbling process as soon as cracks appear in the thread.
- After mixing water with soil, leave it for some time to allow proper permeation of water through the soil.

(C) SHRINKAGE LIMIT

Shrinkage Limit: is the maximum water content at which a decrease in moisture content does not cause any decrease in the volume of the soil mass. For determination of shrinkage limit, the change in volume of soil is found by mercury displacement method.

Preparation of sample

30gm of soil sample passing through 425 micron sieve was thoroughly mixed with distilled water.

Procedure (“IS-2720-PART-6-1972”)

- A clean empty shrinkage dish was weighed.
- Capacity of the shrinkage dish was determined by filling the shrinkage dish to overflowing with mercury which is equal to the volume of the wet soil pat.
- Then the inside of the shrinkage dish was coated with thin layer of silicone grease.
- The dish was filled with the prepared soil paste.
- The dish with the filled soil was weighed.
- Then the dish was placed in the oven for 24 hours at 110°C.
- The dish with the dry soil was weighed.
- Volume of dry soil pat was determined by placing the soil pat in glass cup full of mercury.
- On placing the soil pat in the glass of full of mercury and forcing the pat under the mercury by means of a glass plate, the mercury was displaced.
- The displaced mercury was weighed and its volume is determined by dividing its weight by the unit weight of mercury.

- The obtained volume was the volume of the dry soil pat.

FIGURE 3.5: Shrinkage Limit

Precautions

- Weigh the sample properly without any errors while taking the reading.
- Take proper care of mercury.
- Take out the sample from the shrinkage dish carefully without breaking the sample.

3.2.5 LIGHT WEIGHT COMPACTION TEST

For clayey soil Proctor's Light Weight Compaction Test is performed. It is done to find the optimum moisture content corresponding to maximum dry density (with no voids). Bulk and then dry density is found for different moisture content in soil and the graph between dry density and moisture content is plotted. Point after which dry density will start decreasing gives OMC.

Preparation of sample

Take 5 kg of oven dried soil passing through 4.75mm sieve. Add water in various proportions and mix thoroughly.

FIGURE 3.6: Light Weight Compaction Test

Procedure ("IS-2720-PART-7-1980")

- Took a substantial amount of oven dried soil.
- Sieved it through 4.75mm sieves.
- Used a mould of 10cm diameter and 12.1 cm height when percentage retained on 4.75 mm sieve is less than 20%.
- Took 2.5 kg of soil for mould for compaction.
- Added water to it so that its moisture content reached to 8%.
- After cleaning the mould and base plate, weighed the mould with base plate.
- The wet soil was compacted in three equal layers by the rammer of mass 2.6 kgm, when 25 blows were there in each layer.
- The soil was trimmed off from the mould and flushed the top of the mould.
- The mould was cleaned, and then weighed the mould with soil and base plate.
- The soil was removed from the mould and took a representative sample for water content determination.
- The procedure was repeated at 10%, 12%, 15%, 18%, and 25% respectively.
- Calculated the dry density of the sample.

Precautions

- Sufficient period (about 15 minutes for clayey soil) of time must be provided to allow water to mix properly with the soil before compacting it in the mould.
- Blows must be provided uniformly over the surface of each layer (three layers).
- After compaction mould must be weighed with the plate.

3.2.6 UNCONFINED COMPRESSION TEST

In this a cylindrical specimen of soil having no lateral support is tested for failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen is known as unconfined compressive strength. This test is performed at OMC of soil.

Preparation of sample

- The sampling soil was mixed with the optimum quantity of water and density in the large mould.
- The sampling tube was pushed into the large mould and removes the sampling tube filled with the soil. For undisturbed samples, push the sampling tube into the clay sample.
- The soil sample was saturated in the sampling tube by a suitable method.
- The split mould was coated lightly with a thin layer of grease. Weighed the mould.
- Extruded out the sample out of the sampling tube into the split mould, using the sample extractor and the knife.
- The two ends of the specimen were trimmed in the split mould. Weighed the mould with the specimen.
- The specimen was removed from the split mould by splitting the mould into two parts.

FIGURE 3.7: Unconfined Compressive Strength

Procedure

- Measured the length and diameter of the specimen.
- Placed the specimen on the bottom plate of the compression machine. Adjusted the upper plate to make contact with the specimen.
- The dial gauge was adjusted and the proving ring gauge to zero.
- Applied the compression load to cause an axial strain at the rate of ½ to 2% per minute.
- Recorded the dial gauge reading, and the proving ring reading every thirty seconds upto a strain of 6%. The reading may be taken after every 60 seconds for a strain between 6%, 12% and every 2minutes or so beyond 12%.
- Continued the test until failure surfaces have clearly developed or until an axial strain of 20% is reached.

- Took the sample from the failure zone of the specimen for the water content determination.

Precautions

- Both the ends of sample must be smoothened so that it can rest properly.
- Constant rate of loading should be maintained on the sample.
- Prepare the sample carefully. Soil must be compacted fully to prepare the sample.

CHAPTER 4

OBSERVATIONS AND RESULTS

4.1 MOISTURE CONTENT:

Observations

Weight of empty container=W1

Weight of container with wet soil=W2

Weight of container with oven dried soil=W3

Moisture content (w %) is calculated as:

w%= (W2-W3)/(W3-W1)

Sample	W1	W2	W3	w%
1	20.9	39.9	35.5	30.13
2	19.3	36.3	32.7	27.659
3	19.3	39.3	35	27.388

TABLE 4.1: Moisture Content

Result

The moisture content of the soil = 28.39%

4.2 SPECIFIC GRAVITY:

Observations

Weight of empty density bottle =W1

Weight of density bottle + dry soil =W2

Weight of density bottle+ dry soil+ water=W3

Weight of density bottle+ water =W4

Specific gravity is calculated as:

G = (W2-W1)/((W4-W1)-(W3-W2))

S No.	Observations	sample 1	sample 2	sample 3
1	W1	27.5	27.5	27.5
2	W2	77.5	77.5	77.5
3	W3	106.5	106	105
4	W4	75.4	75	74.1
5	Specific gravity ,G	2.645	2.631	2.618
	Specific gravity of soil	2.631		

TABLE 4.2: Specific Gravity

4.3: ATTERBERG LIMITS

(A) LIQUID LIMIT

Liquid limit is the moisture content corresponding to 25 number of blows.

Graph is plotted between water content and number of blows.

Determination no.	sample 1	sample 2	sample 3	sample 4
No. of blows	70	48	22	6
Weight of container (W1g)	18.7	19.3	18.5	18.8
Weight of container +wet soil (W2g)	35.5	41.6	36.5	31.7
Weight of container +oven dried soil(W3g)	31.7	36.1	31.6	27.4
Weight of water (W2-W3) g	3.8	5.5	4.9	4.3
Weight of oven dried soil (W3-W1) g	13	16.8	13.1	8.6
Moisture content (w)= (W2-W3)*100/(W3-W1)	29.23	32.74	37.40	50

TABLE 4.3: Liquid Limit

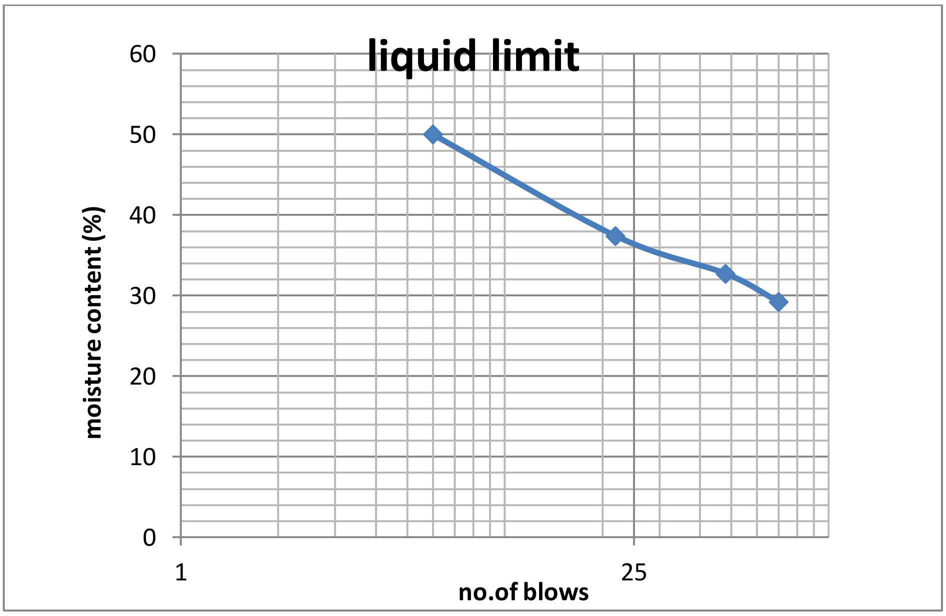


FIGURE 4.1: Flow Curve

Result

The Liquid limit of the soil (the moisture content corresponding to 25 no. of blows)= 37%

(B)PLASTIC LIMIT

Plastic limit is the average of moisture content of all the following samples.

