JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATES STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

COMPARATIVE STUDY ON THE ENGINEERING PROPERTY OF GROUNDNUT SHELL ASH, COAL ASH AND BAMBOO FIBER STABILIZED EXPANSIVE SUBGRADE SOIL: A CASE OF GAMBELLA TOWN

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By: DAWIT SAKATA

May, 2021

Jimma, Ethiopia

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By: DAWIT SAKATA

Advisor: Eng. Elmer C. Agon (Asso. Prof)

Co- Advisor: Eng. Melka Amensa (MSc)

May, 2021

Jimma, Ethiopia

DECLARATION

I, hereby declare that the work which is being presented in this Research Study entitles "COMPARATIVE STUDY ON THE ENGINEERING PROPERTY OF GROUNDNUT SHELL ASH, COAL ASH AND BAMBOO FIBER STABILIZED EXPANSIVE SUBGRADE SOIL" is original work of my own, and It has not been presented for a degree in any other university.

Dawit Sakata	____________	March 28, 2021
Student	Signature	Date

This Research has been submitted for examination with our approval as university supervisors.

Eng. Elmer C. Agon (Asso. Prof)	____________	March 28, 2021
Advisor	Signature	Date
Eng. Melka Amensa (MSc)	____________	March 28, 2021
Co – advisor	Signature	Date

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ABSTRACT

Construction and subsequent maintenance of pavements in good condition has become quite problematic especially in areas where soft or expansive soils are available along the selected route. To solve this problem, soil improvement is necessary because it not only lowers the construction cost (compares with lime, cement etc) but also minimize the risk of any damage of structure later on. The role of groundnut shell ash, coal ash and bamboo fiber in improving the characteristics of expansive sub grade material is analyzed. Generally stabilization of expansive soil using industrial and agricultural wastes is economical and safe for environment. To realize the desired objective a purposive sampling techniques which is non-probability method was adopted. Two expansive subgrade soils were taken for the study by observation and free swell index tests at depth of 1.5m to remove organic matters.

The general objective of this research is to compare the engineering properties of groundnut shell ash, coal ash and bamboo fiber stabilized expansive subgrade soil. The preliminary investigation of the soil shows that it belongs to A-7-5 class of soil in AASHTO and CH in USCS. The BD soil sample has plastic index 49.44 %, free swell index 80 %, linear shrinkage 12.33% and CBR value 2.2%. In addition, the MS soil sample has plastic index 55.86%, free swell index 85%, linear shrinkage 14.02% and CBR value 1.6%. Since both the given soil sample before any stabilizers are added was very high expansive according to their plasticity index and CBR value as comparing with standards and specifications. The soil sample stabilized with different percentages of coal ash ranging from 0%-50% at an interval of 10%, bamboo fiber (1%,1.5%,2%,2.5%, 3%) and groundnut shell ash(2%, 4%, 6%, 8% & 10%).
The analysis of the result shows that (8% GSA, 40% CA and 2.5% BF) was an optimum ratio which achieved by most geotechnical parameters of the study. Comparatively it is observed that Coal ash is effectively improving the engineering property of expansive subgrade soil better than groundnut shell ash and bamboo fiber. The addition of those additives reduces LL, PI, CBR Swell and the optimum moisture content with an increase in PL, MDD & CBR with an increase of additives. A considerable amount of cost savings is also possible when the expansive subgrade soil is stabilized with GSA, CA and BF compares with common stabilizer (lime and cement). Additional parameter like PH value test, volumetric shrinkage and mineralogical tests should also be performed to have more realistic test results.

***Keywords:* bamboo fiber, black cotton soil, CBR, coal ash, cost, compaction, groundnut shell ash, stabilization.**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AASHTO	American Association of State Highway and Transportation Office
ASTM	American Society for Testing and Materials
BA	Bagasse Ash
BF	Bamboo Fiber
BD	Baro Dare
BCS	Black Cotton Soil
CAH	Calcium Aluminate Hydrate
CBR	California bearing ratio
CEC	Cation Exchange Capacity
CSA	Central Statistical Agency
CA	Coal ash
ERA	Ethiopian Road Authority
ETB	Ethiopian Birr
FA	Fly Ash
FSI	Free Swell Index
GI	Group index
GSA	Groundnut shell ash
LL	Liquid Limit
MSc	Master of Science
MDD	Maximum Dry Density
MS	Mikeal sefer
NS	Natural subgrade soil
OMC	Optimum Moisture Content
PE	Potential expansively
PI	Plasticity Index
PL	Plastic Limit
RHA	Rice Husk Ash
RSA	Rice Straw Ash
Gs	Specific Gravity
UCS	Unconfined Compressive Strength
USCS	Unified Soil Classification System

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Generally, lands with black cotton soils are fertile and very good for agriculture, horticulture, sericulture and aquaculture. Good irrigation systems exist, rainfall is high and people are affluent in these areas. Though black cotton soils are very good for agricultural purposes, they are not so good for laying durable roads. Good road network is a basic requirement for the all-round development of an area. Unfortunately, poor road network is hampering the full-fledged development of the otherwise prosperous areas (Bhavanna Rao, 2005). In Ethiopia like many other countries, lands which are fertile, suitable for agriculture and covered by forest are highly dominated with expansive soils. In areas with scarce resources of suitable construction materials, it is common to upgrade the available materials using appropriate stabilization technique, and utilize them for the intended construction. Gambella Town is also dominated by expansive soils especially in areas of forest and fertile lands.

Developing countries like Ethiopia focus their attention on the development of infrastructures like railways, roadways, airways and housing facilities**.** The stability of the structures built on the soil depends entirely on the balance of the land at which it rests so that soil is the basis for any construction. It supports the substructure of any structure, and it is the sub grade which endorses the sub-base/base in the pavement. There are several soils that pose a threat to the stability of the structures because of the existing land at a particular location may not be suitable for the construction due to inadequate bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. This type of land pose severe problem on construction activities; which can lead to expensive design, construction cost, mitigation measure as well as repeated and costly maintenance cost (Fekerte, 2006).

Expansive clay soils are problematic soils because of their inherent potential to undergo volume changes corresponding to changes in the moisture variation. It starts swell or shrink excessively due to change in moisture content (Bhavsar *et al*., 2014). Problematic soils such as expansive soils are normally encountered in foundation engineering designs for highways, embankments, retaining walls, backfills etc. Expansive soils are normally found in semi – arid regions of tropical and temperate climate zones and are abundant, where the annual evaporation exceeds the precipitation and can be found anywhere in the world (Chen, 1975; Warren and Kirby; 2004).

Expansive soil is a problem in Ethiopia (Alemayehu & Mesfin, 1999) as in other countries. To treat this problem, stabilization should implement with different stabilizing additives to achieve the required specification of sub-soil materials.

Researchers attempted to stabilize this soil have reported that the stabilization of this soil with bitumen, lime or cement is effective. Unfortunately, the costs of these stabilizers are on the high side making them economically unattractive as stabilizing agents. So that, based on this many researches are going on for the utilization of waste products for soil stabilization purpose. Recent trend in research works in the field of geotechnical engineering and construction materials focuses more on the search for cheap and locally available materials such as industrial wastes as stabilizing agents for the purpose of full or partially replacement of traditional stabilizers. Industrial waste is increasingly becoming a focus of researchers because of the enhanced pozzolanic capabilities of such waste when oxidized by burning.

Coal ash is an industrial waste obtained from thermal power plants by burning of coal. Coal ash consists of bottom ash (5-15%) and fly ash (85-95%). Addition of coal ash to Expansive soil is one such attempt to understand the possible mechanism governing the behavior of expansive soils-Coal ash mixes. Bulk stabilization of Coal ash becomes very essential in view of huge producing and to reduce the disposal areas under Environmental concerns. Utilization in Geotechnical applications are Sub grades, Embankment Materials, Backfill and Structural Materials (Ahmad *et al*, 2009).

Bamboo fiber is a regenerated cellulosic fiber produced from bamboo. It is a common fact that bamboo can grow naturally without using any pesticide. The root rhizomes of bamboo are tremendous soil binders which can prevent erosion (Huang B *et al.*, 2010). Bamboo fiber is s a satisfactory fiber for incorporation into the cement (Coutts, 1995; Li X, 2004). Effect of bamboo fibers on local soil and based on the current investigation when bamboo fiber quantity is increases, un-soaked and soaked California Bearing Ratio

(CBR) value of soil are considerable increase and this increase is occurred up to 1.2% of bamboo fiber dosage. Usage of more than 1.2% of bamboo fiber dosage is not feasible and optimal proportion of bamboo fiber is found 1.2% by waterless weight of ordinary soil. The unsoaked and soaked CBR test value of soil increases with the increase in bamboo fiber length and diameter (Brahmachary and Rokonuzzaman, 2018).

Groundnut shell can be used to improve soil stabilization in the ground because it is good water proofer and its binding properties are adequate for stabilization (Osinubi, 1999). And also, because of its being usually rich in calcium carbonate, which is good binding agent and its other pozzolanic with good stabilization properties, it can be used in a cement based construction material to improve soil in the ground (Salahudeen, 2014). Groundnut shell ash is a wastes product which is difficult to dispose of; therefore ways of making it useful are derived by using it to solving engineering problems (Osinubi, 2000).

1.2 Statement of the Problem

Expansive soils are also referred to as “black cotton soil” in some parts of the world. This soil owes their expansive character mainly to the constituent clay mineral. The most important clay mineral, which is the cause for expansive nature is montmorillonite. When this mineral is exposed to moisture, water is absorbed between interlay ring lattice structures and exerts an upward pressure. This upward pressure, known as swelling pressure, causes most of the damages associated with expansive soils (Teklu, 2003). Clayey soil present in its natural state at construction site sometimes may not have the suitable strength. It may have swell and shrinkage distinctiveness and causes significant damage to pavement structures. This damage could be attributed to moisture fluctuations caused by seasonal discrepancies. Volumetric changes weaken the sub grade by inducing - cracking which meets out damage to the overlying structures. For imparting high amount of strength and stability soil thus needs to be stabilized (Somal *et al*, 2017).

Worldwide, the cost of constructing stabilized roads is financially high. This is apparently due to the over dependence on industrially manufactured soil improving additives (cement, lime etc). The high amount of money spent has continued to invalidate poor and underdeveloped nations of the world from making accessible roads available to meet the standard of their rural dwellers that constitute large percentage of their population. On the other hand, the safe disposal of waste products from industries and agriculture has been hitherto a challenging issue demanding urgent solution because of the decline effect of these materials on the environment and the hazardous risk it pose to the health of humanity. Peanut (Groundnut shell ash) is generated and some private cultivators active in Gojjeb. After cultivation, they accumulate the residues in large volume and mostly they use it for household fuel and the rest residue they burnt as waste so that it affects the environment. According to the CSA report on area and production of crops, more than 352,077 private peasant holding households have grown groundnut in close to 80,000 hectares of land in the 2013/14 cropping season leading to a total production of well over 0.11 million tons (CSA, 2014). Thus, it is greatly required to consider the use of agricultural waste (such as Groundnut Shell Ash), Industrial waste (coal ash) and Bamboo Fibres in improving the engineering properties of the subgrade soil, in this case Black Cotton soil (BCS) when used in road construction will considerably reduce the cost of constructions compares with common stabilizers (cement, lime etc) and as well as eradicate or reduce the environmental and hazardous risk of wastes.

The above problems are extensively occurring in Ethiopia is estimated to be 23.7 million acres (Nebro, 2002). Especially the sub grade property of Gambella town is inferior which is commonly included with this expansive ground; it will pose several problems on in infrastructure that was going to be built on the city. In line with the foregoing, replacing proportions of the expansive soil with agricultural and industrial waste was going a long way in mitigating the harsh effects of increased in production and costs.

Since most soil which is found in Gambella Town have high plastic index and low CBR value. They are a consequence for expansive and unstable sub grade soil. As a result, they make pavement structure failure. The aim of this study is to compare engineering property of Groundnut shell ash, coal ash and bamboo fiber stabilized expansive subgrade soil.

1.3. Research Questions

1. What are the Engineering properties of stabilized expansive subgrade soil?
2. What is the feasibility effect of stabilizing agents on the stabilization of weak subgrade structures?
3. What are the potential effects of Groundnut shell ash, Coal ash and Bamboo fiber

On engineering properties of expansive subgrade soil treated with varying dosage of stabilizing agent?

4. What optimum amount of stabilizing agents will be needed to attain the required Properties of soils that can be used as sub grade material?

1.4. Objectives of the Study

1.4.1. General Objective

The general objective of this study is to compare the engineering properties of Groundnut shell ash, Coal ash and Bamboo fiber stabilized expansive subgrade soil in Gambella Town.

1.4.2. Specific Objectives

The specific objectives of this study are:

- To identify the engineering properties of stabilized expansive subgrade soil.
- To determine the amount of cost saving for sub grade formation using stabilizer such as groundnut shell ash, coal ash and bamboo fiber.
- To investigate potential effects of groundnut shell ash, coal ash, and bamboo fiber on engineering properties of expansive subgrade soil treated with varying dosage of stabilizing agent.
- To determine optimum amount of stabilizing agent needed to attain the required properties of soil.

1.5 Significance of the Study

This study is to assess the comparative study on the engineering property of groundnut shell ash, coal ash and bamboo fiber stabilized expansive subgrade soil of Gambella Town. Benefits from the studies are cost saving because agricultural waste and other stabilizing agent is typically by far cheaper than traditional stabilizers such as cement and lime. The study will provide lessons that will help the concerned body to come up with appropriate measures to address problems resulting from loose sub grade soil with cost-effective. On the other hand, other researchers will use the findings as a reference for further research on stabilization of sub grade soil.

1.6 Scope of the Study

The Gambella town which is known to abundance of soft soil, experiencing many types of failures such as cracks, large surface deformation and structural deformation of pavement layers and the sub grade. Therefore, the scope of the study was cover stabilization of expansive subgrade soil treated with various percentages of Groundnut shell ash (2%, 4%, 6%, 8%, and 10%), Coal ash (10%, 20%, 30%, 40%, and 50%) and Bamboo fiber (1%, 1.5%, 2%, 2.5%, and 3%) in Gambella town. It has been supported by different source of literatures and a series of laboratory experiments. The stabilizer (groundnut shell ash, coal ash and bamboo fiber) use was limited and test procedures that have been adopted in the experimental work. Soil samples of expansive subgrade soil from two different localities of Gambella Town were collected for the investigation in the laboratory. A sample of soils from 2 test pit has been taken from 1.5m depth below the ground surface after clearing has been done. The relevant laboratory tests have been done by researcher was; grain size distribution (gradation), Natural Moisture Content, Modified Proctor Compaction, CBR, swelling potential (free swell trial), and Atterberg limit taste (includes Liquid Limit (LL), Plasticity Index (PI), Plastic limit(PL), linear shrinkage), Optimum Moisture Content (OMC), Maximum Dry Density, and Specific Gravity). The results were analyzed according to ERA, AASHTO and ASTM specification.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Expansive Soil

The black cotton soil is a type of expansive soil with high plasticity and can retain moisture throughout the dry season which is why they are valuable for growing crops. It exhibits low bearing capacity, low permeability and high volume change due to presence of montmorillonite in its mineralogical content and these properties makes it unfit for construction of embankment and other engineering structures (Bowles, 1979; Das, 1998).

Engineering structures which construct on expansive soil will creates a problem due to swelling and shrinking behavior of sub-soil material. This type of soil becomes swells when it contacts with water and shrinks when it dry. In expansive soil areas, the soils are generally stiff and the chance of lightly loaded structures cracking due to settlement (Chen, 1988) and cause of damage for engineering structure like pavements, bridge and buildings.

For this reason, constructions could be sensitive for structural failure as a result of excessive consolidation settlement. For the expansive soils, because of change in moisture conditions, there could be a significant volume change problem at different seasons. This could affect the stability of lightweight structures as a result of cyclic swell-shrink process (Jemal, 2014). The improvement of problematic soil at a site is indispensable due to rising cost of the land, and there is a huge demand for road construction. There is a need to concentrate on improving properties of soils using cost-effective practices like treating it with low cost and readily available material. There are several treatment methods for improving properties of problematic soil; among this Stabilization is one of the most common ways.

2.2 Stabilization

Soil stabilization is the process of modification on one or more soil properties, by mechanical or chemical stabilization, to create an improved soil material possessing the desired engineering properties. The process may include blending of soils to achieve a desired gradation or mixing with easily accessible additives that can modify the gradation, texture or plasticity, or act as a binder for cementation of the soil (Guyer, 2011).

2.3 Uses of Stabilization

Pavement design is based on the premise that minimum specified structural quality will be achieved for each layer of material in the pavement system. Each layer must resist shearing, avoid excessive deflections that cause fatigue cracking within the layer or in overlying layers, and prevent excessive permanent deformation. As the quality of a soil layer is increase, the ability of that layer to distribute the load over a greater area generally increases so that a reduction in the required thickness of the soil and surface layers may be permitted. Commonly, improvement attained from soil stabilization can be summarized as ;(Guyer, J. P., 2011; US Army, 1994)

- Quality improvement: the most common improvements achieved through stabilization include reduction of plasticity index or swelling potential, and increases in durability and strength with a better soil gradation. In wet weather, stabilization may also be used to provide a working platform for construction operations (Guyer, J. P., 2011; US Army, 1994).
- Thickness reduction: the strength and stiffness of a soil layer can be improved through the use of additives to permit a reduction in design thickness of the stabilized material compared with an un stabilized or unbound material. The design thickness can be reduced if the strength, stability and durability requirement of a base or sub base course is indicated to suitable by further analysis (Guyer, J. P., 2011; US Army, 1994).

2.4 Mechanisms of Stabilization

The stabilization mechanism could vary generally from the formation of new compounds binding the finer soil particles for coating particle surfaces by the additive to decease the moisture sensitivity. Then, the basic understanding of stabilization mechanisms involved with each additive is required before selecting an effective stabilizer suited for a specific application. Chemical stabilization involves mixing or inserting the soil with chemically active compounds such as Portland cement, lime, fly ash, calcium or sodium chloride or with viscoelastic materials such as bitumen. Chemical stabilizers can be broadly divided in to three groups: Traditional stabilizers such as hydrated lime, Portland cement and Fly ash; Non-traditional stabilizers comprised of sulfated oils, ammonium chloride, enzymes, polymers, and potassium compounds; and By-product stabilizers which include cement kiln dust, lime kiln dust and others. Among these, the most widely used chemical additives are lime, Portland cement and fly ash (Petry & Little, 2002). Although stabilization with fly ash could be more economical as compared to the other two, the composition of fly ash can be highly variable.

2.5 Types of Soil Stabilization

2.5.1 Chemical Stabilization

Chemical stabilization refers to mixing of soil with one or a combination of admixtures of powder, slurry or liquid to improve or control its stability, strength, swelling, permeability and durability. Soil improvement by means of chemical stabilization can be grouped into three chemical reactions; Cation exchange, flocculation-agglomeration, and pozzolanic reactions (Mitchell and Soga, 2005).

A) Cation Exchange

The excess ions of opposite charge that of the surface of clay, over those of like charge Present in the diffuse double layer are called exchangeable ions. These ions can be replaced by a group of different ions having the same total charge, by altering the chemical composition of the equilibrium electrolyte solution.

Negatively charged clay particles adsorb cations of specific type and amount. The ease of replacement or exchange of cations depends on several factors, primarily the valence of the cation. Higher valence cations easily replace cations of lower valence. For ions of the same valence, the size of the hydrated ion becomes important; the larger the ion, the greater the replacement power. If other conditions are equal, trivalent cations are held more tightly than divalent and divalent cations are held more tightly than monovalent cations. A typical Replace ability series is:

$NA^{+}<Li^{+}<K^{+}<Rb^{+}<Cs^{+}<Mg^{2+}< Ca^{2+}<Ba^{2+}<Cu^{2+}<Al3^{+}<Fe^{3+}<Th^{4+}$

The exchangeable cations may be present in the surrounding water or be gained from the Stabilizers.

An example of the cation exchange;

$Ca^{2+} + Na^{+}\text{-Clay} \longrightarrow Ca^{2+}\text{-Clay} + Na^{+}$

The thickness of the diffused double layer decreases as replacing the divalent ions (Ca^{2+}) from stabilizers with monovalent ions (Na^{+}) of clay. Thus, swelling potential decreases.

B) Flocculation and Agglomeration

Cation exchange reactions result in the flocculation and agglomeration of the soil particles with consequent reduction in the amount of clay-size materials and hence the soil surface area, which inevitably accounts for the reduction in plasticity. Due to change in texture, a significant reduction in the swelling of the soil occurs.

C) Pozzolanic Reactions

Time dependent pozzolanic reactions play a major role in the stabilization of the soil, since they are responsible for the improvement in the various soil properties. Pozzolanic constituents produces calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH).

$Ca^{2+} + 2(OH)^{-} + SiO2\ (\text{Clay Silica}) \longrightarrow CSH$

$Ca^{2+} + 2(OH)^{-} + Al2O3\ (\text{Clay Alumina}) \longrightarrow CAH$

The calcium silicate gel formed initially coats and binds lumps of clay together. The gel then crystallizes to form an interlocking structure which increases the soil strength (Meron, 2013).

2.5.2 Mechanical Stabilization

Under this category, soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing. The main methods of mechanical stabilization can be categorized into compaction, mixing or blending of two or more gradations, applying geo-reinforcement and mechanical remediation (Makusa, 2012).

2.5.3 Lime Stabilization

When stabilization of soil is done by mixing soil with lime in proper proportion, the process is known as soil-lime stabilization. Lime is an excellent choice for short term modification of soil properties. Lime can modify almost all fine grained soils but the greater improvement occurs in clay soils of moderate to high plasticity (National lime association, 2004).

Lime is one of the most popular additives agent used to improve fine-grained soils. Lime, alone or combined with other materials, can be used to treat a variety of soil types. When soils treated with lime the construction activity becomes facilitate in three ways. First, a reduction in the liquid limit and an increase in the plastic limit results in a significant reduction in plasticity index. Decrease in plasticity index enables higher workability of the treated soil. Second, results from chemical reaction between soil and lime a decrease in water content occurs. This facilitates compaction of very wet soils. Additional, lime addition raises the optimum moisture content but reductions in maximum dry density and finally direct increase in strength and results in a stable platform that facilitates the mobility of equipment. (Meron, 2013)

2.5.4 Soil Stabilization with Bitumen

Asphalts and tars are bituminous materials which are used for stabilization of soil, generally for pavement construction. Bituminous materials when added to a soil, it imparts both cohesion and reduced water absorption. Depending upon the above actions and the nature of soils, bitumen stabilization is classified in following four types:

- Sand bitumen stabilization
- Soil Bitumen stabilization
- Water proofed mechanical stabilization, and
- Oiled earth

2.5.5 Cement Stabilization

Portland cement stabilization, commonly referred to as soil cement, is a mixture of Portland cement, water and soil compacted to a high density. Soil cement is sometimes referred to as a cement treated sub grade or cement stabilized sub base. Cement stabilization differs from other forms of chemical stabilization in such a way that structural strength is primarily obtained from the cementing action rather than from internal friction, cohesion, chemical ion exchange and/or waterproofing of the materials. Almost all types of soils can be used for cement stabilization except highly organic soils and heavy clay soils.

The four fundamental control factors for the design and construction of soil cement are moisture content, curing procedure and duration, compaction and cement content. Cement stabilization is generally considered to be too expensive for workability improvements alone (The Tensar Coporation, 1998).

2.6 Industrial and Agricultural Waste as a Soil Stabilizing Material

Recent research works in the field of geotechnical engineering and construction materials focuses more on the search for cheaper and locally available materials, agricultural and industrial wastes, for use in construction industry.

The use of different industrial and agricultural wastes has become a common practice in the construction industry. Fly ash, sugarcane bagasse ash, coconut husk ash, rice husk, groundnut shell ash and coal ash can be sited as an example. Those by-products are increasingly playing a part in road construction and concrete technology, hence minimizing the problem of resource depletion, environmental degradation and energy consumption.

2.6.1 Groundnut

Groundnut, or peanut, is commonly called the poor man's nut. Today it is an important oil seed and food crop. This plant is native to South America and has never been found uncultivated. The botanical name for groundnut, Arachis *hypogaea* Linn, is derived from two Greek words, *Arachis* meaning a legume and *hypogaea* meaning below ground, referring to the formation of pods in the soil. Groundnut is an upright or prostrate annual plant. It is generally distributed in the tropical, sub-tropical and warm temperate zones (Nautiyal, 2002). Groundnuts are not only rich in proteins which are easily digestible and consequently, a higher biological value, but are also rich in B-complex vitamins. It is an important item in several confectionery products, and in supplementary feeding programs such as in weaning food formulations in combination with cereals and pulses in many developing countries.

2.6.1.1 Groundnut Shell Ash (GSA)

Groundnut Shell Ash (GSA) is an agricultural waste product obtained from the milling of groundnut. During and after the harvest of groundnut, the shells are regarded as waste which when accumulated in large quantities in a particular area will constitute an environmental hazard. Therefore, the utilization of GSA as a possible stabilizer will go a long way in reducing the cost of stabilization of the deficient soil and also alleviate the environmental problem associated with the accumulation of the GSA in a large quantity in a particular area. Meanwhile, the ash from groundnut shell has been categorized under pozzolana (Alabadan *et al*, 2006), with about 8.66% Calcium Oxide (CaO), 1.93% Iron Oxide (Fe_2O_3), 6.12% Magnesium Oxide (MgO), 15.92% Silicon Oxide (SiO_2), and 6.73% Aluminum Oxide (Al_2O_3). The utilization of this pozzolana as a replacement for traditional stabilizers will go a long way in actualizing the dreams of most developing countries of scouting for cheap and readily available construction materials. Groundnut shell ash has been used in concrete as a partial replacement material for cement with a measure of success achieved (Alabadan *et al.*, 2005).

2.6.1.2 Uses OF Groundnut Shell

Of the several million tonnes of groundnut produced each year, hulls form about 25 Per cent of the total mass produced and their utilization thus becomes very important. At present in the developing countries the majority of groundnut shells are either burned, dumped in forest areas or left to deteriorate naturally. Sufficient information is available to use groundnut shell in cattle feed, as carrier of insecticide, in the manufacture of logs and production of pulp and as a fibre component in human diet. Shell digestibility is quite low; research efforts are being directed to improve it as it contains more than 60 per cent fibre. Inoculation and biodegradation of shell have been tried but these efforts have not been successful (Kerr, *et al.*, 1986). The shell is also used for the production of alpha-cellulose. By adopting the neutral sulphate method about 40 to 42 per cent of unbleached

Pulp yield on an average 93 per cent of alpha-cellulose from groundnut shell. Finely ground groundnut shells are often used for polishing tin plate (Nautiyal, 2002).

2.6.1.3 Potential of Groundnut /Peanut in Ethiopia

Groundnut (Arachis hypogaea), is also known as peanuts or monkey nuts, are the edible seeds of a legume plant that grow to maturity in the ground. Groundnut was introduced in the early 1920s and is becoming increasingly important in Ethiopian agriculture and domestic demand has been on a steady increase. They can be consumed directly (roasted and salted), processed into oil or cake/meal, or further processed into confectionary products or snack food.

In Ethiopia, groundnut is the second important lowland oilseed of warm climate next to sesame. It is mainly grown in eastern Harerghe, with immense potential in Gamogofa, Illubabor, West Gojam, North Shoa, North and South Wello, East and West Wellega, and Western Tigray (CSA 2010) (Nega *et al*, 2015). According to the CSA report on area and production of crops, more than 352,077 private peasant holding households have grown groundnut in close to 80,000 hectares of land in the 2013/14 cropping season leading to a total production of well over 0.11 million tons (CSA, 2014). Table 2.1 shows trends in production, area cultivated and productivity of groundnut in Ethiopia. One of the significant features emerged from the data presented in the Table 2.1 is the increasing trend in area and productivity of groundnut.

Table 2. 1: Production and productivity of groundnut in Ethiopia. (Source: CSA 2004 – 2014)

Year	Area (ha)	Production(tons)	Yield (ton/ha)
2013/14	79947	112089	1.40
2012/13	90156	124419	1.38
2011/12	64477	103479	1.60
2010/11	49603	71607	1.44
2009/10	41579	46425	1.12
2008/09	41761	46887	1.12

2007/08	40198	44685	1.11
2006/07	37126	51080	1.38
2005/06	35462	34150	0.96
2004/05	27084	29053	1.07
Growth	12.8%	16.2%	3%

In our country, after harvesting the peanuts, they are transported to a processing facility where they are dried and stored. At this point, they are sent to a Sheller, where the shell or hull is separated from the nut. These peanut shells account for approximately 25–30% of the total weight of the dried peanut pod (Manzano-agugliaro, 2018), meaning there is a substantial amount of shell residual left after peanut processing.

2.6.1.4 Previous Study on Stabilization of Groundnut Shell Ash

Chittaranjan, M., *et al*., (2011) reported the *'Agricultural wastes as soil stabilizers'*. In this study Agricultural wastes such as sugar cane bagasse ash, rice husk ash and groundnut shell ash are used to stabilize the weak sub grade soil. The weak sub grade soil is treated with the above three wastes separately at 0%, 3%, 6%, 9%, 12%and 15% and CBR test is carried out for each percent The results of these tests showed improvement in CBR value with the increase in percentage of waste.

Madhusudhan, P.V *et al*., (2015) have been studied the stabilization of black cotton soil using groundnut shell ash. They reported a decrease in liquid limit, plastic limit and plasticity index with the decrease in the GSA content. There was a uniform change in the OMC value and MDD value increases with the increase in the GSA content. The UCS value and cohesion value decreases with the increase in the GSA content. They have been concluded that with the increment in the GSA content there was a gradual improvement in the geotechnical properties.

Adetoro, A *et al*., (2015) have investigated some laboratory tests (i.e. particle size analysis, Atterberg limits, compaction and California bearing ratio tests were conducted on black cotton soil with 2% -10% (by proportion of soil) groundnut shell ash content.

The results indicated that the soil is silt- clayey with high plasticity and it belongs to A-7-6 soil group. It has general rating of fair to poor for sub grade materials. They have significant constituent materials of mainly clayey soils. The liquid limit and plastic limit did not meet the required specifications for sub grade. These properties however changed after stabilization as the soils Maximum Dry Density (MDD) value decreases while Optimum Moisture Content (OMC) and CBR values increasing with increase in the GSA content. The treatment with the GSA content showed increase in the coarse particles of the soil through cementation. There was also improved in the mechanical strength of the soil as CBR value increased to 18% after treatment.

2.6.2 Bamboo

Bamboo is recognized as a potential natural reinforcing material for improvement and stabilization of soil. Bamboo is a naturally occurring composite material which grows abundantly in most of the tropical countries. Bamboo has a very long history with human kind. Bamboo is also one of the oldest building materials used by human kind. It has been used widely for household products and extended to industrial applications due to advances in processing technology.

Bamboo, a perennial grass, is one of the rapid thriving grasses, which belongs to family of poaceae/graminae. About 43 species and 11 genera bamboo are found in Africa, covering an estimated area of 2.7 million hectare. About 93% of Africa bamboo species are found only in Madagascar (FAO, 2007). In terms of area coverage, 67 % of the African and more than 7% of the world bamboo resource is found in Ethiopia. This indicates that Ethiopia has the greatest bamboo resources in Africa representing a significant proportion of Africa's total bamboo resources. Ethiopia has two bamboo species namely, the highland bamboo, Yushania alpine, (k.Schum) and the lowland bamboo, Oxytenanthera abyssinica (A. rich). It covers one million hectares of highland and lowland bamboo resources, which accounts for about 15% and 85 % respectively (Kassahun E., 2000).

2.6.2.1 Bamboo Fiber

Bamboo fiber is natural fiber, acts as a strengthening material for ordinary soil. It binds the soil particles together and helps in reduction of rapid change in volumetric properties.

Bamboo fiber is thinner as compared to hair and has a round and smooth surface which makes it abrasion proof. Bamboo fiber is naturally anti- bacterial, UV protective, green & biodegradable, breathable & cool, strong, flexible, soft. Bamboo fibers are remarkably strong in tension but have low modulus of elasticity. The main advantage of these materials is that they are locally available with practically little cost. Its low cost makes it attractive for geotechnical applications. Cellulose and lignin are the major constituents and higher lignin content makes the fiber stiffer and tougher.

2.6.2.2 Previous Study on Stabilization of Bamboo Fiber

Effect of fly ash and bamboo fibers on expansive soil and it has been concluded that addition of 20% of fly ash and 1% of Bamboo fiber provides maximum strength in black cotton soil. Fly ash treated BC soil reinforced with 1% bamboo fiber increases the strength and reduces the brittle behavior of soil specimen, whereas the other percentages of fibers used shows a marginal increase (Paul V and Sneha M, 2016).

Shear strength parameters of a local soil without and with bamboo fiber reinforcement are studied and compared. The fibers are distributed randomly with 5 different percentages and 2 different lengths. The % of fiber considered is 1%, 2%, 3%, 4% and 5%. The lengths of the fibers considered are 20mm and 30mm. The results show that shear strength parameters of the fiber reinforced soils start rising till 4% of fiber for both the length of the fiber. The increase in the length of the fiber also causes an increase in the shear strength of the soil (Devi and Jempene, 2016).

2.6.2.3 Physical Properties of Bamboo Fiber

Table 2. 2: Physical Properties of bamboo fiber (Lin D *et al*., 2010)

Parameter	Values
Density	0.6-1.1
Young’s modulus (GPa)	11-17
Tensile strength (MPa)	140-230
Elongation (%)	16

Uniformity index (%)	92.7
Moisture (%)	6.5

2.6.3 Coal

Coal, as a sedimentary rock, is a complex mixture of organic and inorganic matter, containing intimately mixed solid, liquid and gaseous phrase which have allothigenic and authigenic orgins. Each coal deposit has individual plant constituents and regional, deposition and paleo-environmental factors which cause a specification in predictable end products of a definite set of biological, chemical and physical conditions, which provided an environment in which the minerals could form. Hence the final chemical and mineral composition of a given coal is a very important unique genetic code, indicating the changes at different stages during material deposition and coalification. The mineral matter present in coal affects different aspects of coal mining and preparation. This inorganic constituent is responsible for various industrial, technological and environmental problems related to coal use.

2.6.3.1 Coal Ash

The ash yield of coal is the residue derived from the inorganic and organic matter during incineration and combustion of the coal. Yield, content and geochemical characterization were depended on coal quality, coal formation condition. Meanwhile, they are controlled by the temperature of coal combustion and the coal combustion manners. The chemical composition of coal ashes varies widely depending on the mineral and organic constituents associated with studied coal.

Coal is a combustible carbonaceous rock that contains varying amounts of carbon, hydrogen, nitrogen, oxygen, sulphur and mineral matter and nearly 8 gigatonnes per year of coal is produced globally. It is an important energy resource, an organic rock that is composed of minerals and its reserves are abundant fuels necessarily needed to meet the demands of electricity. The combustion of lignite, sub-bituminous, bituminous coal, and anthracite for power generation produces a range of coal combustion residues, also known as coal ash. The growing interest in mineral matter and trace elements in coal and coal fly ash largely stems from environmental standards required for power generation (Odunayo *et al.*, 2016). Historically, the primary fuel used in cement industry is coal. Coal used to energy for firing cement-making kilns, either on their own or in various combinations consumed in cement plants worldwide because of its physiochemical characteristics.

2.6.3.2 Deposit of Coal in Ethiopia

Exploration of coal in Ethiopia was started in the year 1935 at Nejo and Wuchale (Ahmed 2008) Ethiopia is known to have some coal deposits in the Dilbi-Moye basin in the southwest of the country. Deposits are estimated about 14,016,730 tonnes (MME, 2009). Other areas with coal deposits include the Geba basin (250,000,000 tonnes), Chilga basin (19,000,000 tonnes) and Chida Waka (9.38 million tonnes) (MME, 2009). These coals classified under low-medium ash content, medium volatile matter, moderate calorific values lignite to bituminous coal (Ahmed, 2008).

Table 2. 3: Proximate analysis and calorific value of coal deposits in different basins (Ahmed, 2008)

Resource	Moisture (%)	Volatile matter (%)	Ash content (%)	Calorific value (Kcal/Kg)
Delbi-Moye coal	4-8	25-29	11-25	2948-5190
Chilga coal	5-10	21-31	16-41	3072-4560
Mush valley	21	31-40	19-27	2824-3568
Nejo	14-16	30-35	19-23	3400-3987
Wuchale	10-12	18-29	35-48	3700-5445
Yayu coal	8-20	28-46	25-42	3795- 5930

The Yayu basins have the highest coal reserve in Ethiopia. This is the place where coal based fertilizer integrated with electric power generation plants are under establishment by the Ethiopian government. This coal based power generation plant will produce much coal combustions products (ash). And this by products should be utilized by other factories for both economic and environmental reasons.

2.6.3.3 Previous Studies on Stabilization of Coal Ash

Many previous experimental studies reported that most trace and minor elements in coal except K, Mg, Na and halogens are thought not to vapor during coal combustion (Liu *et al* 2000). They constitute the matrix of ash in the form of a homogeneous melt and crystalline matter, formed through a series of physic-chemical processes including fusion or partial melting of discrete mineral matter, coalescence of melted mineral inclusions, agglomeration of droplets, vaporization of volatile elements (Na,K) followed by nucleation. The formation of ash particles in power plant greatly influences the heat and mass transfers in a coal-fired boiler and the particles emission from combustion is a serious hazard source to our health and environment (Liu *et al*., 1999a, 1999b, Yan *et al*., 1999).

Aditya Kumar A *et al*., (2013) Used Industrial waste materials viz. fly ash (FA), rice husk ash (RHA) & bagasse ash (BA) and agricultural waste material rice straw ash (RSA) in the stabilization of soil. Shrinkage limit was improved in all admixture but highest 30 % improve in RHA. CBR value was improved in all admixtures but highest in 20% RSA content, which increased the CBR from 11.87 to 17.74%. Optimum moisture Content was improved and Dry Density was decreased for all admixtures.

2.6.3.4 Characterization of Coal ash

The performance of coal ash is strongly influenced by its physical, mineralogical and chemical properties. The mineralogical and chemical compositions are dependent to a large extent on the composition of the coal and burning conditions. The most widely used specification for coal ash especially fly ash in world is ASTM C618. This specification divides coal ash especially fly ash into two classes based on its source of origin and composition. These are class C and F with the sum of $SiO_2+Al_2O_3+Fe_2O_3 \geq 50\%$ and $\geq 70\%$ respectively. Many fly ashes produced from lignite or sub-bituminous coals meet the chemical requirement of Class F fly ash.

Table 2. 4: chemical composition of Coal ash (Mulatu Tadesse, 2016)

Chemical composition	Coal ash	Class F	Class C
SiO_2	59.83	-	-
Al_2O_3	6.66	-	-
Fe_2O_3	8.48	-	-
SiO_2+ Al_2O_3+ Fe_2O_3	74.97	≥70	≥50
CaO	3.26	≤ 8	≥8
MgO	2.26	-	-
SO_3	3.82	≤ 5	≤ 5
Loss on ingestion	10.04	≤12	≤6

As described on Table 2.6 the Yayu coal ash SiO2+ Al2O3+ Fe2O3 is 74.97% which is greater than 70%, CaO is 3.26% which is less than 8% and loss on ignition is 10.04% which is greater than 6% and less than 12%. These values indicate that the Ethiopian Yayu coal ash is classified as class F fly ash. They are predominantly non crystalline silica, which is the determinant factor for pozzolanic activities. Therefore, the Ethiopian Yayu coal ash is suitable for utilizing it as effective stabilizing agent.

2.7 Identification and Classification of Expansive Soil

Generally, it has two way of identification mechanism for expansive soil.

2.7.1 Field Identification

It is easy to recognize expansive soils in the field during either dry or wet seasons. Their color varies from dark grey to black. During dry seasons, shrinkage cracks are visible on the ground surface with the maximum width of these cracks reaching up to 20 mm or more and they travel deep into the ground.

The soils which have high swelling potential can be identified through field observations without any laboratory test by simply observe the physical behavior of the soil. Those behaviors include (Nelson & Miller, 1992)

- The color was black or gray.
- Wide or deep shrinkage cracks.
- The strength was high when it dry and low during wet.
- Stickiness and low traffic ability when wet.
- Appearance of cracks in nearby structures.
- Cut surfaces have a shiny appearance.

Arid and semi-arid areas are particular trouble spots because of large variations in rainfall and temperature.

2.7.2 Laboratory Identification

There are three different methods of classifying potentially expansive soils. Such as:

2.7.2.1 Mineralogical Identification

This method is used for identifying the mineralogy of clay particles such as characteristic crystal dimensions, characteristic reaction to heat treatment, size and shape of clay particles and charge deficiency and surface activity of clay particle. These properties are a fundamental factor controlling expansive soil behaviour (Nelson & Miller, 1992):

The various techniques under these methods are

- X-ray diffraction
- Differential thermal analysis
- Dye adsorption
- Chemical analysis
- Electron microscope resolution

Using combinations of these methods, the different types of clay minerals present can be evaluated quantitatively.

But these methods are not suitable for routine tests because of the following reason;

- They are time consuming
- They require expensive test equipment; and
- The results are interpreted by specially trained technicians.

2.7.2.2 Indirect method (index properties)

In this method, the simple soil property tests can be used to evaluation of swelling potential of expansive soils. Such tests are easy to perform and should be included as routine tests in the investigation of expansive soils. It is advisable not to use the indirect tests directly, instead direct tests are also important to avoid an error in conclusions. These methods are related to laboratory soil identification and are vital for the intended purposes. Such tests may include (Chen, F.H., 1988; Nelson, D.J., and Miller, J.D., 1992):

A. Atterberg Limits

Atterberg limits define the moisture content boundaries between states of consistency of fine grained soils. In this method, measurements of the Atterberg limits of the soil are conducted for identification of all soils and provide a wide acceptable means of rating. Especially when they are combined with other tests they can be used to classify expansive soils. Clay soil can exist in four distinct state of consistency depending on its water content. The water content at the boundaries between the different states is defined as the shrinkage, plastic and liquid limits. Two useful indices may be computed from the Atterberg limits and the natural moisture content. These are the Plasticity Index and Liquidity Index. (Chen, F.H., 1988; Nelson, D.J., and Miller, J.D., 1992): The relation between the swelling potential of clays and the plasticity index is shown in Table 2.5.

Table 2. 5: Relationship between the swelling potential of clays and the plasticity index: (Chen, 1988).

Swelling Potential	Plasticity Index	Liquid Limit
Low	0-15	<30
Medium	10-35	30-40
High	19-55	40-60
Very High	55 and above	>60

While it may be true that high swelling soil will manifest high index property, the converse is Not true (Nebro, 2002).

B. Free Swell Tests

This test may be considered as amount of volume change in clay upon saturation and this is one of the mostly used easy tests to estimate the swelling potential of expansive clay. Experiments indicated that a good grade of high swelling commercial betonies would have a free swell of from 1190 to 1900 percent. Soils that having a free swell value as low as 100 percent can cause considerable damage to lightly loaded structures, and soils having a free swell value below 50 percent rarely exhibit considerable volume change even under very light loadings. The free swell percentage can be computed using Equation (2.1) below from the relationship between initial and swelled volume (Nelson & Miller, 1992).

Free swell (%) = ((Vf − Vi)/ Vi) *100……………………………………………… (2.1)

Where: Vi = initial volume

Vf = final volume

C. Free Swell Index

The free swell index is also one of the most commonly used simple tests to estimate the swelling Potential of expansive clay. The procedure involves in taking two ovens dried soil samples Passing through the 424μm sieve, 10cc each was placed separately in two 100ml graduated soil Sample. Distilled water was filled with one cylinder and kerosene in the other cylinder up to 100ml mark. The final volume of soil is computed after 23 hours to calculate the free swell index. The free swell index is then calculated using Equation below (Guyer, 2011).

Free Swell Index (%) = $(Vw - vk/Vk)$*100…………………………………... (2.2)

Where;

Vw = final volume in water

Vk = final volume in kerosene

D. Free Swell Ratio test

To determine the swell property, Sridharan and Prakash are proposed the free swell ratio method of characterizing the soil swelling. Free swell ratio is defined as the ratio of sediments volume of 10cc oven dried soil passing through the 424μm sieve in distilled water to that of Kerosene Equation.

Free swell ratio =Vw/ (Vk∗100)……………………………………………….………... (2.3)

The relation between the degree of expansion and differential free swell ratio is given in Table 2.6.

Table 2. 6: Classification of Soils based on free swell ratio (Sridharan and Prakash 2004).

Free Swell Ratio	Soil Expansively	Clay Type
<1	Negligible	Non Swelling
1.0-1.5	Low	Mixture of Non Swelling and Swelling
1.5-2.0	Moderate	Swelling
2.0-4.0	High	High
>4	Very High	Swelling

E. Cation Exchange Capacity (CEC)

The CEC is the quantity of exchangeable cations required to balance the negative charge on the surface of the clay particles. CEC is expressed in milli equivalents per 100 grams of dry clay. CEC is related to clay mineralogy. High CEC values indicate a high surface activity. In general, swell potential increases as the CEC increases. Typical values of CEC for the three basic clay minerals are given in Table 2.7.

Table 2. 7: Typical CEC values of basic clay minerals after Mitchell 1976 (Nelson & Miller, 1992).

Clay Mineral	CEC (meq/100gm)
Kaolinite	3-15
Illite	10-40
Montmrllonite	80-150

2.7.2.3 Direct Methods

The swelling pressure and volume changes of soils are measured directly using representative undisturbed samples. These methods offer the most useful data by direct measurement; and tests are simple to perform and do not require complicated equipment. Testing should be performed on a number of samples to avoid erroneous conclusions. Direct measurement of expansive soils can be achieved by the use of conventional one-dimensional consolidometer. The methods provide quantitative information, which are very useful for design engineers.

2.8 Classification of Expansive Soil

Parameters determined from expansive soil identification tests have been combined in a number of different classification schemes. The classification system used for expansive soils are based on indirect and direct prediction of swell potential as well as combinations to arrive at a rating. There are a number of classification systems. The following are some of the common methods.

2.8.1 Classification Using General Methods

The most widely used soil classification systems are AASHTO and USCS systems According to index properties.

2.8.1.1 Unified Soil Classification Systems

This classification is based on plasticity chart and a correlation is made between swell potential and unified soil classification as follows

Table 2. 8: Unified Soil Classification System Table

Category	Soil Classification Unified System
Little or no expansion	GW, GP, GM, SW, SP, SM
Moderate expansion	GW, SC, ML, MH
High volume change	CL, OL, CH, OH
No Rating	PT

The above classification system can be summarized as follow:

a. All clay soil and organic soils exhibit high volume change.

b. All clayey gravels and sands and all silts exhibit moderate volume changes.

c. All sands and gravels exhibit little or no expansion.

In the above classification soils rated as CL or OH may be considered as potentially expansive.

2.8.1.2 AASHTO Classification System

The AASHTO soil classification system is used to determine the suitability of soils for earthworks, embankments, and road bed materials such as sub grade, sub-base and base course. The AASHTO Classification system is useful for classifying soils for high way. On this research each Soil will be classified using the AASHTO Soil Classification System using particle size distribution and Atterberg limits. According to this classification system, granular soils are soils in which 35% or less are finer than the No. 200 sieve (75 µm). Silt-clay soils are soils in which more than 35% are finer than the No. 200 sieve (75 µm). The system classifies soils into seven major groups, A-1 through A-7. The first three groups, A-1 through A-3 are granular (coarse-grained) soils, while the last four groups, A-4 through A-7 are silt-clay (fine-grained) soils. As shown from AASHTO chart soils rated A-6 or A-7 by AASHTO can be considered potentially expansive (Nelson & Miller, 1992).

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 Study Area

The study area is located in western part of Ethiopia, in Gambella National Regional State, at a distance of 770 Km from Addis Ababa. Its geographical Coordinates are approximately 8º 13'-8º16' North Latitude and 34º 34'- 34º 36'50" East Longitude. The town is found in an area of average altitude, of about 480 m above sea level (ASL). According to the Central Statistical Agency of Ethiopia (CSA, 2012), this Zone has a total population of 240,000. It lies in the climatic zone locally known as Kola which is considered ideal for agriculture as well as human settlement. Most part of the state is covered with dense forests and fertile lands.

The expansive subgrade soils for this research were taken from Baro dare around at Gambella University and Mikeal sefer along abobo road (Baro Mado).

Figure 3. 1: Map of study area *(Source: Google Earth)*

3.2 Population

The population of this research is the soil of the selected study area of Gambella town. In addition to this the collection of stabilizers such as groundnut shell ash in Gojjeb town, Keffa zone, coal ash in Yayo Coal Factory, Yayo and Bamboo Fiber in Dedo kebele.

3.3 Materials

3.3.1 Sub Grade Soil

The weak soil sample is collected from Gambella town, Mikeal Sefer and Baro Dare. The soil is black in color for both sites. The pebbles and vegetative matter is removed in the site itself by hand. The Disturbed soils Sample were collected at 1.5m below the natural ground level. It was air dried and pulverized and sieved through (from sieve 19mm to sieve 0.0075mm) to eliminate the gravel fraction (large particles), if any. The dried and pulverized fraction is stored in air tight containers for further analysis. The collected soil was taken to the Jimma University Institute of Technology Laboratory room by a large polythene bag and dried in air for about 7 days.

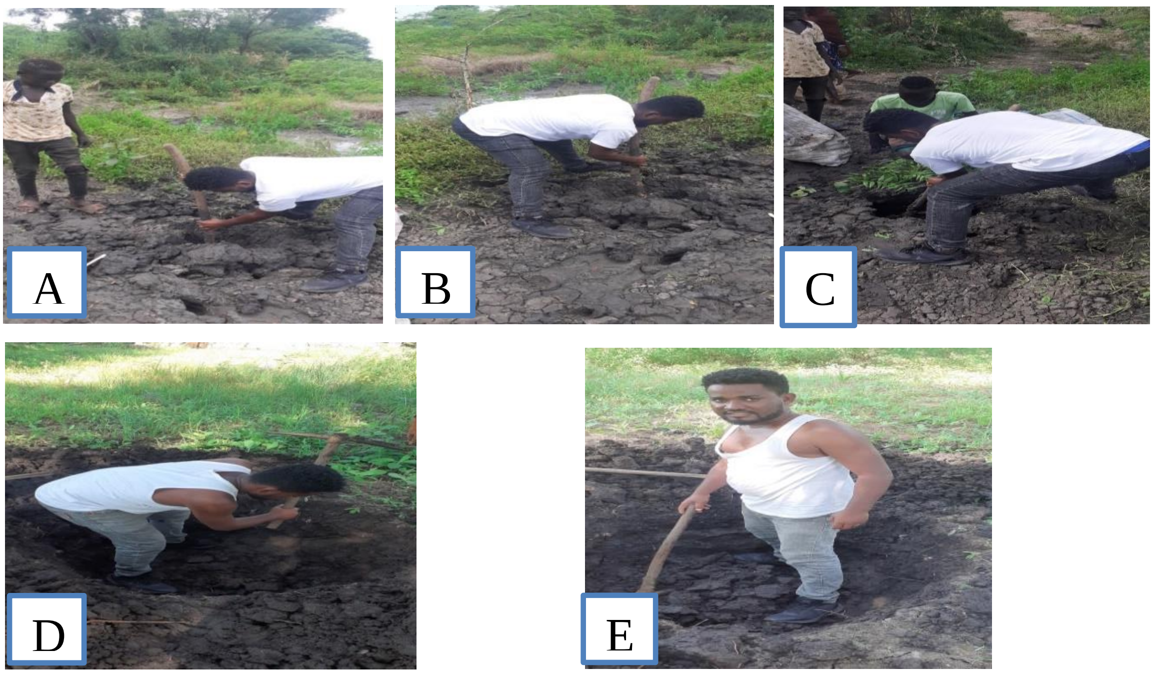

Figure 3. 2: Photos of sample taking from BD and MS soil sample (*Source: Abdi G., 6/02/2013)*

3.3.2 Groundnut Shell Ash

Groundnut shell is obtained from Keffa zone, Gojjeb town. The shells were burned on a metal sheet and the resulting ash is collected. Groundnut shell ash is produced by burning groundnut shell to ash; and groundnut shell is produced by milling of groundnut. The converted ash is sieved through No. 200(0.075mm). The groundnut shell ash treated soil samples were prepared for determination of Atterberg's limits, Compaction behavior, CBR and Specific gravity.