Sample no.	**1**	**2**	**3**	**4**
weight of empty container (W1)g	8.2	7.6	8.1	7.7
weight of container+wet soil (W2)g	10.7	10.4	11.4	10.1
weight of container +dry soil (W3)g	10.3	10	10.9	9.8
weight of water (W2-W3)g	0.4	0.4	0.5	0.3
weight of oven dry soil(W3-W1)g	2.1	2.4	2.8	2.1
moisture content, w% =(W2-W3)/(W3-W1)*100	19.0476	16.6667	17.8571	14.2857

TABLE 4.4: Plastic Limit

Result

The Plastic limit of the soil=16.96%

Plasticity index,I_p is the range of moisture content over which a soil exhibits plasticity.

=liquid limit-plastic limit

=37%-16.96%=20.04%

(C)SHRINKAGE LIMIT

Observations

S no.	**Observations and Calculations**	**sample 1**	**sample 2**	**sample 3**
1	weight of empty mercury dish (W1)g	308.7	308.7	308.7
2	weight of mercury dish +mercury (W2)g	680.9	680.9	680.9
3	weight of mercury dish +mercury displaced(W3)g	512	512	516.3
4	weight of mercury (W2-W1)g	372.2	372.2	372.2
5	weight of mercury displaced (W3-W1)g	203.3	203.3	207.6
6	volume of shrinkage dish V1 =(W2-W1)/13.6 ml	27.37	27.37	27.37
7	volume of dry pat V2 =(W3-W1)/13.6 ml	14.95	14.95	15.26
8	weight of empty shrinkage dish (W4)g	31.7	34	36
9	weight of shrinkage dish +wet soil (W5)g	68	69.2	73.3
10	weight of shrinkage dish +oven dried soil (W6)g	53	55	61.1
11	weight of wet soil,W=(W5-W4)g	36.3	35.2	39
12	weight of dry soil,Ws= (W6-W4)g	21.3	21	25.1
13	shrinkage limit,ws =((W-Ws)-(V1-V2)*1)/Ws)	12.12	8.48	7.16
14	shrinkage ratio,SR=Ws/(V2*1)	1.42	1.40	1.64
15	volumetric shrinkage,Vs=(V1-V2)/V2*100	83.08	83.08	79.29

TABLE 4.5: Shrinkage Limit

Result

The shrinkage limit of the soil is the average of the shrinkage limit values of three samples.

Therefore, the Shrinkage limit of the soil =9.25 %

4.4: PARTICLE SIZE DISTRIBUTION:

(A) DRY SIEVE ANALYSIS
Observations

	Retained		Cumulative		% finer
Sieve sizes(mm)	Retained weight(g)	Retained percent%	Cumulative retained weight(g)	Cumulative retained%	
4.75	100.3	6.69	100.3	6.69	93.31
2.36	218.2	14.55	318.5	21.24	78.76
1.18	281.2	18.75	599.7	39.99	60.01
0.6	198.5	13.23	798.2	53.22	46.78
0.425	100.7	6.71	898.9	59.93	40.07
0.3	70.9	4.73	969.8	64.66	35.34
0.15	250.7	16.71	1220.5	81.37	18.63
0.075	132.9	8.86	1353.4	90.13	9.77

TABLE 4.6: Dry Sieve Analysis

(B) WET SIEVE ANALYSIS
Observations

Graph is plotted between percentage finer and particle size after performing dry and wet sieve analysis:

%finer (%N)	Particle size D(mm)
93.3133	4.75
78.7667	2.36
60.02	1.18
46.7867	0.6
40.0733	0.425
35.3467	0.3
18.6333	0.15
9.77333	0.075
6.651	0.05764
6.428	0.0411
6.266	0.0299
5.943	0.0219
5.782	0.0163
5.62	0.0122
5.459	0.0088
5.136	0.0063

4.489	0.0045
4.005	0.0033
3.844	0.0024
3.682	0.0014

TABLE 4.7: Particle Size Distribution

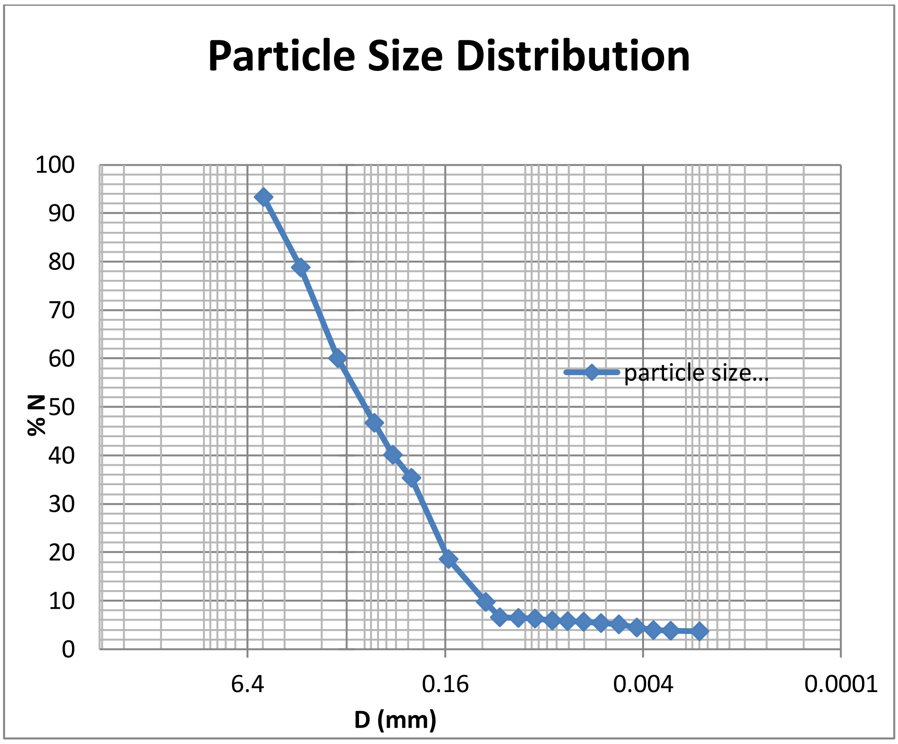


FIGURE 4.2: Particle Size Distribution Curve

Result

Since the percentage fines (%) passing through 0.075mm sieve are more than 5%, the classification of soil particles will be done on the basis of their plasticity characteristics using the I.S. Plasticity chart as shown in figure 4.4.

The liquid limit of the soil is 37% and the plasticity index of the soil is 20 % which lies above the A-line on the plasticity chart. The plasticity index for soil is coming out to be 20% and liquid limit is 37%. Point corresponding to these coordinates on the plasticity chart (A) lies in the region of Inorganic Clay. Therefore our soil is CI which corresponds to inorganic clayey soil. This classification of soil is as per Indian Standard Soil Classification System (ISSCS).