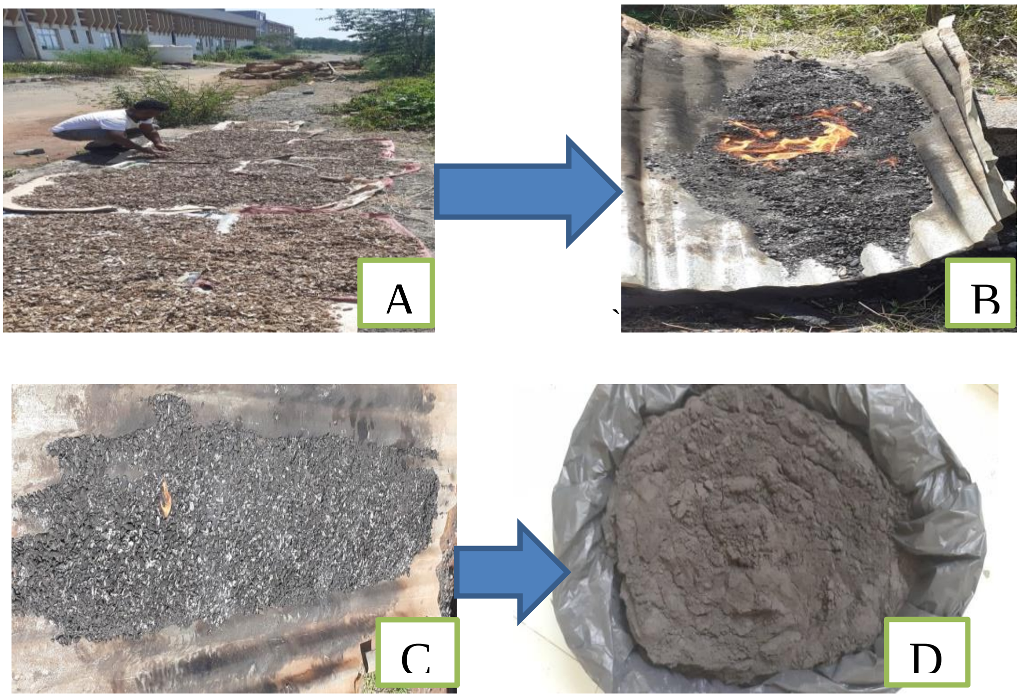

Figure 3. 3: Process of Groundnut shell ash (GSA) preparation *(Source: Dawit S., 1/3/2013)*

3.3.3 Bamboo Fiber

The bamboo fiber is making from the starchy pulp of bamboo plants. Bamboo fiber is natural fiber, acts as a strengthening material for ordinary soil. It binds the soil particles together and helps in reduction of rapid change in volumetric properties. Bamboo Fiber is obtained from Dido kebele.

Table 3. 1: Properties of bamboo fiber

Parameter	Values
Color	Light Brown
Average Diameter(mm)	3
Average Length(mm)	20

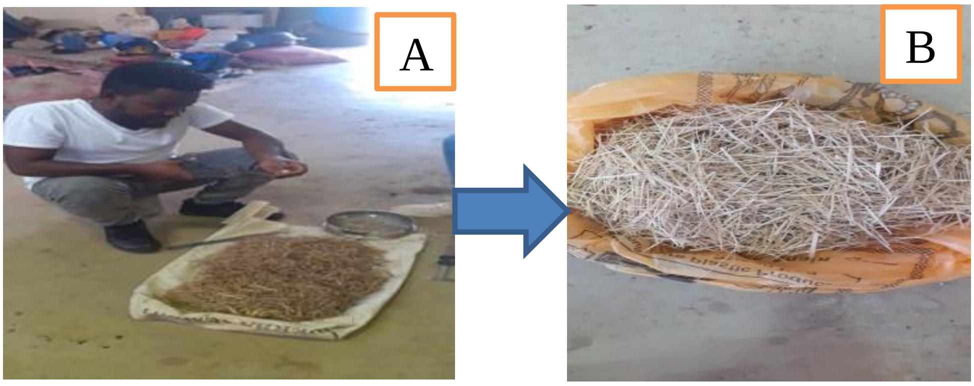

Figure 3. 4 : Preparation of bamboo fiber preparation (*Source: Eyuel M., 21/2/2013*)

3.3.4. Coal Ash

Industrial wastes such as Coal ash is the materials collected for this study. The collected samples were then burnt until it turned to ash by open burning on a metal sheet to protect the ash from mixing of dusts. The burnt coal ash Grounded after cooling using manual method and the burnt ashes were sieved through No. 200(0.075mm). A coal ash is collected from Oromiya region, Yayu Coal Factory. Yayu Coal Field is located in IIlubabor province, which is in the southwestern Ethiopia highland. The exploration district is part of Wittete block in Yayu Coal Field.

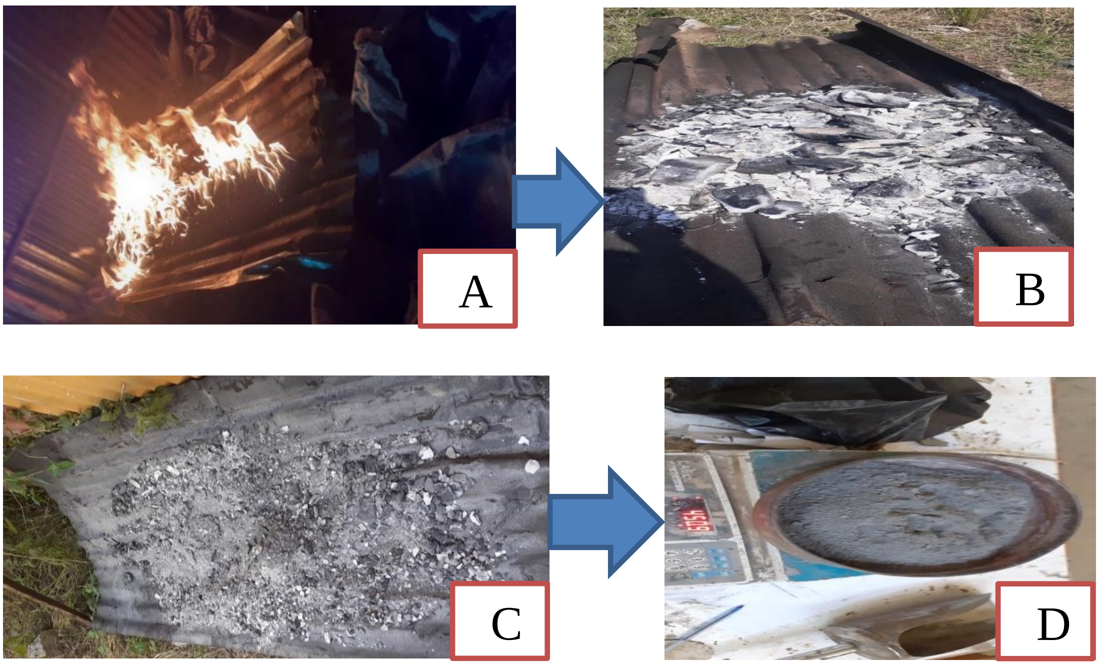

Figure 3. 5: Process of coal ash (CA) preparation *(Source: Dawit S., 8/3/2013)*

3.4 Methodology

3.4.1 Sample Collection Methods

In order to have sufficient and reliable data for the target analysis, laboratory tests is conducted on soil samples obtained from different localities of Gambella Town. The representative disturbed sample is collected by manual excavation from the selected study area on the basis of visual identification & free swell index.

3.4.2 Sources of Data

Both primary data and secondary data sources were used. Primary data for this study were a laboratory experiment output. Secondary data needed for this research were being collected from different journals, book, website and manuals.

3.4.3 Sampling Techniques

Sampling procedures used for this research were be Purposive sampling techniques and non-probability method, because the experimental investigation of the study was executed particularly on the most weak/soft soil samples, since this study pick out the samples in relation to some criterion, which are considered important for the particular study.

A disturbed soil sample was to be collected from this representative sampling area. The expansive soil was to be identified by observation and free swelling index. Samples are reduced with a sample splitter or by quartering and weighting were used as sampling technique. From this, quartering sampling technique were be used for sample preparation. After retrieving samples, laboratory testing were undertaken to assess the material suitability. Initially material classification tests such as grain size analysis, liquid limit, plastic limit, plasticity Index was undertake, followed by assessment of strength parameters such as compaction, and California bearing ratio. All the tests are performed in accordance to AASHTO, ASTM, and ERA Standards.

3.4.4 Sampling Size

After gathering information and field investigations, 3 subgrade soils were taken from different Gambella town. From those two most weak soils were selected by observations and free swell index tests, Because of time constraint and intension of study is to mix expansive subgrade soil with groundnut shell ash, coal ash and bamboo fiber as subgrade stabilizers, therefor the weakest sample is representing other populations by observations and free swell index tests. Therefore the weakest soil from the population are Baro dare approximately around at Gambella University $8^0$14’16” N latitude and $34^0$35’47” E longitude and Mikeal sefer approximately along abobo road $8^0$14’09” N latitude and $34^0$34’29” E longitude. The excavation was made manually using the shovel. The collected samples for this study were disturbed samples at a depth of below 1.5 m to remove organic matter.

3.4.5 Study design

Experimental study designs is used in this study which designed to answer the research questions and achieve its objectives based on experimental findings through quantitative, qualitative and comparative analysis approach.

It was attempt to conducted laboratory tests sieve analysis, Atterberg limits, Specific gravity, CBR test and Proctor compaction tests on expansive sub grade soil samples treated with different proportion of groundnut shell ash, coal ash and bamboo fiber checking to standard specification.

The research followed the experimental type of study which began collecting samples. The stages involved in the study include: -

- Information gathering and Investigating the study area
- collecting expansive subgrade soil and stabilizers
- Preparation of sample for each laboratory tests based on AASHTO and ASTM.
- Process of mixing untreated soil sample blended with (groundnut shell ash alone, coal ash alone and bamboo fiber alone) in appropriate d/t proportion were tested in laboratory.
- Conducting laboratory tests to determine engineering properties of stabilized soil sample.
- Find out maximum replacement amount that satisfies requirement of the standard specification
- the results obtained were compared

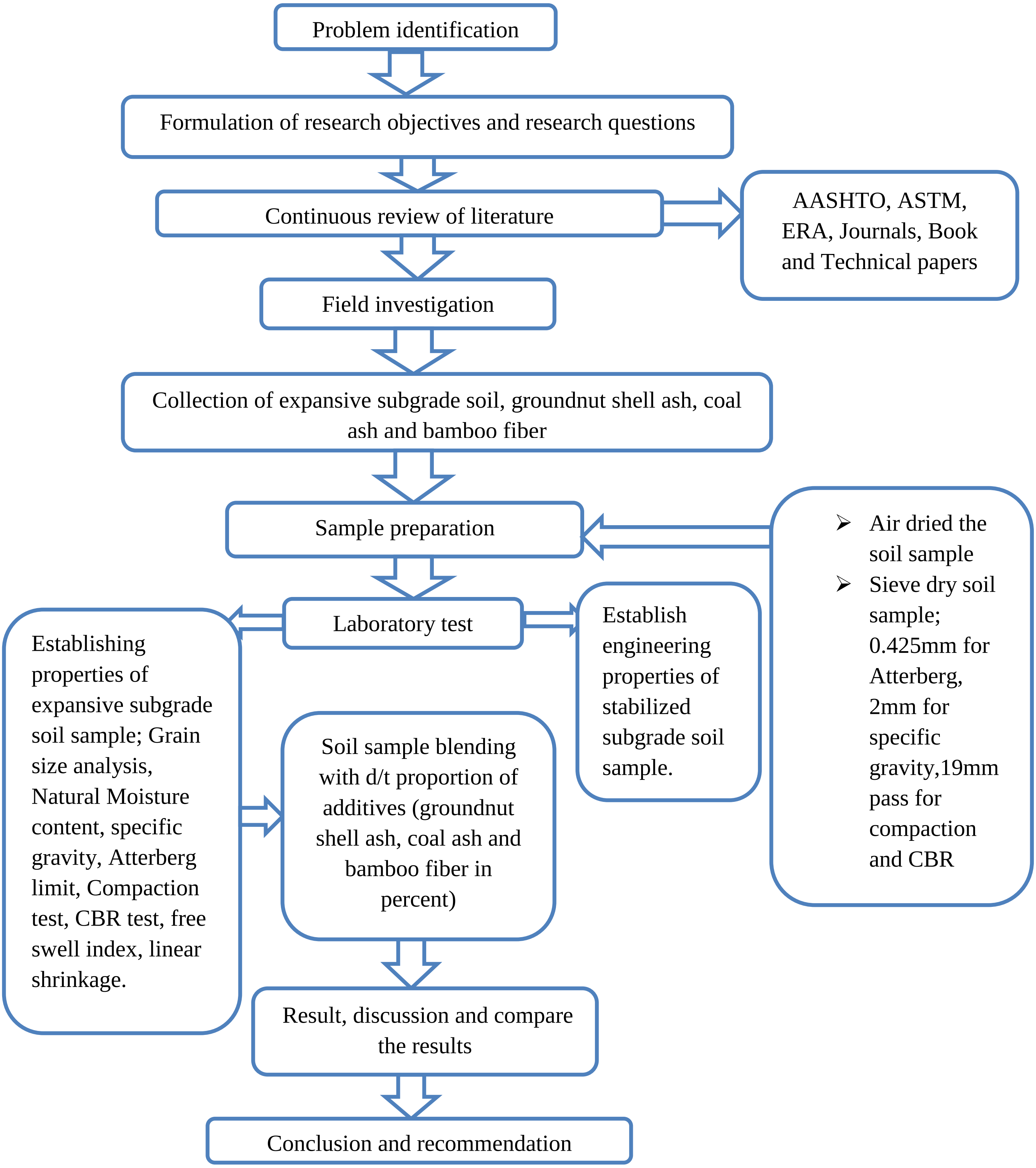

Figure 3. 6: Research Design flow chart

3.5 Study Variables

3.5.1 Dependent Variable:-

- Performance of expansive sub grade soil with stabilizing agents.

3.5.2 Independent Variable:-

- Maximum dry density(MDD)
- Optimum moisture content(OMC)
- Particle Size Distribution
- Free Swell Index
- Atterberg Limits,
- Specific Gravity

3.6 Methods and Standard testing procedure

The standards and specification for this study were adapted from AASHTO, ASTM and IS

Table 3. 2: Standards and Specification for this study

No	Laboratory test	Standards	
		AASHTO	ASTM
1	Moisture content	AASHTO T-80	
2	Grain size analysis	T-88	
3	Atterberg Limits	T089-96	
4	Soil Classifications	M-145	D2487-98
5	Specific gravity		D854-83
6	Modified proctor compaction	AASHTOT-99	ASTM D698
7	CBR	T193-93	

3.7 Laboratory Testing and Analysis

Tests for soil classification which included grain size analysis, free swell, specific gravity and Atterberg limits. These are indicative tests that are usually used to identifying wither the soil is expansive or not. The conducted tests however included Atterberg limit, wet sieve analysis, specific gravity, moisture density relation, free swell, CBR and percent swell of CBR to fully characterize and attain the objective of the research

3.7.1 Subgrade soil

3.7.1.1 Sample Preparation

Before treating the samples the soils were classified according to the AASHTO and ASTM soil classification system, the samples air dried properly and the stabilizer mixed with the prepared soil sample. The air dried sample mixed with the groundnut shell ash, coal ash and bamboo fiber based on the different proportion required. Comparative analyses were performed. This proper mixed soil used for Atterberg limit, Free swell index, compaction, Californian bearing ratio. This test was done by adding water to the proper mixed soil sample. Finally, wet mixing was done by sprinkling water uniformly and thorough blending the whole soil matrix.

Figure 3. 7: Mixing of soil sample with additives *(Source: Ayalew A., 12/3/2013)*

3.7.1.2 Natural Moisture Content (AASHTO T-80)

The Natural moisture content of the soil which is defined as the ratio between mass of water to mass of soil solid was determine immediately after the sample was taken from the site.

The samples were kept in plastic bag to prevent moisture loss during transportation from site to laboratory. The method employed for determining the moisture content was oven drying method. The measured amount of wet soil was put in an oven of thermo statically controlled oven at 110 ± 5°Cdegree centigrade and kept for 24 hours and examined for weight loss.

3.7.1.3 Grain size analysis (AASHTO T-88)

This test is conducted to determine the percentage of different grain sizes contained within a soil. Sieve analysis was carried out to determine the grain size distribution of soil and used to soil classification. Accordingly, wet sieve analysis was employed to determine the grain size distribution of soil sample in accordance with AASHTO T-88 test method for particle size analysis of soil. The grain size distributions for soil sample are presented at appendix A and appendix B. Lastly the analysis was combined particle size distribution curve was plotted as Figure 4.1 and 4.2.

3.7.1.4 Atterberg limits (AASHTO T 089-96)

This test is performed to determine the liquid and plastic limit of a fine grain soils. **Liquid Limit**: The liquid limit (LL) is subjectively defined as the water content, expressed in percent, at which the soil changes from a plastic to liquid and principally it is defined as the water content at which the soil pat cut using standard groove closes for about a distance of 13mm (1/2 in.) when subjected at 25 blows from the cup being dropped 10mm of the liquid limit machine (Casagrande Apparatus) run at rate of two drops per second. The liquid limit of a soil highly depends upon the clay mineral present. A soil containing with high water content is in the liquid state and it offers no shearing resistance.

Plastic Limit: The plastic limit (PL) is the water content, expressed in percentage, below which the soil stops behaving as a plastic material and it begin to crumble when rolled into a thread of soil of 3.0mm (1/2 in.) diameter. The soil in the plastic state can be remolded into several forms. When the water content is reduced the plasticity of the soil decreases changing into semisolid state and it cracks when remolded. The results of Atterberg limit test computed for the collected samples were written in Table 4.5.

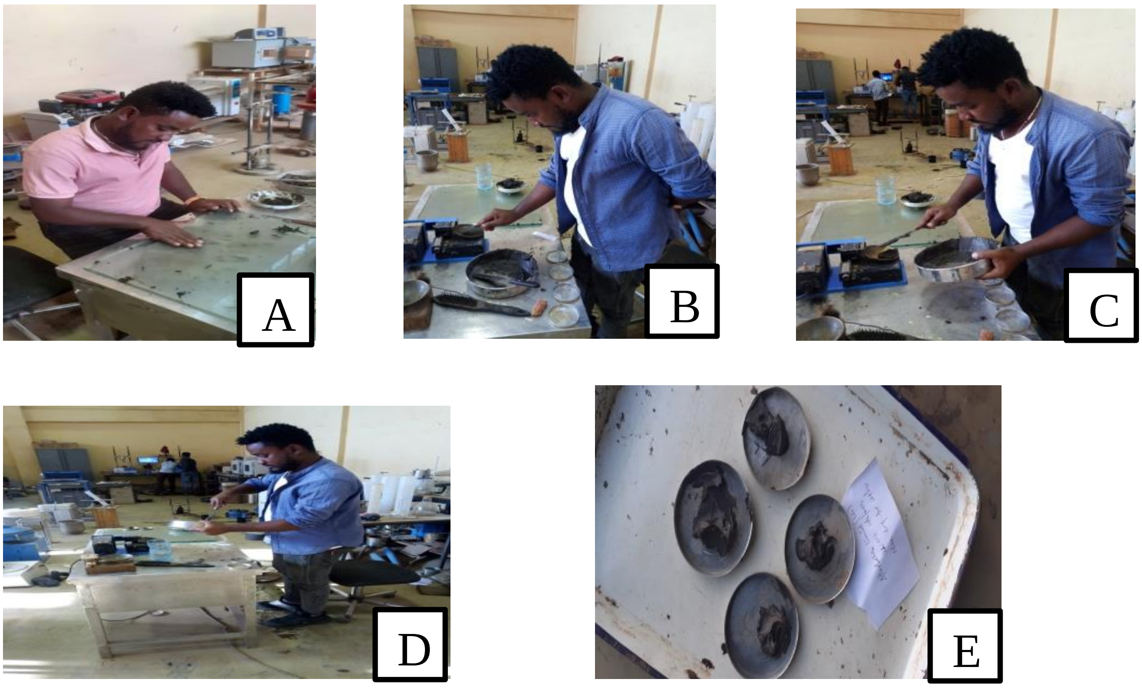

Figure 3. 8: Atterberg limit Determination *(Source: Mered H., 23/3/2013)*

3.7.1.5 Soil Classifications (AASHTO M-145 and ASTM D2487-98)

The most widely used soil classification systems for engineering purposes are American Association of State High Way and Transportation Officials (AASHTO) and Unified soil classification system (USCS). The AASHTO system of soil classification comprises seven groups of inorganic soils from A-1 to A-7 with 12 subgroups in all. The system is based on particle-size distribution, liquid limit and plasticity index. On the other hand, the Unified Soil classification system is based on the recognition of the type and predominance of the constituents considering grain – size (gradation), plasticity and compressibility. It divides soil in to three major divisions: coarse grained soils, fine grained soils and highly organic soils. The classification of soil samples was determined using AASHTO M-145 and D2487-98 and the classification is shown at Table 4.6.

3.7.1.6 Free Swell Index

The free swell index is also one of the most commonly used simple tests to estimate the swelling potential of expansive clay soil. The procedure involves in taking two oven dried soil samples passing through the 425µm sieve, 10g each was placed separately in two 100ml graduated soil sample. Distilled water was filled with one cylinder and kerosene in the other cylinder up to 100ml mark. The final volume of soil is computed after 24 hours to calculate the free swell index.

FSI = ((Vw − Vk)/ Vk)*100………………………………………………………. (3.1)

Where FSI = Free Swell Index

Vw = Final volume in water

Vk= Final volume in kerosene

The free swell Index of the study area soil was presented on Table 4.10.

Figure 3. 9: Free Swell index test *(Source: Dawit S., 13/2/2013)*

3.7.1.7 Specific Gravity (ASTM D-854)

Specific gravity which is the measure of heaviness of the soil particles were determined by the method of small pycnometer method using a soil sample passing 2mm sieve and oven dried at 110±5^{o}c degrees centigrade. Specific gravity is the ratio of the mass of the unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

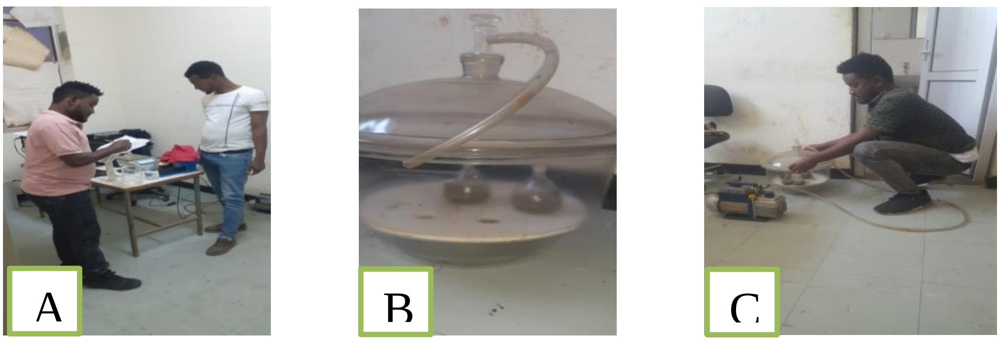

Figure 3. 10: Specific gravity test *(Source: Mered H., 1/4/2013)*

3.7.1.8 Compaction (AASHTO T-99)

Modified Proctor compaction tests were conducted on the soil to determine the relationship between the moisture content and dry density for specific compaction effort according to AASHTO T99. The soil was compacted with different moisture content in five layers each suffering 56 blows. After obtaining the density and moisture of each compacted soil sample, the relationships for dry density and moisture content are obtained as tabulated at Table 4.14.

Figure 3. 11: Compaction test *(Source: Asbew A., 4/4/2013)*

3.7.1.9 California Bearing Ratio (CBR) (AASHTO T 193-93)

The CBR is expressed by force exerted by the plunger and the depth of its penetration into the specimen; it is aimed at determining the relationship between force (load) and penetration. 4.5kg of the natural soil and the soil with GSA, soil with CA and soil with BF mixture are mixed at their respective (optimum moisture contents obtained from compaction mines natural moisture content divided by one hundred and multiplied with the mass of soil sample in gram) moisture contents in 2124 cubic centimeters molds. A three point CBR test at 10, 30 and 65 blows were conducted and the CBR values at 95% MDD was determined. The samples are compacted in five layers with 65blows, 30blows and 10blows from the Automatic compactor. The compacted soil samples of the CBR molds are soaked for 96 hours in a water bath to get the soaked CBR value of the soil. The test consisted of causing a cylindrical plunger of 60 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads for 2.54 mm and 5.08 mm were recorded. The greatest value calculated for penetrations at 2.54mm and 5.08mm was having been recorded as the CBR value. However, if the greater recorded value was obtained first for penetration at 5.08mm the laboratory test was repeated again and result were taken as it is for the next penetration result. The equation to be computing the CBR value is as follows.

CBR (%) =100*(x/y)………………………………………………………………... (3.2)

Where: 'X' = material resistance or the unit load on the piston (pressure) for 2.5 or 5.0 mm of penetration, y = standard unit load (pressure) for well graded crushed stone. For 2.5 mm Penetration = 13.2KN and for 5.0mm penetration = 20KN. The determined laboratory results are tabulated at Table 4.15.

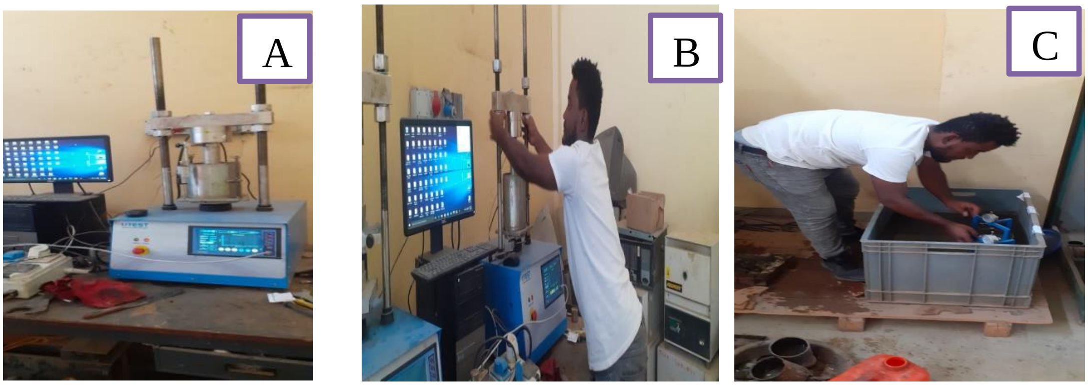

Figure 3. 12: CBR test procedures *(Source: Mulukene G., 10/4/2013)*

3.7.1.10 CBR swell of the soil

The CBR swell of the soil is measured by placing the tripod with the dial indicator on the top of soaked CBR mold. The compacted soil samples of the CBR mold are soaked for 96 hours in a water bath to get the CBR swell of the soil. The initial dial reading of the soil of the dial indicator on the soaked CBR of mold is taken just after soaking the sample. At the end of 96 hours the final dial reading of the dial indicator is taken hence the swell percentage of the initial sample length is 116.43mm, see Table 4.16. Then CBR swell is given by:

CBR Swell = (Change in Length in mm during soaking /116.43) *100 …………. .(3.3)

3.7.1.11 Linear Shrinkage

Linear shrinkage test followed a British standard (BS1377: Part 2:1990), and covers the determination of total linear shrinkage from linear measurement on a standard bar of length 140 mm with a semicircular section of diameter 25 mm, the grove filled by a soil of the fraction passing 0.425 mm test sieve, originally having the moisture content of the liquid limit.

$$\text{Linear shrinkage} = \frac{\text{Initial length-oven dried length of specimen}}{\text{Initial length}} * 100 \quad \ldots\ldots (3.4)$$

Figure 3. 13: Linear Shrinkage test *(Source: Dawit S., 16/3/2013)*

3.7.1.12 Cone Penetrometer Method

The cone penetrometer method is the preferred method to the Casagrande test as it is essentially a static test depending on soil shear strength. This method covers the determination of liquid limit of a sample in its natural state, or a sample from which material passing on 0.425mm test sieve has been used for test. It is based on the measurement of penetration in to the soil of a standardized cone. The liquid limit of the soil sample is the moisture content corresponding to a cone penetration of 20mm and shall be expressed to the nearest whole number.

Figure 3.14 : Cone penetrometer test *(Source: Ayalew A., 22/4/2013)*

3.8 Data quality Assurance

Pre –test of the available instrument was to be done before the main data collection period begins and the data was to be collecting after gaining awareness on how to collect relevant data by principal investigators. A sample was to be collected from appropriate locations and at appropriate depth to avoid organic and weathered materials. A standard format was to be used for recording test results to prevent loss of data.

- Laboratory test and field work manual was to be preparing in order to avoid error of data
- The training was to be given for data collectors to handle the data carefully.

3.9 Plan for Dissemination of Findings

Dissemination of findings is important so that results can be used to improve engineering and technological industries. The findings of the study is presented for Faculty of Civil and Environmental Engineering and School of Graduate Studies as part of evaluation and publically defended in the presence of examiners.

Dissemination plans were designed by implementing the following points effectively.

- Orient toward the needs of the audience, using Amharic, English, and other appropriate languages and information levels.
- Apply various dissemination methods: written text including illustrations, graphs and figures; electronic and web-based tools; and oral presentations at community meetings and scientific conferences.

3.10 Ethical Considerations

- Prior to data collection an official letter had been written by Jimma University to different required office to perform the relevant tests, which were not available in the university that help to take the representative soil samples.
- Before the collection of the data the purpose of the data collection was to be clearly described to the organizations by the data collectors and the principal investigator.
- The data was collected based on the willingness of the organizations.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter presents test results, discussion and analysis of all experimental work that were performed on untreated and treated soil samples with Groundnut shell ash, Coal ash and Bamboo fiber. Primarily, properties of materials (untreated soil, Groundnut shell ash and coal ash) were examined, then the effect of stabilizers on Atterberg limits, Natural moisture content, moisture-density relationship (compaction), CBR, and CBR swell values were investigated by varying percentage of stabilizers and compared with native soil/untreated soil engineering properties. Then effect of stabilizers on the properties of treated soil was compared and contrasted with standard specification and manuals.

4.1 Material Property used in this study

4.1.1 Laboratory test result for engineering properties of Stabilized soil sample

Table 4. 1: Summary of test result for stabilized soil sample with groundnut shell ash

GSA (%)	Test Result, %											
	BD						MS					
	MDD, g/cm3	OMC ,%	CBR, %	CBR, Swell,%	LL,%	PI,%	MDD , g/cm 3	OMC , %	CBR,%	Swell,%	LL,%	PI, %
2	1.62	20.89	3.8	1.23	82.50	43.98	1.62	21.29	3.2	1.75	83.88	47.63
4	1.63	18.37	5.2	0.89	74.03	33.05	1.60	24.91	3.9	1.19	79.02	38.57
6	1.64	16.89	5.9	1.09	63.35	17.85	1.51	25.70	5.1	1.16	65.79	21.45
8	1.59	20.83	7.5	0.55	57.83	8.71	1.49	31.25	5.9	1.02	59.23	12.67
10	1.58	18.4	6.4	0.64	54.49	4.23	1.47	26.54	5.2	1.80	57.36	8.47

Table 4. 2: Summary of test result for stabilized soil sample with Coal ash

CA (%)	Test Result, %											
	BD						MS					
	MDD, g/cm3	OMC ,%	CB R, %	CB R, Swe ll,%	LL,%	PI,%	MDD , g/cm 3	OMC , %	CB R,%	Swe ll,%	LL,%	PI, %
10	1.62	18.58	4.3	1.73	77.71	39.05	1.63	20.55	4.1	1.92	86.23	48.93
20	1.57	20.39	5.3	1.69	69.68	24.95	1.54	24.56	5	1.71	76.03	34.29
30	1.48	21.81	6.90	1	61.16	14.59	1.49	25.86	6.5	0.77	67.05	21.58
40	1.47	25.48	7.8	0.75	58.22	8.09	1.47	29.83	7.5	1.07	60.52	11.45
50	1.56	17.24	6.4	1.30	56.83	3.60	1.44	27.35	6.2	1.49	57.43	7.17

Table 4. 3: Summary of test result for stabilized soil sample with Bamboo Fiber

BF (%)	Test Result, %							
	BD				MS			
	MDD, g/cm3	OMC, %	CBR,%	CBR Swell, %	MDD, g/cm3	OMC, %	CBR, %	CBR Swell, %
1	1.6	20.79	3.7	1.87	1.59	28.55	3.4	2.30
1.5	1.57	18.28	4.9	1.43	1.77	15.22	3.9	1.87
2	1.59	19.05	5.3	1.66	1.69	31.16	4.7	1.31
2.5	1.61	16.2	6.4	0.97	1.52	20.18	6.4	1.14
3	1.56	13.74	4.3	1.86	1.47	19.74	5.1	1.86

4.1.2 Geotechnical Properties of Soil Sample

In order to determine the quality of the materials, laboratory tests were carried out on both BD and MS untreated soil samples. The results of the tests conducted for identification and/or determination of properties of the natural soil before applying Groundnut shell ash, coal ash and bamboo fiber are presented in Table 4.4.

Table 4. 4: General Geotechnical properties of both soil sample

Parameters	Test Result, %	
	BD	MS
Natural moisture content	35.59	40.82
Percentage of passing No.200sieve, %	94.41	92.92
liquid limit (LL)	81.84	89.16
Plastic limit (PL)	32.4	33.3
Plasticity index (PI)	49.44	55.86
AASHTO	A-7-5	A-7-5
USCS	CH	CH
Specific gravity	2.72	2.79
Free swell index	80	85
Linear shrinkage	12.33	14.02
Maximum dry density, g/cm3	1.6	1.59
Optimum moisture content (OMC)	18.99	21.46
Soaked CBR value	2.2	1.6
CBR swell	5.57	6.90
Color	Black	Black

Generally Liquid limit less than 35% is low plasticity, between 35% and 50% intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90%

very high plasticity (Whitlow, 1995). As a result, these values indicate both the soil sample is very high plastic clay. Therefore, the subgrade shrink and swell easily and does not resist internal and external load. Finally, the structure make crack and easily demolished. To protect this failure stabilization using different additives should be required.

4.1.2.1 Particle size distribution

A basic element of a soil classification system is the determination of the amount and distribution of the particle sizes in the soil. Distribution of particle sizes greater than 0.075 mm is determined by sieving, while a sedimentation process (hydrometer test) is used to determine the distribution of particle sizes smaller than 0.075 mm. To determine the distribution of coarser particles, 1200gm of the natural subgrade soil is taken and washed on sieve size of 75µm. The tabular experimental results are presented in appendix A and B, and the particle size distribution curves are shown in Figure 4.1 and Figure 4.2 The soil for sample BD soil sample is black, and almost 94.41% of the soil are passing through No.200 sieve as shown in Figure 4.1.

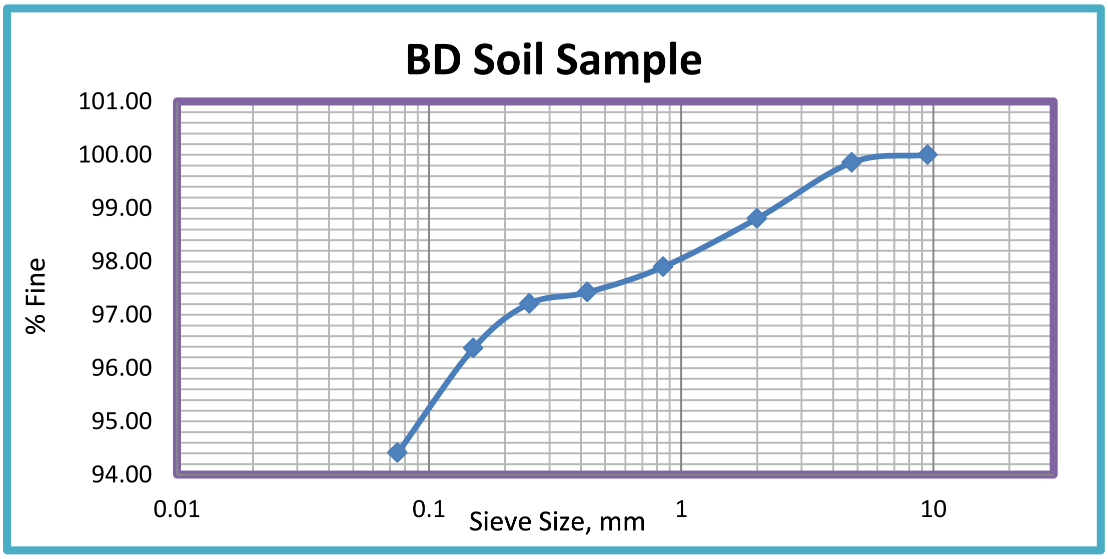

Figure 4. 1: Grain size distribution curve of BD soil sample

According to AASHTO soil classification soils 35% minimum percent pass sieve no.200 sieve (75µm) are classified as silty-clay materials. The minimum percent pass sieve no.200 for the BD soil Sample under study is 94.41% and the soil is categorized as poor clay subgrade soil.

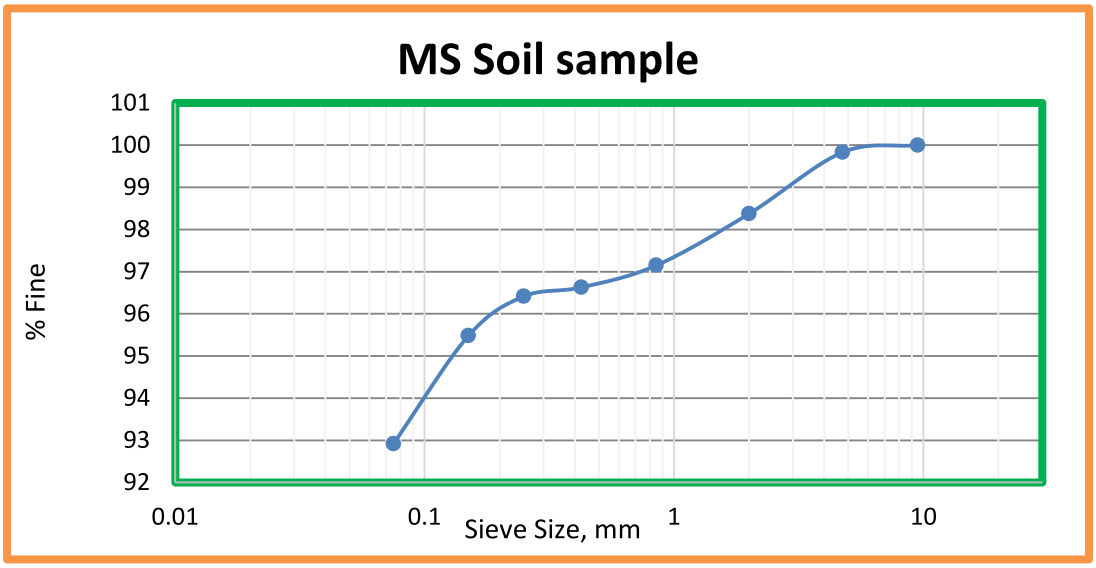

Figure 4. 2: Grain size distribution curve of MS soil sample

The soil for sample MS is Black and almost 92.92 % of the soil is passing through No.200 (75µm) sieve as shown in Figure 4.2. Almost the given soil sample were a fine clay (silty clay) soil.

4.1.2.2 Atterberg's Limits

The nature and response of soil up on change to moisture content is determined by Atterberg limit tests. Following the AASHTO procedure, designation AASHTO T89-96 and T90-00 standard test method, the soil samples obtained from BD and MS were subjected to varying water content and as a result the liquid limit, plastic limit and plastic index of the untreated sample as recorded in Table 4.5 were determined. The laboratory data analysis was attached in Appendix A and B.

. Table 4. 5: Atterberg test results of BD and MS sample soil

	100 % Natural subgrade soil		
Sample Name	Liquid limit (%)	Plastic limit (%)	Plasticity index (PI)
BD	81.84	32.4	49.44
MS	89.16	33.3	55.86

According to Atterberg limit test result as shown by Table 4.5. The BD and MS soil sample changed from liquid state to plastic state and got an average liquid limit of 81.84% and 89.16% respectively. The given soil sample translate from plastic state to semisolid state and got an average plastic limit of 32.4% and 33.3% for BD and MS soil sample respectively. At this state the soil rolled into threads. The difference between the liquid limit and plastic limit is called Plastic Index. The soil sample also has Plastic Index of 49.44% and 55.86% for both soil samples respectively. As result of Plastic Index indicates both the native subgrade soil samples have poor for sub grade material unless it treated.

4.1.2.3 Soil Classifications

4.1.2.3.1 AASHTO Classification system (AASHTO M-145)

The AASHTO system uses similar techniques as that of USCS but the dividing line has an equation of the form PI= LL-30. It generally classifies a soil broadly into granular material and silt-clay material. The granular material is further divided into three groups which are called A-1, A-2 and A-3. The silt-clay material is in turn divided into four groups namely, A-4, A-5, A-6 and A-7. As it can be observed from AASHTO Classification system plasticity chart is as Follows in Figure 4.3.

Table 4. 6: Classification of Soils based on AASHTO classification system

Sample Name	Sieve analysis of percentage of passing			LL (%)	PI (%)	LL-30	Group Index	Soil Group	Material Type
	No.10	No.40	No.200						
BD	98.81	97.42	94.41	81.84	49.44	51.84	167	A-7-5	Clay soil
MS	98.37	96.63	92.92	89.16	55.86	59.16	189	A-7-5	Clay soil

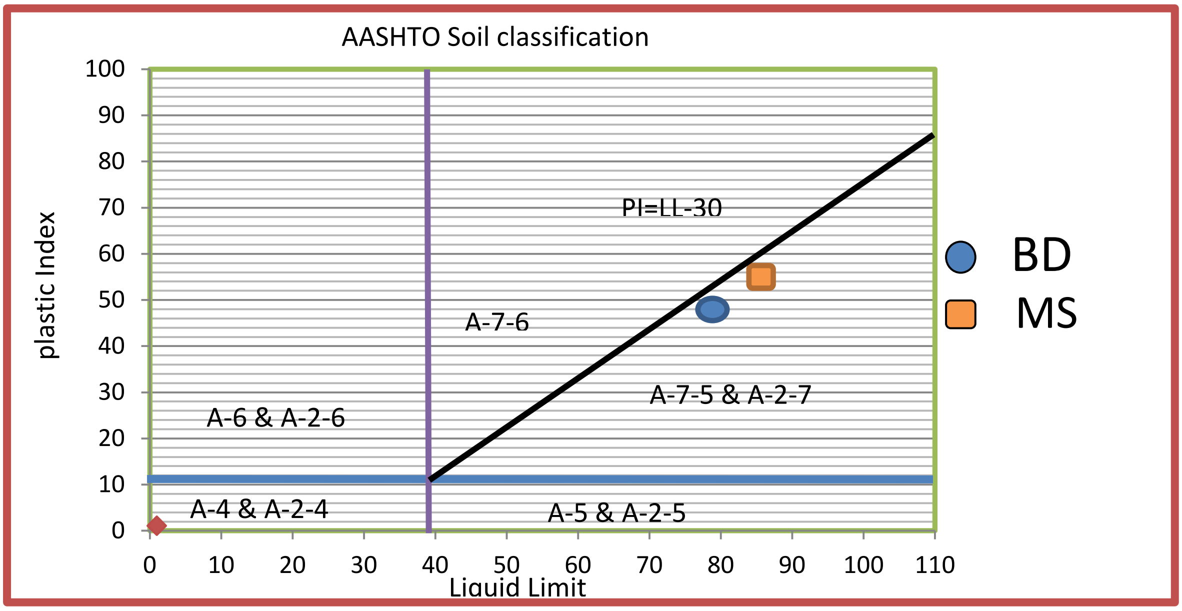

Figure 4. 3 : Plasticity chart of untreated soil samples according to AASHTO

From AASHTO Classification system results shown in Table 4.6 and Figure 4.3 it can be concluded that both BD and MS soil samples fall under A-7-5, which were clayey soils with group index of 167 and 189 respectively. The group index results indicate that generally the soils of the study area were very poor for subgrade material. Thus, the natural subgrade material is unsuitable to be used as subgrade material without employing some improvement methods.

4.1.2.3.2 Unified Soil Classification (USCS) system

This system describes a system for classifying minerals and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit and plasticity index and shall be used when precise classification is required (ASTM). The classification of the soils is presented in Figure 4.4.

Table 4. 7: Soil Classification according to AASHTO and USCS for both soil samples

Sample Name	Liquid limit (%)	Plastic limit (%)	Plastic Index (%)	Group Index	AASHTO	USCS
BD	81.84	32.4	49.44	167	A-7-5	CH
MS	89.16	33.3	55.86	189	A-7-5	CH

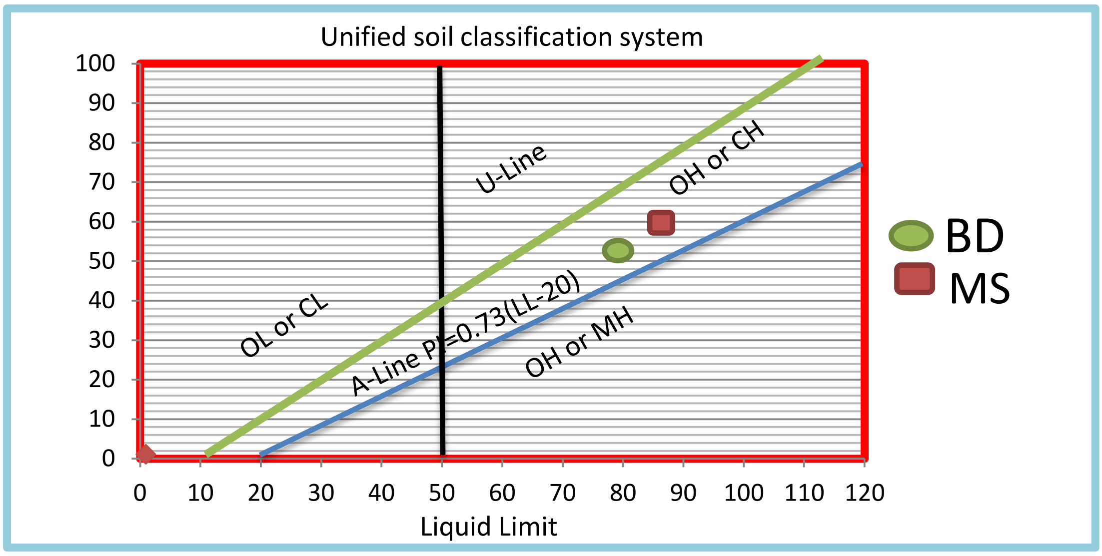

Figure 4. 4: Plasticity chart of untreated soil according to Unified Soil Classification System

According to USCS, if the Liquid limit are greater or equal to 50% the soil can be clay, silt, or organic depends on whether the soil coordinates plot above or below the A line. Based on the lab result the liquid limit soil sample BD and MS are 81.84% and 89.16% respectively since the results are greater than 50% so that the soils are high plasticity (H). to identify the soil is high silt(MH) or high clay (CH) observe the plastic index vs. liquid limit chart to check the point above A line or below A line since both soil samples are above A line so that the soil type is high plastic clay(CH), a ccording to ASTM D2487 -11.

4.1.2.4 Specific gravity of Natural Subgrade Soil, Groundnut shell ash, Coal ash

Specific gravity which is the measuring of the heaviness of soil particle is determined by the method of pycnometer method using the soil sample passing sieve number 10(2mm) and oven dried 105^0c.The test includes the determination the specific gravity for the natural soil. The test was conducted in accordance with ASTM-854 testing procedure.

Table 4. 8: Specific gravity for natural sub grade

Soil Sample	BD	MS
Specific gravity	2.72	2.79

Table 4. 9: Specific gravity for Groundnut shell ash, Coal ash

Sample	Groundnut shell ash	Coal ash
Specific gravity	2.05	1.97

At a Table 4.8 the specific gravity of the soil sample BD and MS are 2.72 and 2.79 respectively. The specific gravity of solid particles most soils vary from 2.5-2.9. For the most of calculation the specific gravity can be assumed as 2.65 for cohesion less soils and 2.70 for clay soils. Therefore at a Table 4.8 the test result indicates that both soil samples are under clay soil.

4.1.2.5 Free swell index

The Free swell test is one of the most commonly used simple tests for estimating soil swelling potential. A result of the free swell tests of the soil was given in Table 4.10.

Table 4. 10: Free swell index test results for natural subgrade soil sample

Sample Name	Free swell Index (%)
BD	80
MS	85

The free swell test value of for sample BD and MS indicates that 80% and 85% respectively. Soils having the free swell value above 100% can cause damage whereas free swell as low as 100% can cause considerable damage to light loaded structures and soils having a free swell value less than 50% seldom exhibits appreciable volume change even under light loads. Hence the free swell value of the soil under study exceeds 50% such soils undergo volumetric changes loading to pavement distortion, cracking and general unevenness due to seasonal wetting and drying (Ranjan and Rao, 2002).

4.1.2.6 Linear Shrinkage Test

This test was conducted to determine the linear shrinkage of the drying soil. Linear shrinkage is the reduction in the length of the sample when completely dries. The linear shrinkage test was conducted on the treated and untreated soil. A result of the Linear Shrinkage Test of the untreated soil sample was given in Table 4.11 and a tabular laboratory test result was given in appendix A and appendix B.