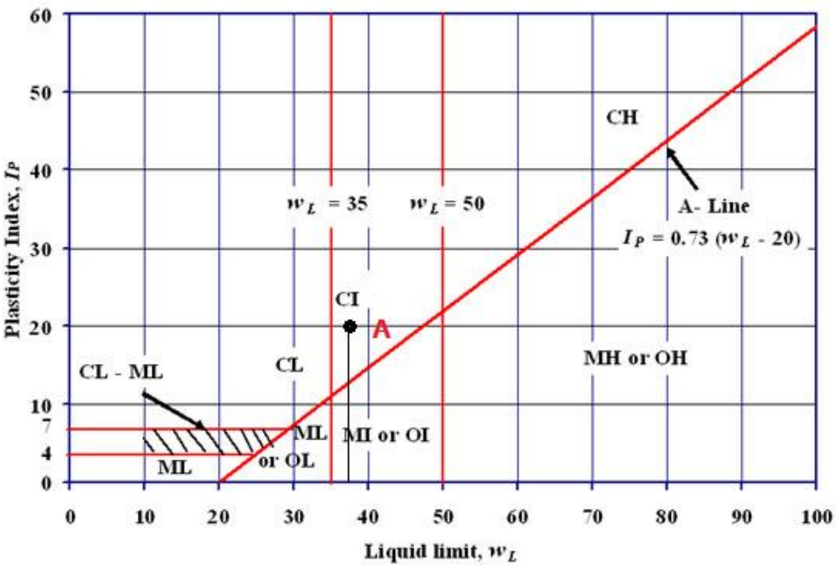


FIGURE 4.3: Plasticity Chart

4.5: LIGHT WEIGHT COMPACTION TEST

Observations

Volume of mould=π*d*d*h/4=π*10*10*12.1/4=950.332cm^3

Sample No.	1	2	3	4	5
assumed water content, w%	8	12	15	18	25
weight of mould with base (W1)g	4317.3	4317.3	4317.3	4317.3	4317.3
weight of mould with base+wet soil (W2)g	5971.3	6154	6222.3	6270.1	6304
weight of moist soil (W2-W1)g	1654	1836.7	1905	1952.8	1986.7
moist unit weight, gamma wet (W2-W1)/950.332	1.74	1.933	2.00	2.055	2.090
weight of container (W3)g	19.2	19.2	20.9	20.4	19.1
weight of container +wet soil (W4)g	40.9	66.3	47.2	86.1	61
weight of container +oven dried soil (W5)g	38.6	59.8	43.4	75.2	52
Moisture content,w' ((W4-W5)/(W5-W3))*100	11.86	16.00	**16.889**	19.890	27.356
dry unit weight gm/(1+w'%/100)	1.55	1.666	**1.715**	1.714	1.641

TABLE 4.8: Compaction Test

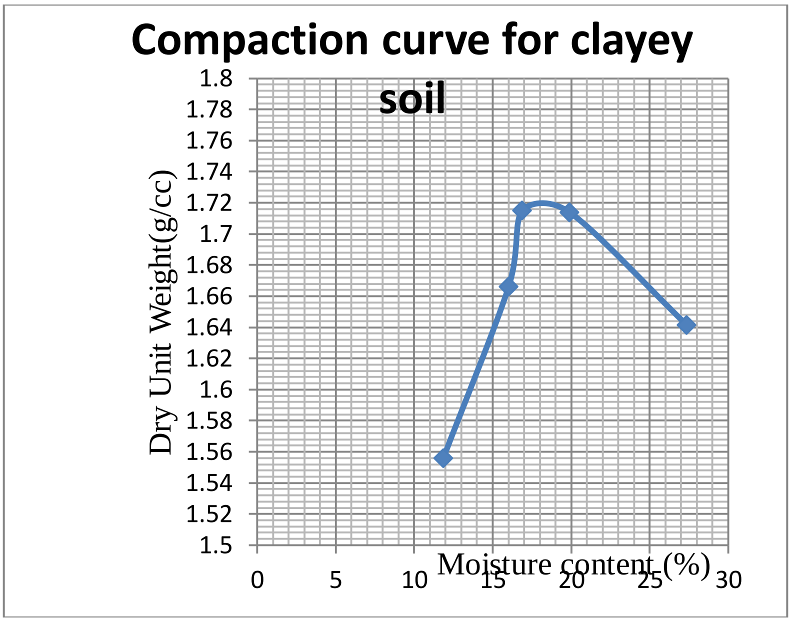


FIGURE 4.4: Compaction Curve

Result

The maximum dry density (from the graph) = 1.714 g/cm^3

The optimum moisture content is the moisture content corresponding to maximum dry density.

Therefore the optimum moisture content =17%

4.6 UNCONFINED COMPRESSION TEST

Diameter of sample=38mm

Height of sample=76mm

Area of sample, A_0=π*38*38/4=1134.115mm^2

S No.	Observations			Calculations		
	Elapsed time	dial gauge reading(dl)mm	load (P)kN	strain,e =dl/l (%)	corr. Area, A=A0/1-e mm^2	compressive stress, q_u=(P/A)
1	0	0	0	0	1134	0
2	0	0.45	0.01	0.592	1140.755	8.766
3	0.5	1.15	0.02	1.513	1151.423	17.369
4	1	1.76	0.03	2.316	1160.884	25.842
5	1.5	2.36	0.05	3.105	1170.342	42.722
6	2	3.03	0.07	3.987	1181.088	59.267
7	2.5	4.25	0.09	5.592	1201.171	74.927
8	3	4.9	0.11	6.447	1212.152	90.748
9	3.5	5.46	0.12	7.184	1221.775	98.218
10	4	6.2	0.13	8.158	1234.728	105.286
11	4.5	7.36	0.14	**9.684**	1255.594	**111.501**
12	5	8.12	0.14	10.684	1269.652	110.266
13	5.5	8.3	0.14	10.921	1273.028	109.974
14	6	9.1	0.13	11.974	1288.251	100.912

TABLE 4.9: UCT

Result

Unconfined compressive strength,q_U of the soil=111.5 kN/m^2

Shear strength, s of the soil= q_U/2= 55.75kN/m^2

4.7 LIGHT WEIGHT COMPACTION TEST FOR SOIL WITH VARIOUS PROPORTIONS OF RHA AND LIME SLUDGE

(A) RHA

Observations

RHA %	OMC (%)	MDD(gm/cm3)
8	17.39	1.62
10	18.85	1.61
12	20	1.59
15	20.23	1.58

TABLE 4.10: Light weight compaction test for soil with various proportions of RHA

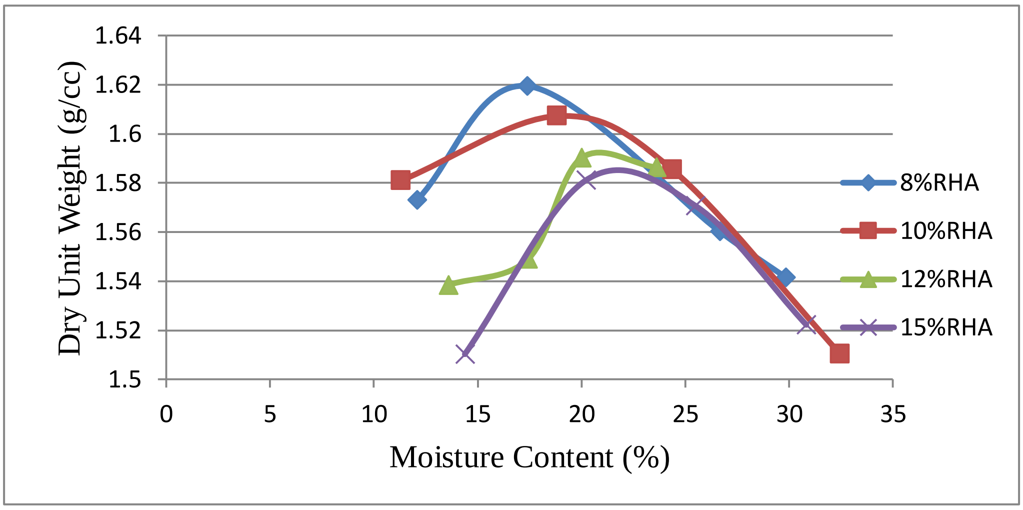


FIGURE 4.5: Compaction curves for different proportions of RHA

Result

The MDD of the soil decreases from 1.64 (with 8% RHA) to 1.58(with 15%RHA) when the OMC increases from 17.39% to 20.23%.

(B) RHA and LIME SLUDGE

Observations

RHA %	Lime Sludge %	OMC (%)	MDD(gm/ Cm3)
12	5	20.37	1.65
12	10	21.43	1.64
12	15	21.48	1.63

TABLE 4.11: Light weight compaction test for soil with various proportions of RHA and lime sludge

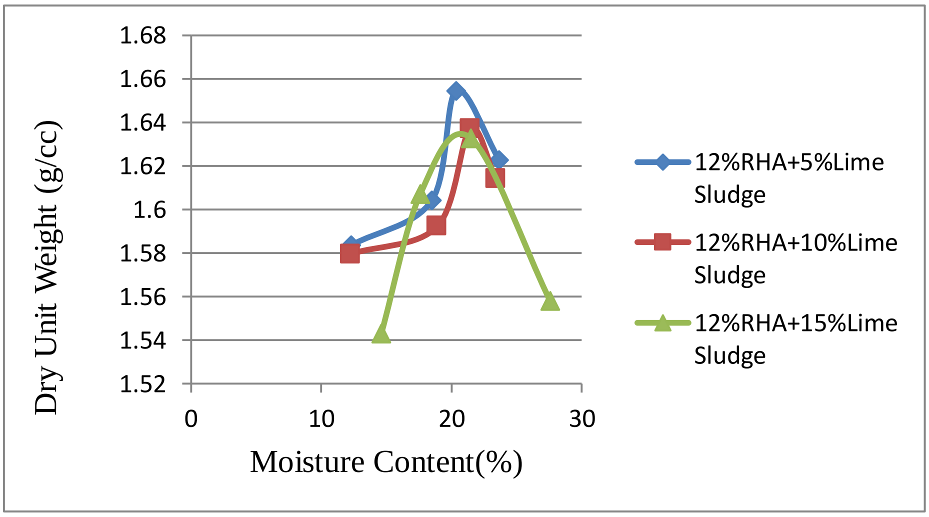


FIGURE 4.6: Compaction curves for different proportions of RHA and lime sludge

Result
The MDD of the soil decreases from 1.65 (with 12% RHA+5% Lime Sludge) to 1.63(with 12%RHA+15% Lime Sludge) when the OMC increases from 20.37% to 21.48%.