Table 4. 11: Linear Shrinkage test results of the untreated soil

Sample Location	Linear shrinkage (%)
BD	12.33
MS	14.02

4.1.2.7 Compaction test results of natural subgrade soil

Modified proctor test was done to determine the maximum dry density (MDD) and optimum moisture content (OMC) natural subgrade soil according to AASHTO T-99. Prepared a sufficient quantity of air dry soil were passing through sieve number 19mm and measured 4500gm of soil sample and compact in Five layers for each proctor compaction test. The BD soil sample has optimum moisture content 18.99% and maximum dry density 1.60gm/cm3. Also, MS soil sample has optimum moisture content 21.46% and maximum dry density 1.59gm/cm3 as shown in Figure 4.5

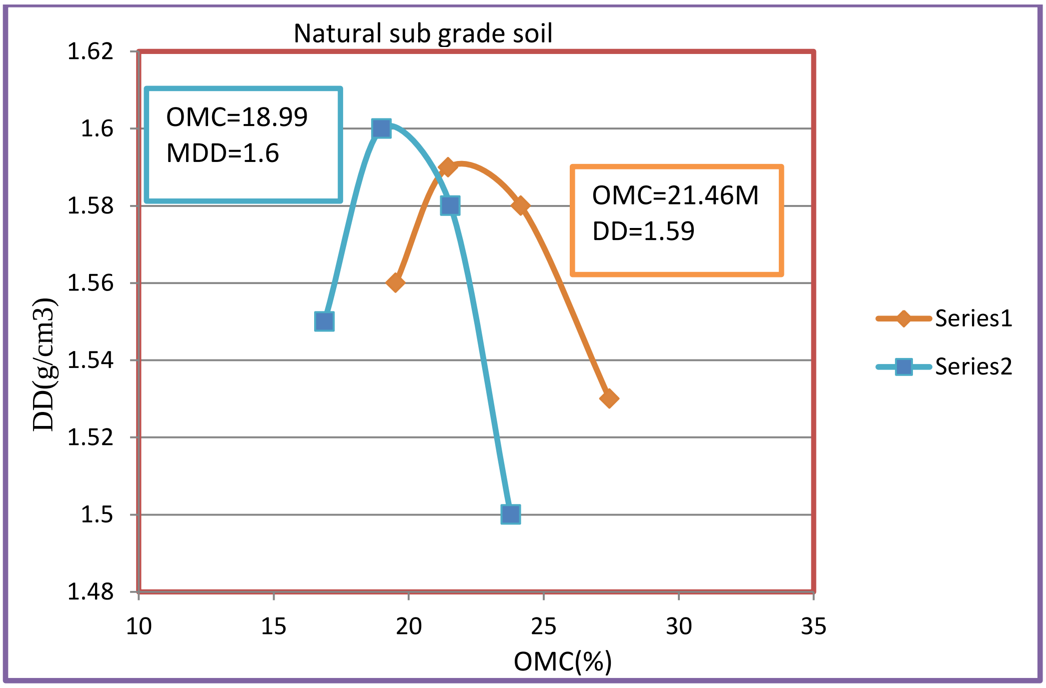

Figure 4. 5: Moisture Density Relation for natural sub grade soil

4.1.2.8 CBR test result of natural subgrade soil (AASHTO T-193)

Three point (65, 30, and 10) bellows in five layer CBR tests were done according to AASHTO T193 to determine the strength of soil sample and how it will behave when subjected to loading. About 4.5kg quantity of air dried soil and passing through sieve size 19mm were mixed at optimum moisture content in large mixing pan. Then compacted in 5 layer with 65, 30, 10 number of bellows for each layer. Compacted soil samples of CBR mold are soaked for 96hrs in water bath to get the soaked CBR value and the CBR swell of the soil.

The CBR swell of the soil is placing the tripod with the dial indicator on the top of soaked CBR mold. The initial dial reading of the dial indicator on the soaked CBR mold is taken just after soaking of the sample. At the end of 96hrs the final dial reading of dial indicator is taken hence the swell percentage of initial sample length is given by

The Summary of the CBR result for natural subgrade soil shows at Table 4.12

Table 4. 12: CBR test results of expansive soil

Sample Name	Number of bellows	Load(KN)		CBR (%)		Swell in (%)	OMC (%)	DD(g/cc)	MDD(g/cm^3)
		2.54	5.08	2.54	5.08				
BD	65	0.331	0.391	2.48	1.96	5.57	18.9	1.520	1.60
	30	0.305	0.372	2.29	1.86				
	10	0.269	0.318	2.02	1.59				
	CBR at MDD (%)			2.2					
MS	65	0.284	0.324	2.13	1.62	6.90	21.5	1.511	1.590
	30	0.243	0.298	1.82	1.49				
	10	0.217	0.267	1.63	1.34				
	CBR at MDD (%)			1.6					

According to the laboratory results as presented Table 4.12 the BD soil sample had 2.2% soaked CBR value with 5.57 % CBR swell and MS soil sample had 1.6 % soaked CBR value with 6.90 % CBR Swell. From the soaked CBR test, it was found that the natural subgrade soil has low CBR value as compared to ERA manual 2013 both subgrade soil samples does not satisfy the minimum requirements as subgrade material. Also CBR swell values are above the specified maximum value of 2% hence this soil needs to be treated before use.

4.1.3 Overall Characterization of the natural subgrade soil

According to the laboratory test results of the natural subgrade soil sample obtained during the present study, the proportion of fines passing no 200 sieve 94.41%, 92.92%, liquid limit 81.84%, 89.16%, and plasticity index 49.44%, 55.86%, for BD and MS soil sample respectively, both soils samples are classified in to A-7-5 as per the AASHTO and CH as per the USCS classification system. As far as the engineering performance of soils of this class is concerned, such soils are expansive soils which have high volume changing properties with variation in moisture content (Chen, 1988). The liquid limit and plasticity index values are very much greater than the Ethiopian Roads Authorities requirements as stated by (Alemayehu, 2015), i.e., liquid limit less than 60% and plasticity index less than 30%. Accordingly, both samples show excess values in each parameter and the soil in general thus had expansive property. The free swell index of 80%, and 85%for BD and MS soil sample respectively, also revealed that the soils are expansive soil, since its free swell index is greater than 50%.

Furthermore, the CBR and percent swell of 2.2%, 1.6% and 5.57%, 6.90% for BD and MS soil samples respectively indicate that the soils has a low load bearing capacity and high swelling potential when compared to ERA's specifications of CBR $\geq$ 5% and percent swell of less than 2% which makes it unsuitable for construction without any suitable treatment measure. However, the comparisons above between ERA design manual and laboratory results of the soil shows that, the soil sample do not full fill the requirements as a sub-grade and are determined to be unsuitable for sub-grade in road construction. Therefore, the sub-grade soil should be treated with appropriate improving methods before use as road sub grade.

4.1.4 Laboratory test results of stabilization of expansive soil

4.1.4.1Atterberg limits

One of the important and principal aims of the present study was to evaluate the changes of liquid limits, plastic limits and plasticity index with addition of Groundnut shell ash and coal ash to the selected soil samples. To achieve this objective, liquid limit and plastic limit tests were conducted on Groundnut shell ash-soil mixtures and Coal ash-soil mixture. A ccording to consistency test of AASHTO T89 and T90, Soil samples were first air dried and pulverized and then sieved with no 40(0.425) sieve. Soil passing no 40 sieve was mixed with different proportion of Groundnut shell ash and coal ash at optimum water content and sealed with plastic for 24 hours in order to give sufficient time for chemical reaction before test. From Table 4.13 Groundnut shell ash (GSA)-soil mixtures and Coal ash-soil mixtures, the following observations have been made and/are illustrated in Figure 4.6 and Figure 4.7 for BD and MS samples respectively.

Table 4. 13: Atterberg limit test result of GSA-Soil and CA-Soil to stabilized BD soil sample

Sample Name	Additives	LL (%)	PL (%)	PI (%)	ERA(2013) Requirement of PI In (%)	Remark
	GSA (%)					
	0	81.84	32.4	49.44	<30	Poor
	2	82.50	38.52	43.98		Poor
	4	74.03	40.98	33.05		Poor
	6	63.35	45.50	17.85		Satisfied
	8	57.83	49.12	8.71		Satisfied
	10	54.49	50.26	4.23		Satisfied
	CA (%)					

BD	0	81.84	32.4	49.44	<30	Poor
	10	77.71	38.66	39.05		Poor
	20	69.68	44.73	24.95		Satisfied
	30	61.16	46.57	14.59		Satisfied
	40	58.22	50.13	8.09		Satisfied
	50	56.83	53.23	3.60		Satisfied
MS	**GSA (%)**	LL (%)	PL (%)	PI (%)	ERA(2013) Requirement of PI in (%)	Remark
	0	89.16	33.3	55.86	<30	Poor
	2	83.88	36.25	47.63		Poor
	4	79.02	40.45	38.57		Poor
	6	65.79	44.34	21.45		Satisfied
	8	59.23	46.56	12.67		Satisfied
	10	57.36	48.89	8.47		Satisfied
	CA (%)				<30	
	0	89.16	33.3	55.86		Poor
	10	86.23	37.30	48.93		Poor
	20	76.03	41.74	34.29		Poor
	30	67.05	45.47	21.58		Satisfied
	40	60.52	49.07	11.45		Satisfied
	50	57.43	50.26	7.17		Satisfied

According to the results observed from the laboratory test, one can judge that the behavior of soil sample was changed from high plasticity soil to low plasticity soil. As a result, when the percentage of GSA & CA increased plasticity index of the treated soil samples are significantly decreased whereas it becomes increase when the percentage of GSA & CA increased, this is the reason due to deficiency of Ca2+ which is required to replace the weakly bonded ions in the clay structure and hence, flocculation did not occur. Instead, there was an increase in the fine fraction which absorbed more water and became more plastic.

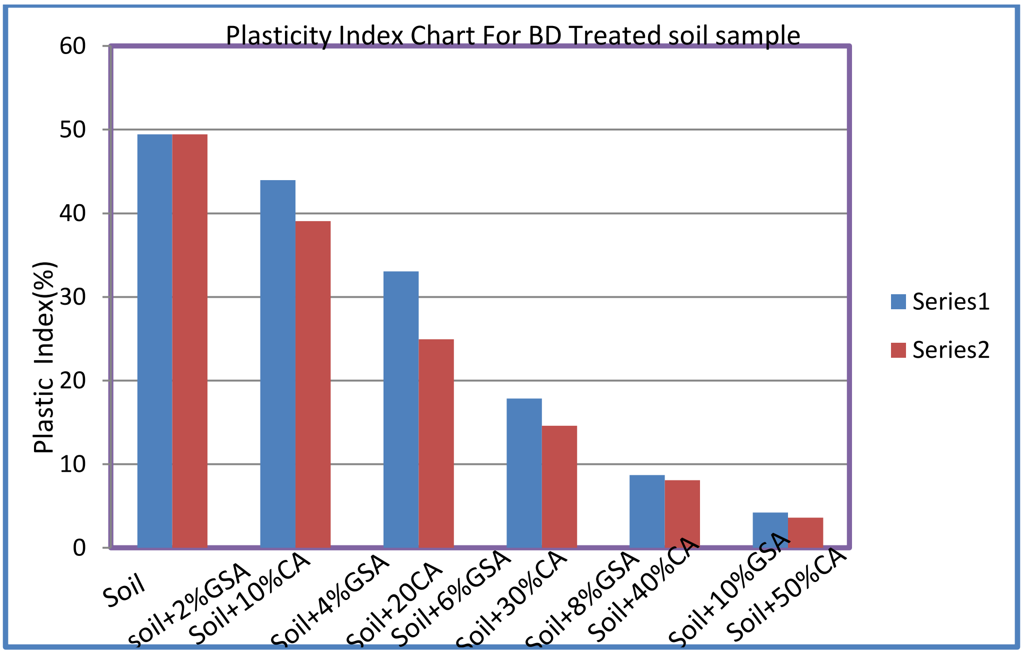

Figure 4. 6: Plasticity index chart for stabilize BD soil sample

The liquid limit decreases for both soil samples from 81.84% to 54.49% (GSA) and 81.84% to 56.83% (CA) for BD Soil sample and 89.18% to 57.36%(GSA) and 89.18% to 57.43%(CA) for MS soil sample. However the additive shows significant change on Liquid limit of the soil because of pozzolanic property of the ash. It has been recognized that the type of mineral present in a soil type determines Cation exchange capacity and hence, the effect the addition of soil stabilizers will have on the Atterberg limits (Dainti, al..., 2005).

From the test data it is observed that addition of GSA and CA decreases Liquid Limit, Plastic Index and increase in Plasticity Limit values. After modification PI reduced from a value of 49.44% to 4.23% (GSA) and 49.44% to 3.60% (CA) for BD soil sample and

55.86% to 8.47% (GSA) and 55.86% to 7.17% (CA) for MS soil sample. Hence GSA and CA have great impact in reduction of PI.

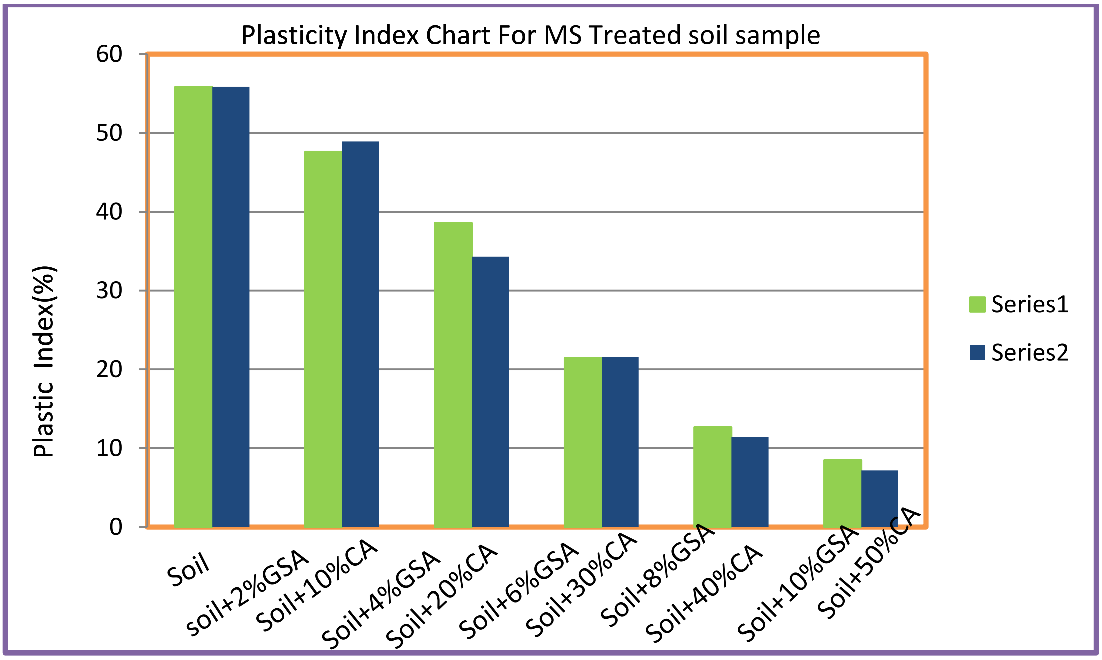

Figure 4. 7: Plasticity index chart for stabilize MS soil sample

The plasticity index decrease with stabilization of additives for all mix-ratio however the percentage of reduction was significantly decreased when the percentages of coal ash increase rather than Groundnut shell ash. Generally the stabilization of weak soil with Coal ash and Groundnut shell ash have brought very appreciable result in decreasing plasticity index of both soil samples.

4.1.2.2 Compaction characteristics of treated soil

The Modified proctor compaction test was carried out according to AASTHO T-99. The moisture density relations are determined based on AASTHTO T-99. Tests were conducted with different percentages of additives. The percentages of additives shown at Table 4.14

Moisture content versus dry density graph is plotted and the optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are determined from the graph. Summarized results are tabulated in Table 4.14. The details of the test results are attached in Appendix C and D.

Table 4. 14: Moisture density relation test results of the mix-ratio of GSA-Soil, CA-soil and BF-Soil.

Sample Name	**GSA (%)**	MDD (g/cm^3)	% decrease /Increase	OMC (%)	% decrease /Increase
BD	0	1.6	0	18.99	0
	2	1.62	1.25	20.89	10.005
	4	1.63	1.875	18.37	-3.26
	6	1.64	2.5	16.89	-11.058
	8	1.59	-0.625	20.83	9.689
	10	1.58	-1.25	18.4	-3.10
	CA (%)				
	10	1.62	1.25	18.58	-2.159
	20	1.57	-1.875	20.39	7.37
	30	1.48	-7.5	21.81	14.85
	40	1.47	-8.125	25.48	34.175
	50	1.56	-2.5	17.24	-9.215
	BF (%)				
	1	1.6	0	20.79	9.478
	1.5	1.57	-1.875	18.28	-3.738
	2	1.59	-0.625	19.05	0.316
	2.5	1.61	0.625	16.2	-14.69
	3	1.56	-2.5	13.74	-27.64

Sample Name	**GSA (%)**	MDD (g/cm^3)	% decrease /Increase	OMC (%)	% decrease /Increase
MS	0	1.59	0	21.46	0
	2	1.62	1.88	21.29	-0.792
	4	1.60	0.628	24.91	16.076
	6	1.51	-5.03	25.70	19.757
	8	1.49	-6.289	31.25	45.619
	10	1.47	-7.547	26.54	23.67
	CA (%)				
	10	1.63	2.51	20.55	-4.24
	20	1.544	-2.893	24.56	14.445
	30	1.491	-6.226	25.86	20.503
	40	1.474	-7.295	29.83	39.002
	50	1.44	-9.433	27.35	27.446
	BF (%)				
	1	1.59	0	28.55	33.038
	1.5	1.77	11.320	15.22	-29.077
	2	1.69	6.289	31.16	45.20
	2.5	1.52	-4.402	20.18	-5.964
	3	1.47	-7.547	19.74	-8.015

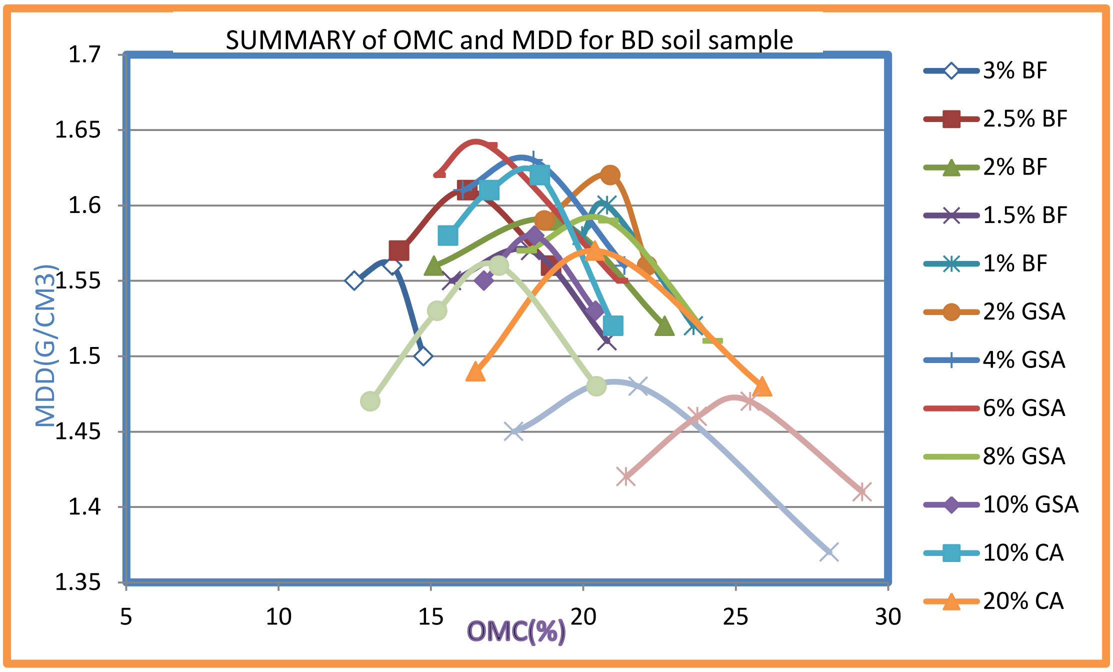

Figure 4. 8: SUMMARY Of OMC and MDD for treated soil sample of BD

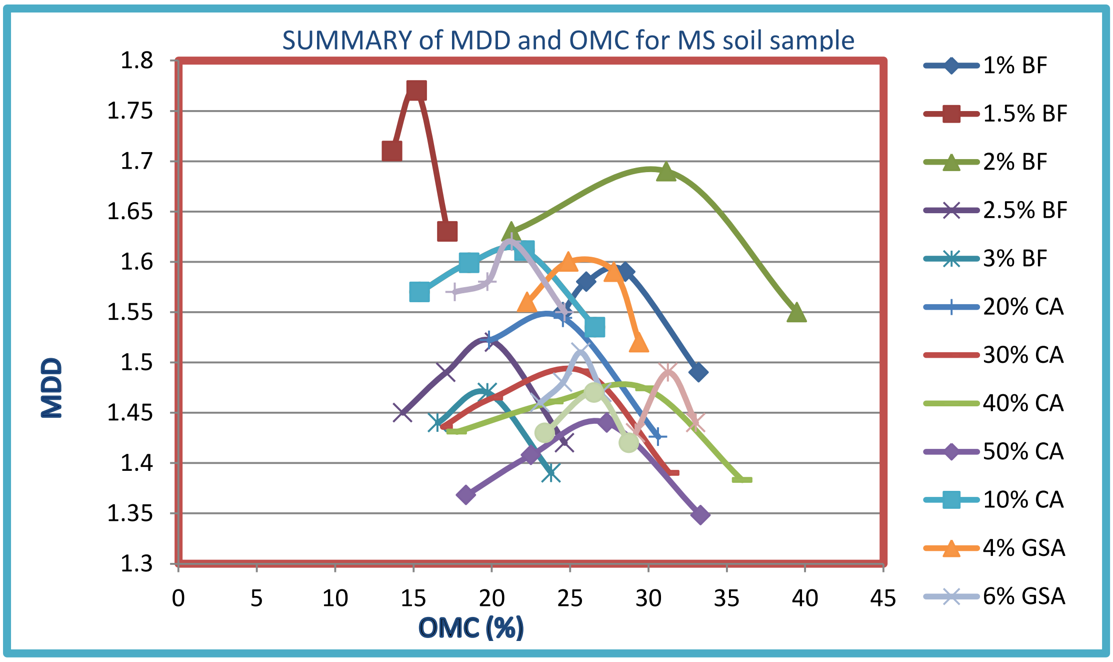

Figure 4. 9: SUMMARY of OMC and MDD for treated soil sample of MS

As observed from Table 4.14, the MDD of untreated sample was observed to be 1.6 g/cm3 and 1.59 g/cm3 for BD and MS soil samples respectively. Even though the compaction curve is normal the curve shifted the left upward in the case of treating the soil with GSA-Soil, BF-soil and CA-Soil, which also means additions of those additives slightly decrease the OMC and increase the MDD for both soil samples.

As it can be seen that from the above Figure, the MDD shows a slight increase and OMC shows a decrease in the treatment of weak subgrade soil with GSA-soil, CA-soil and BF-soil additive agents. The MDD increases from 1.6 g/cm3 to 1.64 g/cm3(GSA), 1.6g/cm3 to 1.62g/cm3(CA), 1.6 g/cm3 to 1.61 g/cm3(BF) and OMC decreases from 18.99% to 16.89% (GSA), 18.99% to 17.24%(CA), 18.99% to 13.74%(BF) for BD soil sample.

The MDD shows a slight increase and OMC shows a decrease in the treatment of weak subgrade soil with GSA-soil, CA-soil and BF-soil additive agents. The MDD increases from 1.59 g/cm3 to 1.62g/cm3(GSA), 1.59g/cm3 to 1.63 g/cm3(CA), 1.59g/cm3 to 1.77g/cm3(BF) and OMC decreases from 21.46% to 21.29%(GSA), 21.46% to 20.55%(CA), 21.46% to 15.22%(BF) for MS soil sample. Generally, increasing the percentage of BF ratio in BF-Soil mix-ratio led increase in the maximum dry density and decrease optimum moisture content rather than GSA and CA.

4.1.2.3 CBR Test results of treated soil sample

CBR is a parameter which is used to measure the strength of subgrade soil. The CBR tests were conducted with the addition of the mixed of GSA-Soil, CA-Soil, and BF-Soil with different percentage of additives.

Specimens are molded at respective optimum moisture content as determined in moisture density relationships. Three-point CBR with 65, 30, 15 blows and 4 days (96 hours) socking is conducted and CBR value at 95% MDD is determined for all tests. The soaked CBR test results for different percentage of GSA- Soil, CA-Soil, and BF-Soil are summarized in the Tables 4.15. The details of the laboratory results are attached in Appendix C and D.

Table 4. 15: CBR test results of treated soil sample

Sample Name	Percent of additives	CBR Value (%)			CBR @95% MDD	Era requirement	Remarks
		65 blow	30 blow	10 blow			

	GSA (%)	2.54	5.08	2.54	5.08	2.54	5.08			
BD	0	2.48	1.96	2.29	1.86	2.02	1.59	2.2	>5%	Poor
	2	4.17	3.19	3.94	2.95	3.62	2.92	3.8		Poor
	4	5.50	4.37	4.88	3.84	4.27	3.31	5.2		Satisfied
	6	6.19	4.77	5.94	4.37	5.63	4.29	5.9		Satisfied
	8	7.59	6.01	7.35	5.87	7.17	5.43	7.5		Satisfied
	10	6.66	5.07	6.36	4.89	6.09	4.78	6.4		Satisfied
	CA (%)									
	10	4.42	3.24	4.05	3.03	3.75	2.84	4.3		Poor
	20	5.43	4.17	5.23	4.03	4.99	3.79	5.3		Satisfied
	30	7.08	5.53	6.80	5.35	6.46	4.92	6.90		Satisfied
	40	9.50	7.74	8.22	6.46	7.10	5.80	7.8		Satisfied
	50	6.59	4.84	6.26	4.62	5.73	4.29	6.4		Satisfied
	BF (%)									
	1	4.23	3.17	3.69	2.83	2.43	1.90	3.7		Poor
	1.5	5.05	3.69	4.74	3.49	4.13	3.14	4.9		Poor
	2	5.73	4.37	4.82	3.66	4.12	3.12	5.3		Satisfied
	2.5	6.93	5.62	6.10	4.84	4.75	3.46	6.4		Satisfied
	3	4.40	3.38	4.32	3.26	4.15	3.07	4.3		Poor
	GSA (%)									
	0	2.13	1.62	1.82	1.49	1.63	1.34	1.6		Poor
	2	4.51	3.59	3.47	3.11	2.74	2.55	3.2		Poor
	4	4.06	3.58	3.69	3.44	3.16	3.01	3.9		Poor

MS	6	5.65	4.47	5.43	4.31	5.05	3.93	5.1	>5%	Satisfied
	8	6.56	5.37	5.58	4.61	4.30	3.49	5.9		Satisfied
	10	5.52	4.29	5.03	3.86	4.60	3.51	5.2		Satisfied
	CA (%)									
	10	4.13	3.26	4.03	3.08	3.98	3.04	4.1		Poor
	20	5.22	4.24	4.96	4.01	4.71	3.73	5		Satisfied
	30	6.65	5.21	6.50	4.84	6.39	4.79	6.5		Satisfied
	40	7.71	6.02	7.56	5.87	7.45	5.73	7.5		Satisfied
	50	7.07	5.92	6.39	4.97	5.91	4.79	6.2		Satisfied
	BF (%)									
	1	4.38	3.49	4.48	3.29	3.88	2.87	3.4		Poor
	1.5	4	2.97	3.51	2.69	3.04	2.38	3.9		Poor
	2	4.78	3.49	4.48	3.29	3.88	2.87	4.7		Poor
	2.5	6.75	4.88	6.55	4.68	5.96	4.27	6.1		Satisfied
	3	5.35	4.23	4.75	3.93	4.30	3.36	5.1		Satisfied

As it may be seen a Table 4.15, CBR result showed that the significant improvement in strength compared to untreated soil sample. Results indicated that the CBR values of treated soils with GSA, CA, and BF increases the strength of weak sub grade soil. However, according to ERA pavement design manual specification, the CBR values of treated soil with (4%GSA, 6%GSA, 8%GSA, 10% GSA, 20%CA, 30%CA, 40%CA,50% CA, 2% BF and 2.5% BF) fulfill the ERA specification but the (2% GSA, 10%CA, 1%BF, 1.5%BF, 3%BF) not fulfill the ERA specification for BD soil sample and with (6%GSA, 8%GSA, 10%GSA, 20%CA, 30%CA, 40%CA, 50%CA and 2.5%BF, 3%BF) alone full fill the specification as subgrade material but the (2%GSA, 4%GSA, 10%CA, 1%BF, 1.5% ,2%BF) not fulfill the ERA specification for MS soil sample. The significant increase in CBR value may attribute to reactions between GSA, CA, BF, soil and water.

4.1.2.4 CBR Swell for treated soil samples

The swells of soil-GSA, soil-CA and soil-BF are measured and determined from Soils with various percentage combination of GSA-soil, CA-soil and BF-soil was conducted on CBR tests, from these Swell measurements are taken at the time of soaking and after four days of soaking. Results are tabulated in Table 4.16.

Table 4. 16: Swell value from CBR test

Sample Name	Additives (%)	CBR swell (%)	ERA requirements	Remarks
BD	**GSA (%)**		<2%	
	0	5.57		Poor
	2	1.23		Satisfied
	4	0.89		Satisfied
	6	1.09		Satisfied
	8	0.55		Satisfied
	10	0.64		Satisfied
	CA (%)			
	10	1.73		Satisfied
	20	1.69		Satisfied
	30	1		Satisfied
	40	0.75		Satisfied
	50	1.30		Satisfied
	BF (%)			
	1	1.87		Satisfied

	1.5	1.43		Satisfied
	2	1.66		Satisfied
	2.5	0.97		Satisfied
	3	1.86		Satisfied
MS	**GSA (%)**		< 2%	
	0	6.90		Poor
	2	1.75		Satisfied
	4	1.19		Satisfied
	6	1.16		Satisfied
	8	1.02		Satisfied
	10	1.80		Satisfied
	CA (%)			
	10	1.92		Satisfied
	20	1.71		Satisfied
	30	0.77		Satisfied
	40	1.07		Satisfied
	50	1.49		Satisfied
	BF (%)			
	1	2.30		Poor
	1.5	1.87		Satisfied
	2	1.31		Satisfied
	2.5	1.14		Satisfied
	3	1.86		Satisfied

Soils with various percentages of GSA-soil, CA-soil and BF-soil mix ratio and 10% GSA, 50% CA and 3% BF alone was conducted as shown in Table 4.16, as results indicted all mix proportion percentages of GSA-soil, CA-soil, BF-soil for BD and MS soil sample are met the requirement specified by ERA pavement design manual as criterion for suitable material except 1%BF for MS soil sample. The CBR swell decreases when increasing the percentage of GSA, CA and BF in the mixed ratio for all mixed ratio for both soil sample.

4.1.5 Cost Estimation

The quantitative cost of for untreated and treated sub grade is given in Tables 4.17 and 4.18 troughs Table 4.19 respectively.

Table 4. 17: Quantity cost for untreated expansive soil (Constructionethiopia.com, 2018)

Item No	Item description	Unit	Rate	Length(m)	Width(m)	Depth(m)	amount
1	Subgrade						
	Site clearing	M^2	15.49	1000	3.5		54215
	Bulk excavation in expansive soil not exceeding 1.5m	M^3	99.58	1000	3.5	0.6	209118
	Disposal of excavated material (5KM hauling distance)	M^3	126.66	1000	3.5	0.6	265986
	Road bed preparation compaction to 93% MMD	M^2	58	1000	3.5		203000
	Selected material(5km)	M^3	145	1000	3.5	0.6	304500

	Placing and compacting selected material to 95% MDD	M^2	78.24	1000	3.5		273840
	Sub total	1310659					

Table 4. 18: Quantitative Cost for Groundnut shell ash, Coal ash and Bamboo fiber stabilized Expansive soil

1, Road section	Unit	Unit price
Clearing and grubbing with in road prism	M^2	15.49
Purchase cost of stabilizer including transport		
Purchase cost of GSA stabilizer only transport cost	M^3	660
Purchase cost of coal ash stabilizer	M^3	850
Purchase cost of bamboo fiber stabilizer including transport and labor cost	M^3	355
*For 1m^3 of Expansive soil,		
1, 0.08m^3 of GSA required(by 8% GSA which is optimum)	M^3	52.8
2, 0.4m^3 of CA required	M^3	340
3, 0.025m^3 of BF required	M^3	9
Purchase cost of GSA stabilizer	M^2	31.8
Purchase cost of CA stabilizer	M^2	204
Purchase cost of BF stabilizer	M^2	5.40

2, placing of stabilizer		
Hauling of stabilizer	M^2	76.91
Mixing of stabilizer	M^2	71.94
Placing of stabilizer	M^2	54.19
Total quantity cost of GSA	M^2	250.33
Total quantity cost of CA	M^2	422.53
Total quantity cost of BF	M^2	223.93

Table 4. 19: Quantitative cost of sub grade after stabilizing

Item No	Item description	Unit	Rate	Length(m)	Width(m)	Depth(m)	Amount
1	Stabilized subgrade with	M^2					
	GSA		250.33	1000	3.5		876155
	CA		422.53	1000	3.5		1478855
	BF		223.93	1000	3.5		783755

The comparisons of the cost benefits were made from Tables 4.16 and 4.18. As shown in the tables, the total quantitative cost of GSA, CA and BF stabilized subgrade was estimated as 876155 Birr/km, 1478855 Birr/km and 783755 Birr/km respectively against the cost of 1,310,659 Birr / km for replacing selective borrow material from a 5km distance. The saving in cost for GSA, CA and BF stabilization thus estimated to be 33.15% (GSA), 12.83% (CA) and 40.20% (BF) respectively of construction cost of sub grade soil.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

On the basis of the results obtained in the experimental investigation, the following conclusions have been drawn.

- According to USCS and AASHTO classification system, BD soil sample was categorized as CH and A-7-5 (167), a plastic index of 49.44%, and low CBR value of 2.2%. For MS soil sample was categorized as CH and A-7-5 (189), a plastic index of 55.86% and low CBR value of 1.6%. Thus, the natural soil was very poor in strength to be used as a subgrade material as per ERA (2013) specification.
- The Natural soil sample mixed with groundnut shell ash, coal ash and bamboo fiber in d/t proportion is CBR > 5%, PI < 30%, LL< 60% and CBR swell < 2%. Therefore the engineering properties of stabilized expansive subgrade soil revealed that it was suitable to use as subgrade materials and the stabilizers are effectively improved the expansive subgrade soil.
- The LL decreases from control value 81.84% to 54.49%, the PL increases from control value of 32.4% to 51.15% and the PI decreased from 49.44% to 4.23% for BD soil sample. Similarly the LL decrease with stabilization of additives of the Mix-ratio from control value of 89.16% to 57.36%, the PL increase from 33.3% to 50.26% and 55.86% to 7.17% for MS soil sample. Also in the mixed ratio of GSA-Soil, CA-Soil the liquid limit decreases when increasing the CA and GSA and the plastic index decreases when increasing the CA and GSA for both soil samples. Also the MDD shows a slight increase and OMC shows a decrease in the treatment of expansive subgrade soil with GSA, CA and BF additive agents.
- CBR test, there was an initial increase from the control value of 2.2% to 7.5%(GSA), 2.2% to 7.8%(CA), 2.2% to 6.4%(BF) for BD and 1.6% to 5.9%(GSA), 1.6% to 7.5%(CA), 1.6% to 6.1%(BF) for MS, at (8%GSA, 40%CA, 2.5%BF). Generally the CBR value (%) increases with increasing the percentage of GSA, CA, and BF in mixed ratio (GSA-soil, CA-soil, BF-soil). The CBR swell value of mixing stabilizers (GSA-soil, CA-soil, BF-soil) fulfills the ERA

specification requirements. However the 1% BF for MS soil sample does not fulfill the ERA requirements for CBR swell.

- As observed from the test was performed under this study, the maximum results were achieved at 8%GSA, 40%CA and 2.5%BF by weight. Since most parameters achieve the ERA requirement and have got maximum strength or CBR value. The optimum ratio for the studied weak subgrade soils is at 8% GSA, 40% CA and 2.5% BF. From this comparatively it is observed that Coal ash (40%) is effectively improving the engineering properties of expansive subgrade soil better than groundnut shell ash (8%) and bamboo fiber (2.5%).
- 8% of GSA, 40% of CA and 2.5% of BF saved construction costs 33.15% (GSA), 12.83% (CA) and 40.20% (BF) respectively when compared with expansive subgrade soil from a distance of 5 Km.

5.2 Recommendations

Based on the findings of this research, the following recommendations are forwarded:

- As stabilization of expansive subgrade soil with groundnut shell ash, coal ash and bamboo fiber is a relatively new concept and are scanty in the literature, chemical interactions and mechanisms involved in GSA, BF, CA, water and expansive subgrade soil shall be studied.
- There is not enough investigation done on Groundnut shell ash, Coal ash and Bamboo fiber as soil stabilizer in Ethiopia. So it is recommended that extensive researches on a large number soil samples taken from different places in Ethiopia with different percentages of GSA, CA and BF should be done considering the benefits of the result.
- The present study was conducted by taking limited parameter such as Atterberg limit, free swell index, moisture density relation, CBR and CBR swell potential on stabilization by Coal ash, Groundnut shell ash and Bamboo fiber. It is recommended to test additional parameter like unconfined compressive strength, PH value test, volumetric shrinkage should also be performed to have more realistic test results.
- This study coal ash, Groundnut shell ash and bamboo fiber can be used as a soil stabilizing material, bearing in mind economic and environmental advantage concerned bodies should be aware of this potential soil stabilizing material and promote its level of quality required, collection , production and application

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APPENDAX

APPENDAX A: laboratory test result for BD soil sample

1) Wet sieve analysis

Sample Location			BD soil sample	
Sieve size (mm)	mass of retain on each sieve (g)	Percentage of retained soil	Cumulative % of retain soil	percentage of passing particle
9.5	0.00	0.00	0.00	100.00
4.75	1.44	0.14	0.14	99.86
2	10.49	1.05	1.19	98.81
0.85	9.07	0.91	2.10	97.90
0.425	4.78	0.48	2.58	97.42
0.25	2.13	0.21	2.79	97.21
0.15	8.35	0.83	3.63	96.37
0.075	19.66	1.97	5.59	94.41
Pan	944.10	94.41	100.00	0.00
Sum	1000.0			

2) Specific Gravity

Determination Code	7	11
Mass of dry, clean Calibrated pycnometer, Mp, in g	30.98	26.05
A. Mass of oven dry sample	25	25
B. Mass of Pycnometer + water(gm)	125.71	122.01
C. Mass of Pycnometer + water + sample(gm)	141.33	138.01
Observed temperature of water,Ti	24	23
Temperature of contents of pycnometer when Mpsw was taken, Tx, in oc	26	25
K for Tx	0.9997	1.0000
Specific gravity at 20oc, Gs Gs=A*k/(A+B-C)	2.66	2.78
Average Specific gravity at 20oc, Gs	2.72	

3) Free Swell Index

Additive Content	Natural subgrade soil	
reading on the glass jar		
Vw=volume of soil specimen read from the from the graduated cylinder containing distilled water	17.5	18.5
Vk=volume of soil specimen read from the graduated cylinder containing kerosene	10	10
FSI=(Vw-Vk)/Vk *100	75	85
A average Free swell index	80	

4) Linear Shrinkage

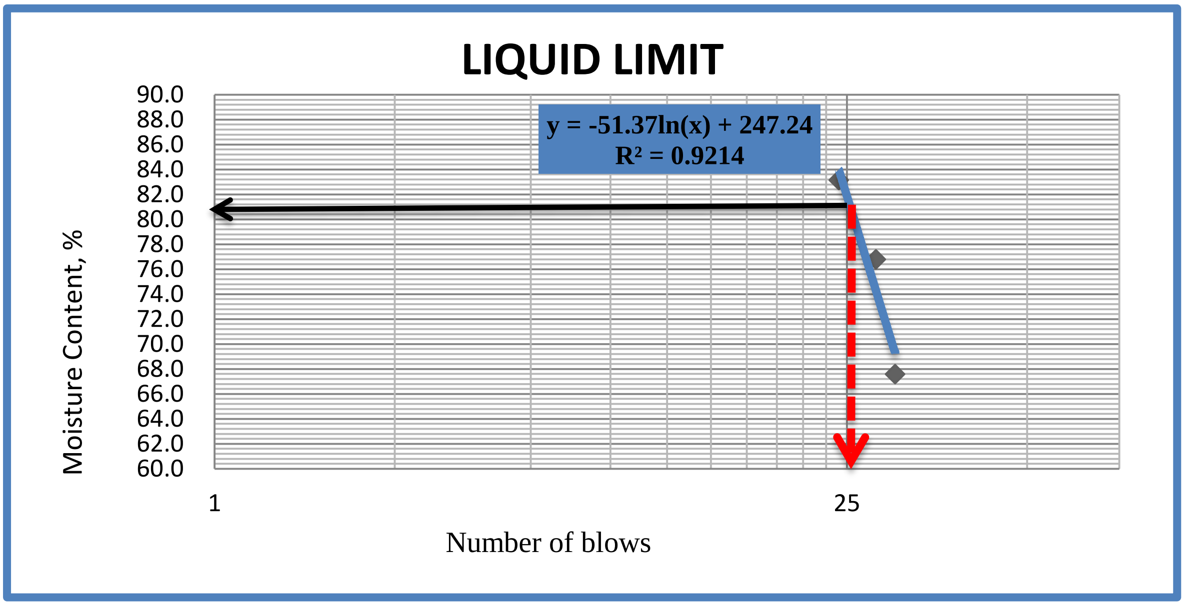
Measure Length of Mould	Trial – 1	Trial - 2
1. Original Length, Lo(mm)	140	140
2. Length of sample after Dry, Ld.(mm)	123.4	122.08
3. (1-Ld/Lo) * 100, %	11.86	12.80
Average of Linear Shrinkage (%)	12.33	

5) Atterberg test result

Liquid Limit			
Number of blows	32	29	24
Test No	1	2	3
Container No	B12	3L	G8
Wt. of container + wet soil, g	19.45	36.01	32.32
Wt. of container + dry soil, g	14.03	28.74	24.23
Wt. of container, g	6.01	19.27	14.50
Wt. of water, g	5.42	7.27	8.09
Wt. of dry soil, g	8.02	9.47	9.73
Moisture content, %	67.6	76.8	83.1

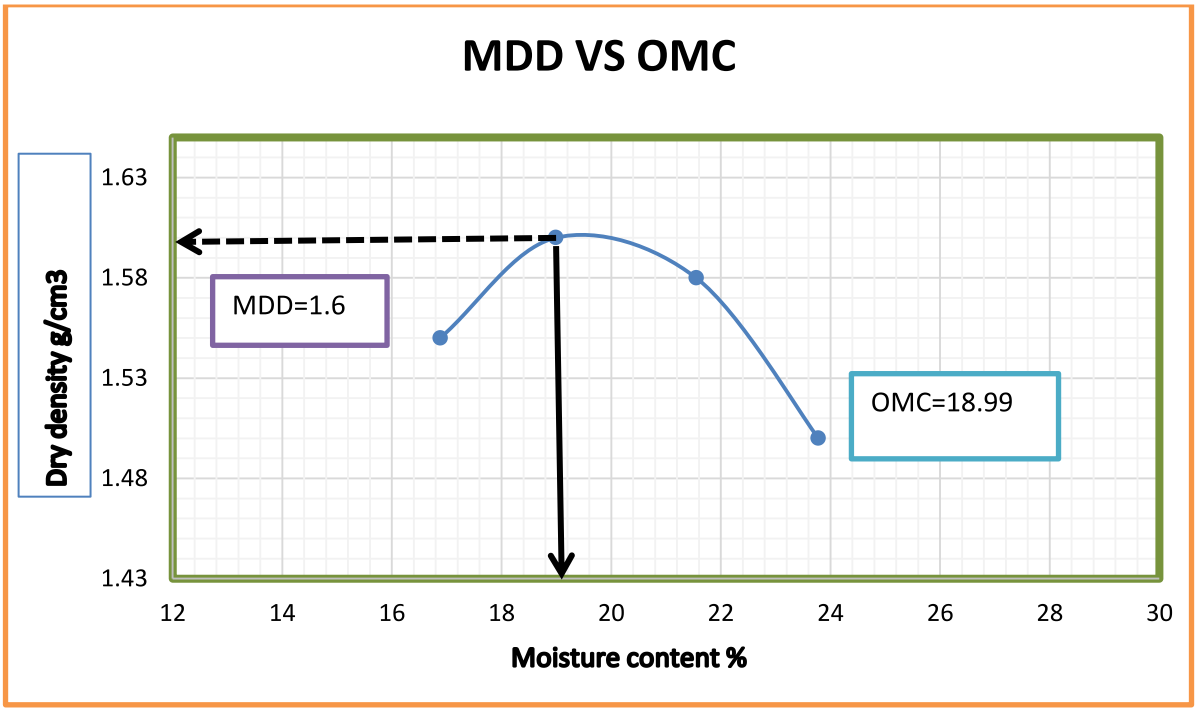
Plastic Limit		
Test	1	2
Container	B9	13
Wt. of container + wet soil, g	14.25	15.01
Wt. of container + dry soil, g	12.25	13.01
Wt. of container, g	6.23	6.66
Wt. of water, g	2.00	2.00
Wt. of dry soil, g	6.02	6.35
Moisture container, %	33.22	31.5
Average Moisture Content, %	32.4	

LL	81.84
PL	32.4
PI	49.44



6) Compaction Laboratory test

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	350	530	710	890	
Mass of Mold+Wet soil(gm)(A)	10857.2	11076.2	11112.4	10985.6	
Mass of Mold(gm)(B)	6731.4	6731.4	6731.4	6731.4	
Mass of Wet Soil(gm)A-B=C	4125.8	4344.8	4381	4254.2	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.81	1.90	1.92	1.86	
Moisture Content Determination					**NMC**
Container Code	G3T3	P65	G10	P1	A1
Mass of Wet soil+ Container(gm)(F)	141.23	158.1	142.32	153.12	2030.9
Mass of dry soil+ container (gm)(G)	126.43	138.87	120.12	127.12	1964.4
Mass of container (gm)(H)	37.7	37.6	17.1	17.8	924.2
Mass of moisture(gm)F-G=(I)	14.8	19.23	22.2	26	66.5
Mass of Dry soil(gm)G-H=(J)	88.73	101.27	103.02	109.32	1040.2
Moisture content % (I/J)*100=K	**16.68**	**18.99**	**21.55**	**23.78**	**6.39**
Dry Density gm/cm^3 E/(100+K)*100	**1.55**	**1.60**	**1.58**	**1.50**	



7) CBR Laboratory test

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		T8	T8	N12	N12	T4	T4
Mass of soil + Mould	g	13584.1	13830.1	13389.8	13715.2	12919.1	13471.7
Mass Mould	g	9327.1	9327.1	9358.1	9358.1	9330.1	9330.1
Mass of Soil	g	4257	4503	4031.7	4357.1	3589	4141.6
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	2.004	2.120	1.898	2.051	1.690	1.950
Dry density of soil	g/cc	1.651	1.653	1.552	1.582	1.376	1.467

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G-53	G19	A-3	B-53	10G	A-16
Mass of wet soil + Container	g	160.80	140.47	137.78	146.63	110.10	118.32
Mass of dry soil + Container	g	137.54	113.34	119.56	117.12	92.95	93.32
Mass of container	g	28.73	17.36	37.81	17.53	17.60	17.32
Mass of water	g	23.26	27.13	18.22	29.51	17.15	25.00
Mass of dry soil	g	108.81	95.98	81.75	99.59	75.35	76.00
Moisture content	%	21.38	28.27	22.29	29.63	22.76	32.89

CBR Penetration Determination

Penetration after 96 hrs Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.198		0.64	0.187		0.64	0.165	
1.27	0.264		1.27	0.241		1.27	0.215	
1.91	0.301		1.91	0.276		1.91	0.247	
2.54	0.331	2.48	2.54	0.305	2.29	2.54	0.269	2.02
3.81	0.367		3.81	0.345		3.81	0.299	
5.08	0.391	1.96	5.08	0.372	1.86	5.08	0.318	1.59
7.62	0.415		7.62	0.412		7.62	0.346	

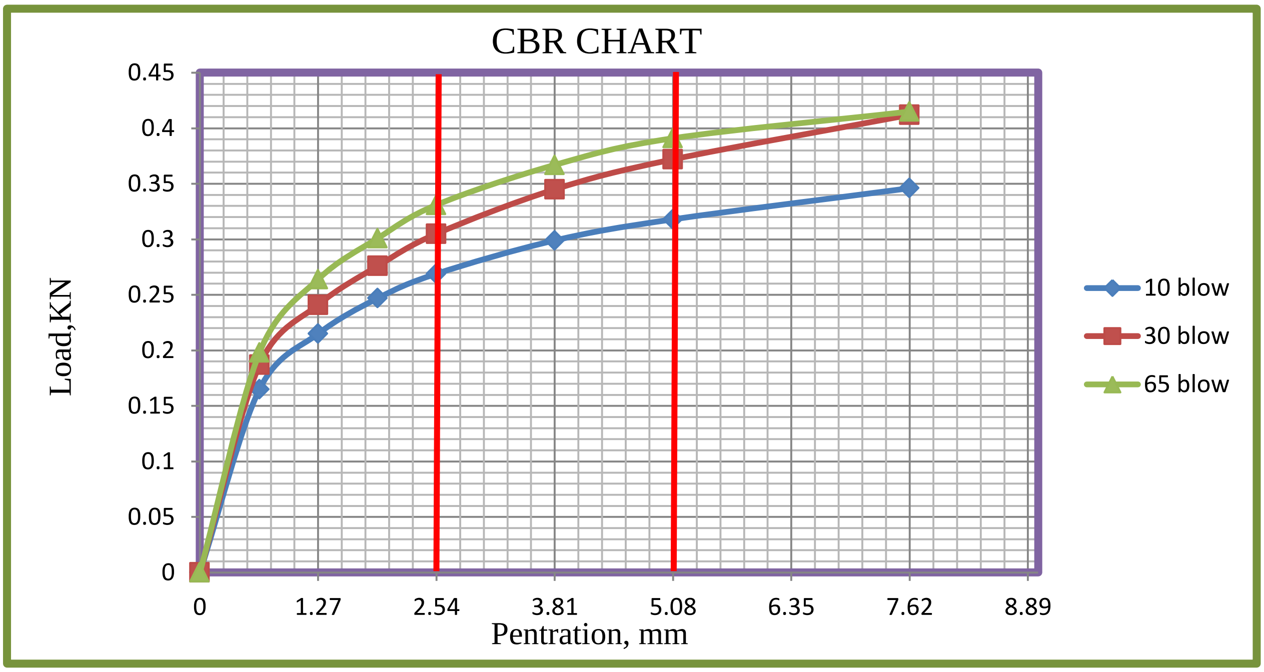
Modified Max.Dry Density g/cc	1.600	OMC %	18.9

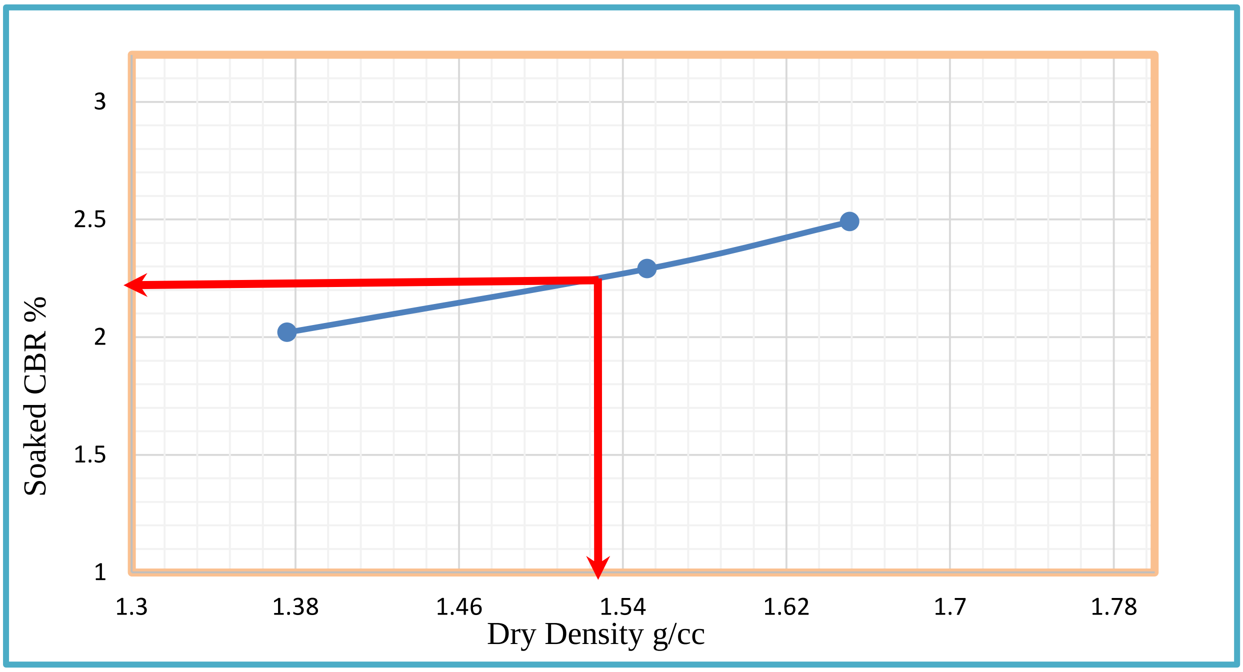
Swell Determination

Date		65 Blows Gauge rdg mm	Swell in %	30 Blows Gauge rdg mm	Swell in %	10 Blows Gauge rdg mm	Swell in %
27/02/2013	Initial	0.90	4.39	5.3	5.57	3.08	6.06
01/03/2013	Final	6.01		11.78		10.13	

		Dry Density at 95% of MDD:		1.520
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	22.8	1.376	2.02	86
30	22.3	1.552	2.29	97
65	21.4	1.651	2.49	103

CBR % at 95 % MDD	2.2	Swell %	5.57





APPENDAX B: Laboratory test result for MS soil sample

1) Wet sieve analysis

Sieve size (mm)	mass of retain on each sieve(g)	Percentage of retained soil	cumulative % of retain soil	percentage of passing particle
9.5	0.00	0.00	0.00	100.00
4.75	1.67	0.17	0.17	99.83
2	14.60	1.46	1.63	98.37
0.85	12.23	1.22	2.85	97.15
0.425	5.23	0.52	3.37	96.63
0.25	2.13	0.21	3.59	96.41
0.15	9.32	0.93	4.52	95.48
0.075	25.64	2.56	7.08	92.92
Pan	929.20	92.92	100.00	0.00
Sum	1000.0			

2) Specific Gravity

Determination Code		B1	P6
Mass of dry, clean Calibrated pycnometer, Mp, in g		31.65	27.05
A. Mass of oven dry sample(gm)		25	25
B. Mass of Pycnometer + water(gm) g		126.11	123.55
C. Mass of Pycnometer + water + sample(gm)		141.6	140.1
Observed temperature of water,Ti		24	23
Temperature of contents of pycnometer when Mpsw was taken, Tx, in oc		26	25
K for Tx		0.9997	1.0000
Specific gravity at 20oc, Gs	Gs=A*k/(A+B-C)	2.63	2.96
Average Specific gravity at 20oc, Gs		2.79	

3) Free Swell Index

Additive Content	Natural subgrade soil	
reading on the glass jar		
Vw=volume of soil specimen read from graduated cylinder containing distilled water	18	19
Vk=volume of soil specimen read from the		

graduated cylinder containing kerosene	10	10
FSI=(Vw-Vk)/Vk *100	80	90
A average Free swell index	85	

4) Linear shrinkage

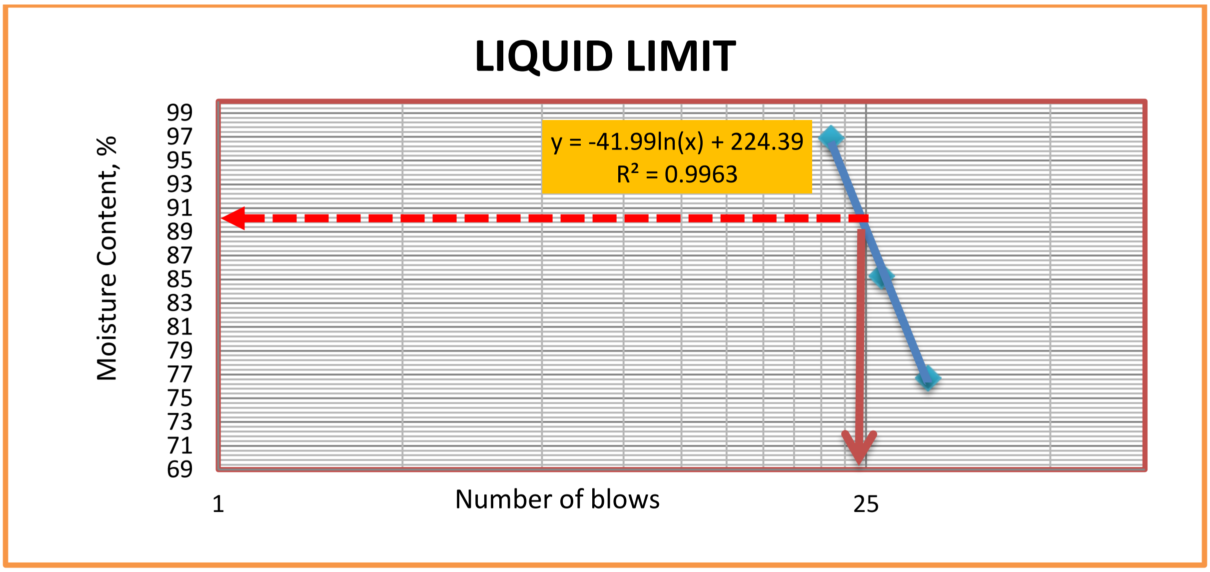
Measure Length of Mould	Trial - 1	Trial – 2
1. Original Length, Lo (mm)	140	140
2. Length of sample after Dry, Ld. (mm)	120.06	121.7
3. (1-Ld/Lo) * 100, %	14.24	13.80
Average of Linear Shrinkage (%)	14.02	

5) Atterberg limit

Determination	**Liquid Limit**		
Number of blows	34	27	21
Test No	1	2	3
Container No	C77	AA	B01
Wt. of container + wet soil, g	29.91	36.51	31.42
Wt. of container + dry soil, g	22.31	27.00	24.64
Wt. of container, g	12.40	15.85	17.64
Wt. of water, g	7.60	9.51	6.78
Wt. of dry soil, g	9.91	11.15	7.00
Moisture content, %	76.7	85.3	96.9
Plastic Limit			
Test	1	2	
Container	G1	1	
Wt. of container + wet soil, g	16.82	15.40	
Wt. of container + dry soil, g	14.53	13.20	

Wt. of container, g`	7.86	6.40
Wt. of water, g	2.29	2.20
Wt. of dry soil, g	6.67	6.80
Moisture container, %	34.33	32.4
Average Moisture Content, %	33.3	

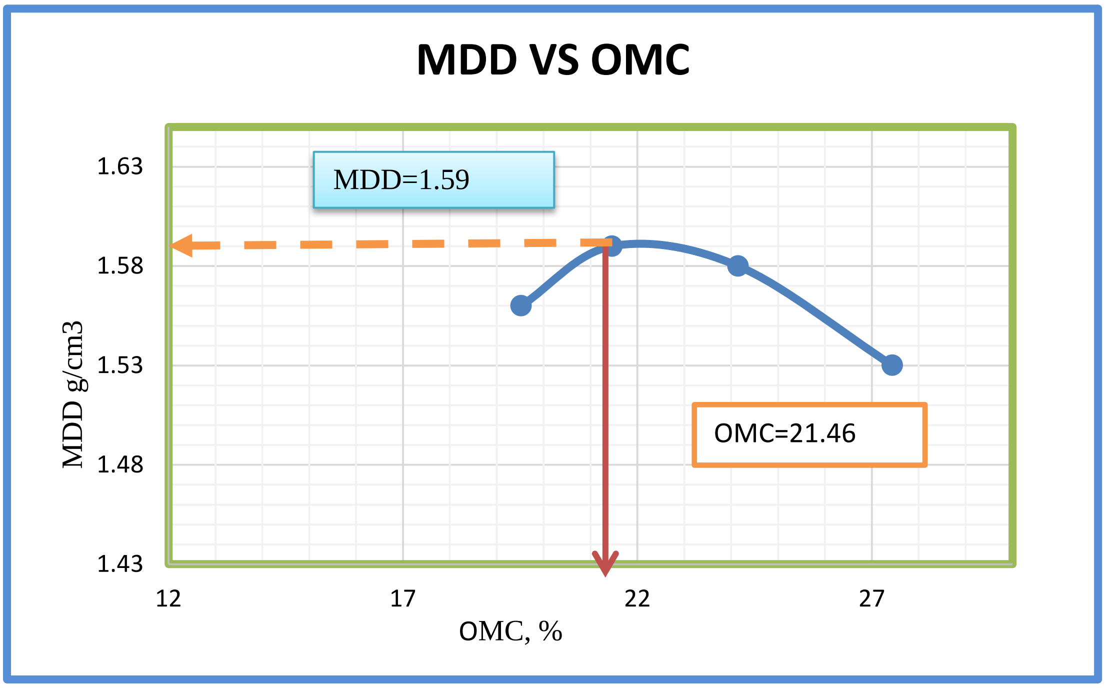
LL	89.16
PL	33.3
PI	55.86



6) Compaction Laboratory Test

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	350	530	710	890	
Mass of Mold+Wet soil(gm)(A)	10989.6	11156.2	11220.4	11196.8	
Mass of Mold(gm)(B)	6731.4	6731.4	6731.4	6731.4	
Mass of Wet Soil(gm)A-B=C	4258.2	4424.83	4489	4465.4	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.86	1.94	1.96	1.95	
Moisture Content Determination					NMC
Container Code.	G3T3	P65	G10	P1	D10
Mass of Wet soil+Container(gm)(F)	147.31	160.6	145	157.12	181.1
Mass of dry soil+container(gm)(G)	129.41	138.87	120.12	127.12	171.4

Mass of container(gm)(H)	37.7	37.6	17.1	17.8	33.2
Mass of moisture(gm)F-G=(I)	17.9	21.73	24.88	30	9.7
Mass of Dry soil(gm)G-H=(J)	91.71	101.27	103.02	109.32	138.20
Moisture content % (I/J)*100=K	**19.52**	**21.46**	**24.15**	**27.44**	**7.01**
Dry Density gm/cm^3 E/(100+K)*100	**1.56**	**1.59**	**1.58**	**1.53**	



7) CBR Laboratory test

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		A15	A15	B-4	B-4	F2	F2
Mass of soil + Mould	g	12385.7	12900	12346.7	12785.4	11502.8	11890.3
Mass Mould	g	8150.8	8150.8	7915.3	7915.3	7330.1	7330.1
Mass of Soil	g	4234.9	4749.2	4431.4	4870.1	4172.7	4560.2
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.994	2.236	2.086	2.293	1.965	2.147
Dry density of soil	g/cc	1.607	1.585	1.551	1.605	1.518	1.622
Moisture Determination							
MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		W-60	G40	43-A	49K	36H	AJ
Mass of wet soil +	g	140.16	161.45	149.48	174.23	112.54	138.74

Container							
Mass of dry soil + Container	g	120.46	122.56	119.56	132.60	91.65	116.34
Mass of container	g	38.73	27.81	32.84	35.53	20.60	47.10
Mass of water	g	19.70	38.89	29.92	41.63	20.89	22.40
Mass of dry soil	g	81.73	94.75	86.72	97.07	71.05	69.24
Moisture content	%	24.10	41.04	34.50	42.89	29.40	32.35

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.156		0.64	0.146		0.64	0.128	
1.27	0.218		1.27	0.194		1.27	0.176	
1.91	0.261		1.91	0.221		1.91	0.198	
2.54	0.284	2.13	2.54	0.243	1.82	2.54	0.217	1.63
3.81	0.307		3.81	0.276		3.81	0.246	
5.08	0.324	1.62	5.08	0.298	1.49	5.08	0.267	1.34
7.62	0.351		7.62	0.321		7.62	0.296	

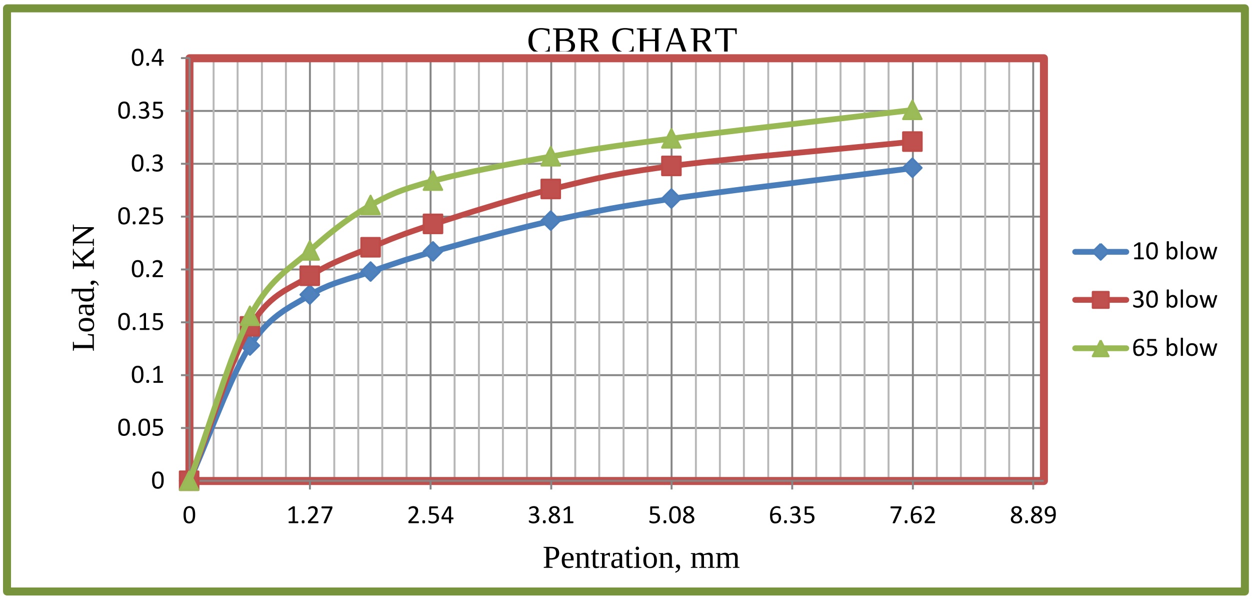
Modified Max.Dry Density g/cc	1.590	OMC %	21.5

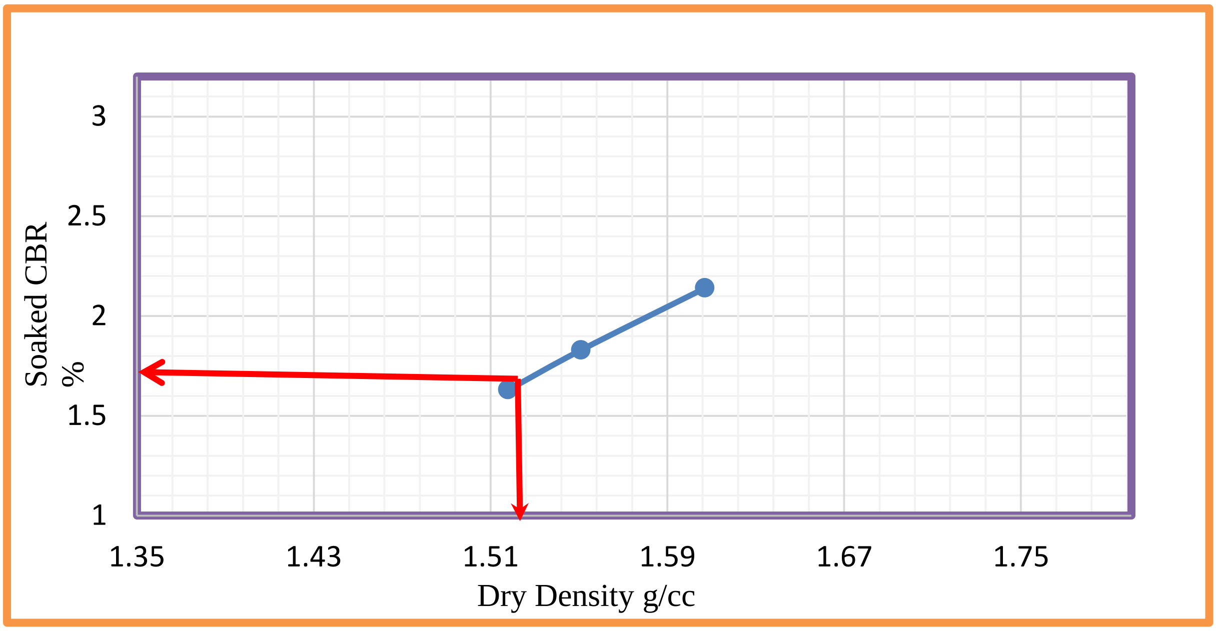
Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	2.87	5.74	4.51	6.90	3.22	7.15
01/03/2013	Final	9.55		12.54		11.54	

Dry Density at 95% of MDD:				1.511
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	29.4	1.518	1.63	95
30	34.5	1.551	1.83	98
65	24.1	1.607	2.14	101

CBR % at 95 % MDD	1.6	Swell %	6.9


CBR CHART
Load, KN
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1.27
2.54
3.81
5.08
6.35
7.62
8.89
Pentration, mm
10 blow
30 blow
65 blow

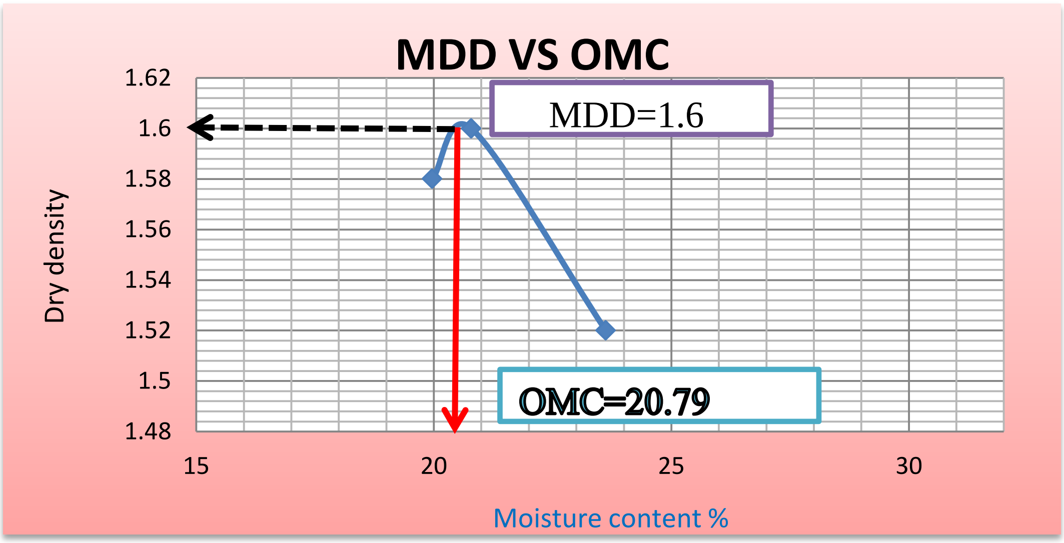

Soaked CBR %
3
2.5
2
1.5
1
1.35
1.43
1.51
1.59
1.67
1.75
Dry Density g/cc

APPENDAX C: Laboratory test result of stabilizing BD Soil Sample using soil-CA, soil-GSA and soil-BF.

1) **Compaction test result**

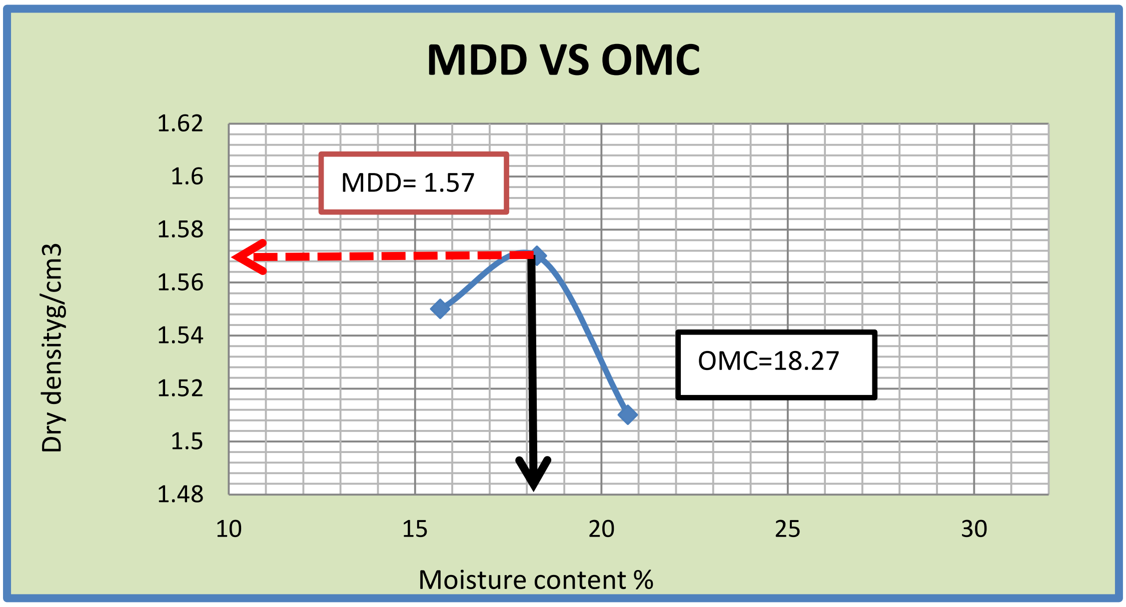
1.1) 1% BF

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	450	630	810	
Mass of Mold+Wet soil(gm)(A)	10912	10990.1	10858.4	
Mass of Mold(gm)(B)	6569.1	6569.1	6569.1	
Mass of Wet Soil(gm)A-B=C	4342.7	4421	4289.3	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.90	1.93	1.88	
Moisture Content Determination				**NMC**
Container Code.	K4	SSB	G	G-10
Mass of Wet soil+Container(gm)(F)	104.2	100.1	116.5	106.9
Mass of dry soil+container(gm)(G)	89.87	85.9	97.7	100.9
Mass of container(gm)(H)	18.1	17.6	18.1	17.2
Mass of moisture(gm)F-G=(I)	14.33	14.2	18.8	6
Mass of Dry soil(gm)G-H=(J)	71.77	68.3	79.6	83.7
Moisture content % (I/J)*100=K	**19.97**	**20.79**	**23.62**	**7.16**
Dry Density gm/cm^3 E/(100+K)*100	**1.58**	**1.60**	**1.52**	



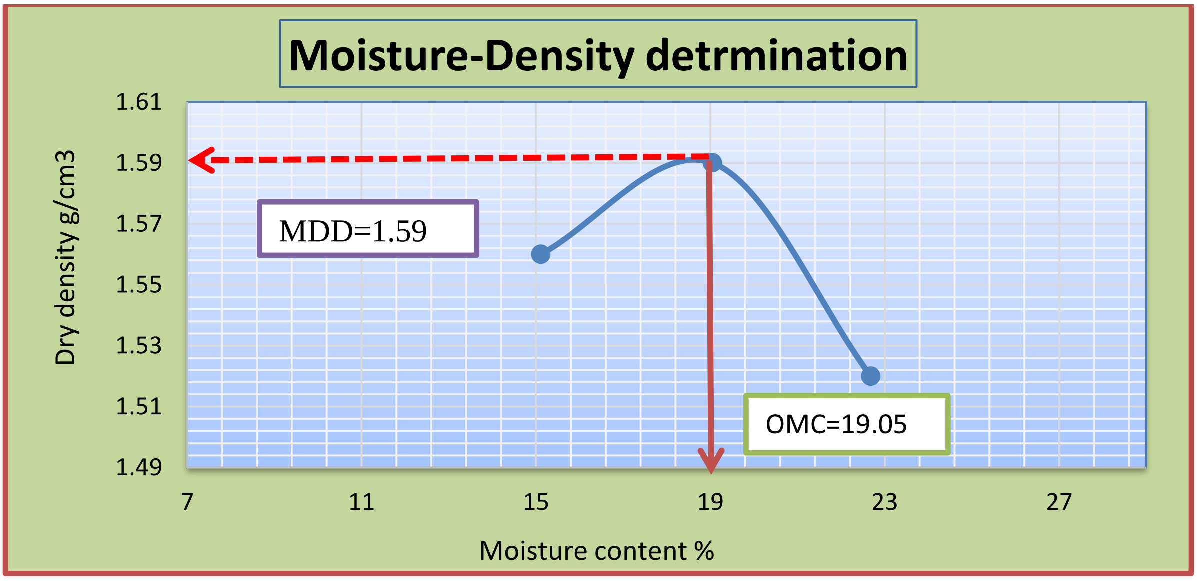
1.2) 1.5%BF

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	450	630	810	
Mass of Mold+Wet soil(gm)(A)	10897.2	10967.5	10906.1	
Mass of Mold(gm)(B)	6731.4	6731.4	6731.4	
Mass of Wet Soil(gm)A-B=C	4165.8	4236.1	4174.7	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.82	1.85	1.83	
Moisture Content Determination				
Container Code .	A-12	G-19	K43	
Mass of Wet soil+Container(gm)(F)	142.21	134.53	145.76	
Mass of dry soil+container(gm)(G)	127.36	120.12	125.12	
Mass of container(gm)(H)	32.65	41.3	25.5	
Mass of moisture(gm)F-G=(I)	14.85	14.41	20.64	
Mass of Dry soil(gm)G-H=(J)	94.71	78.82	99.62	
Moisture content % (I/J)*100=K	**15.68**	**18.28**	**20.72**	
Dry Density gm/cm^3 E/(100+K)*100	**1.58**	**1.57**	**1.51**	



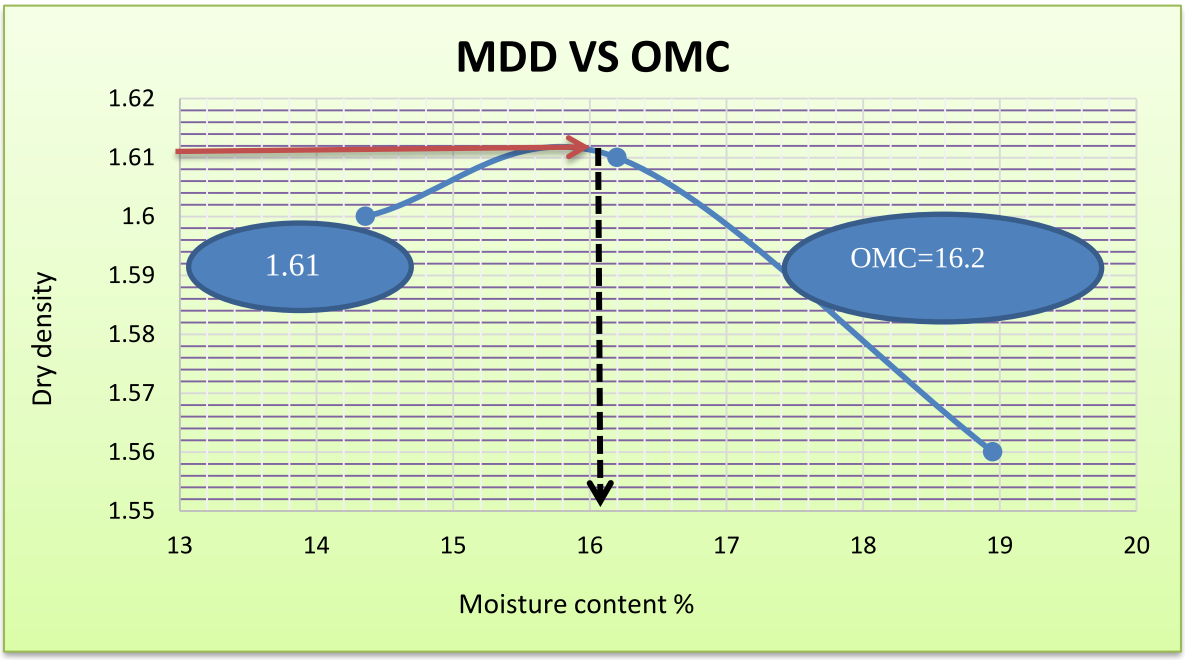
1.3) 2% BF

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	380	550	730	
Mass of Mold+Wet soil(gm)(A)	10672.9	10888.9	10819.1	
Mass of Mold(gm)(B)	6566.6	6566.6	6566.6	
Mass of Wet Soil(gm)A-B=C	4106.3	4322.3	4252.5	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.80	1.89	1.86	
Moisture Content Determination				**NMC**
Container Code .	E-12	G19	F	P65
Mass of Wet soil+Container(gm)(F)	159.1	142.6	112.9	148
Mass of dry soil+container(gm)(G)	142.74	126.39	98.35	140.96
Mass of container(gm)(H)	34.5	41.3	34.2	37.7
Mass of moisture(gm)F-G=(I)	16.36	16.21	14.55	7.04
Mass of Dry soil(gm)G-H=(J)	108.24	85.09	64.15	103.26
Moisture content % (I/J)*100=K	**15.11**	**19.05**	**22.68**	**6.81**
Dry Density gm/cm^3 E/(100+K)*100	**1.56**	**1.59**	**1.52**	



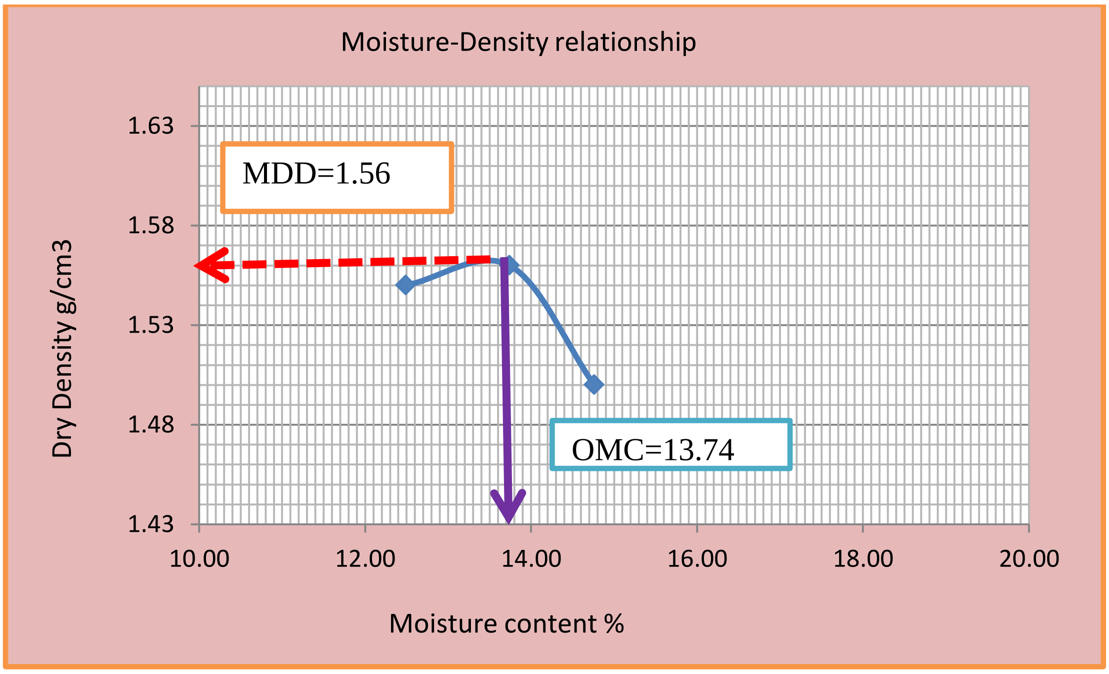
1.4) 2.5% BF

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	380	550	730
Mass of Mold+Wet soil(gm)(A)	10762.5	10832.1	10819.1
Mass of Mold(gm)(B)	6569.1	6569.1	6569.1
Mass of Wet Soil(gm)A-B=C	4193.4	4263	4250
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00
Bulk Density gm/cm^3 C/D=(E)	1.84	1.87	1.86
Moisture Content Determination			
Container Code .	G3T2	J41	2WE
Mass of Wet soil+Container(gm)(F)	176.21	153.21	122.13
Mass of dry soil+container(gm)(G)	158.8	136.35	108.21
Mass of container(gm)(H)	37.6	32.3	34.76
Mass of moisture(gm)F-G=(I)	16.98	16.86	13.92
Mass of Dry soil(gm)G-H=(J)	121.63	104.05	73.45
Moisture content % (I/J)*100=K	**14.36**	**16.20**	**18.95**
Dry Density gm/cm^3 E/(100+K)*100	**1.60**	**1.61**	**1.56**



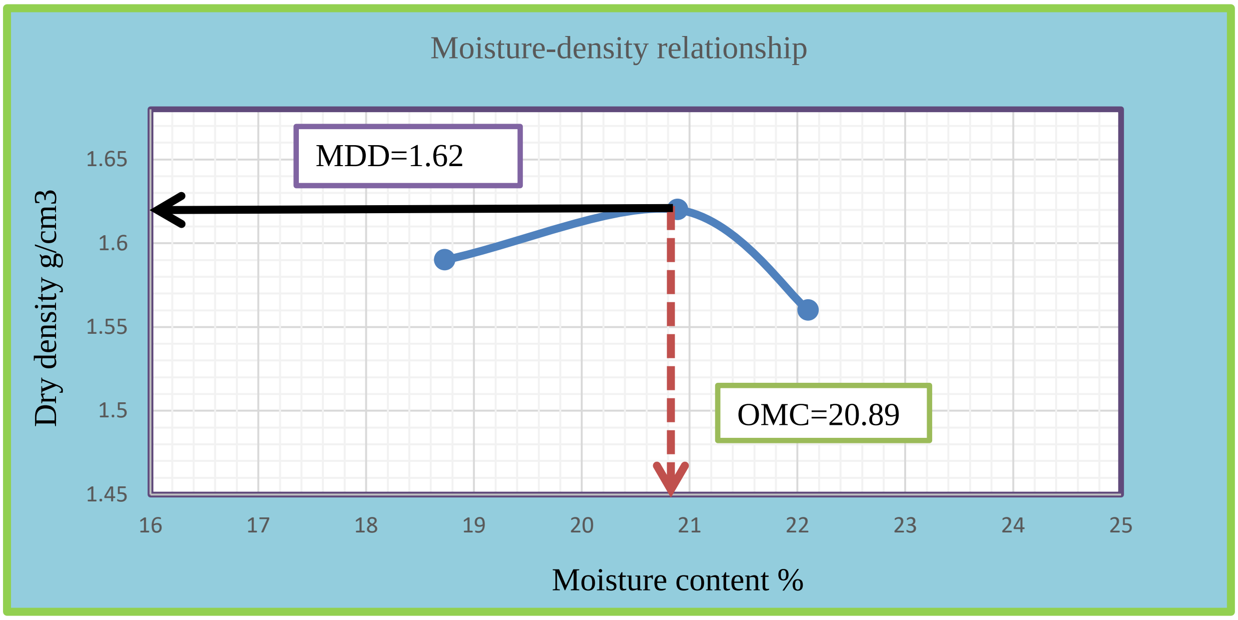
1.5) 3% BF

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	380	550	730
Mass of Mold+Wet soil(gm)(A)	10541.2	10622.3	10495.3
Mass of Mold(gm)(B)	6566.2	6566.2	6566.2
Mass of Wet Soil(gm)A-B=C	3975	4056.1	3929.1
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00
Bulk Density gm/cm^3 C/D=(E)	1.74	1.78	1.72
Moisture Content Determination			
Container Code .	AQ	G53	E12
Mass of Wet soil+Container(gm)(F)	154.23	143.12	159.63
Mass of dry soil+container(gm)(G)	140.84	130.12	143.54
Mass of container(gm)(H)	33.6	35.5	34.5
Mass of moisture(gm)F-G=(I)	13.39	13	16.09
Mass of Dry soil(gm)G-H=(J)	107.24	94.62	109.04
Moisture content % (I/J)*100=K	**12.49**	**13.74**	**14.76**
Dry Density gm/cm^3 E/(100+K)*100	**1.55**	**1.56**	**1.50**



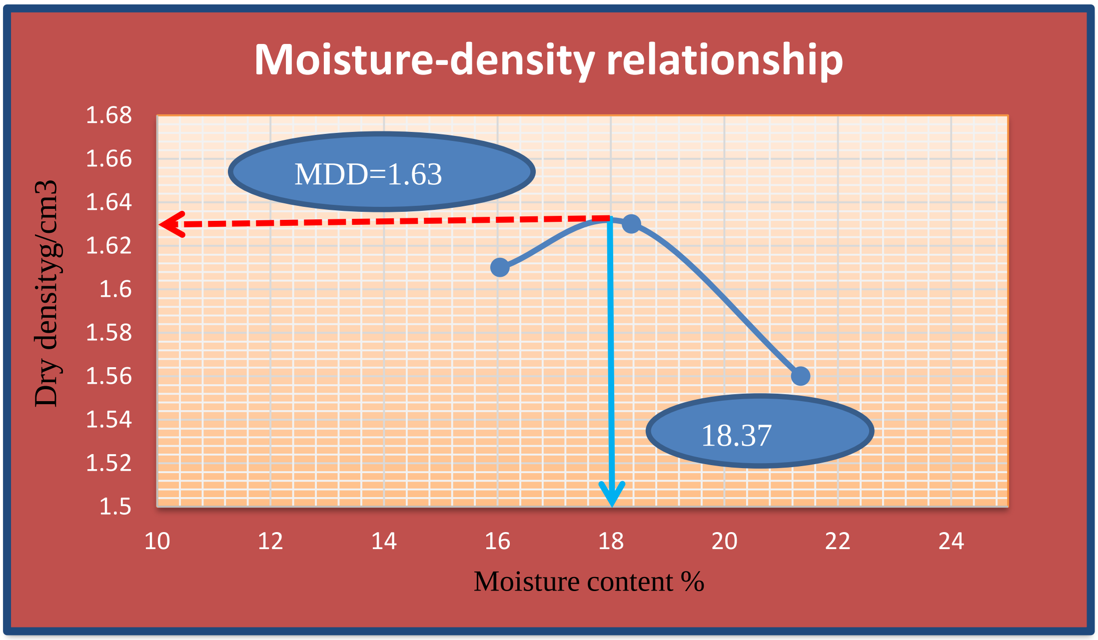
1.6) 2% GSA

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	380	550	730	
Mass of Mold+Wet soil(gm)(A)	10672.9	10888.9	10819.1	
Mass of Mold(gm)(B)	6566.6	6566.6	6566.6	
Mass of Wet Soil(gm)A-B=C	4106.3	4322.3	4252.5	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.80	1.89	1.86	
Moisture Content Determination				**NMC**
Container Code.	E-12	G19	F	P65
Mass of Wet soil+Container(gm)(F)	159.1	142.6	112.9	148
Mass of dry soil+container(gm)(G)	142.74	126.39	98.35	140.96
Mass of container(gm)(H)	34.5	41.3	34.2	37.7
Mass of moisture(gm)F-G=(I)	16.36	16.21	14.55	7.04
Mass of Dry soil(gm)G-H=(J)	108.24	85.09	64.15	103.26
Moisture content % (I/J)*100=K	**15.11**	**19.05**	**22.68**	**6.81**
Dry Density gm/cm^3 E/(100+K)*100	**1.56**	**1.59**	**1.52**	



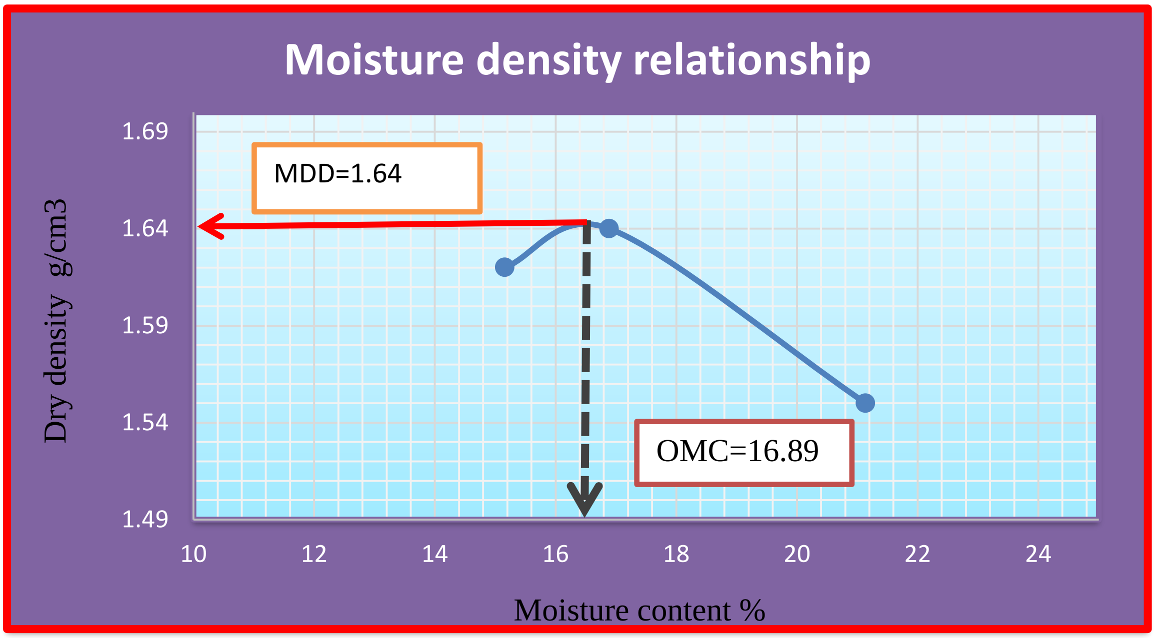
1.7) 4% GSA

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	380	550	730
Mass of Mold+Wet soil(gm)(A)	6684.5	6824.3	6737.65
Mass of Mold(gm)(B)	2716.2	2716.2	2716.2
Mass of Wet Soil(gm)A-B=C	3968.3	4108.1	4021.45
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00
Bulk Density gm/cm^3 C/D=(E)	1.87	1.93	1.89
Moisture Content Determination			
Container Code .	HC12	D2	F12
Mass of Wet soil+Container(gm)(F)	155.42	162.15	152.25
Mass of dry soil+container(gm)(G)	138.42	140.88	131.71
Mass of container(gm)(H)	32.5	25.1	35.5
Mass of moisture(gm)F-G=(I)	17	21.27	20.54
Mass of Dry soil(gm)G-H=(J)	105.92	115.78	96.21
Moisture content % (I/J)*100=K	**16.05**	**18.37**	**21.35**
Dry Density gm/cm^3 E/(100+K)*100	**1.61**	**1.63**	**1.56**



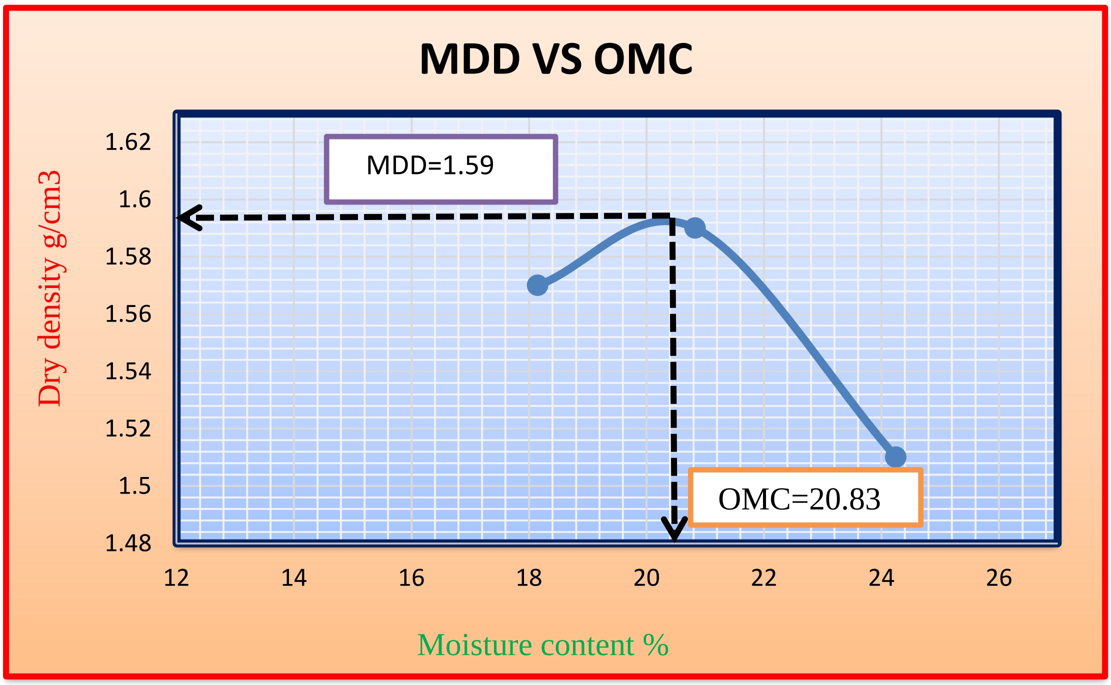
1.8) 6% GSA

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	380	550	730
Mass of Mold+Wet soil(gm)(A)	6681.5	6782.1	6716.2
Mass of Mold(gm)(B)	2716.2	2716.2	2716.2
Mass of Wet Soil(gm)A-B=C	3965.3	4065.9	4000
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00
Bulk Density gm/cm^3 C/D=(E)	1.87	1.91	1.88
Moisture Content Determination			
Container Code.	E-12	RE	G19
Mass of Wet soil+Container(gm)(F)	188.5	152.1	148
Mass of dry soil+container(gm)(G)	169.23	135.25	128.47
Mass of container(gm)(H)	42.1	35.5	36.1
Mass of moisture(gm)F-G=(I)	19.27	16.85	19.53
Mass of Dry soil(gm)G-H=(J)	127.13	99.75	92.37
Moisture content % (I/J)*100=K	**15.16**	**16.89**	**21.14**
Dry Density gm/cm^3 E/(100+K)*100	**1.62**	**1.64**	**1.55**



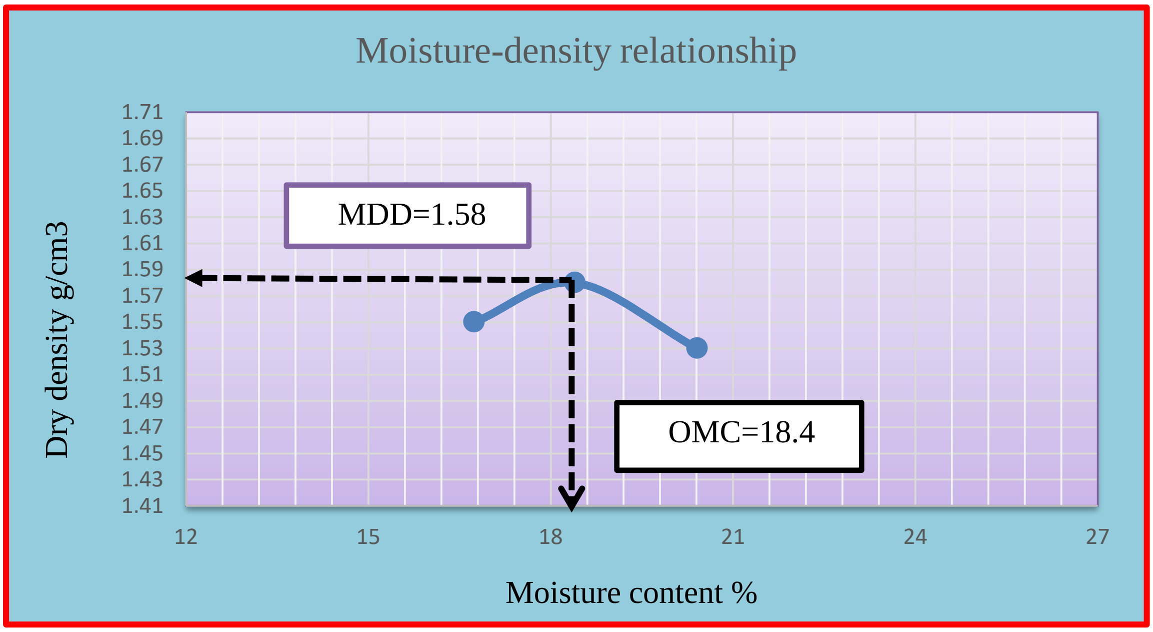
1.9) 8% GSA

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	550	730	910
Mass of Mold+Wet soil(gm)(A)	6654.2	6796.2	6698.2
Mass of Mold(gm)(B)	2716.2	2716.2	2716.2
Mass of Wet Soil(gm)A-B=C	3938	4080	3982
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00
Bulk Density gm/cm^3 C/D=(E)	1.85	1.92	1.87
Moisture Content Determination			
Container Code .	WE	FD	H43
Mass of Wet soil+Container(gm)(F)	175.76	166.47	160.53
Mass of dry soil+container(gm)(G)	154.21	143.99	136.245
Mass of container(gm)(H)	35.5	36.06	36.1
Mass of moisture(gm)F-G=(I)	21.55	22.48	24.285
Mass of Dry soil(gm)G-H=(J)	118.71	107.93	100.145
Moisture content % (I/J)*100=K	**18.15**	**20.83**	**24.25**
Dry Density gm/cm^3 E/(100+K)*100	**1.57**	**1.59**	**1.51**