4.8 UNCONFINED COMPRESSION TEST

Diameter of sample=38mm

Height of sample=76mm

Area of sample, A_0= (π*38*38/4) =1134.115mm^2

(A) 8%RHA

Unconfined compressive strength, q_u=115 kN/m^2

Shear strength of soil, s=q_u/2=57.5kN/m^2

(B) 10%RHA

Unconfined compressive strength, q_u=120 kN/m2

Shear strength of soil, s=q_u/2 =60 kN/m^2

(C) 12%RHA

Unconfined compressive strength, q_u=126 kN/m2

Shear strength of soil, s=q_u/2 =63 kN/m^2

(D) 15%RHA

Unconfined compressive strength, q_u=124 kN/m^2

Shear strength of soil, s=q_u/2 =62 kN/m^2

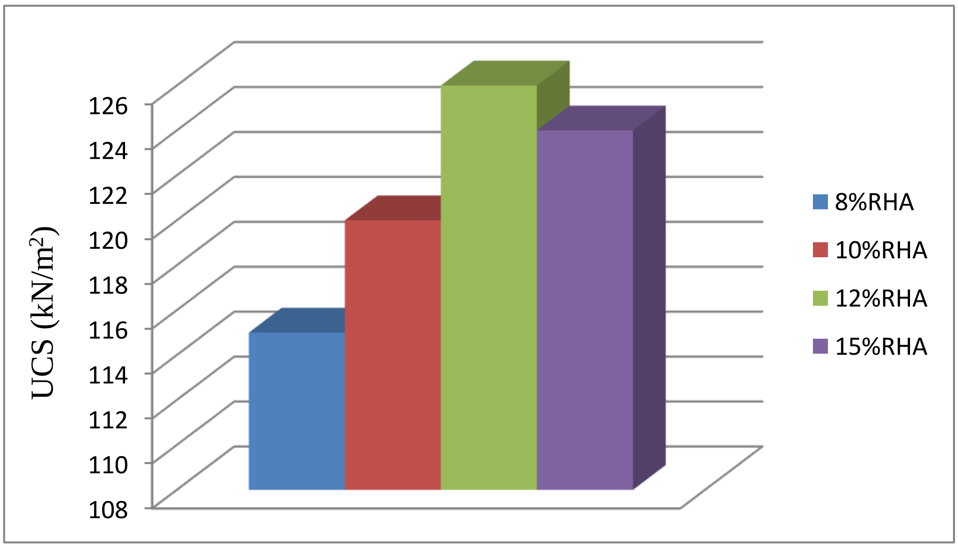


FIGURE 4.7: UCS for various proportions of RHA

(E) 12%RHA and 5% Lime Sludge

Unconfined compressive strength,q_u=136.6kN/m^2

Shear strength of soil,s=q_u/2 =68.3 kN/m^2

(F) 12%RHA and 10% Lime Sludge

Unconfined compressive strength,q_u=151kN/m^2

Shear strength of soil,s=q_u/2 =75.5 kN/m^2

(G) 12%RHA and 15% Lime Sludge

Unconfined compressive strength,q_u=146.2kN/m^2

Shear strength of soil,s=q_u/2 =73.1kN/m^2

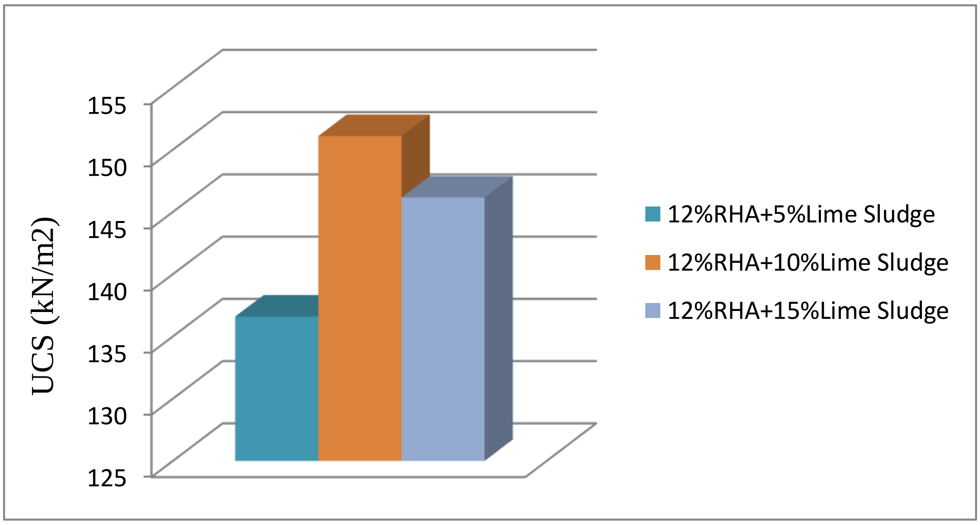


FIGURE 4.8: UCS for various proportions of RHA and Lime sludge

Result

- The maximum value of UCS of the soil is 126kN/m^2 with 12% RHA when only RHA is added. Therefore, we mix various proportions of lime sludge with 12% RHA.
- The maximum value of UCS of the soil is 151kN/m^2 with 12% RHA and 10% Lime Sludge.

CHAPTER 5

CONCLUSIONS

- The Liquid Limit of the soil is 37% and Plasticity Index is calculated to be 20%. Therefore the soil is inorganic clay (CI) as per ISSCS.
- Since the Plasticity Index is greater than 17% the soil is highly plastic in nature.
- The MDD of the soil decreases from 1.64 (with 8% RHA) to 1.58(with 15%RHA) when the OMC increases from 17.39% to 20.23%. Thus with increase in content of RHA in the soil, MDD of the soil decreases.
- The MDD of the soil decreases from 1.65 (with 12% RHA+5% Lime Sludge) to 1.63(with 12%RHA+15% Lime Sludge) when the OMC increases from 20.37% to 21.48%. Thus with increase in content of RHA and Lime sludge in the soil, MDD of the soil decreases.
- The maximum value of UCS of the soil is 126kN/m^2 with 12% RHA when only RHA is added.
- The maximum value of UCS of the soil is 151kN/m^2 with 12% RHA and 10% Lime Sludge. UCS of soil is found to be maximum with 12% RHA and 10% Lime Sludge content, therefore giving us the optimum ratio.

FUTURE SCOPE

- In this project the two parameters that have been checked are compaction properties and UCS. Further research can be done by performing California Bearing Ratio Test (CBR) on the soil with different proportions of RHA and Lime Sludge in order to improve the bearing capacity of the sub-base of flexible pavements.
- Based on the above study and literature review the study of RHA and Lime sludge for soil reinforcement has a good scope in terms of future perspectives. Sufficient research can be done to find an optimum ratio of the two based on other parameters too.
- RHA and Lime sludge are waste materials produced in lump sum and are a threat to environmental protection and public health efforts. Further research can be done to make the construction processes economical.

REFERENCES

1. BROOKS,ROBERT M.(2009).”SOIL STABILIZATION WITH FLYASH AND RICE HUSK ASH “International Journal of Research and Reviews in Applied Sciences.,3(1).

2. Francis,Iloeje Amechi and Venantus, Aniago (2013).“Models and Optimization of Rice Husk Ash-Clay Soil Stabilization” Journal of Civil Engineering and Architechture.,10(7).