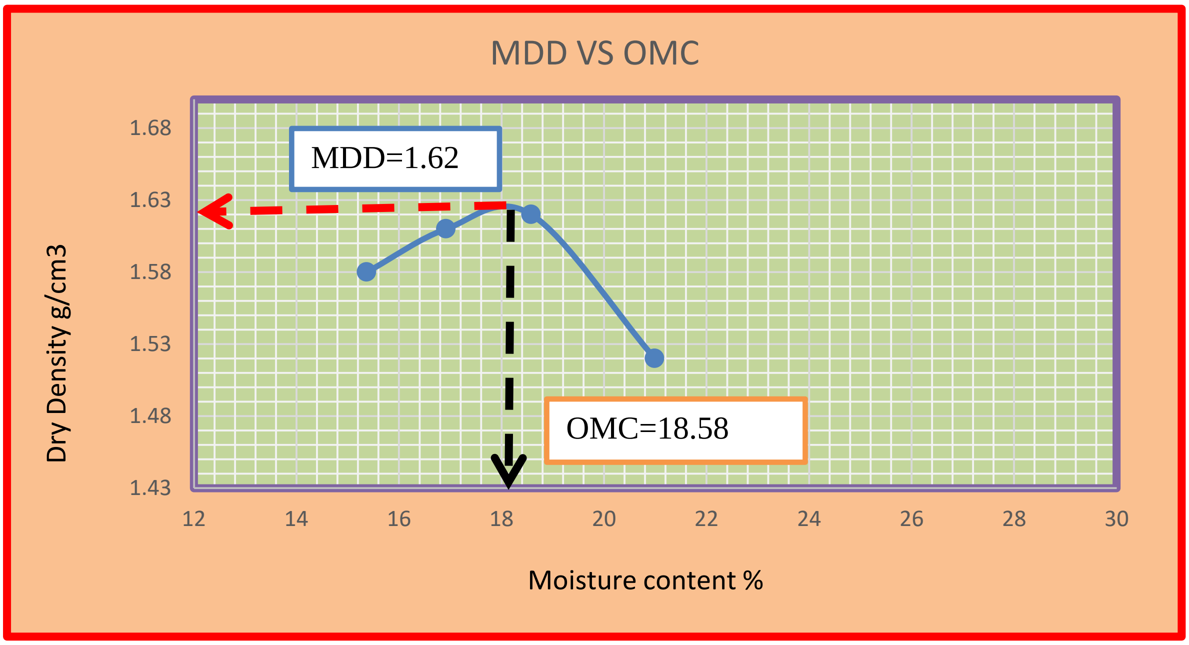
1.10) 10% GSA

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	550	730	910
Mass of Mold+Wet soil(gm)(A)	6561.2	6701.25	6622.4
Mass of Mold(gm)(B)	2716.2	2716.2	2716.2
Mass of Wet Soil(gm)A-B=C	3845	3985.05	3906.2
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00
Bulk Density gm/cm^3 C/D=(E)	1.81	1.88	1.84
Moisture Content Determination			
Container Code.	C3	P67	2WE
Mass of Wet soil+Container(gm)(F)	160.08	172.84	166.32
Mass of dry soil+container(gm)(G)	142.3	150.74	144.02
Mass of container(gm)(H)	36.06	30.66	34.76
Mass of moisture(gm)F-G=(I)	17.78	22.1	22.3
Mass of Dry soil(gm)G-H=(J)	106.24	120.08	109.26
Moisture content % (I/J)*100=K	**16.74**	**18.40**	**20.41**
Dry Density gm/cm^3 E/(100+K)*100	**1.55**	**1.58**	**1.53**



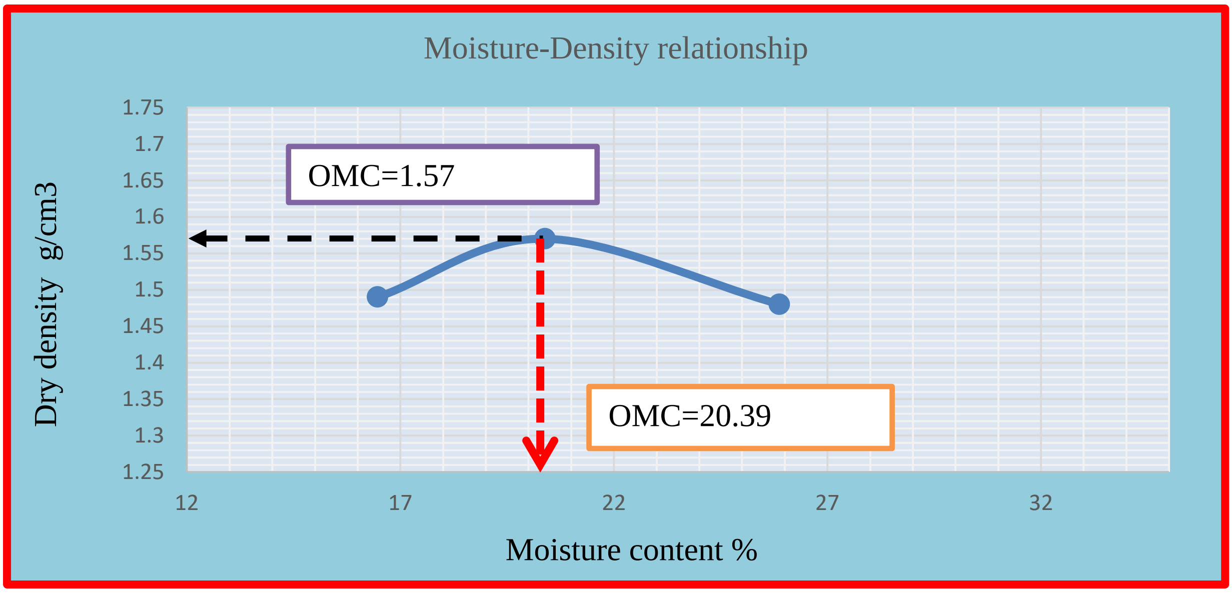
1.11) 10% CA

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	550	730	910	1000	
Mass of Mold+Wet soil(gm)(A)	6590.8	6719.8	6814.5	6650.8	
Mass of Mold(gm)(B)	2724	2724	2724	2724	
Mass of Wet Soil(gm)A-B=C	3866.8	3995.8	4090.5	3926.8	
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00	2124.00	
Bulk Density gm/cm^3 C/D=(E)	1.82	1.88	1.93	1.85	
Moisture Content Determination					**NMC**
Container Code.	ZE	P6	A	P15	E
Mass of Wet soil+Container(gm)(F)	177.01	184.63	189.06	155.94	220.97
Mass of dry soil+container(gm)(G)	157.83	163.42	165.24	134.7	208.1
Mass of container(gm)(H)	33.07	38.08	37.01	33.53	37.95
Mass of moisture(gm)F-G=(I)	19.18	21.21	23.82	21.24	12.87
Mass of Dry soil(gm)G-H=(J)	124.76	125.34	128.23	101.17	170.15
Moisture content % (I/J)*100=K	**15.37**	**16.92**	**18.58**	**20.99**	**7.56**
Dry Density gm/cm^3 E/(100+K)*100	**1.58**	**1.61**	**1.62**	**1.52**	



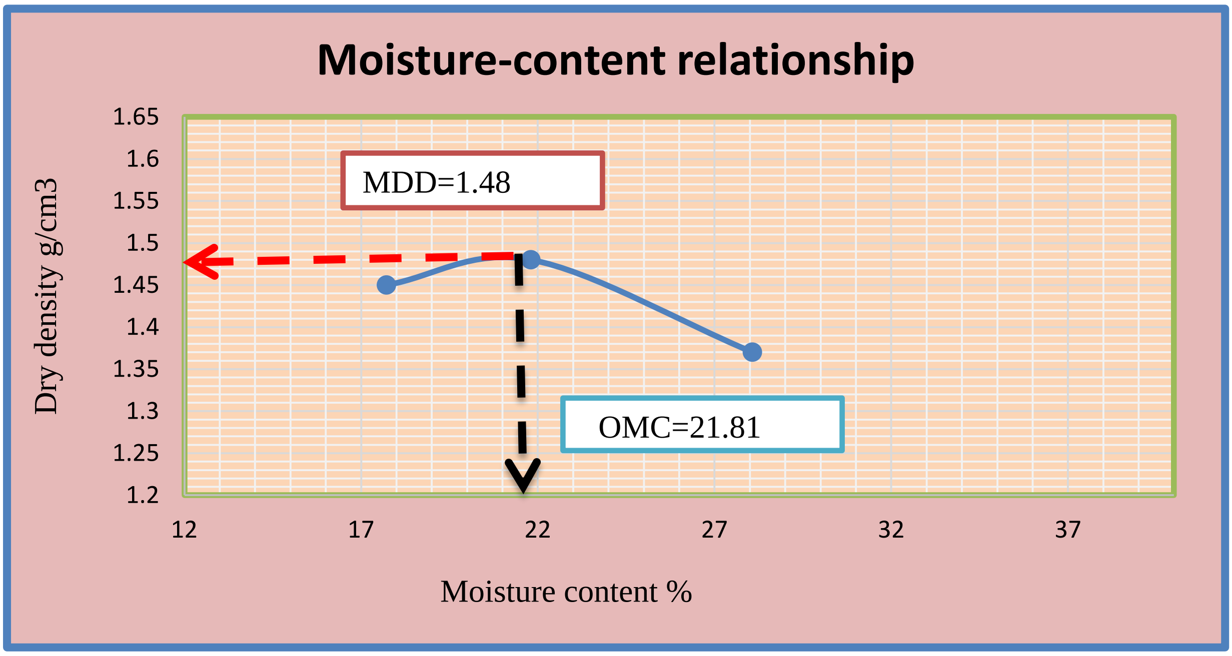
1.12) 20% CA

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	700	980	1160	
Mass of Mold+Wet soil(gm)(A)	6514.27	6718.36	6651.14	
Mass of Mold(gm)(B)	2706.5	2706.5	2706.5	
Mass of Wet Soil(gm)A-B=C	3807.77	4011.86	3944.64	
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00	
Bulk Density gm/cm^3 C/D=(E)	1.79	1.89	1.86	
Moisture Content Determination				**NMC**
Container Code .	C19	G41	O3	E
Mass of Wet soil+Container(gm)(F)	153.24	166.34	151.24	220.97
Mass of dry soil+container(gm)(G)	133.26	144.32	143.41	204.35
Mass of container(gm)(H)	34.24	36.33	31.24	37.95
Mass of moisture(gm)F-G=(I)	19.98	22.02	29.03	16.62
Mass of Dry soil(gm)G-H=(J)	99.02	107.99	112.17	166.4
Moisture content % (I/J)*100=K	**20.18**	**20.39**	**25.88**	**9.98**
Dry Density gm/cm^3 E/(100+K)*100	**1.49**	**1.57**	**1.48**	



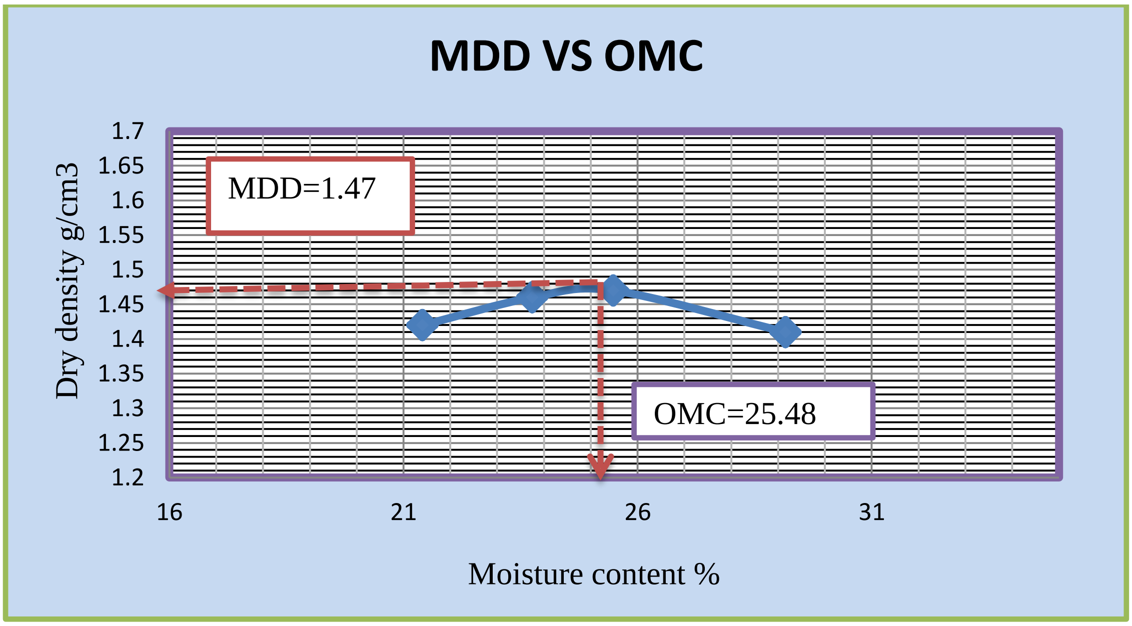
1.13) 30% CA

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	700	880	1060	
Mass of Mold+Wet soil(gm)(A)	6326.7	6531.4	6441.5	
Mass of Mold(gm)(B)	2706.5	2706.5	2706.5	
Mass of Wet Soil(gm)A-B=C	3620.2	3824.9	3735	
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00	
Bulk Density gm/cm^3 C/D=(E)	1.70	1.80	1.76	
Moisture Content Determination				**NMC**
Container Code .	G19	G3T3	2	E
Mass of Wet soil+Container(gm)(F)	150.21	163.96	147.09	220.97
Mass of dry soil+container(gm)(G)	130.25	141.36	138.05	204.35
Mass of container(gm)(H)	34.24	37.76	34.66	37.95
Mass of moisture(gm)F-G=(I)	19.96	22.6	29.03	16.62
Mass of Dry soil(gm)G-H=(J)	96.01	103.6	103.39	166.4
Moisture content % (I/J)*100=K	**20.79**	**21.81**	**28.08**	**9.98**
Dry Density gm/cm^3 E/(100+K)*100	**1.41**	**1.48**	**1.37**	



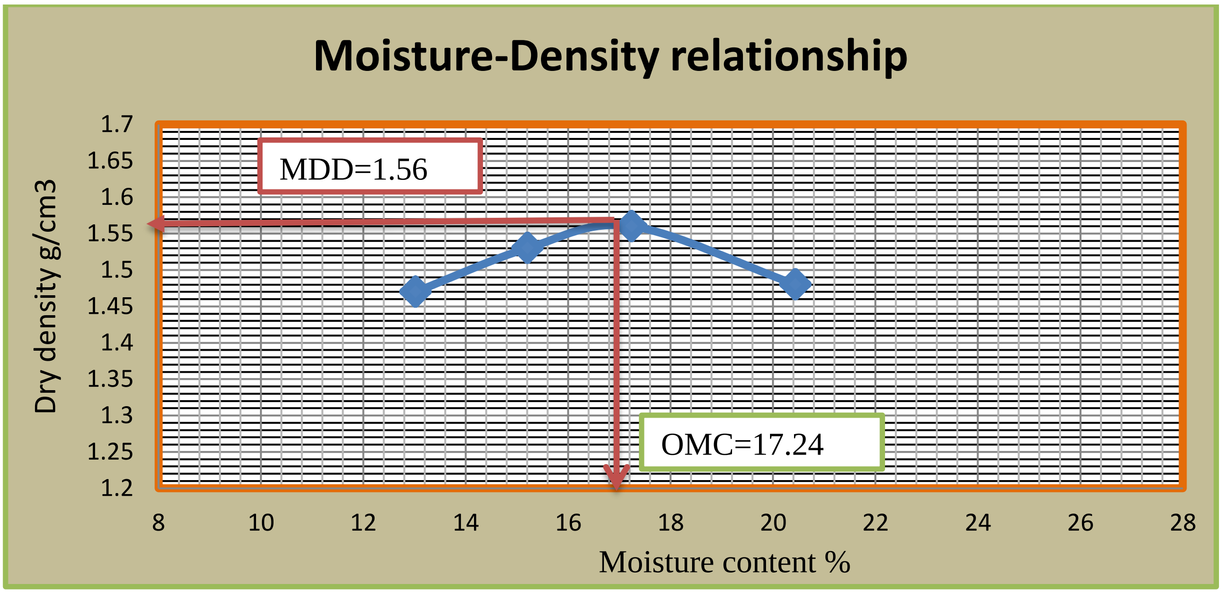
1.14) 40% CA

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	700	980	1110	1290	
Mass of Mold+Wet soil(gm)(A)	6309.84	6485.78	6573.5	6524.71	
Mass of Mold(gm)(B)	2654	2654	2654	2654	
Mass of Wet Soil(gm)A-B=C	3655.84	3831.78	3919.5	3870.71	
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00	2124.00	
Bulk Density gm/cm^3 C/D=(E)	1.72	1.80	1.85	1.82	
Moisture Content Determination					**NMC**
Container Code.	CA	FG2	Q12	MO6	E
Mass of Wet soil+Container(gm)(F)	131.28	146.53	165.34	157.23	220.97
Mass of dry soil+container(gm)(G)	114.75	124.46	139.67	128.96	204.35
Mass of container(gm)(H)	37.54	31.52	38.94	32.01	37.95
Mass of moisture(gm)F-G=(I)	16.53	22.07	25.67	28.27	16.62
Mass of Dry soil(gm)G-H=(J)	77.21	92.94	100.73	96.95	166.4
Moisture content % (I/J)*100=K	**21.41**	**23.75**	**25.48**	**29.16**	**9.98**
Dry Density gm/cm^3 E/(100+K)*100	**1.42**	**1.46**	**1.47**	**1.41**	



1.15) 50% CA

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	750	930	1110	1290	
Mass of Mold+Wet soil(gm)(A)	6254.6	6468.9	6612.7	6547.8	
Mass of Mold(gm)(B)	2724	2724	2724	2724	
Mass of Wet Soil(gm)A-B=C	3530.6	3744.9	3888.7	3823.8	
Volume of Mold cm^3(D)	2124.00	2124.00	2124.00	2124.00	
Bulk Density gm/cm^3 C/D=(E)	1.66	1.76	1.83	1.80	
Moisture Content Determination					**NMC**
Container Code .	AR	K-15	A50	Z-10	E
Mass of Wet soil+Container(gm)(F)	121.63	136.7	184.4	142.53	220.97
Mass of dry soil+container(gm)(G)	111.83	123.68	162.89	123.85	204.35
Mass of container(gm)(H)	36.54	38.08	38.14	32.48	37.95
Mass of moisture(gm)F-G=(I)	9.8	13.02	21.51	18.68	16.62
Mass of Dry soil(gm)G-H=(J)	75.29	85.6	124.75	91.37	166.4
Moisture content % (I/J)*100=K	**13.02**	**15.21**	**17.24**	**20.44**	**9.98**
Dry Density gm/cm^3 E/(100+K)*100	**1.47**	**1.53**	**1.56**	**1.49**	



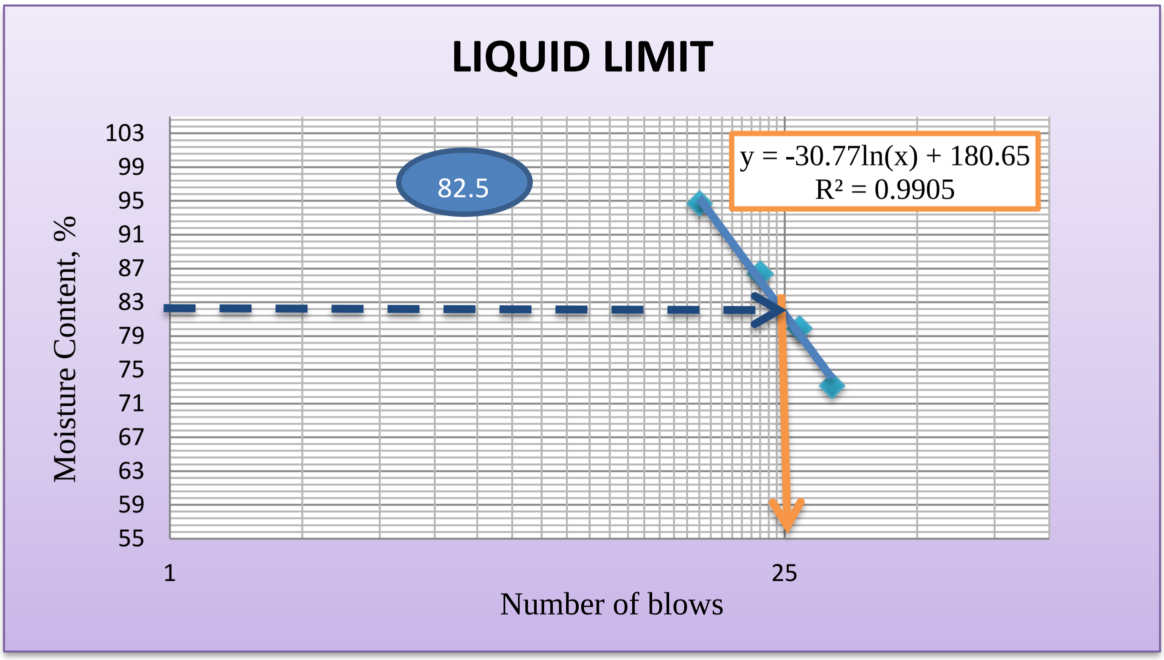
2) Atterberg Limit

2.1) 2% GSA

	Liquid Limit				Plastic Limit	
No of blows	32	27	22	16		
Container No	T-2	B	G14	LL	C9	A5
Wt. of Container+Wet soil(g)	24.49	19.46	42.72	24.81	25.43	21.94
Wt. of Container+Dry soil(g)	21.69	13.49	29.17	15.68	21.73	20.18
Wt. of Container(g)	17.86	6.02	20.19	6.04	11.11	16.01
Wt. of Moisture(g)	2.80	6.0	7.76	9.13	3.70	1.76
Wt. of Dry soil(g)	3.83	7.47	8.98	9.6	10.62	4.17
Moisture Content (%)	73.11	79.92	86.41	94.71	34.84	42.21

LIQUIDLIMIT	LL	82.50
PLASTIC LIMIT	PL	38.52
PLASTICITY INDEX =	LL-PL	43.98

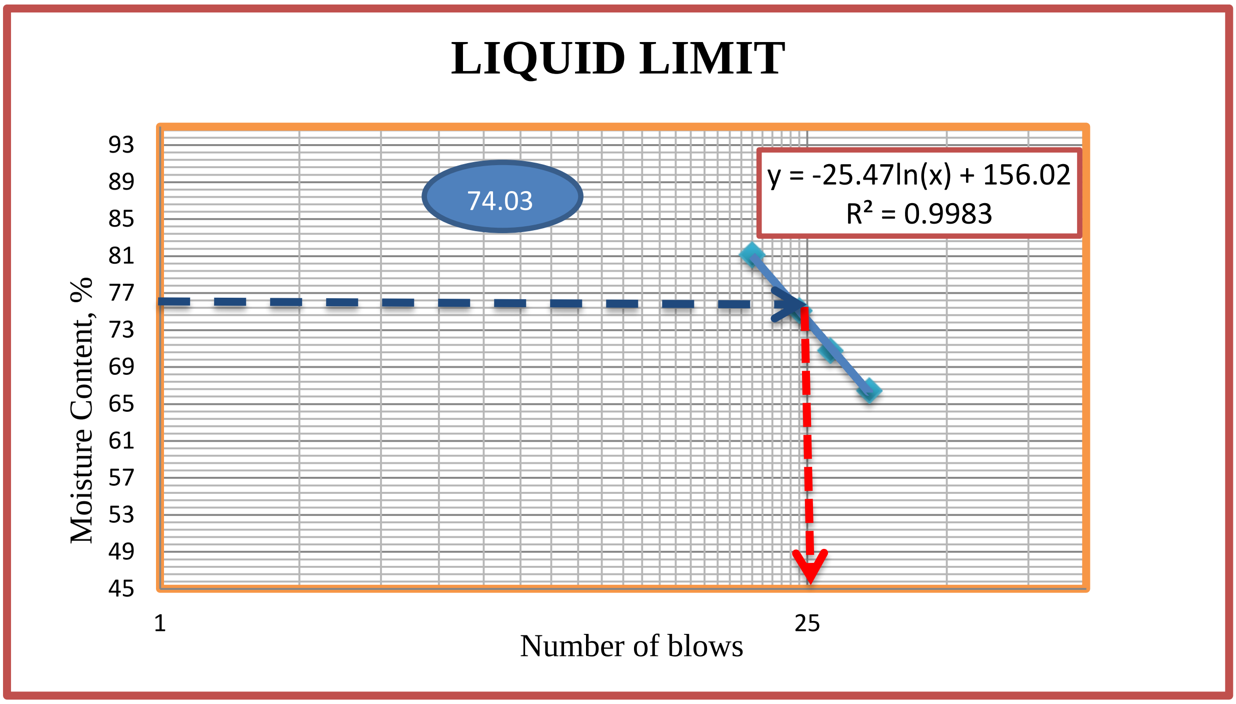
AV. Plas. Lim.	38.5



2.2) 4% GSA

	Liquid Limit				Plastic Limit	
No of blows	34	28	24	19		
Container No	4A	O2	C3B	SS	SP	B-4
Wt. of Container+Wet soil(g)	61.21	46.32	49.88	45.19	23.21	18.74
Wt. of Container+Dry soil(g)	47.90	34.30	28.50	33.10	21.58	14.96
Wt. of Container(g)	27.87	17.32	18.17	18.20	17.28	6.38
Wt. of Moisture(g)	13.31	12.0	7.76	12.09	1.63	3.78
Wt. of Dry soil(g)	20.03	16.98	10.33	14.9	4.30	8.58
Moisture Content (%)	66.45	70.79	75.12	81.14	37.91	44.06
				AV. Plas. Lim.	41.0	

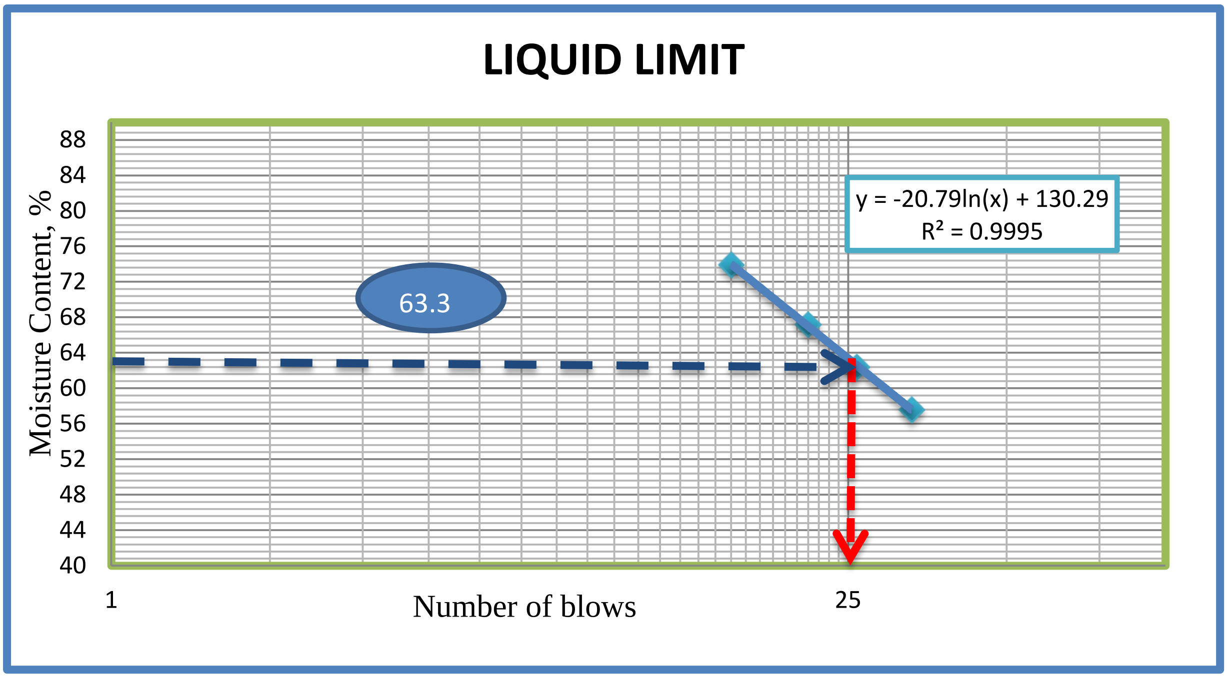
LIQUIDLIMIT	LL	74.03
PLASTIC LIMIT	PL	40.98
PLASTICITY INDEX =	LL-PL	33.05



2.3) 6% GSA

	Liquid Limit				Plastic Limit	
No of blows	33	26	21	15		
Container No	B12	4A	C9	3	DD	A12
Wt. of Container+Wet soil(g)	38.39	41.95	34.96	26.41	28.31	30.53
Wt. of Container+Dry soil(g)	31.52	36.54	22.66	17.86	21.17	26.03
Wt. of Container(g)	19.59	27.87	11.11	6.29	5.60	16.06
Wt. of Moisture(g)	6.87	5.4	7.76	8.55	7.14	4.50
Wt. of Dry soil(g)	11.93	8.67	11.55	11.6	15.57	9.97
Moisture Content (%)	57.59	62.40	67.19	73.90	45.86	45.14
				AV. Plas. Lim.	45.5	

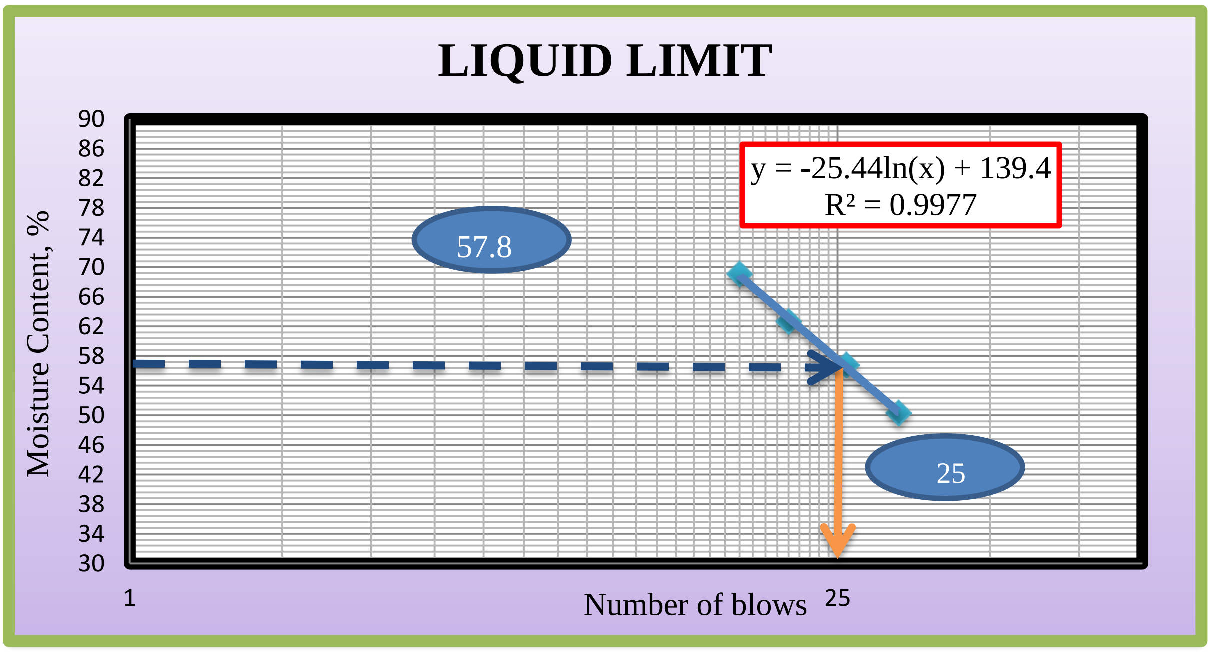
LIQUIDLIMIT	LL	63.35
PLASTIC LIMIT	PL	45.50
PLASTICITY INDEX =	LL-PL	17.85



2.4) 8% GSA

	Liquid Limit				Plastic Limit	
No of blows	33	26	20	16		
Container No	L3	B-4	3rdB	L-14	3	A12
Wt. of Container+Wet soil(g)	30.97	30.49	26.05	42.20	14.00	25.02
Wt. of Container+Dry soil(g)	22.79	21.75	18.79	32.92	11.40	22.14
Wt. of Container(g)	6.55	6.38	6.41	19.49	6.29	16.06
Wt. of Moisture(g)	8.18	8.7	7.76	9.28	2.60	2.88
Wt. of Dry soil(g)	16.24	15.37	12.38	13.4	5.11	6.08
Moisture Content (%)	50.37	56.86	62.68	69.10	50.88	47.37

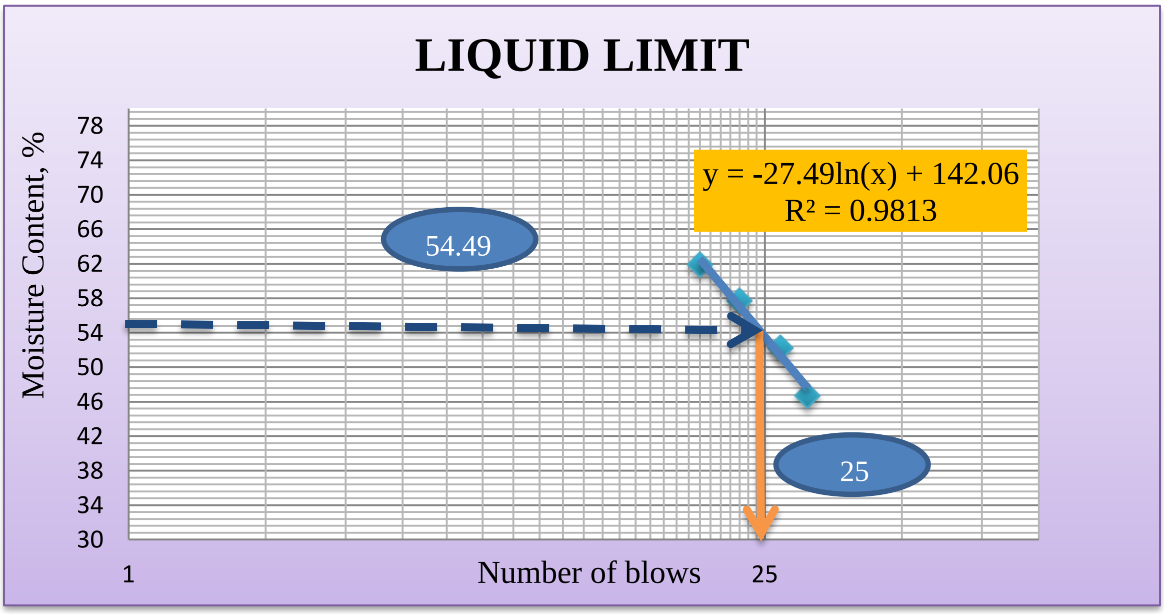
LIQUIDLIMIT	LL	57.83	AV. Plas. Lim.	49.1
PLASTIC LIMIT	PL	49.12		
PLASTICITY INDEX =	LL-PL	8.71		



2.5) 10% GSA

	Liquid Limit				Plastic Limit	
No of blows	31	27	22	18		
Container No	C8	1	A20	G-2	SP	L3
Wt. of Container+Wet soil(g)	26.43	24.71	35.16	38.76	25.82	19.47
Wt. of Container+Dry soil(g)	19.86	18.34	33.08	30.51	22.93	15.20
Wt. of Container(g)	5.81	6.16	19.65	17.19	17.28	6.55
Wt. of Moisture(g)	6.57	6.4	7.76	8.25	2.89	4.27
Wt. of Dry soil(g)	14.05	12.18	13.43	13.3	5.65	8.65
Moisture Content(%)	46.76	52.30	57.78	61.94	51.15	49.36
				AV. Plas. Lim.	50.3	

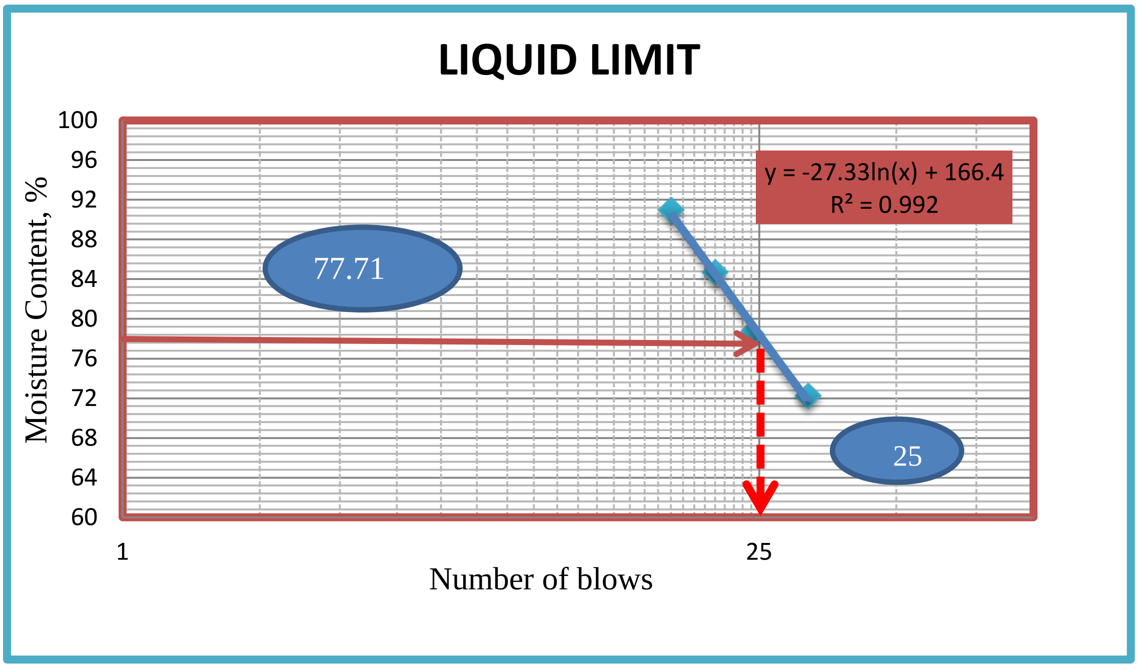
LIQUIDLIMIT	**LL**	**54.49**
PLASTIC LIMIT	**PL**	**50.26**
PLASTICITY INDEX =	**LL-PL**	**4.23**



2.6) 10% CA

	Liquid Limit				Plastic Limit	
No of blows	32	24	20	16		
Container No	C2	03L1	LL	B-3	SP	A36
Wt. of Container+Wet soil(g)	24.50	30.00	27.30	25.50	24.69	23.87
Wt. of Container+Dry soil(g)	16.82	19.74	17.55	15.95	22.54	22.19
Wt. of Container(g)	6.19	6.67	6.04	5.45	17.28	17.58
Wt. of Moisture(g)	7.68	10.3	9.75	9.55	2.15	1.68
Wt. of Dry soil(g)	10.63	13.07	11.51	10.5	5.26	4.61
Moisture Content (%)	72.25	78.50	84.71	90.95	40.87	36.44
				AV. Plas. Lim.	38.7	

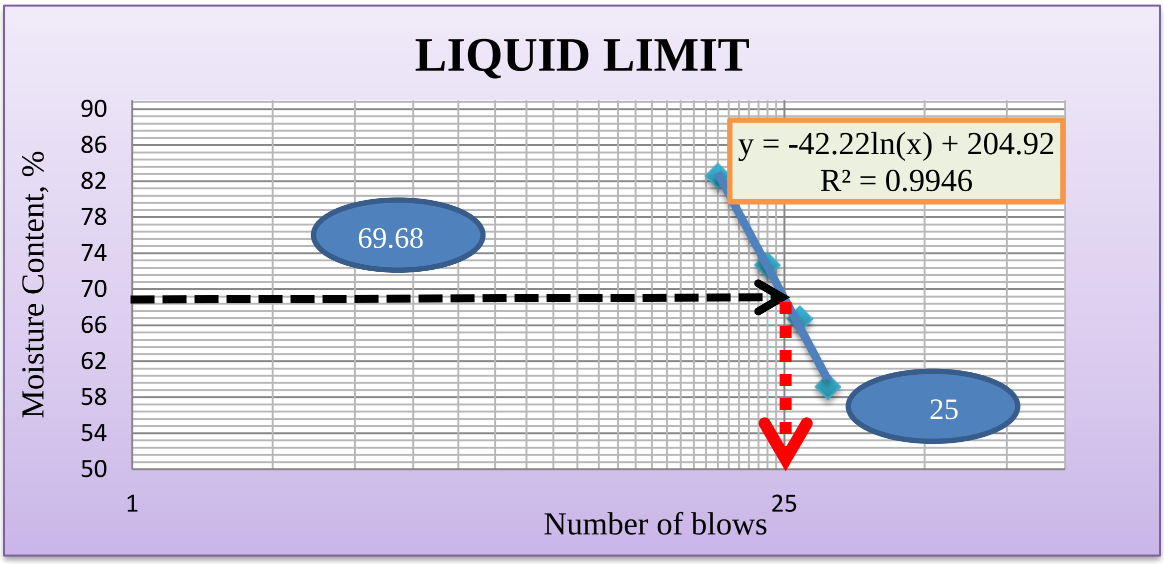
LIQUIDLIMIT	**LL**	**77.71**
PLASTIC LIMIT	**PL**	**38.66**
Plastic index	**LL-PL**	**39.05**



2.7) 20% CA

	Liquid Limit				Plastic Limit	
No of blows	31	27	23	18		
Container No	L3	3	G10	C3B	A13	A1
Wt. of Container+Wet soil(g)	28.55	31.55	25.39	30.86	20.79	23.47
Wt. of Container+Dry soil(g)	20.37	21.44	21.93	25.12	16.35	22.13
Wt. of Container(g)	6.55	6.29	17.17	18.17	6.01	19.25
Wt. of Moisture(g)	8.18	10.1	3.46	5.74	4.44	1.34
Wt. of Dry soil(g)	13.82	15.15	4.76	7.0	10.34	2.88
Moisture Content (%)	59.19	66.73	72.69	82.59	42.94	46.53

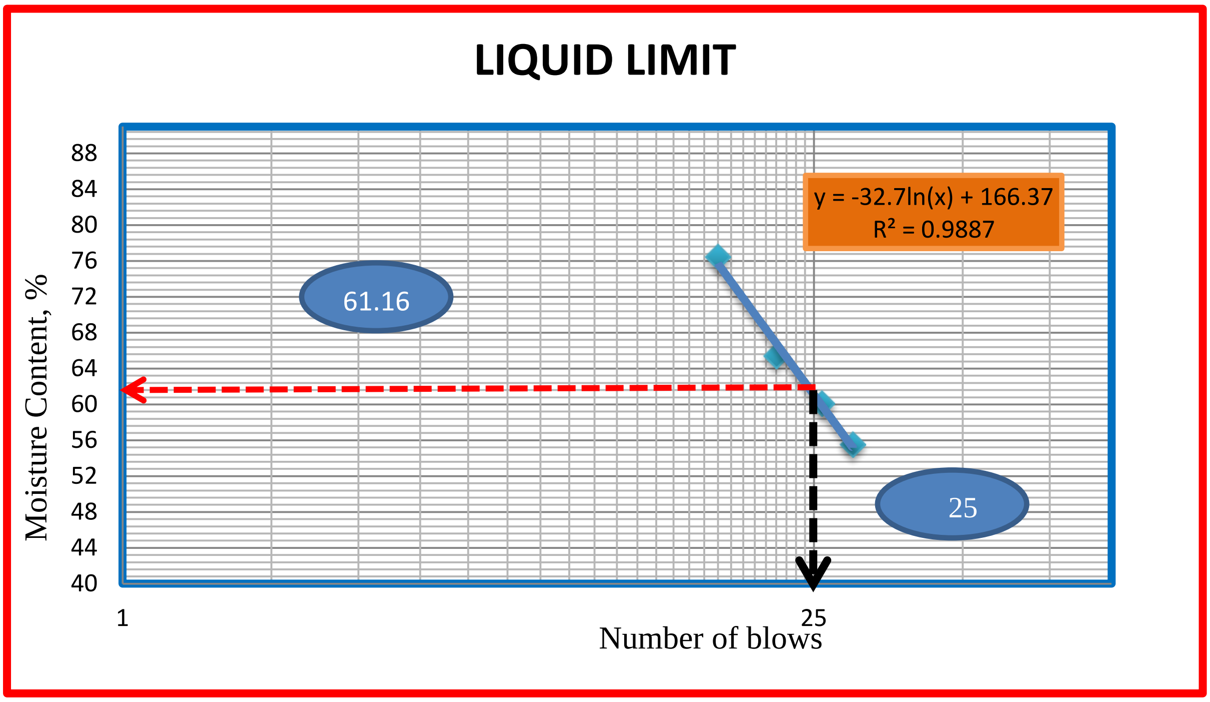
LIQUIDLIMIT	LL	69.68	AV. Plas. Lim.	44.7
PLASTIC LIMIT	PL	44.73		
PLASTICITY INDEX =	LL-PL	24.95		



2.8) 30% CA

	Liquid Limit				Plastic Limit	
No of blows	30	26	21	16		
Container No	B-3	C2	03L1	LL	A12	3
Wt. of Container+Wet soil(g)	29.09	28.70	25.46	29.10	22.60	16.11
Wt. of Container+Dry soil(g)	20.65	20.25	18.03	19.11	20.47	13.07
Wt. of Container(g)	5.45	6.19	6.67	6.04	16.06	6.29
Wt. of Moisture(g)	8.44	8.5	7.43	9.99	2.13	3.04
Wt. of Dry soil(g)	15.20	14.06	11.36	13.1	4.41	6.78
Moisture Content(%)	55.53	60.10	65.40	76.43	48.30	44.84

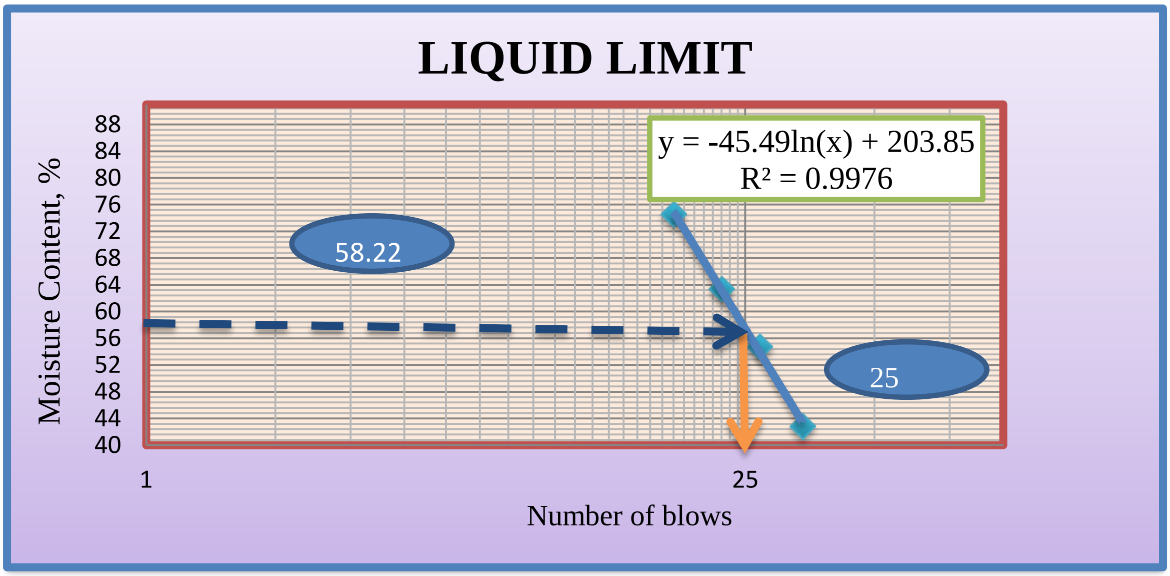
LIQUIDLIMIT	**LL**	**61.16**	AV. Plas. Lim.	46.6
PLASTIC LIMIT	**PL**	**46.57**		
PLASTICITY INDEX =	**LL-PL**	**14.59**		



2.9) 40% CA

	Liquid Limit				Plastic Limit	
No of blows	34	27	22	17		
Container No	C4	B9	C8	L3	F2	A12
Wt. of Container+Wet soil(g)	26.78	34.08	23.77	26.88	20.43	19.26
Wt. of Container+Dry soil(g)	21.06	28.98	16.81	18.19	15.50	14.52
Wt. of Container(g)	7.70	19.67	5.83	6.54	5.70	5.03
Wt. of Moisture(g)	5.72	5.1	6.96	8.69	4.93	4.74
Wt. of Dry soil(g)	13.36	9.31	10.98	11.7	9.80	9.49
Moisture Content (%)	42.81	54.78	63.39	74.59	50.31	49.95
				AV. Plas. Lim.	50.1	

LIQUIDLIMIT	LL	**58.22**
PLASTIC LIMIT	PL	**50.13**
PLASTICITY INDEX =	LL-PL	**8.09**

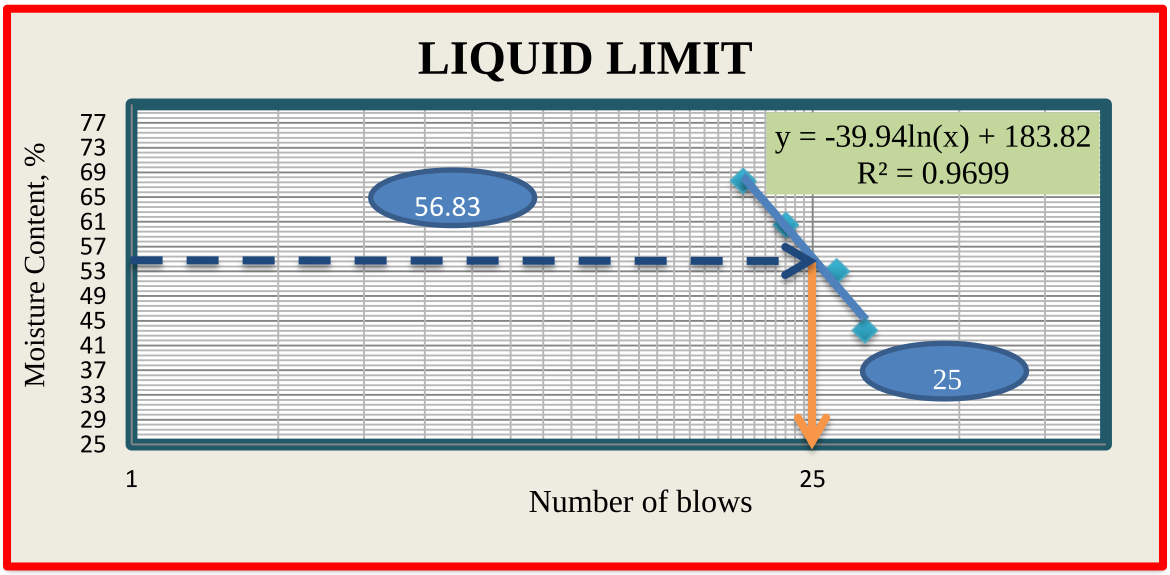


2.10) 50% CA

	Liquid Limit				Plastic Limit	
No of blows	32	28	22	18		
Container No	S6	B	DD	6A	A5	B11
Wt. of Container+Wet soil(g)	31.49	29.58	28.13	34.98	27.11	32.26
Wt. of Container+Dry soil(g)	23.76	21.41	19.63	26.33	23.21	27.03
Wt. of Container(g)	5.99	6.02	5.60	13.55	16.01	17.03
Wt. of Moisture(g)	7.73	8.2	8.50	8.65	3.90	5.23
Wt. of Dry soil(g)	17.77	15.39	14.03	12.8	7.20	10.00
Moisture Content (%)	43.50	53.09	60.58	67.68	54.17	52.30

LIQUIDLIMIT	LL	56.83
PLASTIC LIMIT	PL	53.23
PLASTICITY INDEX =	LL-PL	3.60

AV. Plas. Lim.	53.2



3) CBR Laboratory test result

3.1) 1% BF

		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N4	N4	N7	N7	N1	N1
Mass of soil + Mould	g	11111.6	11292.3	10992.6	11192.2	10802.6	11071.6
Mass Mould	g	7025	7025	6965.7	6965.7	6942	6942
Mass of Soil	g	4086.6	4267.3	4026.9	4226.5	3860.6	4129.6
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.924	2.009	1.896	1.990	1.818	1.944
Dry density of soil	g/cc	1.619	1.649	1.578	1.444	1.507	1.382

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P15	2W	E	A-13	2Q	G19
Mass of wet soil + Container	g	155.21	160.40	137.71	171.88	162.50	157.84
Mass of dry soil + Container	g	135.92	137.41	121.01	133.96	140.64	122.12
Mass of container	g	33.59	32.30	37.96	33.58	34.59	34.27
Mass of water	g	19.29	22.99	16.70	37.92	21.86	35.72
Mass of dry soil	g	102.33	105.11	83.05	100.38	106.05	87.85
Moisture content	%	18.85	21.87	20.11	37.78	20.61	40.66

CBR Penetration Determination

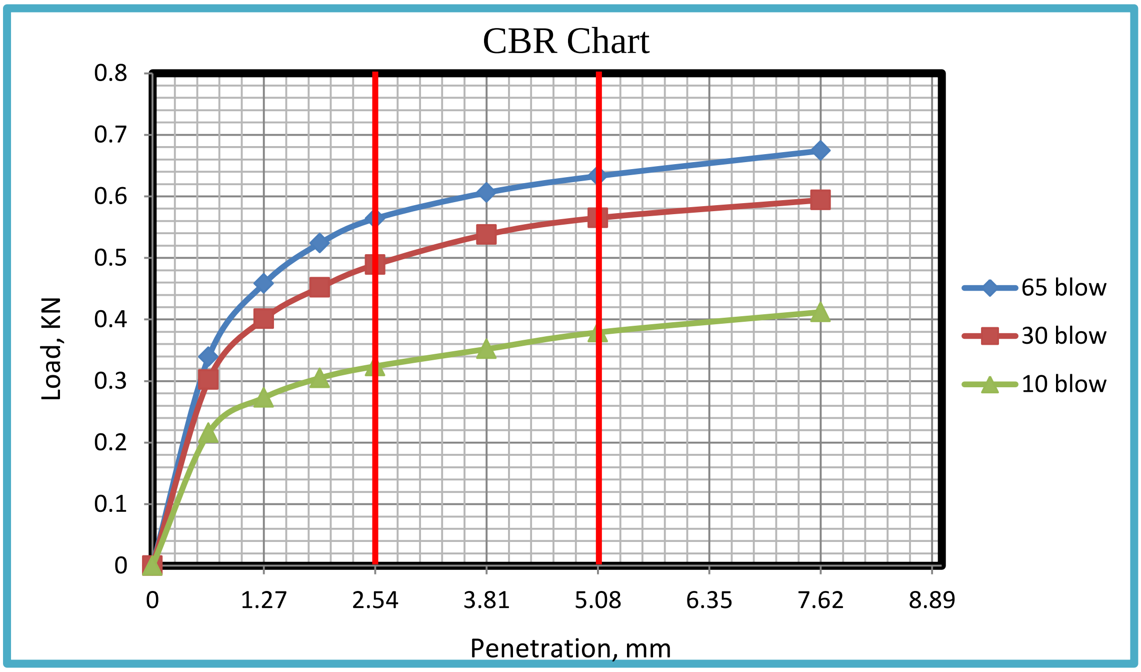
Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.339		0.64	0.302		0.64	0.216	
1.27	0.458		1.27	0.401		1.27	0.273	
1.91	0.524		1.91	0.452		1.91	0.305	
2.54	0.564	4.23	2.54	0.489	3.67	2.54	0.324	2.43
3.81	0.606		3.81	0.538		3.81	0.352	
5.08	0.633	3.17	5.08	0.565	2.83	5.08	0.379	1.90
7.62	0.674		7.62	0.594		7.62	0.412	

Modified Max.Dry Density g/cc	1.660	OMC %	20.8

Swell Determination							
Date		65Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.10	1.77	3.24	1.87	4.95	1.98
01/03/2013	Final	6.16		5.42		7.25	

Dry Density at 95% of MDD				**1.577**
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	20.6	1.507	2.43	91
30	20.1	1.578	3.68	95
65	18.9	1.619	4.24	98

CBR % at 95 % MDD	**3.7**	**Swell %**	**1.87**



3.2) 1.5% BF

		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N4	N4	N7	N7	N1	N1
Mass of soil + Mould	g	11223.2	11432.2	11087.6	11298.5	10802.6	11223.2
Mass Mould	g	7025	7025	6965.7	6965.7	6942	6942
Mass of Soil	g	4198.2	4407.2	4121.9	4332.8	3860.6	4281.2
Volume of Mould	g	2124	2124	2124	2124	2124	2124

Wet density of soil	g/cc	1.977	2.075	1.941	2.040	1.818	2.016
Dry density of soil	g/cc	1.559	1.614	1.489	1.526	1.386	1.433

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P15	2W	E	A-13	2Q	G19
Mass of wet soil + Container	g	143.43	166.53	137.01	165.32	162.50	157.84
Mass of dry soil + Container	g	120.21	137.21	113.97	132.12	132.12	122.12
Mass of container	g	33.59	34.67	37.96	33.58	34.59	34.27
Mass of water	g	23.22	29.32	23.04	33.20	30.38	35.72
Mass of dry soil	g	86.62	102.54	76.01	98.54	97.53	87.85
Moisture content	%	26.81	28.59	30.31	33.69	31.15	40.66

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — **Surcharge Weight:-4.55 KG**

65 Blows			30 Blows			10 Blows		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.407		0.64	0.434		0.64	0.246	
1.27	0.556		1.27	0.547		1.27	0.424	
1.91	0.633		1.91	0.598		1.91	0.507	
2.54	0.674	5.05	2.54	0.632	4.74	2.54	0.551	4.13
3.81	0.718		3.81	0.674		3.81	0.592	
5.08	0.758	3.79	5.08	0.698	3.49	5.08	0.627	3.14
7.62	0.801		7.62	0.733		7.62	0.651	

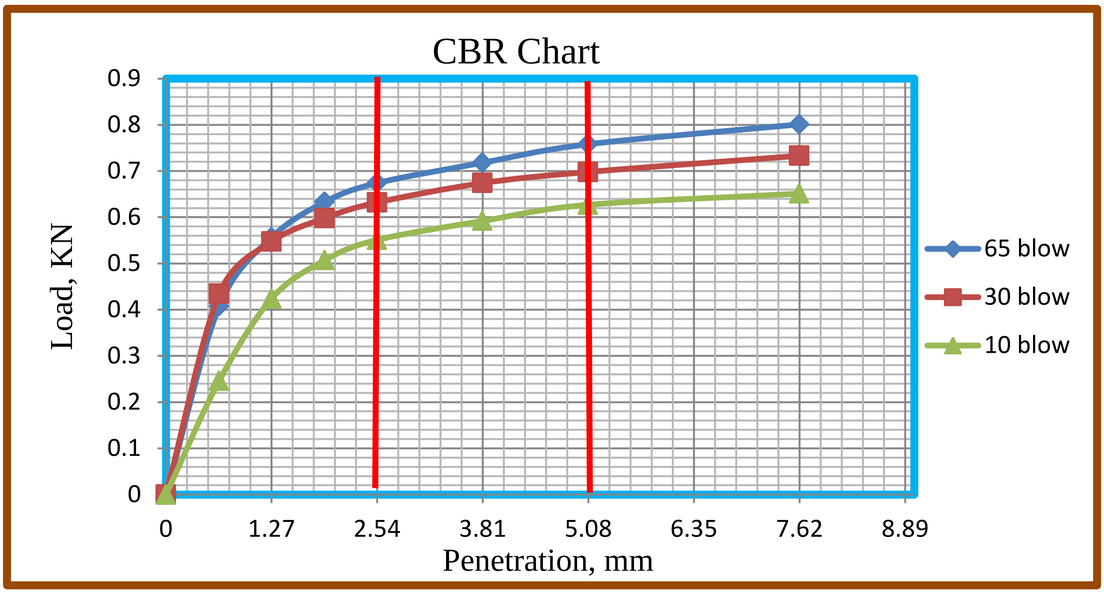
Modified Max.Dry Density g/cc	**1.600**	**OMC %**	**18.3**

Swell Determination

Date		**65 Blows**		**30 Blows**		**10 Blows**	
		Gauge rdg mm	**Swell in %**	**Gauge rdg mm**	**Swell in %**	**Gauge rdg mm**	**Swell in %**
27/02/2013	Initial	3.28	1.36	6.2	1.43	3.13	2.07
01/03/2013	Final	4.86		7.87		5.54	

Dry Density at 95% of MDD:				**1.520**
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	31.1	1.386	4.13	87
30	30.3	1.489	4.75	93
65	26.8	1.559	5.07	97

CBR % at 95 % MDD	**4.9**	**Swell %**	**1.43**



3.3) 2% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N12	N12	I65	I65	N10	N10
Mass of soil + Mould	g	11185.5	11303.5	11010.8	11162.5	10854.7	11023.6
Mass Mould	g	7006.1	7006.1	6917.3	6917.3	6950.1	6950.1
Mass of Soil	g	4179.4	4297.4	4093.5	4245.2	3904.6	4073.5
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.968	2.023	1.927	1.999	1.838	1.918
Dry density of soil	g/cc	1.572	1.458	1.457	1.447	1.377	1.264

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P65	A2	D21	E12	G3T3	T1
Mass of wet soil + Container	g	154.12	136.80	163.70	152.72	154.72	166.56
Mass of dry soil + Container	g	130.74	109.11	132.12	121.00	125.40	122.60
Mass of container	g	37.81	37.62	34.20	37.90	37.81	37.63
Mass of water	g	23.38	27.69	31.58	31.72	29.32	43.96
Mass of dry soil	g	92.93	71.49	97.92	83.10	87.59	84.97
Moisture content	%	25.16	38.73	32.25	38.17	33.47	51.74

CBR Penetration Determination

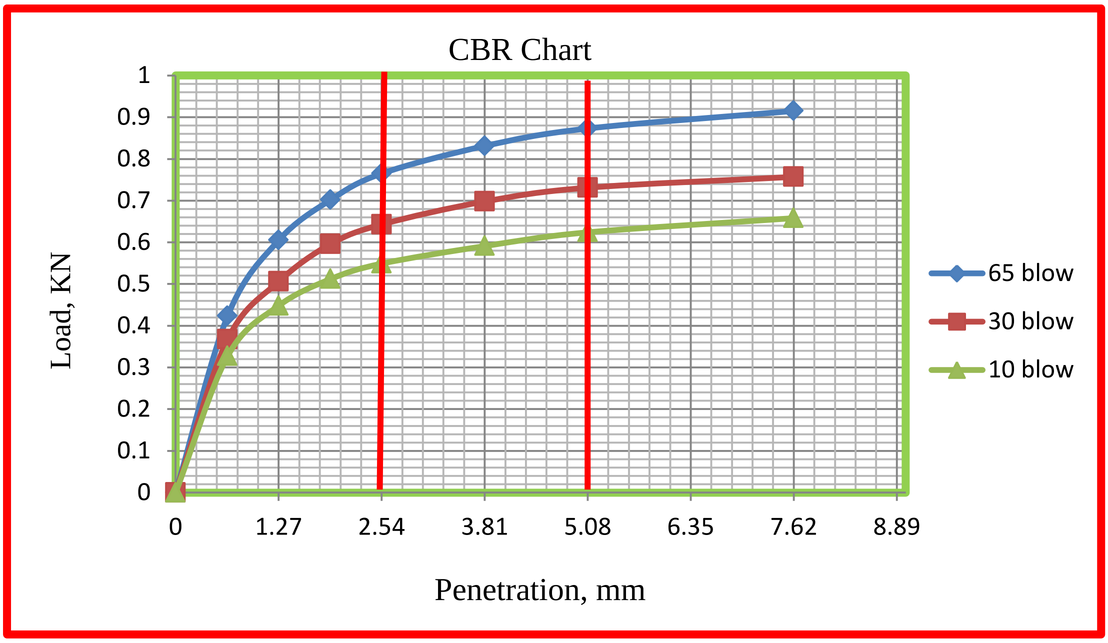
Penetration after 96 hrs. Soaking Period	**Surcharge Weight:-4.55 KG**

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.423		0.64	0.367		0.64	0.327	
1.27	0.605		1.27	0.506		1.27	0.448	
1.91	0.702		1.91	0.596		1.91	0.512	
2.54	0.765	5.73	2.54	0.643	4.82	2.54	0.549	4.12
3.81	0.831		3.81	0.698		3.81	0.591	
5.08	0.873	4.37	5.08	0.731	3.66	5.08	0.624	3.12
7.62	0.915		7.62	0.757		7.62	0.658	
Modified Max.Dry Density g/cc			**1.590**			**OMC %**	**19.1**	

Swell Determination

Date		65 Blows Gauge rdg mm	65 Blows Swell in %	30 Blows Gauge rdg mm	30 Blows Swell in %	10 Blows Gauge rdg mm	10 Blows Swell in %
27/02/2013	Initial	2.05	1.45	2.37	1.66	3.52	2.30
01/03/2013	Final	3.74		4.30		6.20	

Dry Density at 95% of MDD:				**1.511**
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	33.5	1.377	4.12	87
30	32.3	1.457	4.83	92
65	25.2	1.572	5.75	99
CBR % at 95 % MDD			**5.3**	**Swell %** **1.66**



3.4) 2.5% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N12	N12	I65	I65	N10	N10
Mass of soil + Mould	g	11142.1	11303.5	10965.4	11162.5	10646.2	10903
Mass Mould	g	7006.1	7006.1	6981.5	6981.5	6951.3	6951.3
Mass of Soil	g	4136	4297.4	3983.9	4181	3694.9	3951.7
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.947	2.023	1.876	1.968	1.740	1.860
Dry density of soil	g/cc	1.590	1.633	1.499	1.571	1.363	1.443

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P65	A2	D21	E12	G3T3	T1
Mass of wet soil + Container	g	143.21	136.80	153.21	152.72	148.12	167.21
Mass of dry soil + Container	g	123.87	117.65	129.34	129.54	124.21	138.12
Mass of container	g	37.81	37.62	34.20	37.90	37.81	37.63
Mass of water	g	19.34	19.15	23.87	23.18	23.91	29.09
Mass of dry soil	g	86.06	80.03	95.14	91.64	86.40	100.49
Moisture content	%	22.47	23.93	25.09	25.29	27.67	28.95

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.524		0.64	0.654		0.64	0.462	
1.27	0.711		1.27	0.687		1.27	0.552	
1.91	0.824		1.91	0.765		1.91	0.601	
2.54	0.925	6.93	2.54	0.814	6.10	2.54	0.634	4.75
3.81	1.042		3.81	0.895		3.81	0.665	
5.08	1.123	5.62	5.08	0.967	4.84	5.08	0.691	3.46
7.62	1.213		7.62	1.043		7.62	0.734	

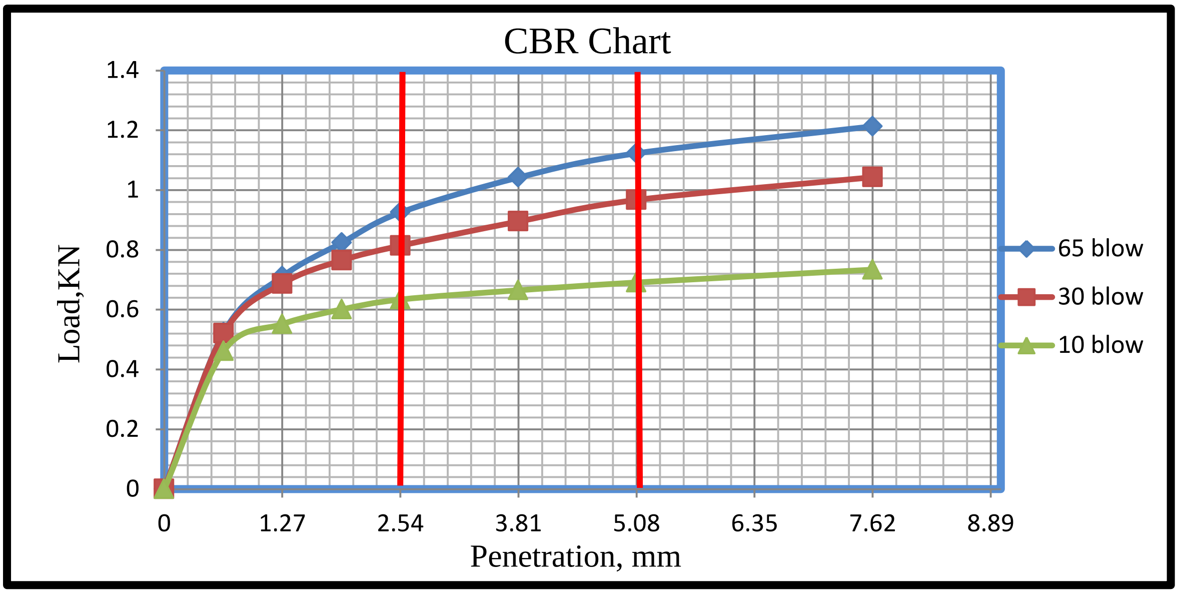
Modified Max.Dry Density g/cc	1.610	OMC %	16.2

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.96	0.88	6.4	0.97	3.08	1.32
01/03/2013	Final	5.98		7.53		4.62	

Dry Density at 95% of MDD:				1.530
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction

10	27.7	1.363	4.75		85
30	25.1	1.499	6.12		93
65	22.5	1.590	6.95		99
CBR % at 95 % MDD			**6.4**	**Swell %**	**0.97**



3.5) 3% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		MN8	MN8	P56	P56	G37	G37
Mass of soil + Mould	g	11074.2	11180.3	10900.2	11000.1	10801.2	10948.3
Mass Mould	g	7041.2	7041.2	6003.5	6003.5	5600.2	5600.2
Mass of Soil	g	4033	4139.1	4896.7	4996.6	5201	5348.1
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.899	1.949	2.305	2.352	2.449	2.518
Dry density of soil	g/cc	1.564	1.424	1.504	1.757	1.387	1.550

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		S40	G19	P1	45D	A22	C150
Mass of wet soil + Container	g	160.80	148.70	163.10	150.90	150.60	140.78
Mass of dry soil + Container	g	137.54	113.34	119.56	117.12	92.95	93.32
Mass of container	g	28.73	17.36	37.81	17.53	17.60	17.32
Mass of water	g	23.26	35.36	43.54	33.78	57.65	47.46
Mass of dry soil	g	108.81	95.98	81.75	99.59	75.35	76.00
Moisture content	%	21.38	36.84	53.26	33.92	76.51	62.45

CBR Penetration Determination								
Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.358		0.64	0.364		0.64	0.371	
1.27	0.473		1.27	0.478		1.27	0.468	
1.91	0.546		1.91	0.544		1.91	0.517	
2.54	0.587	4.40	2.54	0.576	4.32	2.54	0.553	4.15
3.81	0.642		3.81	0.617		3.81	0.592	
5.08	0.676	3.38	5.08	0.651	3.26	5.08	0.614	3.07
7.62	0.704		7.62	0.695		7.62	0.648	

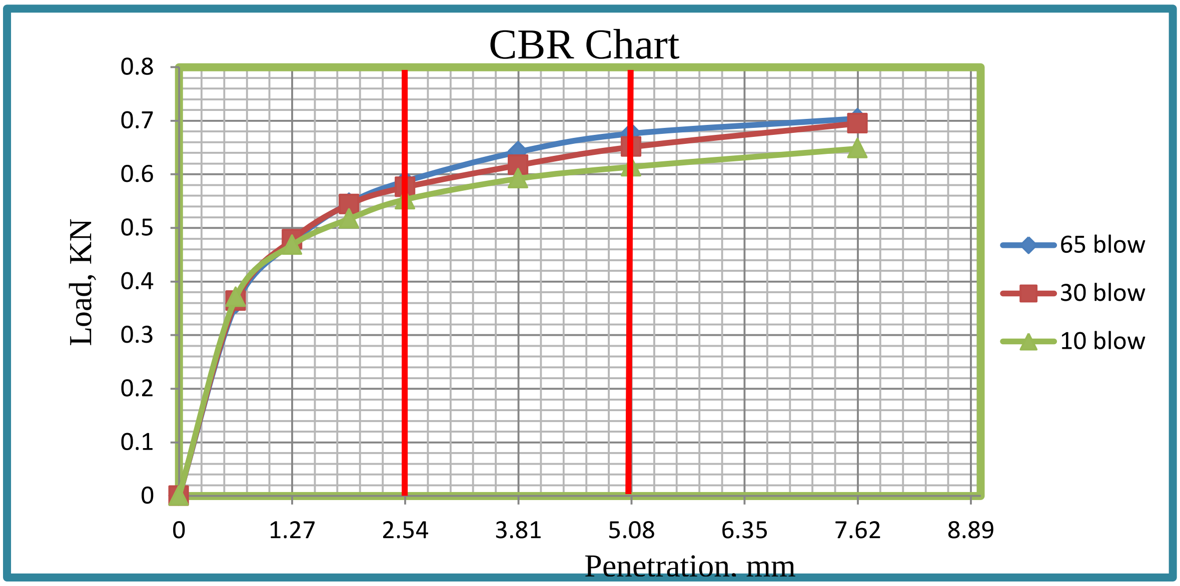
Modified Max.Dry Density g/cc	1.560	OMC %	13.7

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.01	1.66	3.25	1.86	3.08	2.71
01/03/2013	Final	5.94		5.42		6.23	

Dry Density at 95% of MDD:				1.482
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	76.5	1.387	4.15	89
30	53.3	1.504	4.33	96
65	21.4	1.564	4.41	100

CBR % at 95 % MDD	4.3	Swell %	1.86



3.6) 2% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		MN8	MN8	N5	N5	N2	N2
Mass of soil + Mould	g	11241.2	11376.7	11129.8	11263.1	11067.3	11168.9
Mass Mould	g	7041.2	7041.2	6931.5	6931.5	6935.6	6935.6
Mass of Soil	g	4200	4335.5	4198.3	4331.6	4131.7	4233.3
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.977	2.041	1.977	2.039	1.945	1.993
Dry density of soil	g/cc	1.657	1.651	1.591	1.613	1.488	1.503

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		2Q	T5C2	P10	J41	P1	A
Mass of wet soil + Container	g	151.71	136.89	147.16	142.93	174.38	158.37
Mass of dry soil + Container	g	132.76	114.15	124.43	119.83	142.29	128.56
Mass of container	g	34.59	17.90	30.68	32.50	37.81	37.03
Mass of water	g	18.95	22.74	22.73	23.10	32.09	29.81
Mass of dry soil	g	98.17	96.25	93.75	87.33	104.48	91.53
Moisture content	%	19.30	23.63	24.25	26.45	30.71	32.57

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — **Surcharge Weight:-4.55 KG**

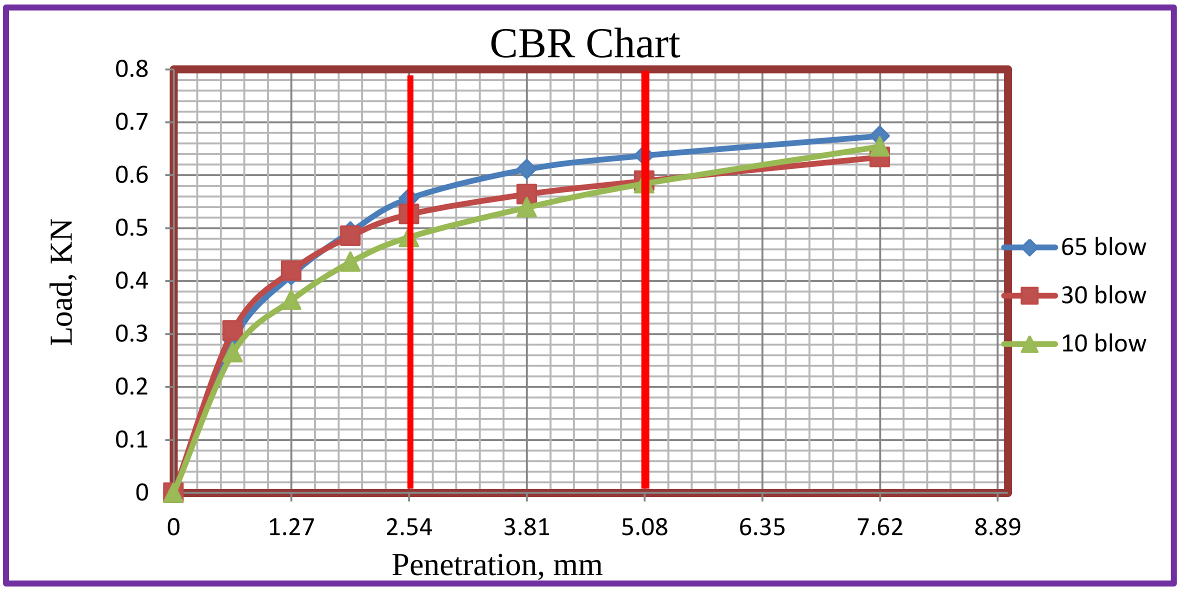
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.289		0.64	0.306		0.64	0.265	
1.27	0.411		1.27	0.419		1.27	0.364	
1.91	0.493		1.91	0.485		1.91	0.436	
2.54	0.556	4.17	2.54	0.526	3.94	2.54	0.483	3.62
3.81	0.611		3.81	0.564		3.81	0.539	
5.08	0.637	3.19	5.08	0.589	2.95	5.08	0.584	2.92
7.62	0.674		7.62	0.634		7.62	0.654	

Modified Max.Dry Density g/cc	1.620	OMC %	20.9

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	1.26	1.46	1.33	1.23	2.06	1.50
01/03/2013	Final	2.96		2.76		3.81	

Dry Density at 95% of MDD:					1.539
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %		% OF Compaction
10	30.7	1.488	3.62		92
30	24.2	1.591	3.95		98
65	19.3	1.657	4.18		102
CBR % at 95 % MDD			3.8	Swell %	1.23



3.7) 4% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N7	N7	N12	N12	N10	N10
Mass of soil + Mould	g	11129.8	11276.9	11129.8	11255.1	10976.8	11179.4
Mass Mould	g	6965.7	6965.7	7006.1	7006.1	6935.6	6935.6
Mass of Soil	g	4164.1	4311.2	4123.7	4249	4041.2	4243.8
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.960	2.030	1.941	2.000	1.903	1.998
Dry density of soil	g/cc	1.600	1.620	1.501	1.510	1.398	1.422

Moisture Determination

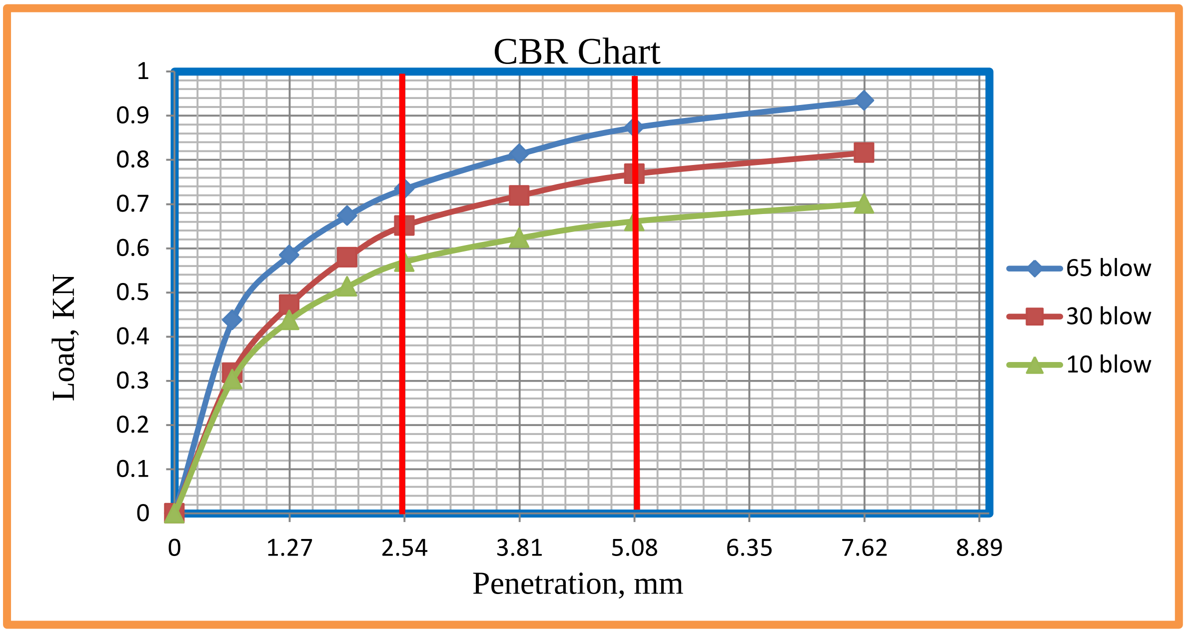
MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		B	G4	WX-4	F22	C41	AB30
Mass of wet soil + Container	g	156.63	162.37	172.39	150.40	181.46	168.49
Mass of dry soil + Container	g	134.15	135.71	140.83	123.12	142.74	131.06
Mass of container	g	34.50	30.15	33.20	39.10	35.51	38.60

Mass of water	g	22.48	26.66	31.56	27.28	38.72	37.43
Mass of dry soil	g	99.65	105.56	107.63	84.02	107.23	92.46
Moisture content	%	22.56	25.26	29.32	32.47	36.11	40.48

CBR Penetration Determination								
Penetration after 96 hrs. Soaking Period			**Surcharge Weight:-4.55 KG**					
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.437		0.64	0.318		0.64	0.303	
1.27	0.584		1.27	0.472		1.27	0.437	
1.91	0.673		1.91	0.579		1.91	0.513	
2.54	0.734	5.50	2.54	0.651	4.88	2.54	0.569	4.27
3.81	0.813		3.81	0.719		3.81	0.623	
5.08	0.873	4.37	5.08	0.768	3.84	5.08	0.661	3.31
7.62	0.934		7.62	0.816		7.62	0.701	

Modified Max.Dry Density g/cc	**1.630**	**OMC %**	**18.4**

Swell Determination							
Date		**65 Blows**		**30 Blows**		**10 Blows**	
		Gauge rdg mm	**Swell in %**	**Gauge rdg mm**	**Swell in %**	**Gauge rdg mm**	**Swell in %**
27/02/2013	Initial	0.00	0.75	0.00	0.89	0.00	1.13
01/03/2013	Final	0.87		1.04		1.32	



3.8) 6% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		K64	K64	D40	D40	A-50	A-50
Mass of soil + Mould	g	11052.41	11149.68	10829.7	11016.76	10635.96	10887.31
Mass Mould	g	6897.2	6897.2	6523.4	6523.4	6935.6	6935.6
Mass of Soil	g	4155.21	4252.48	4306.3	4493.36	3700.36	3951.71
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.956	2.002	2.027	2.116	1.742	1.861
Dry density of soil	g/cc	1.740	1.720	1.572	1.604	1.345	1.367

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G3T4	P65	P67	G19	T1	S40
Mass of wet soil + Container	g	145.35	176.99	158.26	147.86	155.63	175.56
Mass of dry soil + Container	g	131.25	157.37	130.68	120.39	128.75	136.59
Mass of container	g	17.59	37.76	35.53	34.22	37.65	28.73
Mass of water	g	14.10	19.62	27.58	27.47	26.88	38.97
Mass of dry soil	g	113.66	119.61	95.15	86.17	91.10	107.86
Moisture content	%	12.41	16.40	28.99	31.88	29.51	36.13

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.452		0.64	0.482		0.64	0.457	
1.27	0.641		1.27	0.634		1.27	0.618	
1.91	0.754		1.91	0.735		1.91	0.698	
2.54	0.826	6.19	2.54	0.793	5.94	2.54	0.751	5.63
3.81	0.894		3.81	0.839		3.81	0.811	
5.08	0.953	4.77	5.08	0.873	4.37	5.08	0.857	4.29
7.62	1.046		7.62	0.924		7.62	0.943	

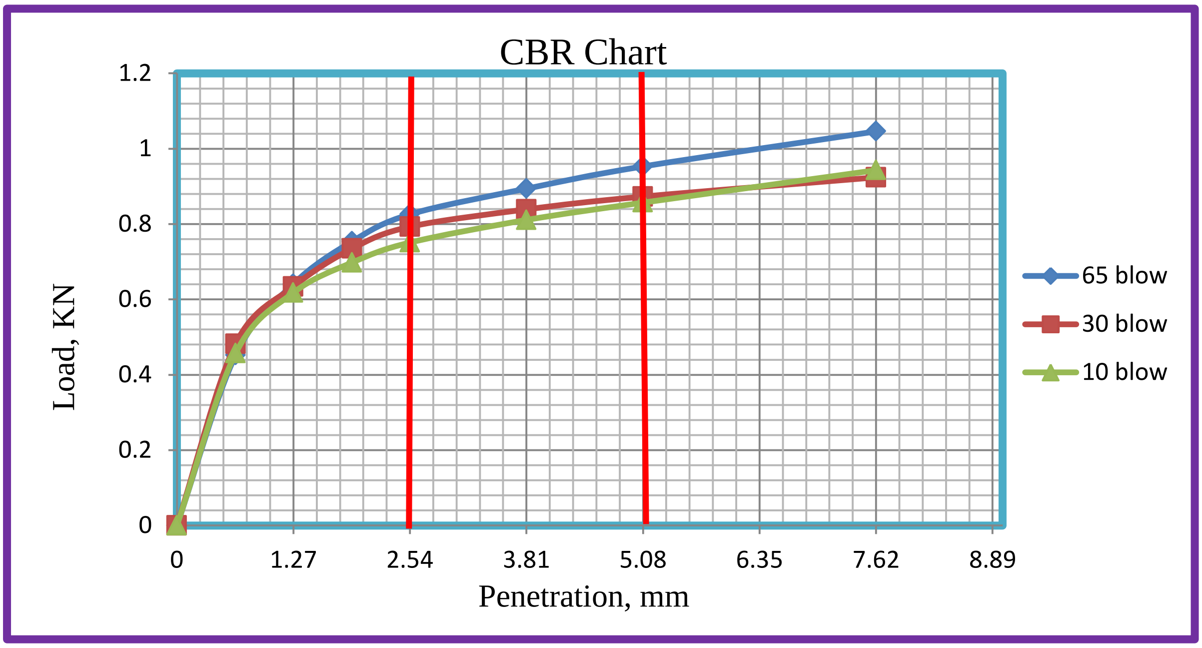
Modified Max.Dry Density g/cc	1.640	OMC %	16.9

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	0.00	0.96	0.00	1.09	0.00	1.37
01/03/2013	Final	1.12		1.27		1.59	

Dry Density at 95% of MDD:	1.558

No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %		% OF Compaction
10	29.5	1.345	5.63		82
30	29.0	1.572	5.96		96
65	12.4	1.740	6.21		106
CBR % at 95 % MDD			5.9	Swell %	1.09



3.9) 8% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		MN8	MN8	P85	P85	TP01	TP01
Mass of soil + Mould	g	10842.6	11013.2	10647.9	10842.1	10573.5	10819.3
Mass Mould	g	7041.2	7041.2	7056.5	7056.5	6785.6	6785.6
Mass of Soil	g	3801.4	3972	3591.4	3785.6	3787.9	4033.7
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.790	1.870	1.691	1.782	1.783	1.899
Dry density of soil	g/cc	1.588	1.639	1.405	1.420	1.271	1.331
Moisture Determination							
MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		49K	W-60	4AA	W56	85K	K-20
Mass of wet soil + Container	g	143.24	158.00	167.38	133.74	124.36	176.91
Mass of dry soil + Container	g	131.11	143.26	145.63	114.26	97.39	133.29
Mass of container	g	35.53	38.73	38.81	37.96	30.50	31.02

Mass of water	g	12.13	14.74	21.75	19.48	26.97	43.62
Mass of dry soil	g	95.58	104.53	106.82	76.30	66.89	102.27
Moisture content	%	12.69	14.10	20.36	25.53	40.32	42.65

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.624		0.64	0.587		0.64	0.548	
1.27	0.841		1.27	0.795		1.27	0.753	
1.91	0.945		1.91	0.904		1.91	0.876	
2.54	1.012	7.59	2.54	0.981	7.35	2.54	0.956	7.17
3.81	1.112		3.81	1.089		3.81	1.024	
5.08	1.202	6.01	5.08	1.174	5.87	5.08	1.086	5.43
7.62	1.291		7.62	1.269		7.62	1.143	

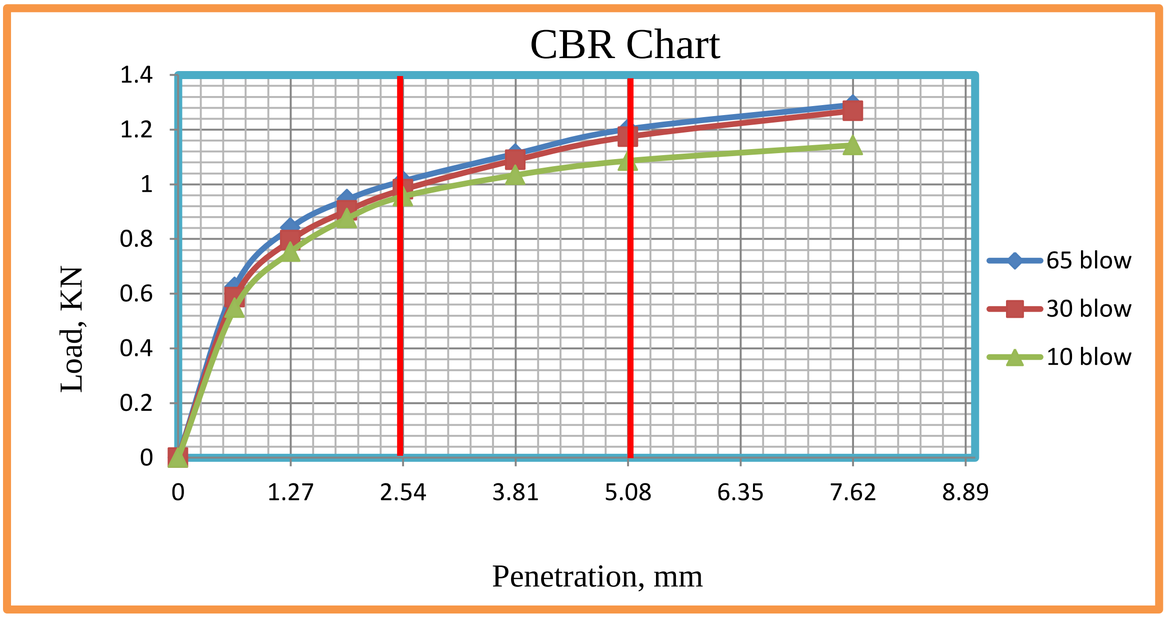
Modified Max.Dry Density g/cc	**1.590**	**OMC %**	**20.8**

Swell Determination

Date		**65 Blows**		**30 Blows**		**10 Blows**	
		Gauge rdg mm	**Swell in %**	**Gauge rdg mm**	**Swell in %**	**Gauge rdg mm**	**Swell in %**
27/02/2013	Initial	1.41	0.19	1.69	0.55	1.55	0.74
01/03/2013	Final	1.63		2.33		2.41	

Dry Density at 95% of MDD:				**1.511**
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**40.3**	**1.271**	**7.17**	**80**
30	**20.4**	**1.405**	**7.38**	**88**
65	**12.7**	**1.588**	**7.61**	**100**

CBR % at 95 % MDD	**7.5**	**Swell %**	**0.55**



3.11) 10% CA

DENSITY DETERMINATION						
SOAKING CONDITION	10 Blows		30 Blows		65 Blows	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
MOLD NUMBER	N5	N5	N7	N7	I65	I65
WEIGHT OF SOIL + MOLD g	10763.00	11133.40	10893.90	11231.20	10990.83	11228.40
WEIGHT OF MOLD g	6931.50	6931.50	6991.80	6991.80	6974.60	6974.60
WEIGHT OF SOIL g	3831.50	4201.90	3902.10	4239.40	4016.23	4253.80
VOLUME OF MOLD g/cc	2124.00	2124.00	2124.00	2124.00	2124.00	2124.00
WET DENSITY OF SOIL g/cc	1.80	1.98	1.84	2.00	1.89	2.00
DRY DENSITY OF SOIL g/cc	1.39	1.40	1.48	1.59	1.59	1.71

MOISTURE DETERMINATION									
SOAKING CONDITION	10 Blows			30 Blows			65 Blows		
	BEFORE	AFTER	AVG.	BEFORE	AFTER	AVG.	BEFORE	AFTER	AVG.
CONTAINER NUMBER	G19	ZE		A	E		P65	P67	
WET SOIL + CONTAINER g	162.80	192.64		169.80	169.74		149.72	190.61	
DRY SOIL + CONTAINER g	133.41	146.26		143.80	142.74		131.93	167.82	
WEIGHT OF WATER g	29.39	46.38		26.00	27.00		17.79	22.79	
WEIGHT OF CONTAINER g	34.22	33.05		37.03	37.91		37.75	35.53	
WEIGHT OF DRY SOIL g	99.19	113.21		106.77	104.83		94.18	132.29	
MOISTURE CONTENT %	29.63	40.97		24.35	25.76		18.89	17.23	

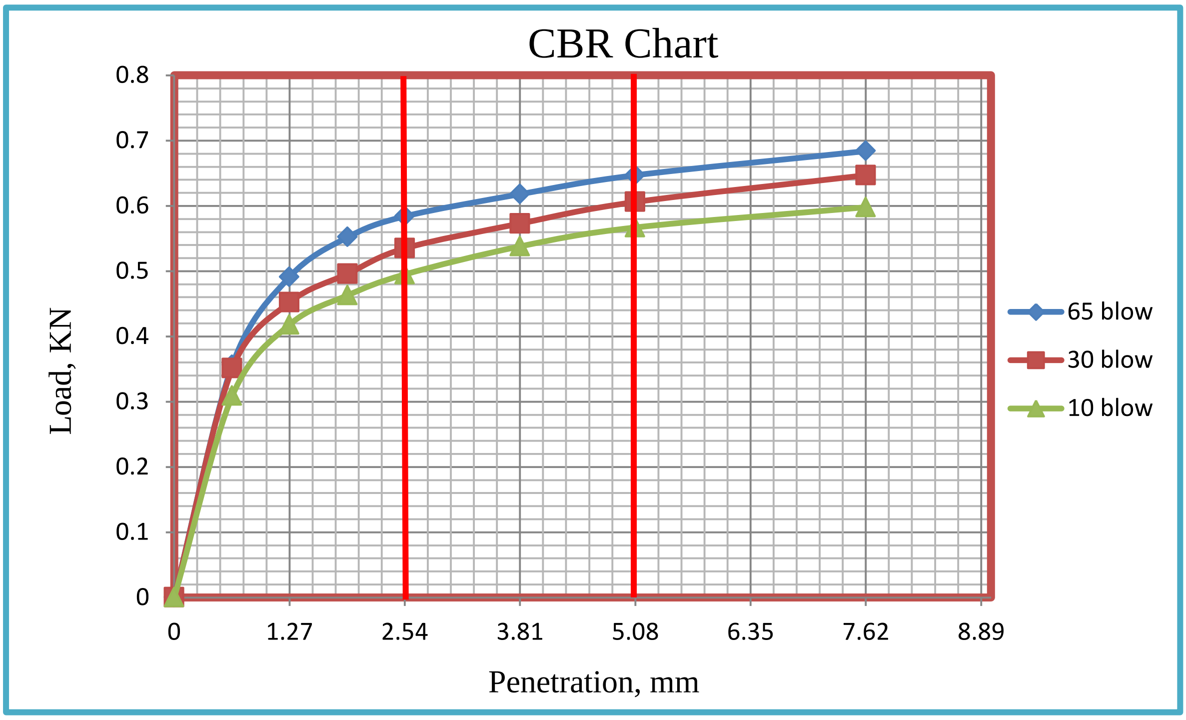
PENETRATION TEST DATA												
PENETRATION (mm)	10 Blows				30 Blows				65 Blows			
	DIAL RDG	LOAD (kn)	COR. LOAD(kn)	CBR %	DIAL RDG	LOAD (kn)	COR. LOAD(kn)	CBR %	DIAL RDG	LOAD (kn)	COR LOAD(kn)	CBR %
0		0.00				0.000				0.000		
0.64		0.309				0.351				0.356		
1.27		0.418				0.452				0.491		
1.91		0.463				0.496				0.552		
2.54		0.495		3.75		0.535		4.05		0.584		4.42
3.18												
3.81		0.538				0.573				0.618		
4.45												
5.08		0.567		2.84		0.606		3.03		0.647		3.24
7.62		0.598				0.647				0.684		

SWELL %			
Height of Specimen(mm)		**116.43**	
No.of BLOWS	**10**	**30**	**65**
RDG (BEFORE SOAKING)	0.00	0.00	0.00
RDG(AFTER SOAKING)	2.11	2.01	1.49
PERCENT SWELL	1.81	1.73	1.28
AVERAGE PERCENT SWELL			

MODIFIED PROCTOR : T 180, METHOD D			
MDD (g/cc)	1.620	OMC (%)	18.6

CBR Value at standard Force Factor					
Blow	**LOAD (KN)**		**CBR (%)**		**Swell %**
	2.54mm	5.08mm	2.54mm	5.08mm	
10	0.50	0.57	3.75	2.84	1.81
30	0.54	0.61	4.05	3.03	1.73
65	0.58	0.65	4.42	3.24	1.28

CBR Test summary value				
Blow	**Dry density**	**CBR%**	**Swell %**	**% of compaction**
10	1.392	3.75		85.90
30	1.477	4.05		91.20
65	1.590	4.42	1.73	98.18
95 % MDD	**1.539**	**CBR at 95 % MDD**	**4.3**	



3.12) 20% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N4	N4	N1	N1	N12	N12
Mass of soil + Mould	g	11166.35	11366.5	10986.37	11266.7	10842.3	11186.9
Mass Mould	g	7025	7025	6942	6942	7006.1	7006.1
Mass of Soil	g	4141.35	4341.5	4044.37	4324.7	3836.2	4180.8
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.950	2.044	1.904	2.036	1.806	1.968
Dry density of soil	g/cc	1.551	1.600	1.465	1.573	1.375	1.450

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P65	P1	10G	J41	2Q	E-12
Mass of wet soil + Container	g	169.10	151.50	139.54	161.27	170.18	121.32
Mass of dry soil + Container	g	142.25	126.81	111.42	131.97	137.84	99.34
Mass of container	g	37.75	37.81	17.60	32.50	34.59	37.90
Mass of water	g	26.85	24.69	28.12	29.30	32.34	21.98
Mass of dry soil	g	104.50	89.00	93.82	99.47	103.25	61.44
Moisture content	%	25.69	27.74	29.97	29.46	31.32	35.77

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — **Surcharge Weight:-4.55 KG**

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.454		0.64	0.473		0.64	0.452	
1.27	0.593		1.27	0.594		1.27	0.565	
1.91	0.674		1.91	0.654		1.91	0.618	
2.54	0.724	5.43	2.54	0.698	5.23	2.54	0.665	4.99
3.81	0.784		3.81	0.754		3.81	0.715	
5.08	0.833	4.17	5.08	0.805	4.03	5.08	0.758	3.79
7.62	0.895		7.62	0.872		7.62	0.816	

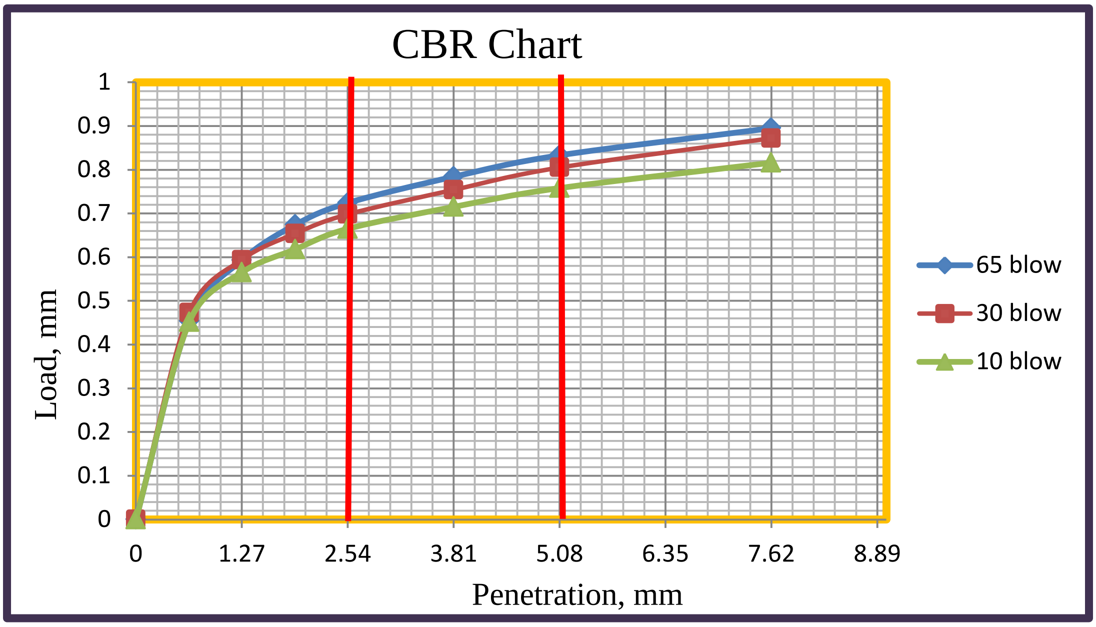
Modified Max.Dry Density g/cc	1.570	OMC %	20.4