3. IS:460-1962,Indian Standard Specifications for Sieves

4. IS:2720,(Part V-1970),Indian Standard Method of Test for Soils Part V,Determination of Liquid and Plastic limits.

5. Negi,AnkitSingh,Faizan,Mohammed,Pandey,Devashish, Rehanjotsingh,Siddharth, (2013).“SOIL STABILIZATION USING LIME” International Journal of Innovative Research in Science,Engineering and Technology.,2(2).

6. Rao,Gopal Ranjan ASR, Basic And Applied Soil Mechanics, New Age International(P) Limited, New Delhi.

7. Shyambhushan , Kumar,Rajesh ,VedParkash(2015).“Stability of Clay Soil using Rice Husk Ash and Stone Dust” International Journal of Enhanced Research in Educational Development.,5(3).

8. Talukdar, Dilip Kumar (2015).“A Study of Paper Mill Lime Sludge for Stabilization of Village Road Sub-Base” International Journal of Emerging Technology and Advanced Engineering.,2(5).

ANNEXURE

ANNEXURE 1:

1. Hydrometer analysis

Effective time lapsed,t (min)	Actual hydrometer reading,Rh	Temperature,T (°C)	Corrected hydrometer reading, Rh1=Rh+Cm+-Ct-Cd	Effective depth,h (cm)
0.5	23	19	20.9	8.85
1	22	19	19.9	9
2	21.5	19	19.4	9.5
4	20.5	19	18.4	10.3
8	20	20	17.9	11.3
15	19.5	20	17.4	11.8
30	18	20	16.9	12.3
60	17	20	15.9	12.8
120	15	22	13.9	13.25
240	13.5	24	12.4	14.25
480	13	19	11.9	14.4
1440	12.5	18	11.4	15.2

2. 8%RHA

S. No.	Observations			Calculations		
	Elapsed time	dial gauge reading(dl) mm	load (P)kN	strain,e=dl/l %	corr. Area,A=A 0/1-e mm2	compressive stress,q_u=(P/A)
1	0	0	0	0	1134	0
2	0	0.55	0.01	0.72368421	1142.26640	8.754525202
3	0.5	1.21	0.02	1.59210526	1152.34657	17.35588972
4	1	1.76	0.03	2.31578947	1160.88362	25.84238374
5	1.5	2.36	0.05	3.10526315	1170.34220	42.72254711
6	2	3.03	0.07	3.98684210	1181.08811	59.26738142
7	2.5	4.25	0.09	5.59210526	1201.17073	74.92690058
8	3	4.9	0.11	6.44736842	1212.15189	90.74770259
9	3.5	5.8	0.12	7.63157894	1227.69230	97.7443609
10	4	6.8	0.13	8.94736842	1245.43352	104.3813237
11	4.5	5.2	0.14	**6.84210526**	1217.28813	**115.0097466**
12	5	8.12	0.14	10.6842105	1269.65232	110.2664068
13	5.5	8.2	0.14	10.7894736	1271.15044	110.1364522
14	6	8.2	0.13	10.7894736	1271.15044	102.2695628

3. 10%RHA

s no.	Observations			Calculations		
	Elapsed time	**dial gauge reading(dl) mm**	**load (P)kN**	**strain,e=dl/l %**	**corr. Area,A=A0/ 1-e mm2**	**compressive stress,q_u=(P/A)**
1	0	0	0	0	1134	0
2	0	0.41	0.01	0.53947368	1140.1508	8.770769516
3	0.5	1.2	0.02	1.57894736	1152.1925	17.35821034
4	1	1.54	0.03	2.02631578	1157.4536	25.91896408
5	1.5	2.24	0.04	2.94736842	1168.4381	34.23373248
6	2	3.01	0.06	3.96052631	1180.7644	50.81453634
7	2.5	4.23	0.07	5.56578947	1200.8360	58.29272255
8	3	4.9	0.08	6.44736842	1212.1518	65.99832916
9	3.5	5.1	0.1	6.71052631	1215.5712	82.26584981
10	4	5.4	0.12	7.10526315	1220.7365	98.30130883
11	4.5	5.5	0.12	7.23684210	1222.4680	98.16207185
12	5	6.2	0.14	8.15789473	1234.7277	113.3853151
13	5.5	7.2	0.15	**9.47368421**	1252.6744	**119.743804**
14	6	7.5	0.13	9.86842105	1258.160584	103.3254432
15	6.5	7.6	0.13	10	1260	103.1746032
16	7	7.6	0.11	10	1260	87.3015873

4. 12%RHA

s no.	Observations			Calculations		
	Elapsed time	**dial gauge reading(dl) mm**	**load (P)kN**	**strain,e=dl/l %**	**corr. Area,A=A0/1-e mm2**	**compressive stress,q_u=(P/A)**
1	0	0	0	0	1134	0
2	0	0.51	0.01	0.67105263	1141.66114	8.759166435
3	0.5	1.2	0.02	1.57894736	1152.19251	17.35821034
4	1	1.62	0.03	2.13157894	1158.69857	25.89111668
5	1.5	2.36	0.05	3.10526315	1170.34220	42.72254711
6	2	3.02	0.07	3.9736842	1180.92628	59.27550357
7	2.5	4.2	0.09	5.52631578	1200.33426	74.97911445
8	3	4.8	0.11	6.31578947	1210.44943	90.87533649
9	3.5	5.7	0.12	7.5	1225.94594	97.88359788
10	4	5.8	0.13	7.63157894	1227.69230	105.8897243
11	4.5	6.2	0.14	8.15789473	1234.72779	113.3853151
12	5	6.6	0.14	8.68421052	1241.84438	112.7355426
13	5.5	7.7	0.14	10.1315789	1261.84480	110.948668
14	6	8	0.15	10.5263157	1267.41176	118.3514341
15	6.5	8.1	0.16	**10.6578947**	1269.27835	**126.0558804**
16	7	8.2	0.16	10.7894736	1271.15044	125.8702311

5. 15%RHA

s no.	Observations			Calculations		
	Elapsed time	dial gauge reading(dl) mm	load (P)kN	strain,e=dl/l %	corr. Area,A=A0/1-e mm2	compressive stress,q_u=(P/A)
1	0	0	0	0	1134	0
2	0	0.51	0.01	0.67105263	1141.66114	8.759166435
3	0.5	1.2	0.02	1.57894736	1152.19251	17.35821034
4	1	1.62	0.03	2.13157894	1158.69857	25.89111668
5	1.5	2.36	0.05	3.1052631	1170.34220	42.72254711
6	2	3.02	0.07	3.97368421	1180.92628	59.27550357
7	2.5	4.2	0.09	5.52631578	1200.33426	74.97911445
8	3	4.8	0.11	6.31578947	1210.44943	90.87533649
9	3.5	6	0.12	7.89473684	1231.2	97.46588694
10	4	6.4	0.13	8.42105263	1238.2758	104.9846839
11	4.5	6.8	0.13	8.94736842	1245.43352	104.3813237
12	5	7.3	0.14	9.60526315	1254.49781	111.5984405
13	5.5	8.6	0.15	11.3157894	1278.69436	117.3071568
14	6	9	0.16	**11.8421052**	1286.32835	**124.3850367**
15	6.5	9.1	0.15	11.9736842	1288.25112	116.4369256
16	7	9.3	0.15	12.2368421	1292.11394	116.0888332

6. 12%RHA and 5%Lime Sludge

s no.	Observations			Calculations		
	Elapsed time	dial gauge reading(dl) mm	load (P)kN	strain,e=dl/l %	corr. Area,A=A0/1-e mm2	compressive stress,q_u=(P/A)
1	0	0	0	0	1134	0
2	0	0.51	0.01	0.67105263	1141.661147	8.759166435
3	0.5	1.2	0.02	1.57894736	1152.192513	17.35821034
4	1	1.62	0.03	2.13157894	1158.698575	25.89111668
5	1.5	2.36	0.05	3.10526315	1170.342205	42.72254711
6	2	3.02	0.07	3.97368421	1180.926281	59.27550357
7	2.5	4.2	0.09	5.52631578	1200.334262	74.97911445
8	3	4.8	0.11	6.31578947	1210.449438	90.87533649
9	3.5	6	0.12	7.8947368	1231.2	97.46588694
10	4	6.4	0.13	8.42105263	1238.275862	104.9846839
11	4.5	6.8	0.13	8.9473684	1245.433526	104.3813237
12	5	7.1	0.13	9.34210526	1250.856313	103.9288035
13	5.5	7.5	0.14	9.86842105	1258.160584	111.2735543
14	6	7.9	0.15	10.3947368	1265.550661	118.5254804
15	6.5	8.3	0.15	10.9210526	1273.028065	117.8292955
16	7	8.8	0.16	11.5789473	1282.5	124.7563353
17	7.5	9.8	0.16	12.8947368	1301.873112	122.8998422