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	2.64	0.79	5.3	1.69	4.33	1.90
01/03/2013	Final	3.56		7.27		6.54	

Dry Density at 95% of MDD:				1.492
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	31.3	1.375	4.99	88
30	30.0	1.465	5.25	93

65	**25.7**	**1.551**	**5.44**	**99**
CBR % at 95 % MDD		**5.3**	**Swell %**	**1.69**



3.13) 30% CA

DENSITY DETERMINATION						
SOAKING CONDITION	10 Blows		30 Blows		65 Blows	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
MOLD NUMBER	N2	N2	T4	T4	N10	N10
WEIGHT OF SOIL + MOLD g	10301.40	10874.20	10650.50	11106.50	10842.50	11264.20
WEIGHT OF MOLD g	6935.60	6935.60	6950.00	6950.00	6967.30	6967.30
WEIGHT OF SOIL g	3365.80	3938.60	3700.50	4156.50	3875.20	4296.90
VOLUME OF MOLD g/cc	2124.00	2124.00	2124.00	2124.00	2124.00	2124.00
WET DENSITY OF SOIL g/cc	1.58	1.85	1.74	1.96	1.82	2.02
DRY DENSITY OF SOIL g/cc	1.22	1.27	1.36	1.39	1.50	1.52

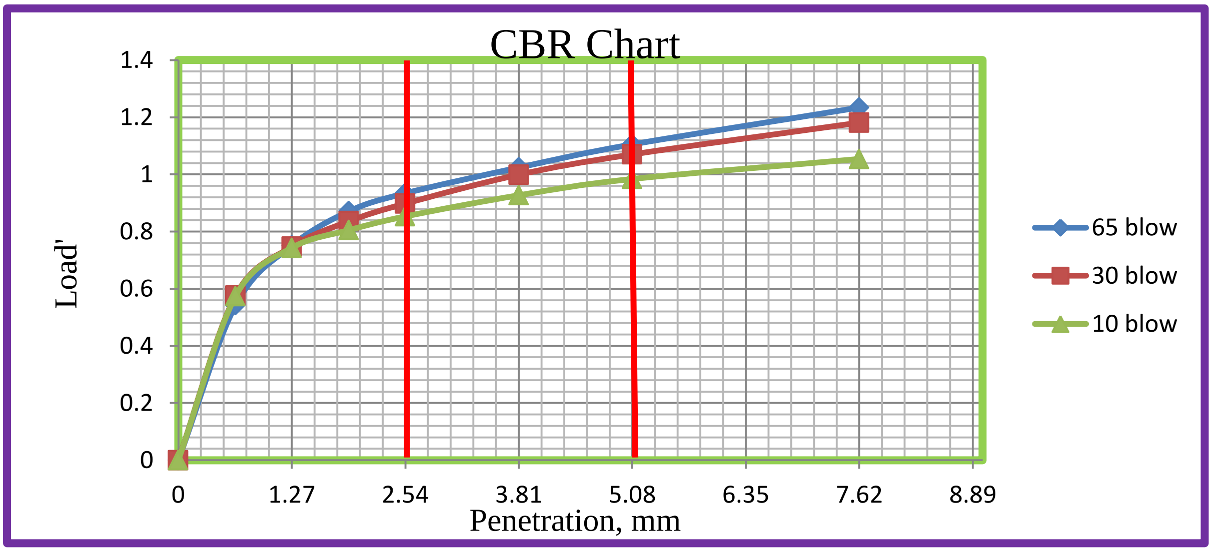
MOISTURE DETERMINATION									
SOAKING CONDITION	10 Blows			30 Blows			65 Blows		
	BEFORE	AFTER	AVG.	BEFORE	AFTER	AVG.	BEFORE	AFTER	AVG.
CONTAINER NUMBER	P10	A		G3T4	2		T5C2	P65	
WET SOIL + CONTAINER g	157.78	150.37		108.40	150.03		108.79	190.10	
DRY SOIL +	127.10	115.10		88.50	116.50		92.40	152.50	

CONTAINER g									
WEIGHT OF WATER g	30.68	35.27		19.90	33.53		16.39	37.60	
WEIGHT OF CONTAINER g	25.48	37.65		17.59	34.64		17.90	37.76	
WEIGHT OF DRY SOIL g	101.62	77.45		70.91	81.86		74.50	114.74	
MOISTURE CONTENT %	30.19	45.54		28.06	40.96		22.00	32.77	

`PENETRATION TEST DATA												
PENETRATION (mm)	10 Blows				30 Blows				65 Blows			
	DIAL RDG	LOAD (kn)	COR. LOAD(kn)	CBR %	DIAL RDG	LOAD (kn)	COR. LOAD(kn)	CBR %	DIAL RDG	LOAD (kn)	COR LOAD(kn)	CBR %
0		0.00				0.000				0.000		
0.64		0.574				0.576				0.542		
1.27		0.743				0.747				0.751		
1.91		0.805				0.836				0.871		
2.54		0.853		6.46		0.898		6.80		0.934		7.08
3.18												
3.81		0.927				0.999				1.024		
4.45												
5.08		0.984		4.92		1.070		5.35		1.105		5.53
7.62		1.054				1.181				1.234		

Height of Specimen(mm)	116.43		
No.of BLOWS	**10**	**30**	**65**
RDG (BEFORE SOAKING)	0.00	0.00	0.00
RDG(AFTER SOAKING)	1.38	1.16	1.05
PERCENT SWELL	1.19	1.00	0.90

Blow	**Dry density**	**CBR%**	**Swell %**	**% of compaction**
10	1.217	6.46		82
30	1.360	6.80		`92
65	1.495	7.08	1.00	101
95 % MDD	**1.406**	**CBR at 95 % MDD**	**6.9**	



3.14) 40% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N1	N1	N5	N5	I65	I65
Mass of soil + Mould	g	10811.3	11128.6	10736.8	11059.1	10597.4	10857.5
Mass Mould	g	6942	6942	6931.5	6931.5	6974.6	6974.6
Mass of Soil	g	3869.3	4186.6	3805.3	4127.6	3622.8	3882.9
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.822	1.971	1.792	1.943	1.706	1.828
Dry density of soil	g/cc	1.564	1.611	1.442	1.531	1.315	1.372

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		A-13	G-53	2Q	P67	G19	C150
Mass of wet soil + Container	g	149.70	158.52	132.54	130.27	178.74	110.64
Mass of dry soil + Container	g	133.28	134.84	113.42	107.46	145.68	87.37
Mass of container	g	33.58	28.73	34.59	22.79	34.27	17.32
Mass of water	g	16.42	23.68	19.12	22.81	33.06	23.27
Mass of dry soil	g	99.70	106.11	78.83	84.67	111.41	70.05
Moisture content	%	16.47	22.32	24.25	26.94	29.67	33.22

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.712		0.64	0.627		0.64	0.452	
1.27	0.984		1.27	0.864		1.27	0.684	
1.91	1.148		1.91	1.005		1.91	0.843	
2.54	1.267	9.50	2.54	1.097	8.22	2.54	0.947	7.10
3.81	1.432		3.81	1.213		3.81	1.091	
5.08	1.547	7.74	5.08	1.291	6.46	5.08	1.209	6.05
7.62	1.689		7.62	1.401		7.62	1.367	

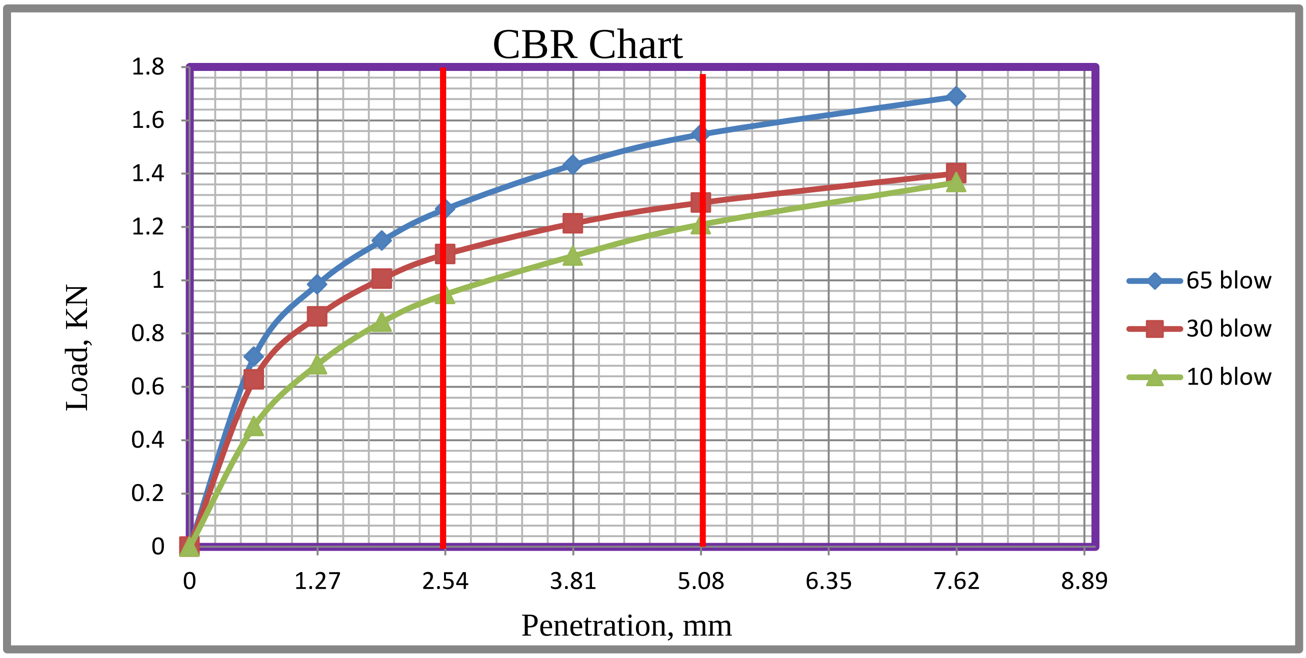
Modified Max.Dry Density g/cc	1.470	OMC %	25.5

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	1.58	0.65	3.4	0.75	3.90	1.81
01/03/2013	Final	2.34		4.27		6.01	

Dry Density at 95% of MDD:				1.397
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction

10	**29.7**	**1.315**	**7.10**	**89**
30	**24.3**	**1.442**	**8.25**	**98**
65	**16.5**	**1.564**	**9.53**	**106**
CBR % at 95 % MDD		**7.8**	**Swell %**	**0.75**



3.15) 50% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N12	N12	N4	N4	N1	N1
Mass of soil + Mould	g	10750.6	10928.7	10634.8	10881.6	10421.5	10687.5
Mass Mould	g	7006.1	7006.1	7025	7025	6942	6942
Mass of Soil	g	3744.5	3922.6	3609.8	3856.6	3479.5	3745.5
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.763	1.847	1.700	1.816	1.638	1.763
Dry density of soil	g/cc	1.556	1.566	1.410	1.429	1.240	1.290

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G3T4	2	P1	E	ZE	A
Mass of wet soil + Container	g	128.43	164.23	157.54	168.31	169.24	140.39
Mass of dry soil + Container	g	115.43	144.51	137.12	140.55	136.15	112.67
Mass of container	g	17.59	34.64	37.81	37.96	33.05	37.03
Mass of water	g	13.00	19.72	20.42	27.76	33.09	27.72
Mass of dry soil	g	97.84	109.87	99.31	102.59	103.10	75.64
Moisture content	%	13.29	17.95	20.56	27.06	32.10	36.65

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.513		0.64	0.512		0.64	0.432	
1.27	0.721		1.27	0.691		1.27	0.635	
1.91	0.819		1.91	0.786		1.91	0.716	
2.54	0.879	6.59	2.54	0.835	6.26	2.54	0.764	5.73
3.81	0.934		3.81	0.883		3.81	0.826	
5.08	0.967	4.84	5.08	0.924	4.62	5.08	0.857	4.29
7.62	1.021		7.62	0.961		7.62	0.914	

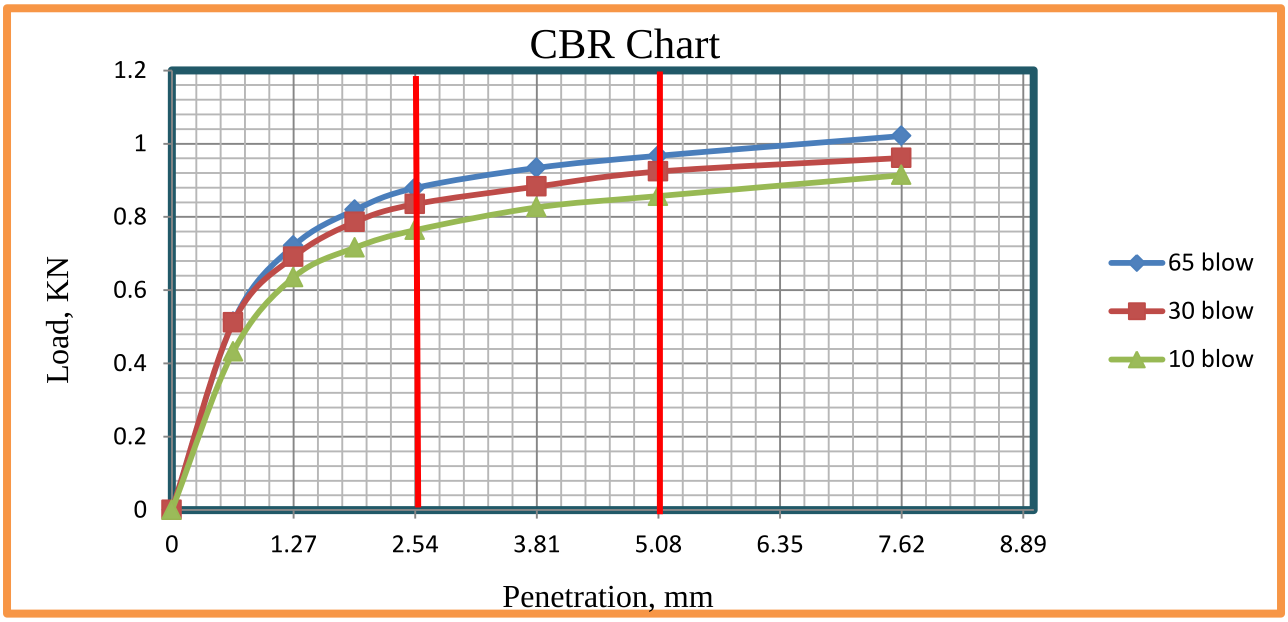
Modified Max.Dry Density g/cc	1.560	OMC %	17.2

Swell Determination

Date		65 Blows Gauge rdg mm	Swell in %	30 Blows Gauge rdg mm	Swell in %	10 Blows Gauge rdg mm	Swell in %
27/02/2013	Initial	1.08	1.17	3.61	1.30	2.43	1.36
01/03/2013	Final	2.44		5.12		4.01	

Dry Density at 95% of MDD:				1.482
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**32.1**	**1.240**	**5.73**	**79**
30	**20.6**	**1.410**	**6.28**	**90**
65	**13.3**	**1.556**	**6.61**	**100**

CBR % at 95 % MDD	6.4	Swell %	1.30

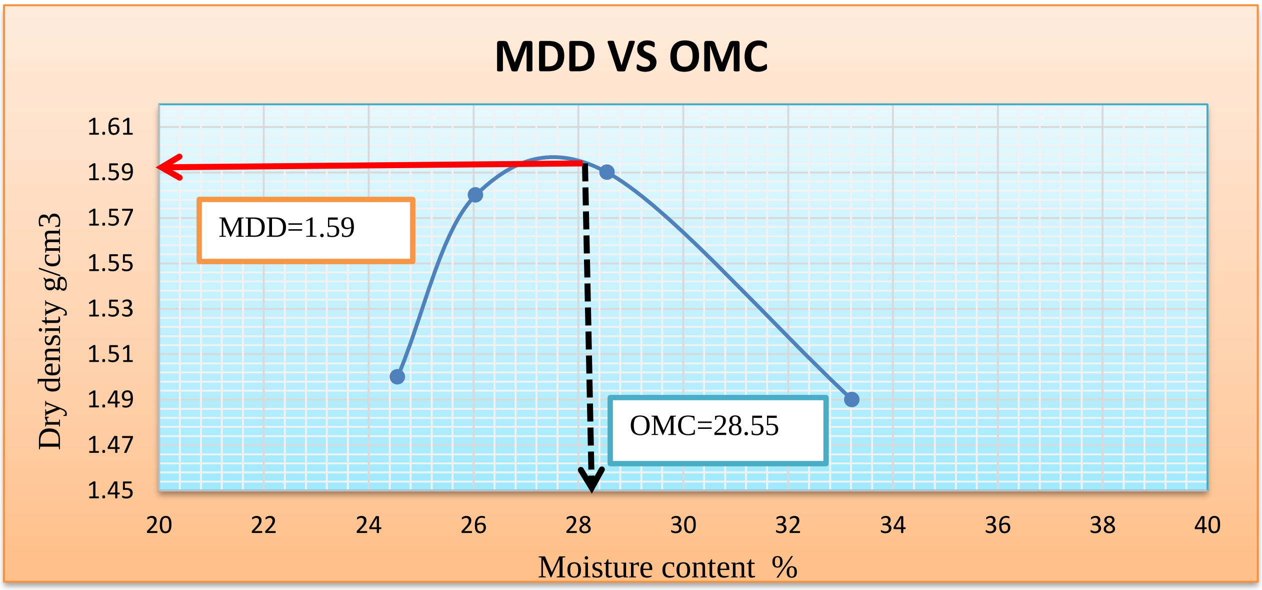


APPENDAX D: Laboratory test result of stabilizing MS Soil Sample using soil-CA, soil-GSA and soil-BF.

1) **Compaction test Result**

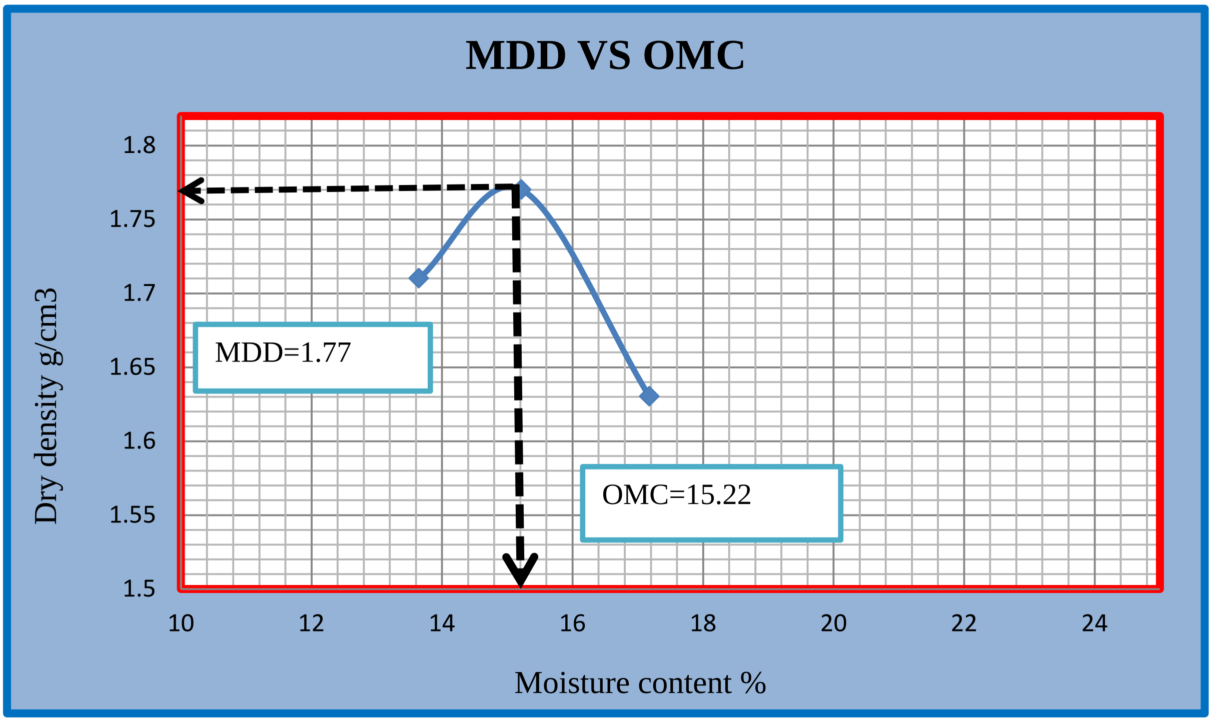
1.1) 1% BF

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	270	450	630	810	
Mass of Mold+Wet soil(gm)(A)	10856.3	11129.3	11225.6	11112.4	
Mass of Mold(gm)(B)	6569.1	6569.1	6569.1	6569.1	
Mass of Wet Soil(gm)A-B=C	4287.2	4560.2	4656.5	4543.3	
Volume of Mold cm^3(D)	2285	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.87	2.00	2.04	1.99	
Moisture Content Determination					**NMC**
Container Code .	A2	P01	4P	10L	B-06
Mass of Wet soil+Container(gm)(F)	141.8	114.2	98.7	102.3	122.9
Mass of dry soil+container(gm)(G)	121.3	93.87	80.2	82.1	113.4
Mass of container(gm)(H)	37.8	15.8	15.4	21.3	18.5
Mass of moisture(gm)F-G=(I)	20.5	20.33	18.5	20.2	9.5
Mass of Dry soil(gm)G-H=(J)	83.5	78.07	64.8	60.8	94.9
Moisture content % (I/J)*100=K	**24.55**	**26.04**	**28.55**	**33.22**	**10.01**
Dry Density gm/cm^3 E/(100+K)*100	**1.5**	**1.58**	**1.59**	**1.49**	



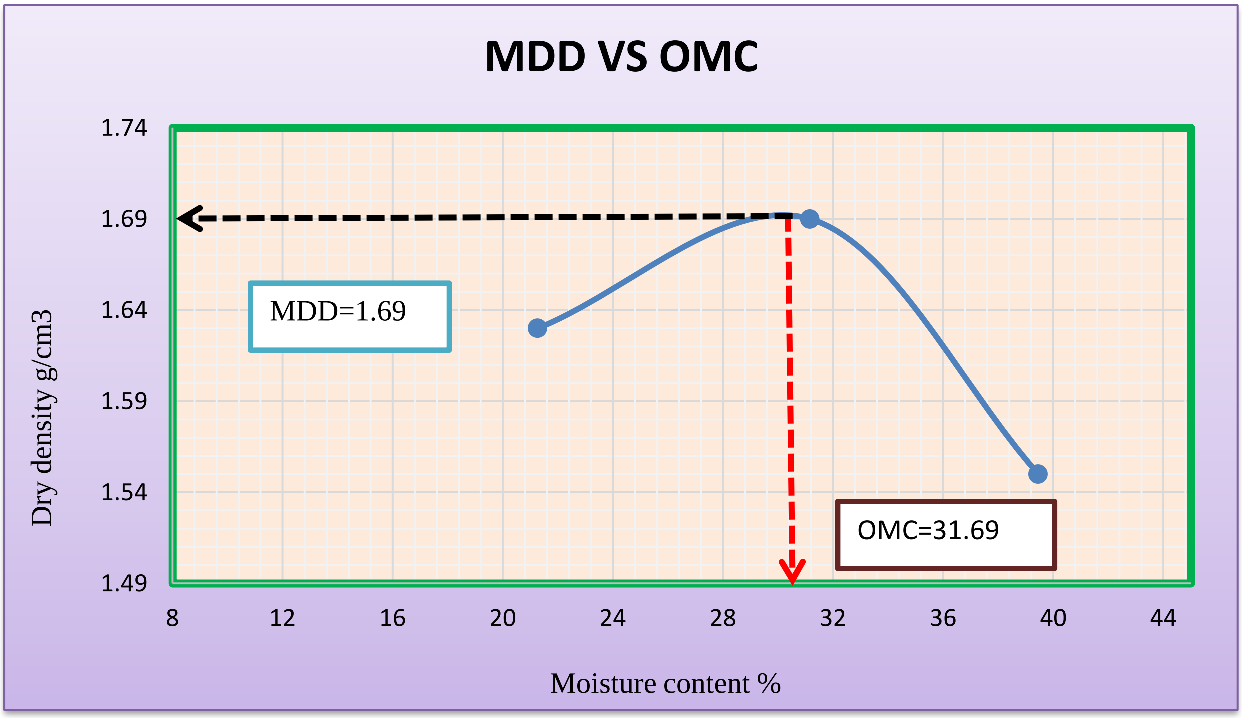
1.2) 1.5% BF

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	450	630	810	
Mass of Mold+Wet soil(gm)(A)	10978.4	11189.64	10906.1	
Mass of Mold(gm)(B)	6533.3	6533.3	6533.3	
Mass of Wet Soil(gm)A-B=C	4445.1	4656.34	4372.8	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.95	2.04	1.91	
Moisture Content Determination				**NMC**
Container Code .	G4	A15	LM6	E-12
Mass of Wet soil+Container(gm)(F)	155.4	144.53	168.43	195.63
Mass of dry soil+container(gm)(G)	140.36	130.86	158.74	184.3
Mass of container(gm)(H)	30.15	41.07	38.63	38.65
Mass of moisture(gm)F-G=(I)	15.04	13.67	20.64	11.33
Mass of Dry soil(gm)G-H=(J)	110.21	89.79	120.11	145.65
Moisture content % (I/J)*100=K	**13.65**	**15.22**	**17.18**	**7.77**
Dry Density gm/cm^3 E/(100+K)*100	**1.71**	**1.77**	**1.63**	



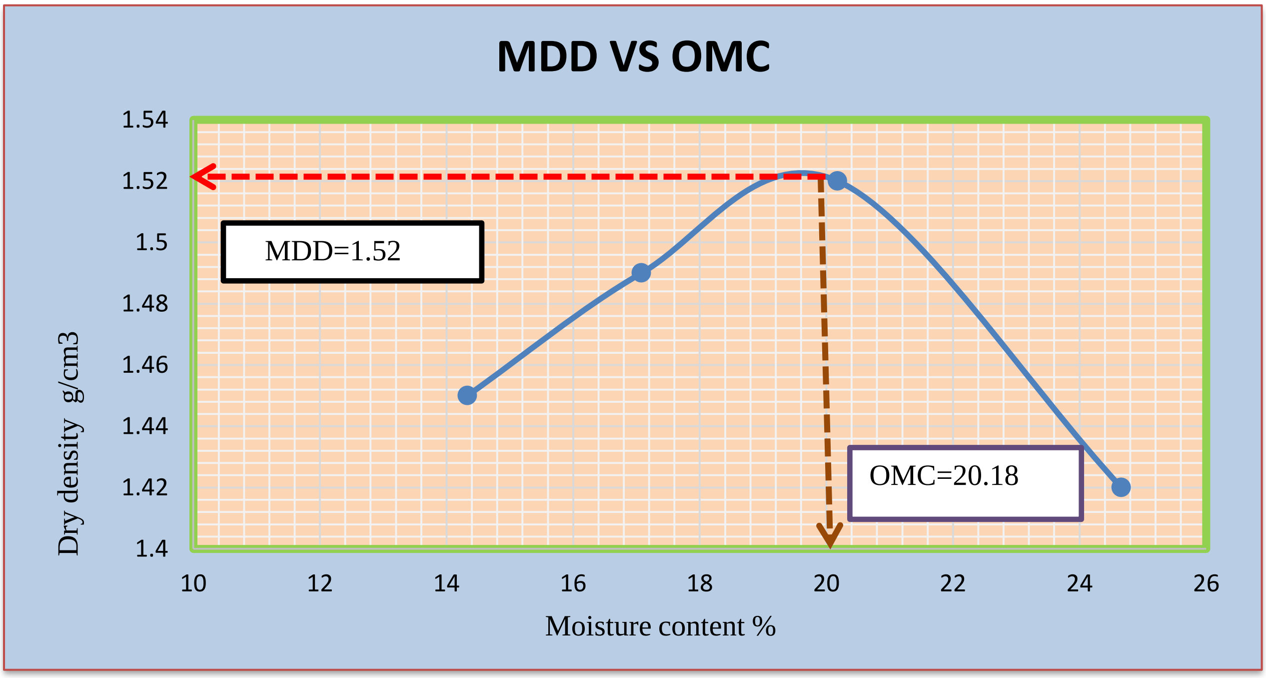
1.3) 2% BF

Density Determination				
Test No.	1	2	3	
Mass of sample (gm)	4500	4500	4500	
Water Added(cc)	380	550	730	
Mass of Mold+Wet soil(gm)(A)	10559.6	11112.3	10984.6	
Mass of Mold(gm)(B)	6054.3	6054.3	6054.3	
Mass of Wet Soil(gm)A-B=C	4505.3	5058	4930.3	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.97	2.21	2.16	
Moisture Content Determination				**NMC**
Container Code .	E-12	G19	F	P65
Mass of Wet soil+Container(gm)(F)	166.3	152.9	114.8	178.9
Mass of dry soil+container(gm)(G)	143.9	126.39	92.7	163.4
Mass of container(gm)(H)	38.6	41.3	36.7	33.5
Mass of moisture(gm)F-G=(I)	22.4	26.51	22.1	15.5
Mass of Dry soil(gm)G-H=(J)	105.3	85.09	56	129.9
Moisture content % (I/J)*100=K	**21.27**	**31.16**	**39.46**	**11.93**
Dry Density gm/cm^3 E/(100+K)*100	**1.63**	**1.69**	**1.55**	



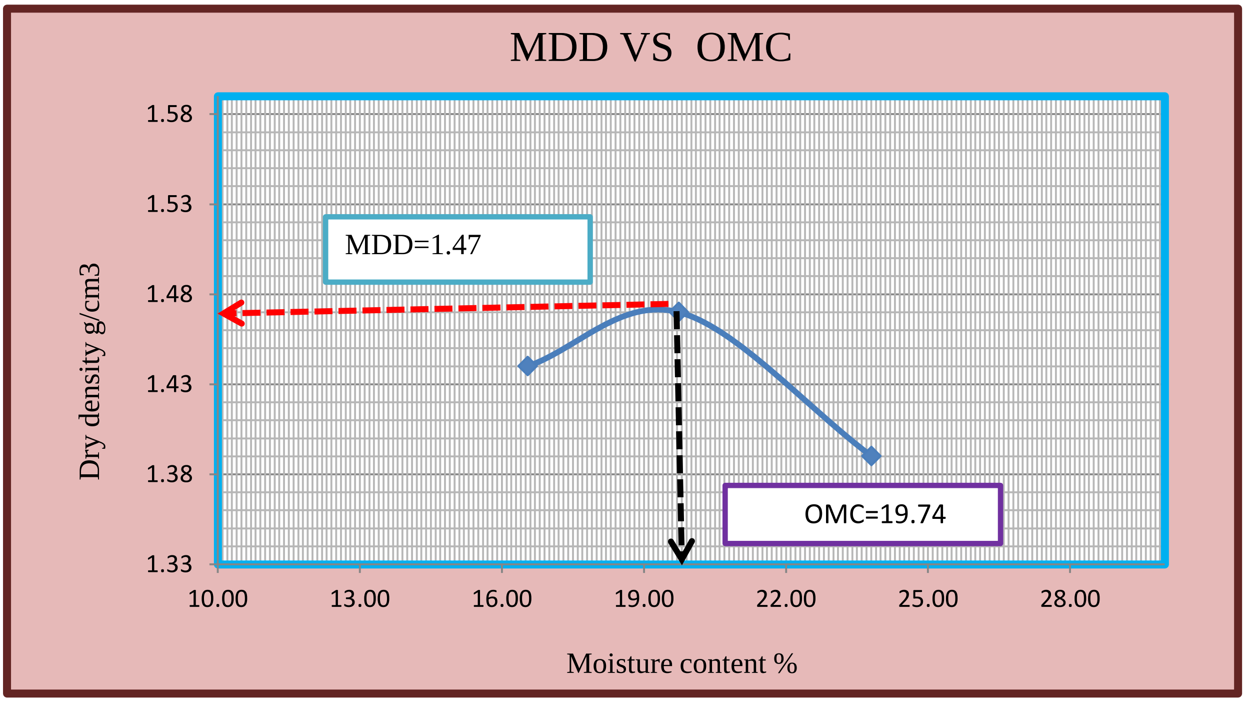
1.4) 2.5% BF

Density Determination					
Test No.	1	2	3	4	
Mass of sample (gm)	4500	4500	4500	4500	
Water Added(cc)	380	550	730	910	
Mass of Mold+Wet soil(gm)(A)	10382.9	10546.3	10736.8	10623	
Mass of Mold(gm)(B)	6569.1	6569.1	6569.1	6569.1	
Mass of Wet Soil(gm)A-B=C	3813.8	3977.2	4167.7	4054.3	
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00	2285.00	
Bulk Density gm/cm^3 C/D=(E)	1.67	1.74	1.82	1.77	
Moisture Content Determination					NMC
Container Code .	C-54	AB-36	C4	D4	E-12
Mass of Wet soil+Container(gm)(F)	141.56	123.74	148.63	127.39	195.63
Mass of dry soil+container(gm)(G)	127.85	109.6	129.86	106.3	184.3
Mass of container(gm)(H)	32.15	26.8	36.85	20.76	38.65
Mass of moisture(gm)F-G=(I)	13.71	14.14	18.77	21.09	11.33
Mass of Dry soil(gm)G-H=(J)	95.7	82.8	93.01	85.54	145.65
Moisture content % (I/J)*100=K	**14.33**	**17.08**	**20.18**	**24.66**	**7.77**
Dry Density gm/cm^3 E/(100+K)*100	**1.46**	**1.49**	**1.52**	**1.42**	



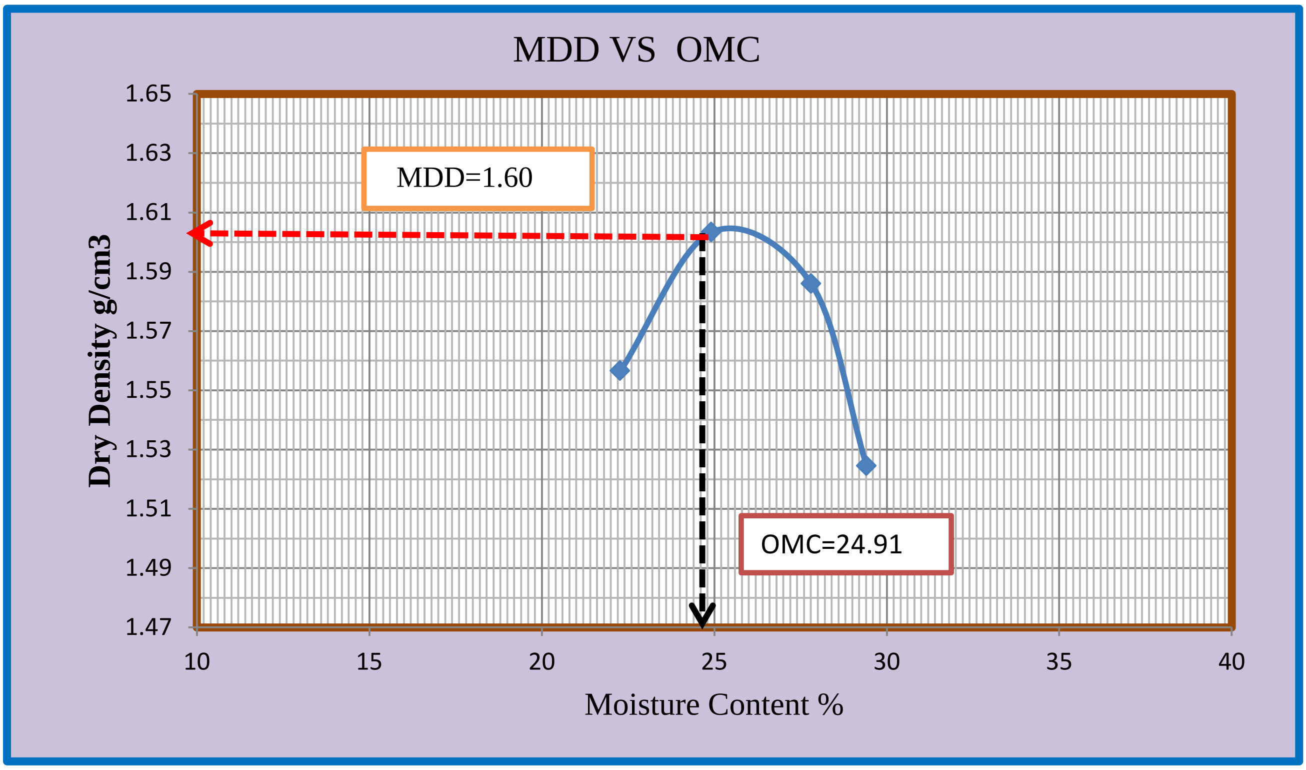
1.5) 3% BF

Density Determination			
Test No.	1	2	3
Mass of sample (gm)	4500	4500	4500
Water Added(cc)	380	550	730
Mass of Mold+Wet soil(gm)(A)	10347.6	10526.7	10445.9
Mass of Mold(gm)(B)	6513.4	6513.4	6513.4
Mass of Wet Soil(gm)A-B=C	3834.16	4013.3	3932.5
Volume of Mold cm^3(D)	2285.00	2285.00	2285.00
Bulk Density gm/cm^3 C/D=(E)	1.68	1.76	1.72
Moisture Content Determination			
Container Code .	F35	G23	B
Mass of Wet soil+Container(gm)(F)	127.36	151.32	187.96
Mass of dry soil+container(gm)(G)	113.6	131.56	158.45
Mass of container(gm)(H)	30.45	31.45	34.5
Mass of moisture(gm)F-G=(I)	13.76	19.76	29.51
Mass of Dry soil(gm)G-H=(J)	83.15	100.11	123.95
Moisture content % (I/J)*100=K	**16.55**	**19.74**	**23.81**
Dry Density gm/cm^3 E/(100+K)*100	**1.44**	**1.47**	**1.39**



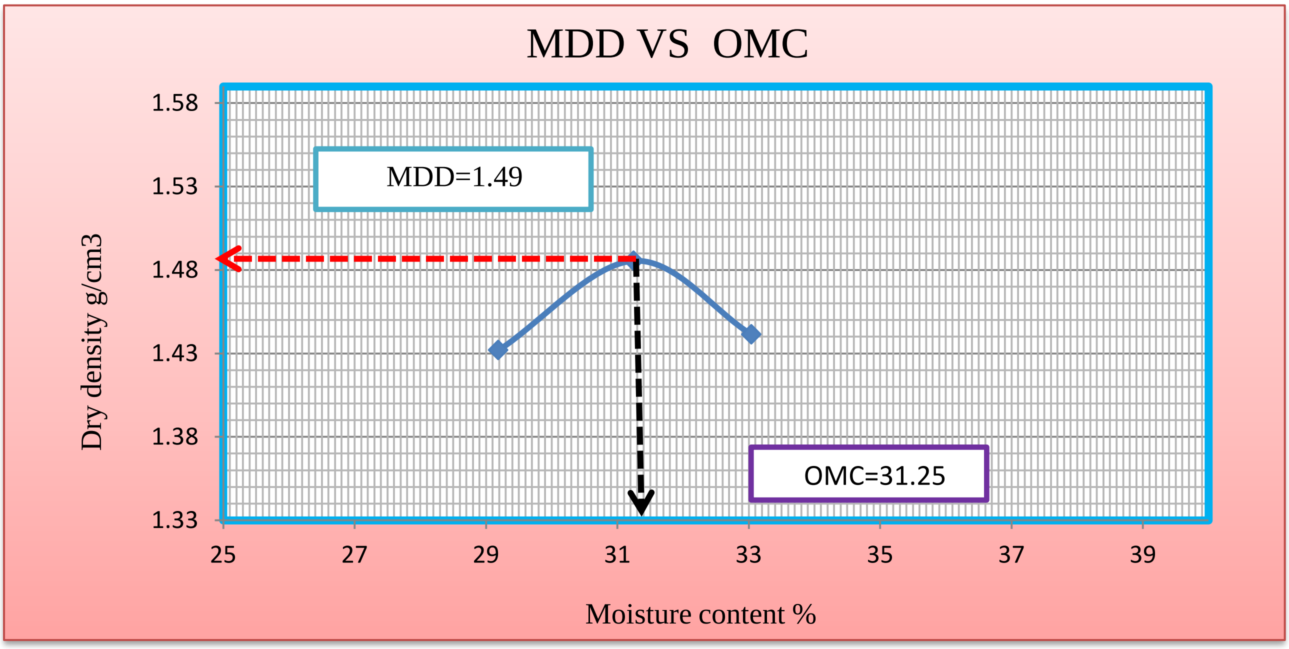
1.6) 4% GSA

DENSITY	TRIAL NUMBER	1	2	3	4	
	WEIGHT OF SOIL + MOLD (g) W_1	6758.49	6,970	7,021.60	6,907	
	WEIGHT OF MOLD (g) W_2	2716.2	2716.2	2716.2	2716.2	
	VOLUME OF MOLD (Cm^3) V	2124	2124	2124	2124	
	WEIGHT OF WET SOIL (g) $W_3 = W_1-W_2$	4042.29	4,254	4,305	4,190	
	WET DENSITY OF SOIL (g/Cm^3) $W_d = W_3/V$	1.90	2.00	2.03	1.97	
MOISTURE	CONTAINER NUMBER	A	P65	M10	C86	
	WET SOIL + CONTAINER (g) a	159.78	176.6	121.3	140.7	
	DRY SOIL + CONTAINER (g) b	137.42	148.9	99.0	117.1	
	WEIGHT OF CONTAINER (g) c	37.03	37.8	18.85	36.9	
	WEIGHT OF WATER (g) d = a-b	22.36	27.7	22.3	23.6	
	WEIGHT OF DRY SOIL (g) e =b-c	100.39	111.2	80.2	80.2	
	MOISTURE CONTENT (%) m= (d/e)*100	**22.27**	24.91	27.81	29.41	
DRY DENSITY OF SOIL (g/Cm3) $D_d = W_d/(100+m)*100$		**1.56**	1.60	1.59	1.52	



1.7) 8% GSA

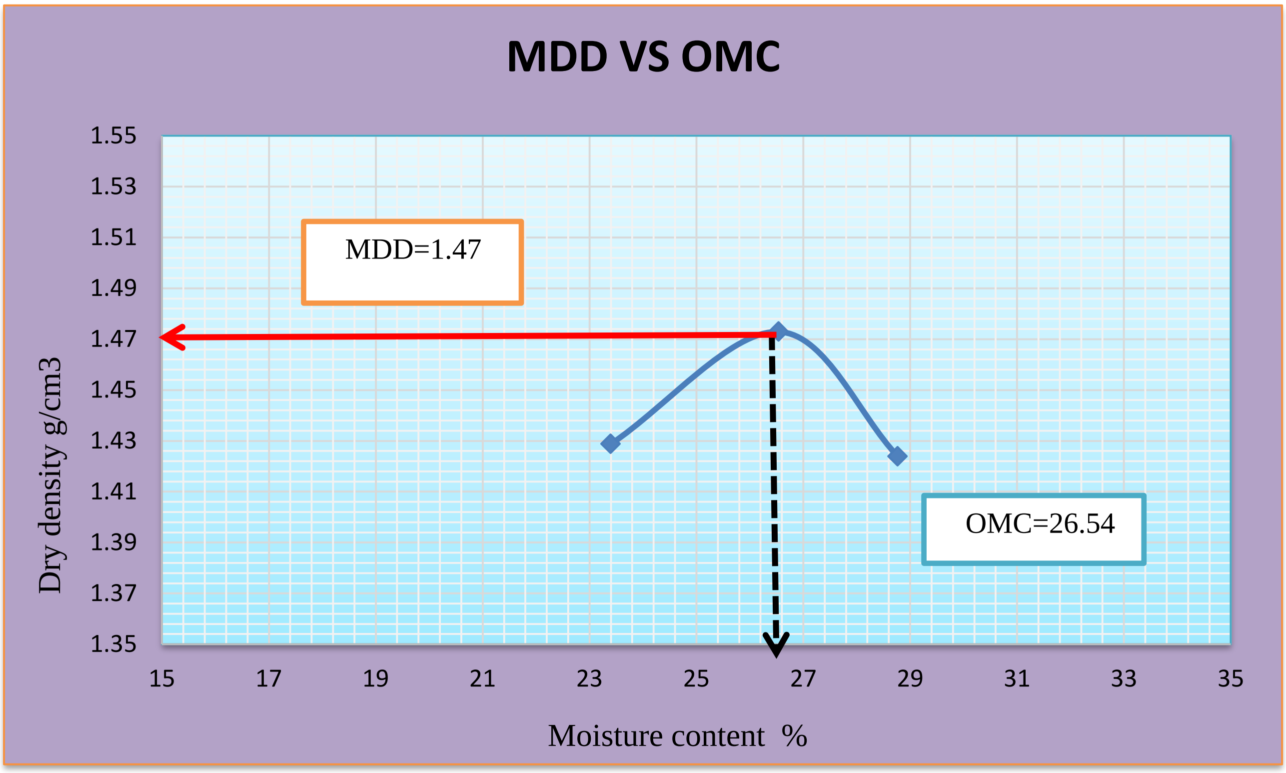
DENSITY	TRIAL NUMBER	1	2	3	
	WEIGHT OF SOIL + MOLD (g) W_1	6719.6	6931.56	6,863.18	
	WEIGHT OF MOLD (g) W_2	2790.5	2790.5	2790.5	
	VOLUME OF MOLD (Cm^3) V	2124	2124	2124	
	WEIGHT OF WET SOIL (g) $W_3 = W_1 - W_2$	3929.1	4141.06	4,073	
	WET DENSITY OF SOIL (g/Cm^3) $W_d = W_3/V$	1.85	1.95	1.92	
MOISTURE	CONTAINER NUMBER	F12	ZE	2WE	
	WET SOIL + CONTAINER (g) a	156.94	160.29	183.9	
	DRY SOIL + CONTAINER (g) b	129.5	130	146.9	
	WEIGHT OF CONTAINER (g) c	35.5	33.07	34.8	
	WEIGHT OF WATER (g) d = a-b	27.44	30.29	37.1	
	WEIGHT OF DRY SOIL (g) e =b-c	94	96.93	112.1	
	MOISTURE CONTENT (%) m= (d/e)*100	29.19	31.25	33.04	
DRY DENSITY OF SOIL (g/Cm3) $D_d = W_d/(100+m)*100$		1.43	1.49	1.44	



1.8) 10% GSA

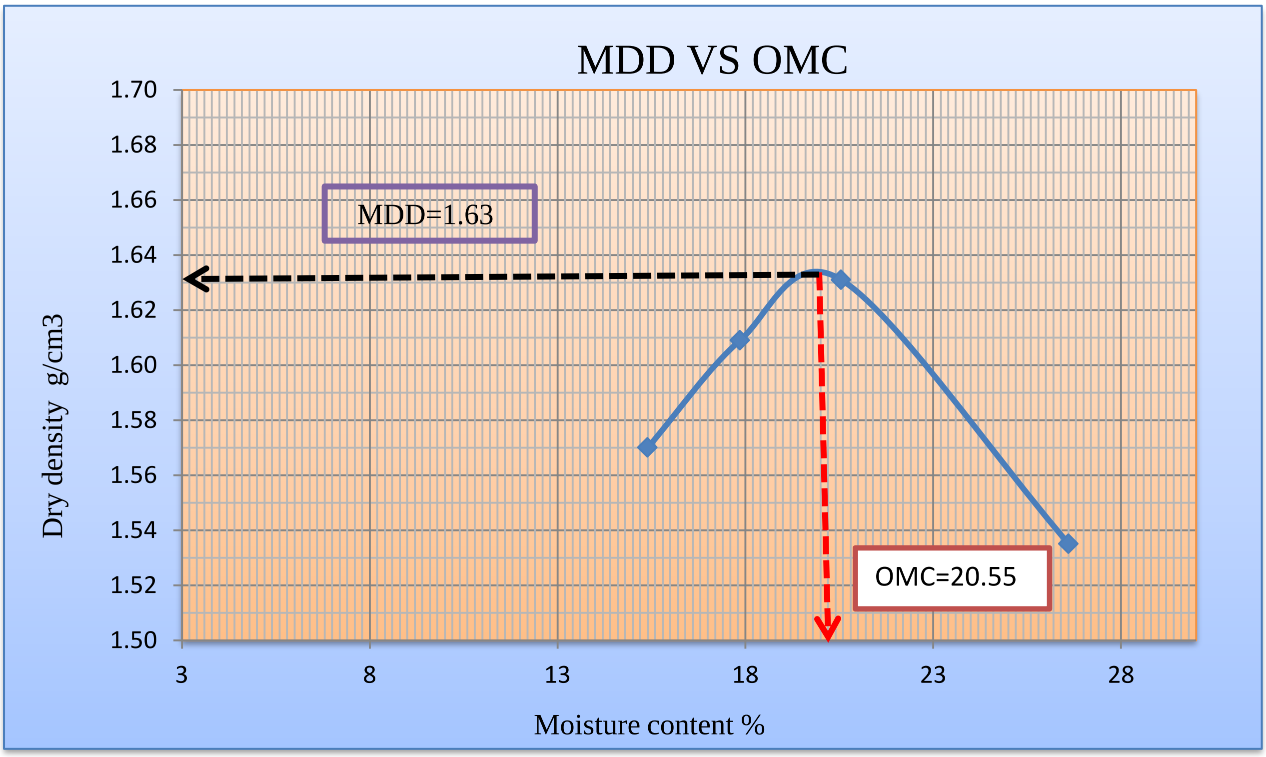
DENSITY	TRIAL NUMBER	1	2	3	
	WEIGHT OF SOIL + MOLD (g) W_1	6620.1	6834.24	6,769.68	
	WEIGHT OF MOLD (g) W_2	2875.4	2875.4	2875.4	

	VOLUME OF MOLD (Cm^3) V	2124	2124	2124	
	WEIGHT OF WET SOIL (g) $W_3 = W_1-W_2$	3744.70	3958.84	3,894	
	WET DENSITY OF SOIL (g/Cm^3) $W_d = W_3/V$	1.76	1.86	1.83	
MOISTURE	CONTAINER NUMBER	A	E	P15	
	WET SOIL + CONTAINER (g) a	149.29	180.5	143.0	
	DRY SOIL + CONTAINER (g) b	128	150.6	118.5	
	WEIGHT OF CONTAINER (g) c	37.01	37.95	33.5	
	WEIGHT OF WATER (g) d = a-b	21.29	29.9	24.5	
	WEIGHT OF DRY SOIL (g) e =b-c	90.99	112.65	85.0	
	MOISTURE CONTENT (%) m= (d/e)*100	23.40	26.54	28.77	
DRY DENSITY OF SOIL (g/Cm3) $D_d = W_d/(100+m)*100$		1.43	1.47	1.42	