18	8	10.2	0.17	13.4210526	1309.787234	129.7920728
19	8.5	10.6	0.18	**13.9473684**	1317.798165	**136.5914787**
20	9	11	0.17	14.4736842	1325.907692	128.2140537
21	9.5	12.3	0.16	16.1842105	1352.967033	118.2586095
22	10	12.3	0.16	16.1842105	1352.967033	118.2586095
23	10.5	12.3	0.16	16.1842105	1352.967033	118.2586095

7. 12%RHA and 10%Lime Sludge

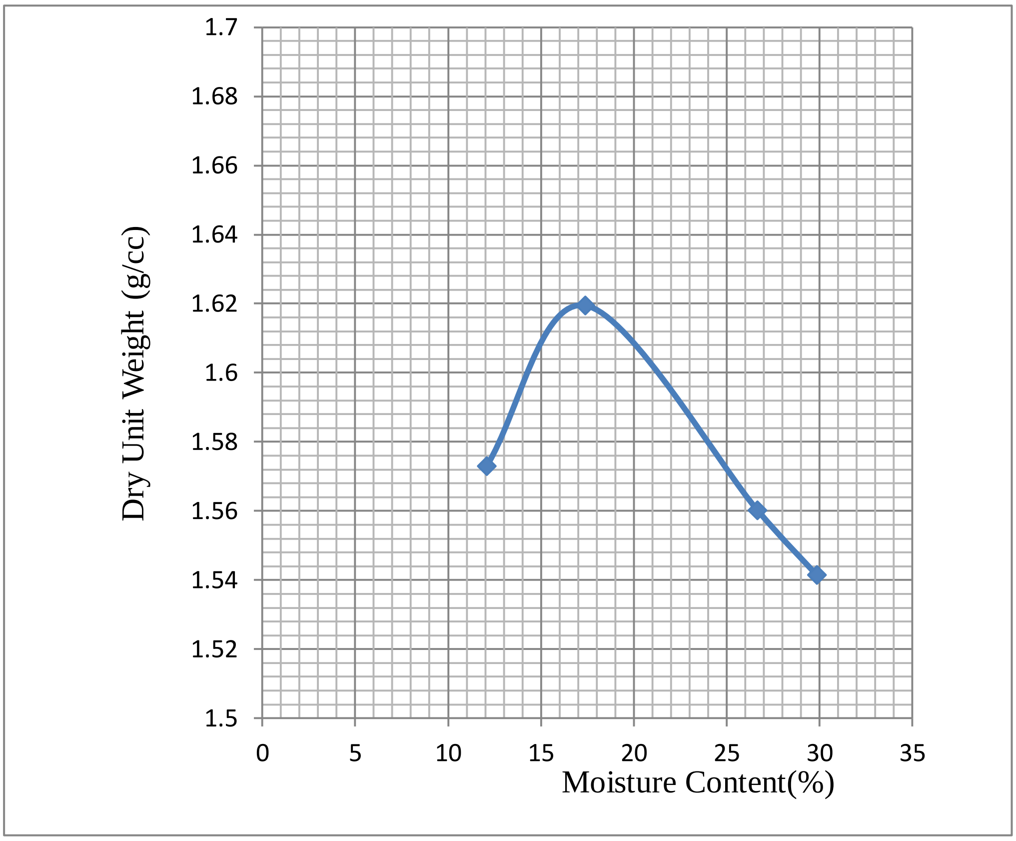
	Observations			**Calculations**		
s no.	**Elapsed time**	**dial gauge reading(dl)mm**	**load (P)kN**	**strain,e=dl/l %**	**corr. Area,A=A0/1-e mm2**	**compressive stress,q_u=(P/A)**
1	0	0	0	0	1134	0
2	0	0.51	0.01	0.671052632	1141.661147	8.759166435
3	0.5	1.2	0.02	1.578947368	1152.192513	17.35821034
4	1	1.62	0.03	2.131578947	1158.698575	25.89111668
5	1.5	2.36	0.05	3.105263158	1170.342205	42.72254711
6	2	3.02	0.07	3.973684211	1180.926281	59.27550357
7	2.5	4.2	0.09	5.526315789	1200.334262	74.97911445
8	3	4.8	0.11	6.315789474	1210.449438	90.87533649
9	3.5	5.1	0.12	6.710526316	1215.571227	98.71901977
10	4	5.7	0.13	7.5	1225.945946	106.0405644
11	4.5	6	0.13	7.894736842	1231.2	105.5880442
12	5	6.4	0.13	8.421052632	1238.275862	104.9846839
13	5.5	7.8	0.14	10.26315789	1263.695015	110.7862248
14	6	8.6	0.15	11.31578947	1278.694362	117.3071568
15	6.5	9	0.16	11.84210526	1286.328358	124.3850367
16	7	10	0.17	13.15789474	1305.818182	130.1865776
17	7.5	10.5	0.18	13.81578947	1315.78626	136.8003342
18	8	11.2	0.19	14.73684211	1330	142.8571429
19	8.5	12	0.2	15.78947368	1346.625	148.5194468
20	9	13.6	0.2	17.89473684	1381.153846	144.8064606
21	9.5	14	0.21	**18.42105263**	1390.064516	**151.0721248**
22	10	14.1	0.2	18.55263158	1392.310178	143.6461524
23	10.5	14.1	0.19	18.55263158	1392.310178	136.4638448

8. 12%RHA and 15%Lime Sludge

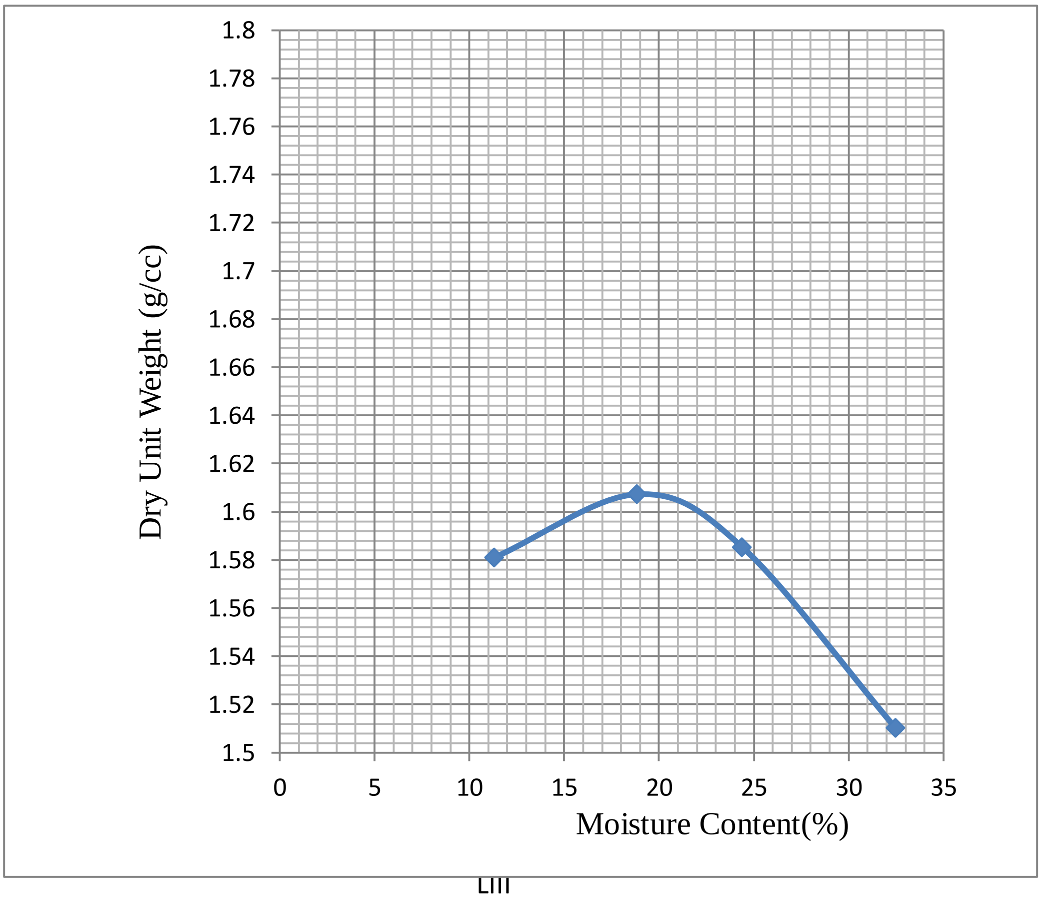
s no.	Observations			Calculations		
	Elapsed time	**dial gauge reading(dl)mm**	**load (P)kN**	**strain,e=dl/l %**	**corr. Area,A=A0/1-e mm2**	**compressive stress,q_u=(P/A)**
1	0	0	0	0	1134	0
2	0	0.51	0.01	0.671052632	1141.661147	8.759166435
3	0.5	1.2	0.02	1.578947368	1152.192513	17.35821034
4	1	1.62	0.03	2.131578947	1158.698575	25.89111668
5	1.5	2.36	0.05	3.105263158	1170.342205	42.72254711
6	2	3.02	0.07	3.973684211	1180.926281	59.27550357
7	2.5	4.2	0.09	5.526315789	1200.334262	74.97911445
8	3	4.8	0.11	6.315789474	1210.449438	90.87533649
9	3.5	5.1	0.12	6.710526316	1215.571227	98.71901977
10	4	5.7	0.13	7.5	1225.945946	106.0405644
11	4.5	6	0.14	7.894736842	1231.2	113.7102014
12	5	6.2	0.15	8.157894737	1234.727794	121.4842662
13	5.5	7.3	0.16	9.605263158	1254.497817	127.5410749
14	6	8.5	0.17	11.18421053	1276.8	133.1453634
15	6.5	9.1	0.18	11.97368421	1288.251121	139.7243108
16	7	9.7	0.19	**12.76315789**	1299.909502	**146.1640212**
17	7.5	9.8	0.18	12.89473684	1301.873112	138.2623225
18	8	9.8	0.16	12.89473684	1301.873112	122.8998422

ANNEXURE2:

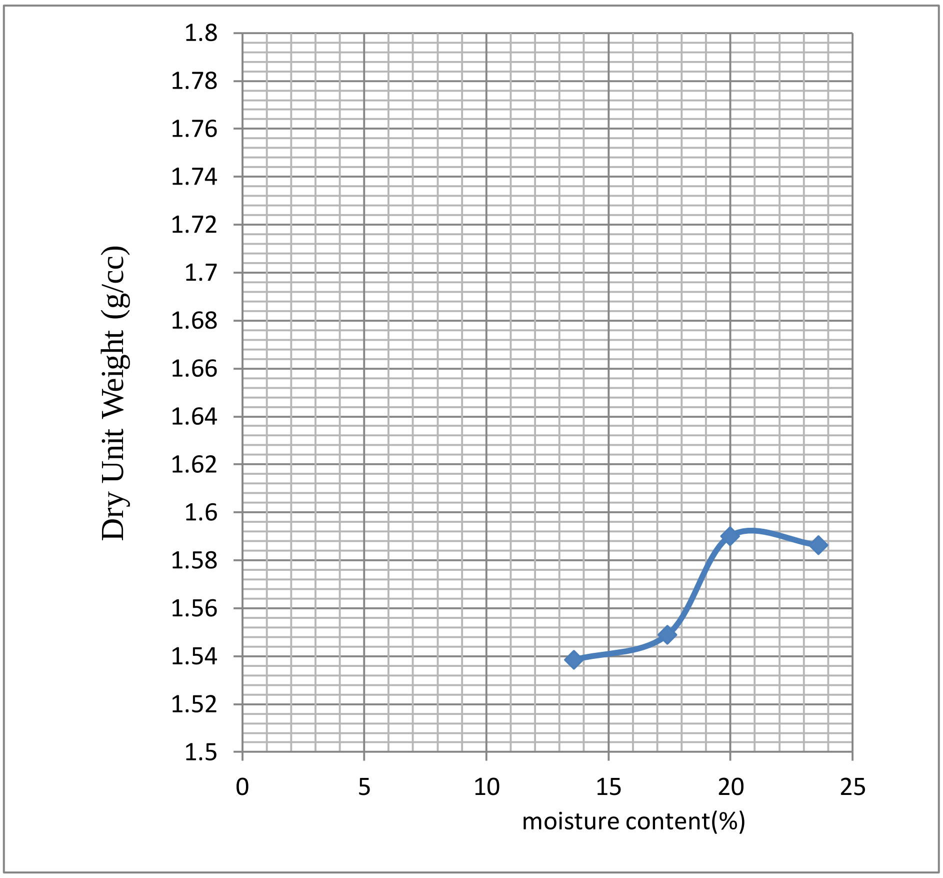
1. 8%RHA



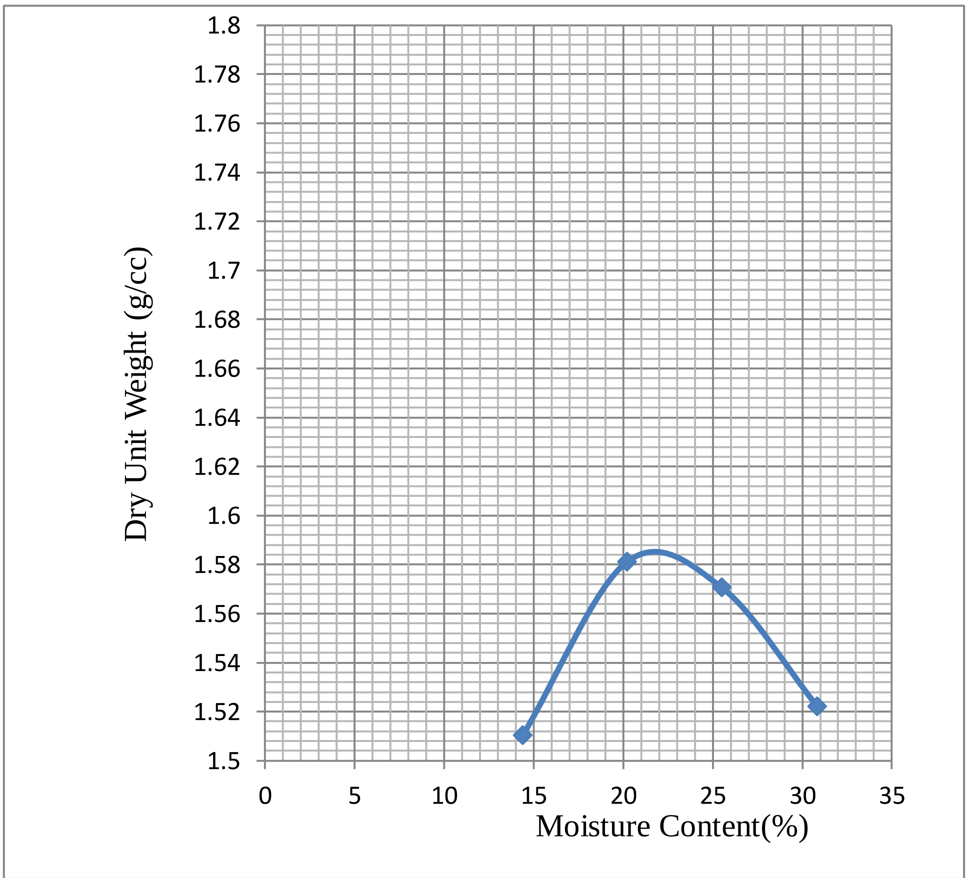
2. 10%RHA



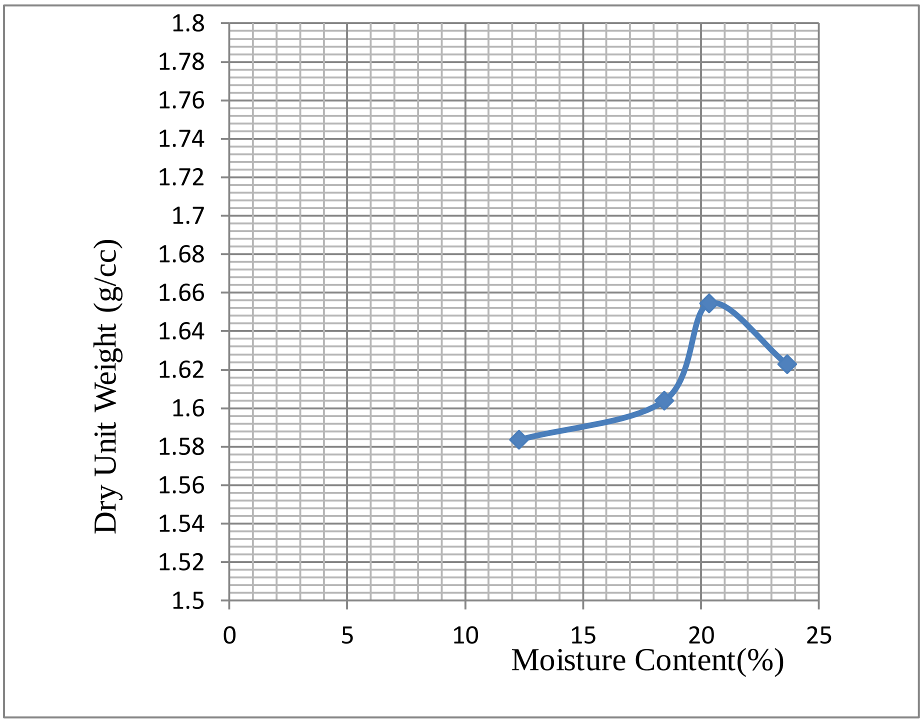
3. 12%RHA



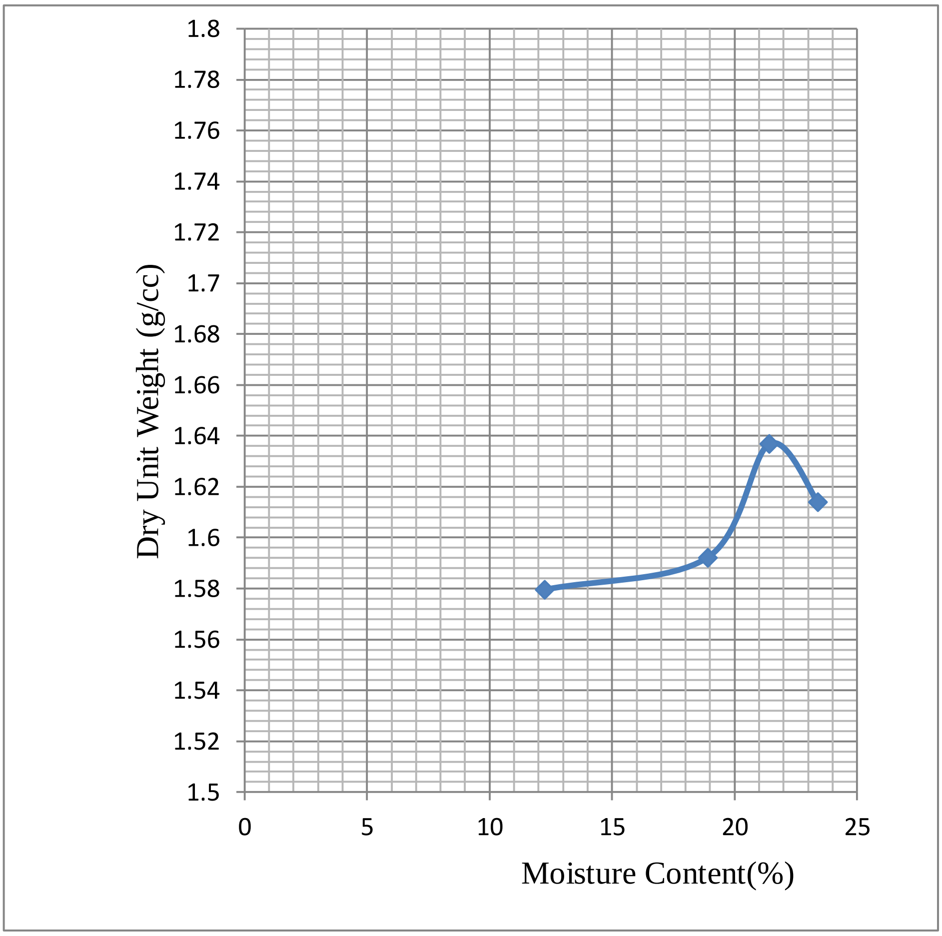
4. 15%RHA



5. 12%RHA and 5% Lime Sludge



6. 12%RHA and 10% Lime Sludge



ANNEXURE 3

1. 8%RHA

Sample no.	**1**	**2**	**3**	**4**
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5415	5551	5625	5650
weight of moist soil (W2-W1)g	1736.5	1872.5	1946.5	1971.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.763034	1.901112	1.976242	2.001624
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	35	30.8	38	36
weight of container +oven dried soil (W5)g	33.2	28.8	34	32
moisture content,w'=((W4-W5)/(W5-W3))*100	12.08054	**17.3913**	26.66667	29.85075
dry unit weight=gm/(1+w'%/100)	1.573006	**1.619466**	1.560191	1.541481

2. 10%RHA.

sample no.	**1**	**2**	**3**	**4**
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5412	5560	5620.8	5649
weight of moist soil (W2-W1)g	1733.5	1881.5	1942.3	1970.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.759988	1.910249	1.971978	2.000609
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	36	31.8	39.4	39
weight of container +oven dried soil (W5)g	34.2	29.5	35.4	34
moisture content,w'=((W4-W5)/(W5-W3))*100	11.32075	**18.85246**	24.39024	32.46753
dry unit weight=gm/(1+w'%/100)	1.581006	**1.607244**	1.585316	1.510264

3. 12% RHA

sample no.	**1**	**2**	**3**	**4**
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5400	5470	5558	5610
weight of moist soil (W2-W1)g	1721.5	1791.5	1879.5	1931.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.747804	1.818874	1.908219	1.961013
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	35	32.8	39.4	50
weight of container +oven dried soil (W5)g	33	30.5	36	44
moisture content,w'=((W4-W5)/(W5-W3))*100	13.60544	17.42424	**20**	23.62205
dry unit weight=gm/(1+w'%/100)	1.538487	1.548977	**1.590182**	1.586297

4. 15% RHA

sample no.	1	2	3	4
assumed water content, w%	15	20	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5380	5551	5620	5640
weight of moist soil (W2-W1)g	1701.5	1872.5	1941.5	1961.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.727499	1.901112	1.971166	1.991472
weight of container (W3)g	18.3	19	17.3	18.6
weight of container +wet soil (W4)g	35	39.8	36	36
weight of container +oven dried soil (W5)g	32.9	36.3	32.2	31.9
moisture content,w'=((W4-W5)/(W5-W3))*100	14.38356	**20.23121**	25.50336	30.82707
dry unit weight=gm/(1+w'%/100)	1.510268	**1.581213**	1.570608	1.522217

5. 12%RHA and 5%Lime Sludge

sample no.	1	2	3	4
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5430	5550	5640	5655
weight of moist soil (W2-W1)g	1751.5	1871.5	1961.5	1976.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.778263	1.900096	1.991472	2.006701
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	32	32.7	38.5	51
weight of container +oven dried soil (W5)g	30.5	30.3	35.2	44.8
moisture content,w'=((W4-W5)/(W5-W3))*100	12.29508	18.46154	**20.37037**	23.66412
dry unit weight=gm/(1+w'%/100)	1.583563	1.603978	**1.654453**	1.622703

6. 12% RHA and 10%Lime Sludge

sample no.	1	2	3	4
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5424.8	5543.1	5636.2	5640.1
weight of moist soil (W2-W1)g	1746.3	1864.6	1957.7	1961.6
moist unit weight, gamma wet=(W2-W1)/984.95	1.772983	1.893091	1.987614	1.991573
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	34.8	32.4	39.4	51.3
weight of container +oven dried soil (W5)g	33	30	35.8	45.1
moisture content,w'=((W4-W5)/(W5-W3))*100	12.2449	18.89764	**21.42857**	23.39623
dry unit weight=gm/(1+w'%/100)	1.579567	1.592202	**1.636858**	1.613966

7. 12% RHA and 15%Lime Sludge

sample no.	**1**	**2**	**3**	**4**
assumed water content, w%	12	18	22	26
weight of mould with base (W1)g	3678.5	3678.5	3678.5	3678.5
weight of mould with base+wet soil (W2)g	5420	5540	5632	5636
weight of moist soil (W2-W1)g	1741.5	1861.5	1953.5	1957.5
moist unit weight, gamma wet=(W2-W1)/984.95	1.76811	1.889944	1.983349	1.987411
weight of container (W3)g	18.3	17.3	19	18.6
weight of container +wet soil (W4)g	34	32	37.1	51
weight of container +oven dried soil (W5)g	32	29.8	33.9	44
moisture content,w'=((W4-W5)/(W5-W3))*100	14.59854	17.6	**21.47651**	27.55906
dry unit weight=gm/(1+w'%/100)	1.542873	1.607095	**1.632702**	1.558032