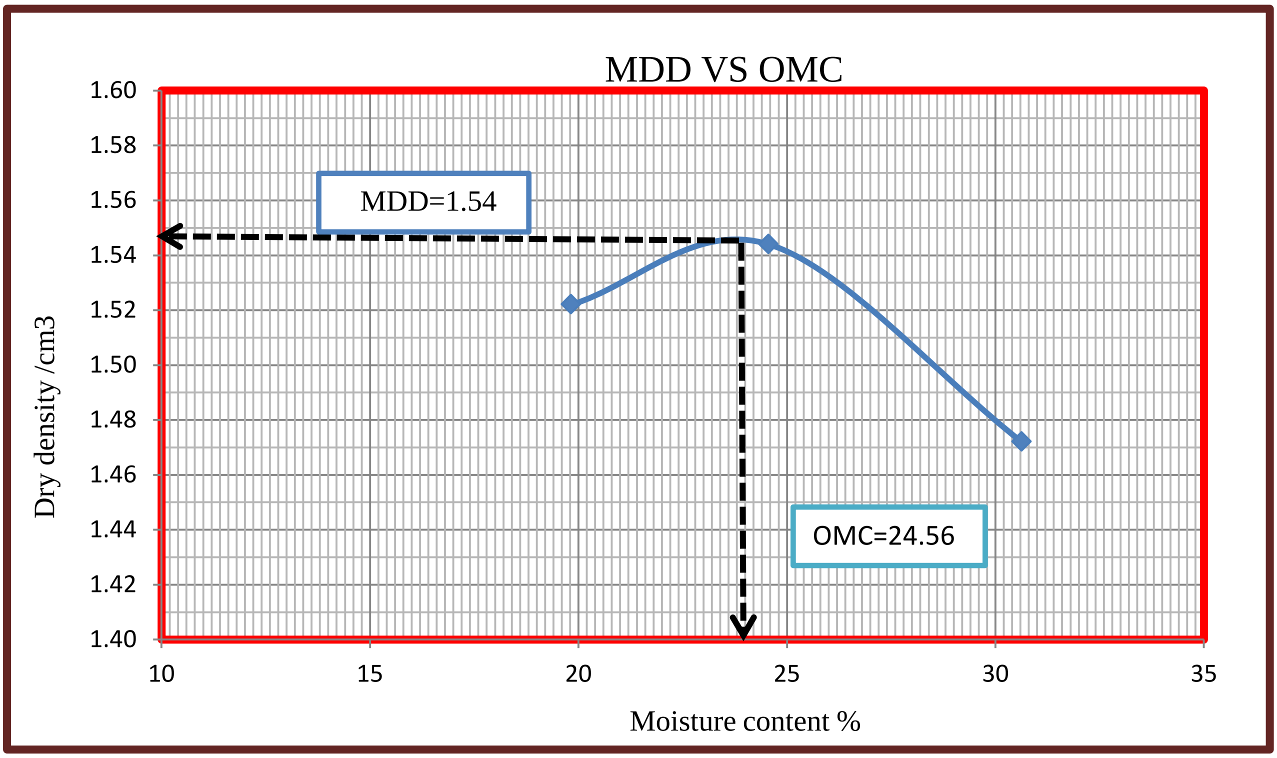
1.9) 10% CA

DENSITY	TRIAL NUMBER	1	2	3	4	5
	WEIGHT OF SAMPLE (g)	4500	4500	4500	4500	
	WATER ADDED (%)	550.0	730.0	910.0	1090.0	
	WEIGHT OF Mold	2624.14	2624.14	2624.14	2650	
	WEIGHT OF SOIL (g)	3847.49	4027.86	4176.98	4127	
	VOLUME OF MOLD	2124	2124	2124	2124	
	Wet DENSITY OF Soil (cc)	1.811	1.896	1.967	1.943	NMC
MOISTURE	CONTAINER NUMBER	AB	P12	KL10	U10	S-10
	WET SOIL + CONTAINER (g)	188.91	116.53	196.23	174.39	140.63
	DRY SOIL + CONTAINER (g)	167.85	101.73	169.81	145.23	128.39
	WEIGHT OF WATER (g)	21.06	14.80	26.42	29.16	12.24
	WEIGHT OF CONTAINER (g)	31.05	18.85	41.25	35.64	31.05
	WEIGHT OF DRY SOIL (g)	136.80	82.88	128.56	109.59	97.34
	MOISTURE CONTENT (%)	15.40	17.86	20.55	26.61	12.57
	DRY DENSITY OF Soil (cc)	1.570	1.609	1.631	1.535	



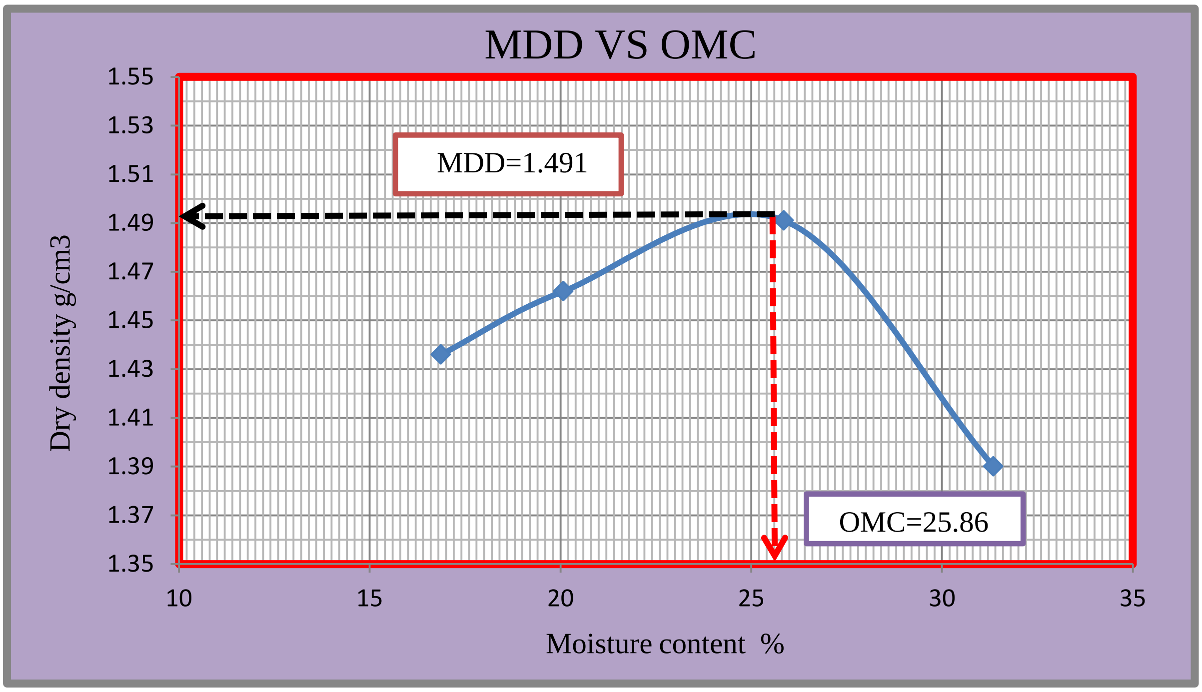
1.10) 20% CA

DENSITY	TRIAL NUMBER	1	2	3	4
	WEIGHT OF SAMPLE	4500	4500	4500	
	WATER ADDED	700.0	980.0	1160.0	
	WEIGHT OF SOIL + MOLD (g)	6556.94	6768.39	6639.61	
	WEIGHT OF MOLD (g)	2683.01	2683.27	2683.27	
	WEIGHT OF SOIL (g)	3873.93	4085.12	3956.34	
	VOLUME OF MOLD (cc)	2124	2124	2124	
	Wet DENSITY OF SOIL (g/cc)	1.824	1.923	1.863	
MOISTURE	CONTAINER NUMBER	DE	M10	A11	
	WET SOIL + CONTAINER (g)	170.23	123.67	143.86	
	DRY SOIL + CONTAINER (g)	148.73	103.00	118.37	
	WEIGHT OF WATER (g)	21.50	20.67	25.49	
	WEIGHT OF CONTAINER (g)	40.32	18.85	35.16	
	WEIGHT OF DRY SOIL (g)	108.41	84.15	83.21	
	MOISTURE CONTENT (%)	19.83	24.56	30.63	
	DRY DENSITY OF SOIL (g/cc)	1.522	1.544	1.426	



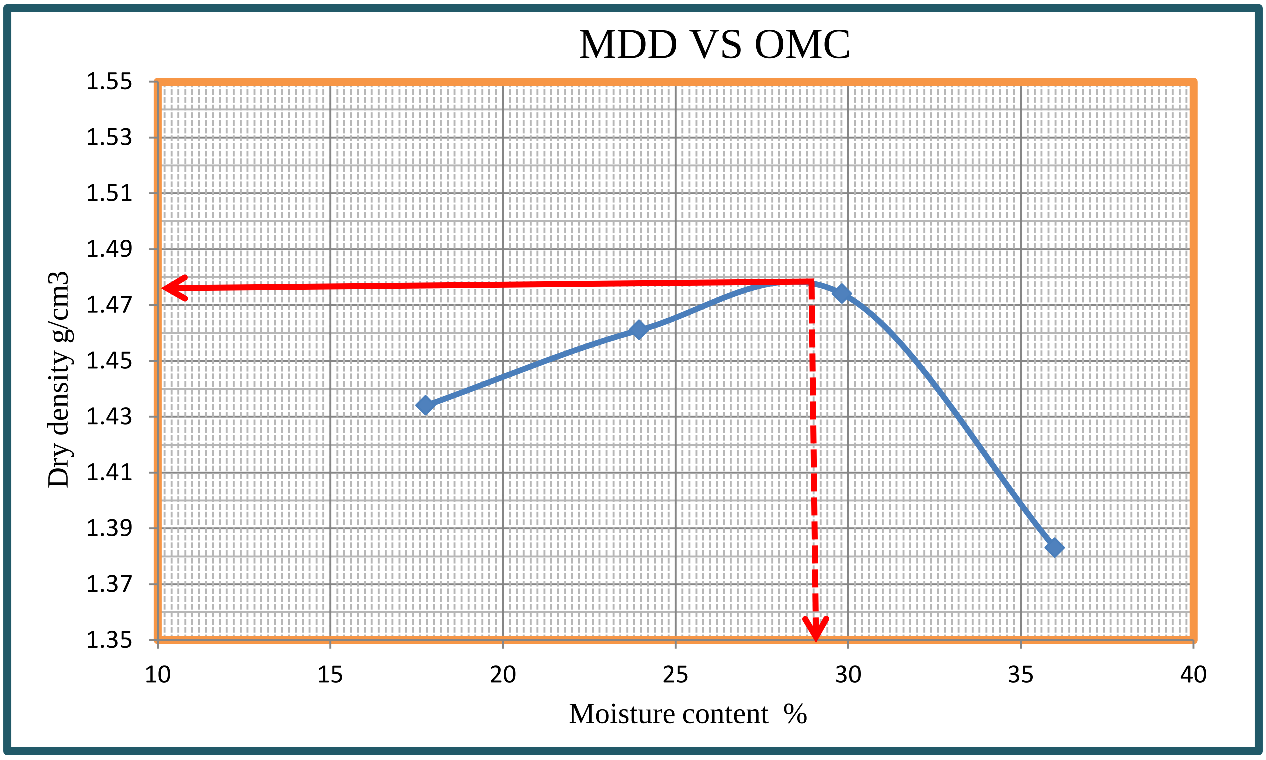
1.11) 30% CA

	TRIAL NUMBER	1	2	3	4	5
DENSITY	WEIGHT OF SAMPLE	4500	4500	4500	4500	
	WATER ADDED	570.0	750.0	930.0	1110.0	
	WEIGHT OF SOIL + MOLD (g)	6271.49	6442.39	6692.51	6584	
	WEIGHT OF MOLD（g）	2706.5	2706.5	2706.5	2706.5	
	WEIGHT OF SOIL（g）	3564.99	3735.89	3986.01	3878	
	VOLUME OF MOLD（cc）	2124	2124	2124	2124	
	Wet DENSITY OF SOIL（g/cc）	1.678	1.759	1.877	1.826	
MOISTURE	CONTAINER NUMBER	AW	8KO	O-12	K-20	
	WET SOIL + CONTAINER (g)	155.96	171.42	133.67	169.38	
	DRY SOIL + CONTAINER (g)	138.67	148.63	113.64	138.36	
	WEIGHT OF WATER (g)	17.29	22.79	20.03	31.02	
	WEIGHT OF CONTAINER (g)	36.19	35.16	36.19	39.40	
	WEIGHT OF DRY SOIL (g)	102.48	113.47	77.45	98.96	
	MOISTURE CONTENT（%）	16.87	20.08	25.86	31.35	
	DRY DENSITY OF SOIL（g/cc）	1.436	1.465	1.491	1.390	



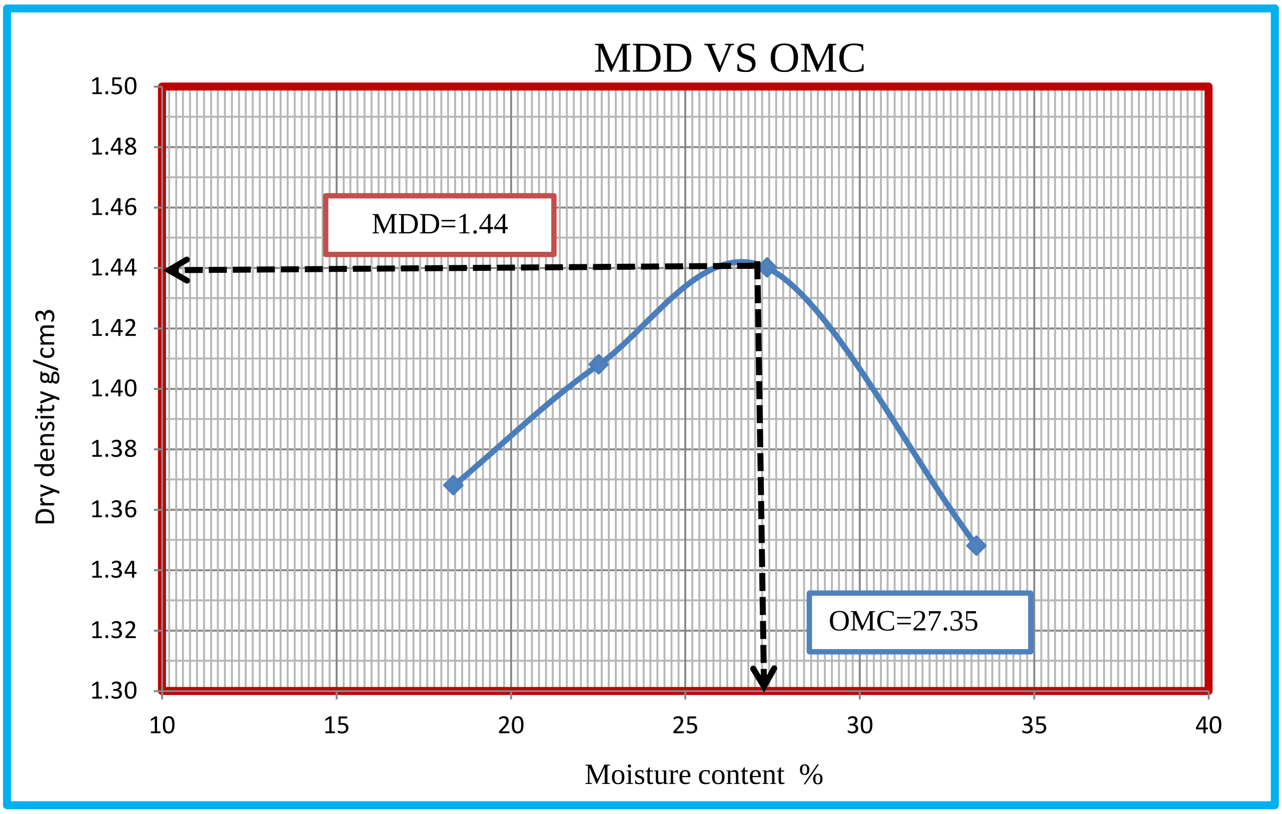
1.12) 40% CA

DENSITY	TRIAL NUMBER	1	2	3	4	5
	WEIGHT OF SAMPLE	4500	4500	4500	4500	
	WATER ADDED	700.0	980.0	1110.0	1290.0	
	WEIGHT OF SOIL + MOLD (g)	6303.39	6569.35	6788.96	6718	
	WEIGHT OF MOLD (g)	2724	2724	2724	2724	
	WEIGHT OF SOIL (g)	3579.39	3845.35	4064.96	3994	
	VOLUME OF MOLD (cc)	2124	2124	2124	2124	
	Wet DENSITY OF SOIL (g/cc)	1.685	1.810	1.914	1.881	
MOISTURE	CONTAINER NUMBER	50D	51D	52D	53D	
	WET SOIL + CONTAINER (g)	128.18	134.61	159.67	173.74	
	DRY SOIL + CONTAINER (g)	114.00	116.51	131.26	138.00	
	WEIGHT OF WATER (g)	14.18	18.10	28.41	35.74	
	WEIGHT OF CONTAINER (g)	34.22	40.94	36.01	38.69	
	WEIGHT OF DRY SOIL (g)	79.78	75.57	95.25	99.31	
	MOISTURE CONTENT (%)	17.77	23.95	29.83	35.99	
	DRY DENSITY OF SOIL (g/cc)	1.431	1.461	1.474	1.383	



1.13) 50% CA

DENSITY	TRIAL NUMBER	1	2	3	4	5
	WEIGHT OF SAMPLE	4500	4500	4500	4500	
	WATER ADDED	650.0	830.0	1010.0	1190.0	
	WEIGHT OF SOIL + MOLD (g)	6120.57	6345.28	6574.93	6499	
	WEIGHT OF MOLD（g）	2680.3	2680.3	2680.3	2680.3	
	WEIGHT OF SOIL（g）	3440.27	3664.98	3894.63	3818	
	VOLUME OF MOLD（cc）	2124	2124	2124	2124	
	Wet DENSITY OF SOIL（g/cc）	1.620	1.726	1.834	1.798	
MOISTURE	CONTAINER NUMBER	P1	P2	P3	P4	
	WET SOIL + CONTAINER (g)	134.73	186.39	148.79	124.16	
	DRY SOIL + CONTAINER (g)	119.00	158.00	125.00	101.00	
	WEIGHT OF WATER (g)	15.73	28.39	23.79	23.16	
	WEIGHT OF CONTAINER (g)	33.34	31.96	38.01	31.55	
	WEIGHT OF DRY SOIL (g)	85.66	126.04	86.99	69.45	
	MOISTURE CONTENT（%）	18.36	22.52	27.35	33.35	
	DRY DENSITY OF SOIL（g/cc）	1.368	1.408	1.440	1.348	

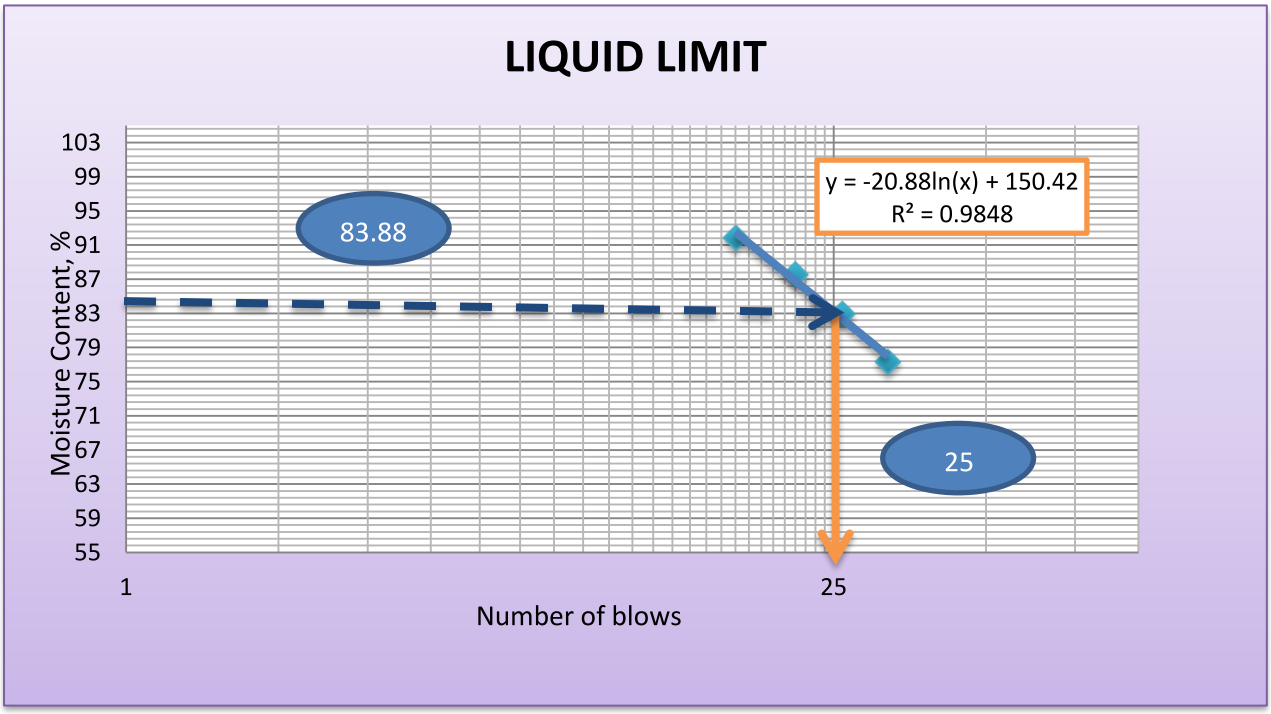


2) Atterberg limit laboratory test

2.1) 2% GSA

	Liquid Limit				Plastic Limit	
No of blows	32	26	21	16		
Container No	AA	B8	6A	LL	L3	C8
Wt. of Container+Wet soil(g)	36.89	30.96	24.61	22.37	19.41	21.53
Wt. of Container+Dry soil(g)	29.21	25.41	22.41	14.55	16.04	17.29
Wt. of Container(g)	19.28	18.72	13.55	6.04	6.55	5.83
Wt. of Moisture(g)	7.68	5.6	7.76	7.82	3.37	4.24
Wt. of Dry soil(g)	9.93	6.69	8.86	8.5	9.49	11.46
Moisture Content(%)	77.34	82.96	87.58	91.89	35.51	37.00

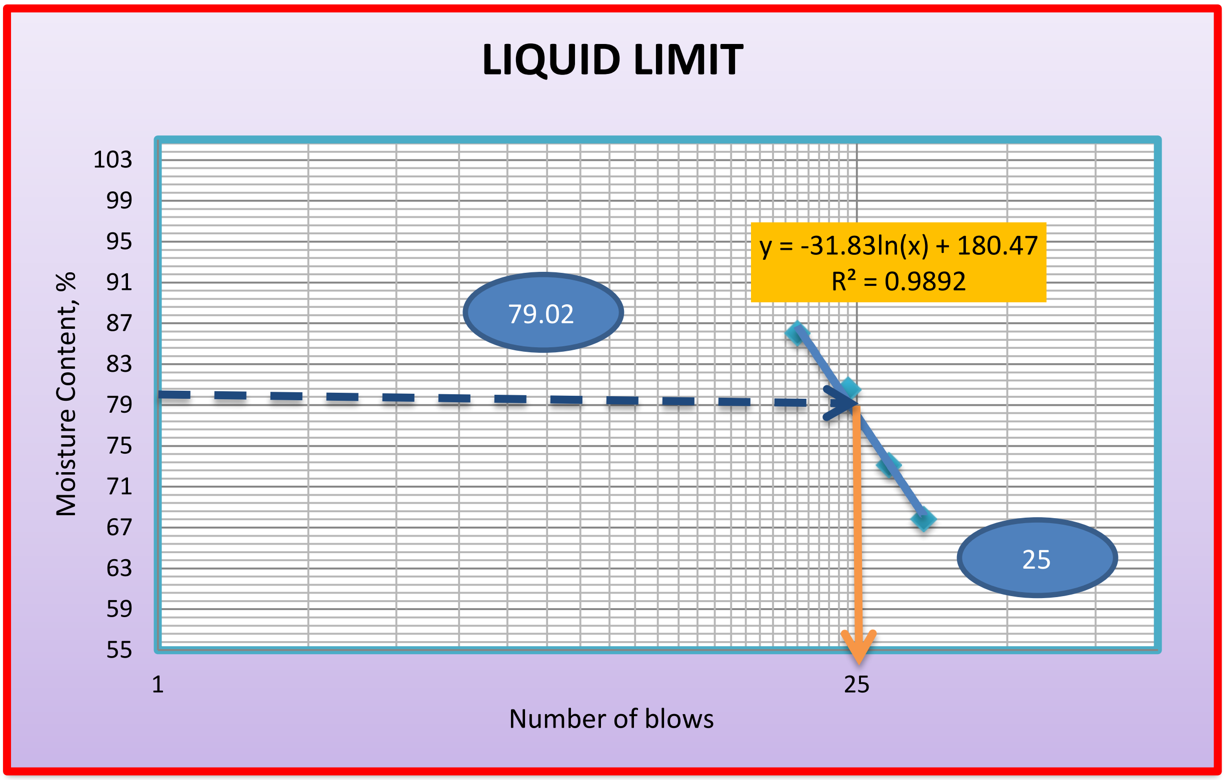
LIQUIDLIMIT	LL	83.88	AV. Plas. Lim.	36.3
PLASTIC LIMIT	PL	36.25		
PLASTICITY INDEX =	LL-PL	47.63		



2.2) 4% GSA

	Liquid Limit				Plastic Limit	
No of blows	34	29	24	19		
Container No	C15	A1	C7	C3B	T69	C9
Wt. of Container+Wet soil(g)	40.53	32.84	30.29	28.44	21.39	18.64
Wt. of Container+Dry soil(g)	32.35	27.10	26.87	23.69	17.04	15.00
Wt. of Container(g)	20.29	19.25	17.23	18.17	5.85	6.34
Wt. of Moisture(g)	8.18	5.7	7.76	4.75	4.35	3.64
Wt. of Dry soil(g)	12.06	7.85	9.64	5.5	11.19	8.66
Moisture Content(%)	67.83	73.12	80.50	86.05	38.87	42.03
				AV. Plas. Lim.	40.5	

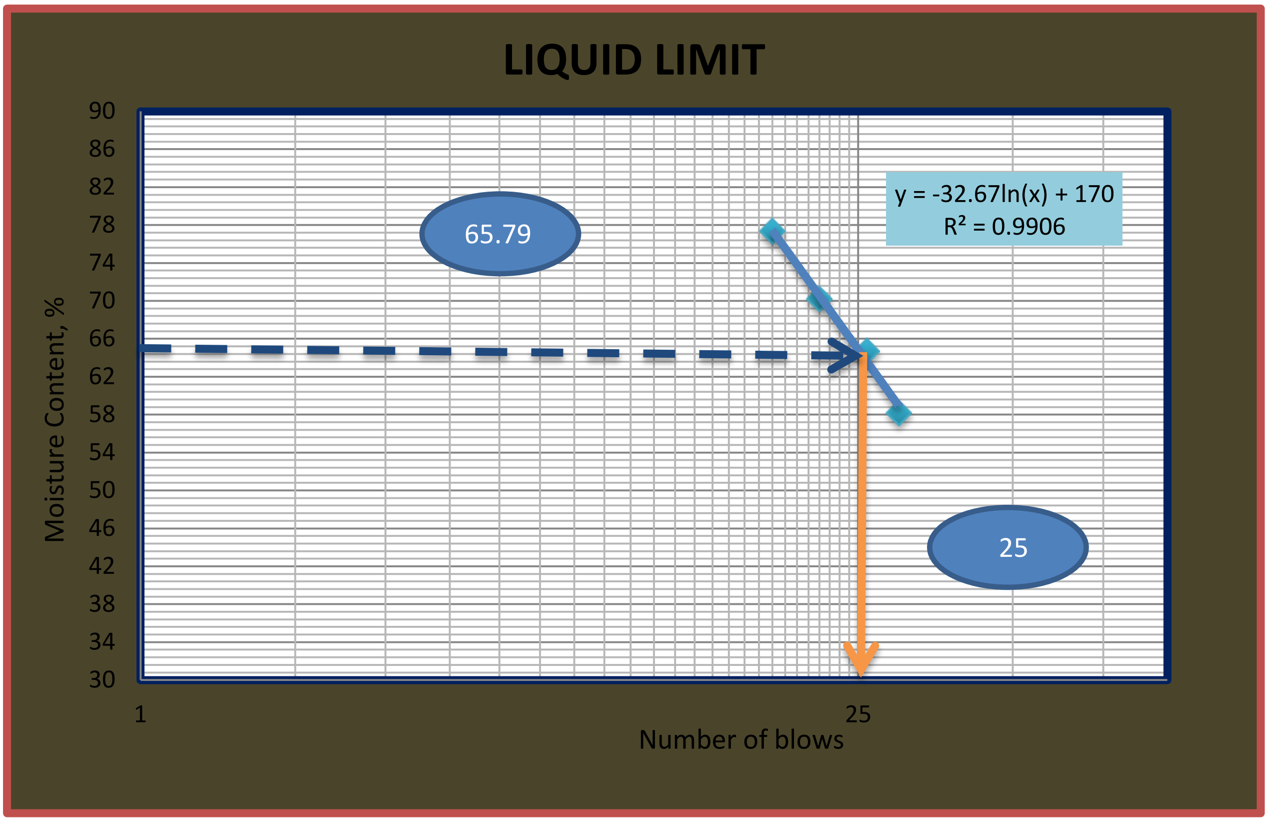
LIQUIDLIMIT	LL	**79.02**
PLASTIC LIMIT	PL	**40.45**
PLASTICITY INDEX =	LL-PL	**38.57**



2.3) 6% GSA

	Liquid Limit				Plastic Limit	
No of blows	30	26	21	17		
Container No	O2	SS	S6	G14	O3L1	F2
Wt. of Container+Wet soil(g)	38.26	34.52	21.22	36.79	18.98	19.76
Wt. of Container+Dry soil(g)	30.56	28.11	17.04	29.55	15.44	15.18
Wt. of Container(g)	17.32	18.20	5.99	20.19	6.67	5.70
Wt. of Moisture(g)	7.70	6.4	7.76	7.24	3.54	4.58
Wt. of Dry soil(g)	13.24	9.91	11.05	9.4	8.77	9.48
Moisture Content(%)	58.16	64.68	70.23	77.35	40.36	48.31
				AV. Plas. Lim.	44.3	

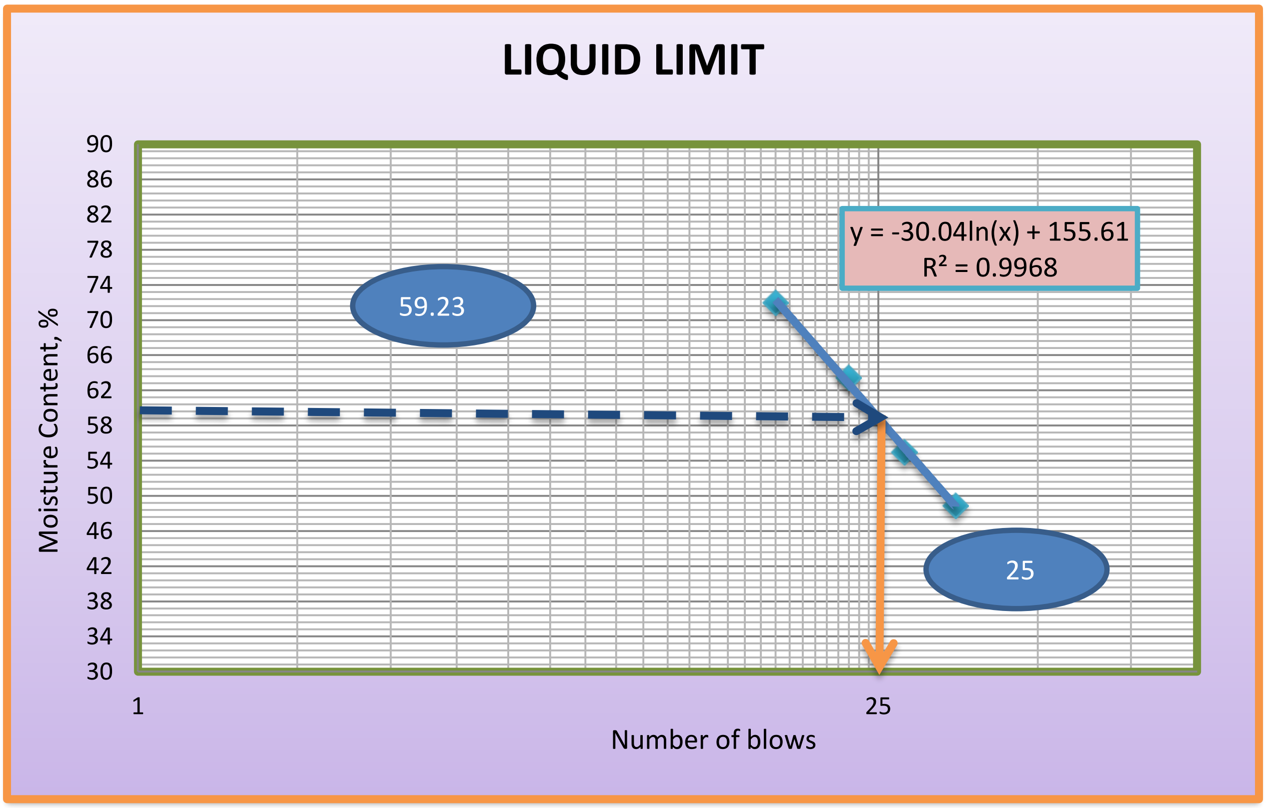
LIQUIDLIMIT	LL	**65.79**
PLASTIC LIMIT	PL	**44.34**
PLASTICITY INDEX =	LL-PL	**21.45**



2.4) 8% GSA

	Liquid Limit				Plastic Limit	
No of blows	35	28	22	16		
Container No	DD	C14	A5	N4	1	B-3
Wt. of Container+Wet soil(g)	21.59	26.24	31.29	22.94	22.13	20.83
Wt. of Container+Dry soil(g)	16.34	19.05	28.23	15.81	17.04	15.96
Wt. of Container(g)	5.60	5.97	16.01	5.91	6.16	5.45
Wt. of Moisture(g)	5.25	7.2	7.76	7.13	5.09	4.87
Wt. of Dry soil(g)	10.74	13.09	12.22	9.9	10.88	10.51
Moisture Content(%)	48.88	54.95	63.50	72.02	46.78	46.34

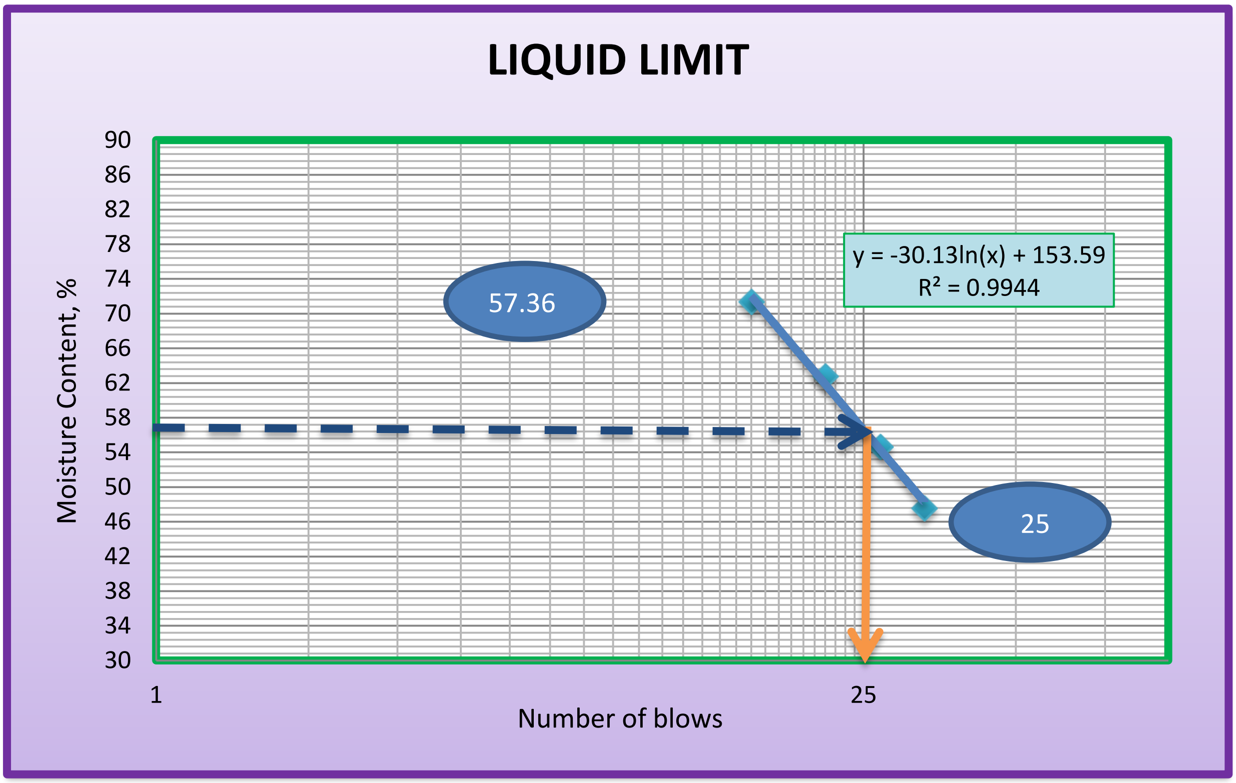
LIQUIDLIMIT	LL	**59.23**	AV. Plas. Lim.	46.6
PLASTIC LIMIT	PL	**46.56**		
PLASTICITY INDEX =	LL-PL	**12.67**		



2.5) 10% GSA

	Liquid Limit				Plastic Limit	
No of blows	33	27	21	15		
Container No	3L	G-7	I6	B8	D3	C2
Wt. of Container+Wet soil(g)	24.82	27.49	21.06	29.98	21.36	22.51
Wt. of Container+Dry soil(g)	23.14	23.91	20.12	25.29	16.23	17.18
Wt. of Container(g)	19.61	17.36	7.76	18.72	5.82	6.19
Wt. of Moisture(g)	1.68	3.6	7.76	4.69	5.13	5.33
Wt. of Dry soil(g)	3.53	6.55	12.36	6.6	10.41	10.99
Moisture Content(%)	47.59	54.66	62.78	71.39	49.28	48.50
				AV. Plas. Lim.	48.9	

LIQUIDLIMIT	**LL**	**57.36**
PLASTIC LIMIT	**PL**	**48.89**
PLASTICITY INDEX =	**LL-PL**	**8.47**

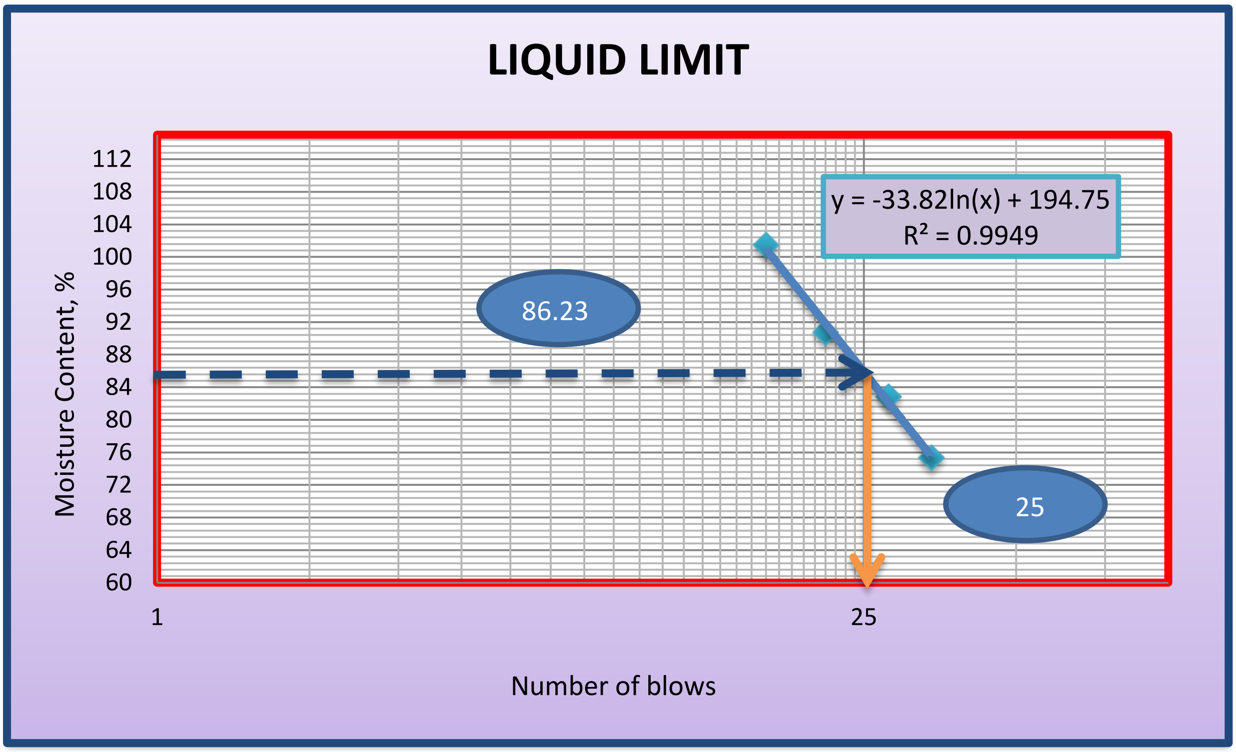


2.6) 10% CA

	Liquid Limit				Plastic Limit	
No of blows	34	28	21	16		
Container No	B8	I6	3L	L3	A13	3
Wt. of Container+Wet soil(g)	33.78	32.26	35.91	25.78	21.51	25.53
Wt. of Container+Dry soil(g)	27.31	21.16	28.16	16.09	17.35	20.24
Wt. of Container(g)	18.72	7.76	19.61	6.54	6.01	6.29
Wt. of Moisture(g)	6.47	11.1	7.76	9.69	4.16	5.29
Wt. of Dry soil(g)	8.59	13.40	8.55	9.6	11.34	13.95
Moisture Content(%)	75.32	82.84	90.76	101.47	36.68	37.92

LIQUIDLIMIT	LL	86.23
PLASTIC LIMIT	PL	37.30
PLASTICITY INDEX =	LL-PL	48.93

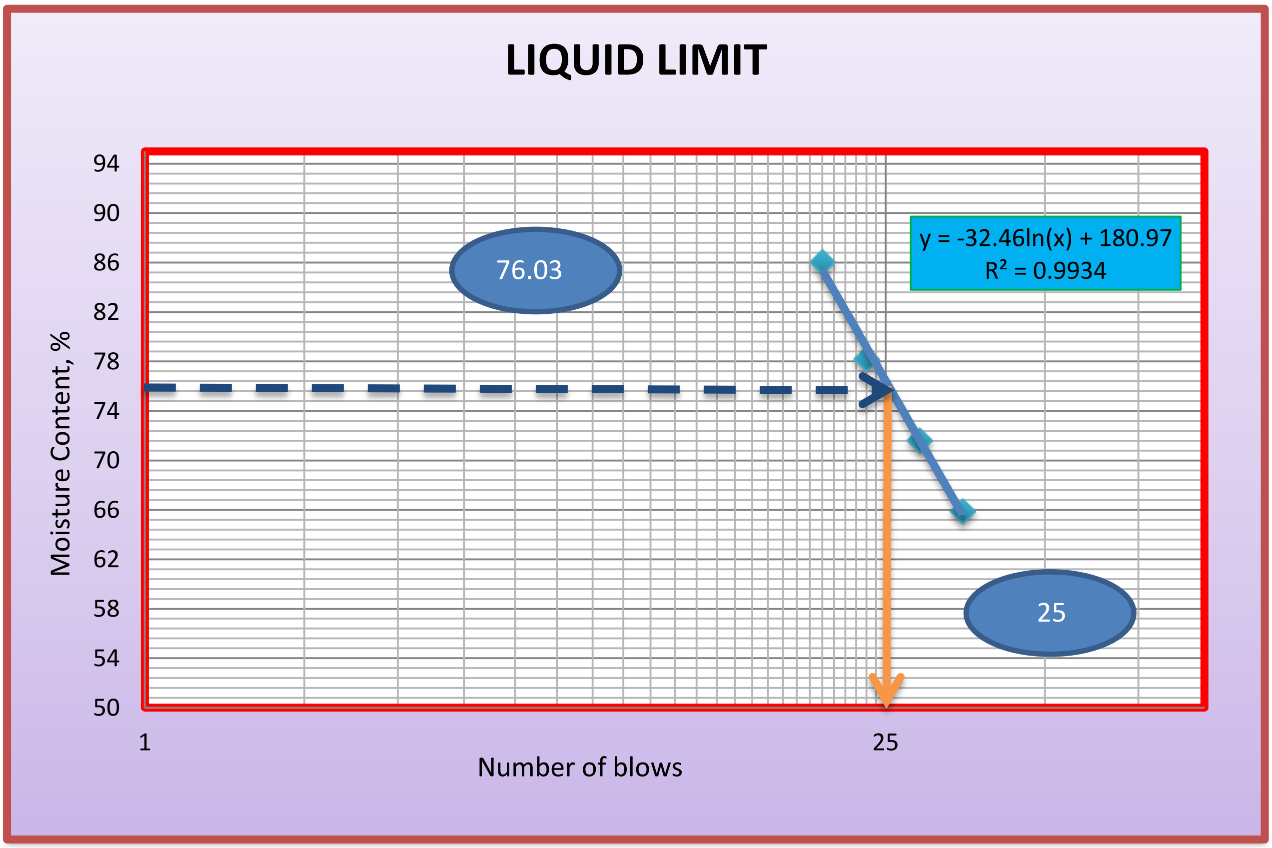
AV. Plas. Lim.	37.3



2.7) 20% CA

	Liquid Limit				Plastic Limit	
No of blows	35	29	23	19		
Container No	AA	F2	C4	A1	SP	C14
Wt. of Container+Wet soil(g)	35.62	27.43	33.87	37.41	31.62	23.79
Wt. of Container+Dry soil(g)	29.13	18.36	17.62	29.01	27.39	18.55
Wt. of Container(g)	19.28	5.70	7.70	19.25	17.28	5.97
Wt. of Moisture(g)	6.49	9.1	7.76	8.40	4.23	5.24
Wt. of Dry soil(g)	9.85	12.66	9.92	9.8	10.11	12.59
Moisture Content(%)	65.89	71.64	78.23	86.07	41.84	41.64

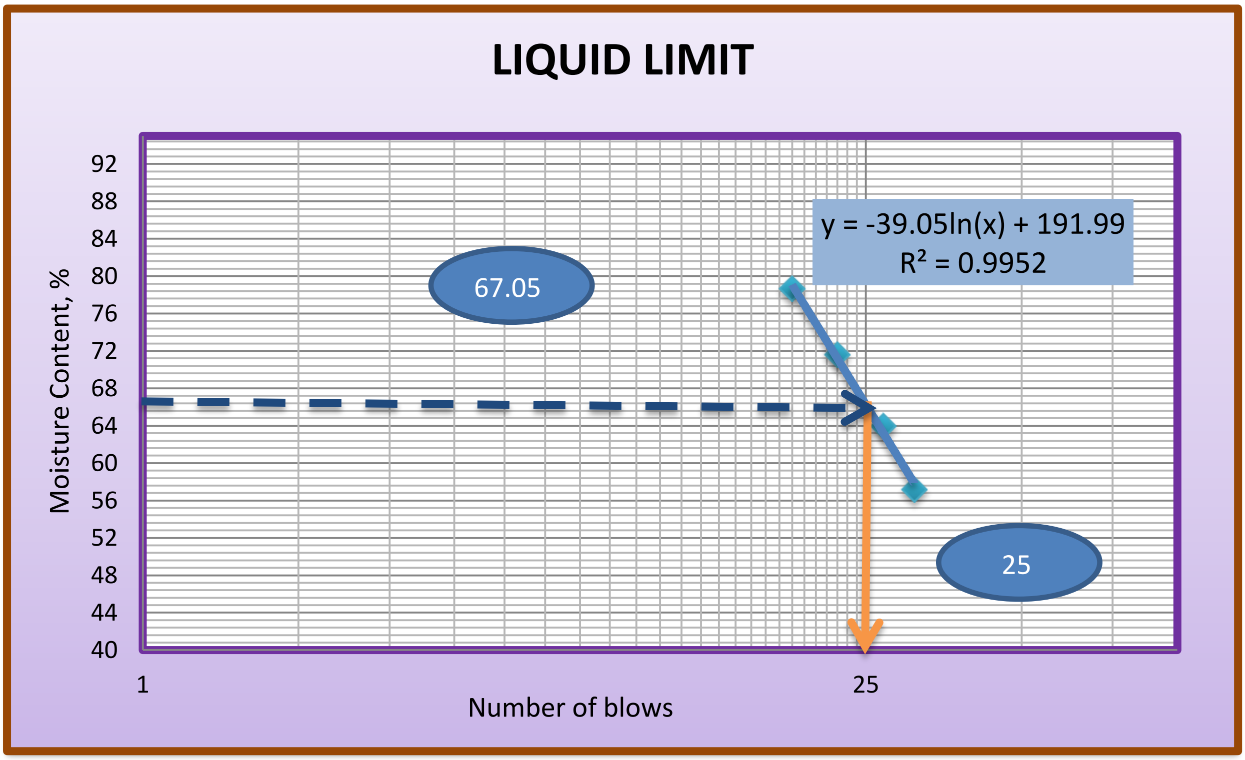
LIQUIDLIMIT	LL	76.03	AV. Plas. Lim.	41.7
PLASTIC LIMIT	PL	41.74		
PLASTICITY INDEX =	LL-PL	34.29		



2.8) 30% CA

	Liquid Limit				Plastic Limit	
No of blows	31	27	22	18		
Container No	G-7	A25	O3L1	C2	B-4	3CB
Wt. of Container+Wet soil(g)	32.50	36.98	23.14	30.44	31.96	33.26
Wt. of Container+Dry soil(g)	26.99	31.65	17.50	19.76	24.22	28.39
Wt. of Container(g)	17.36	23.32	6.67	6.19	6.34	18.17
Wt. of Moisture(g)	5.51	5.3	7.76	10.68	7.74	4.87
Wt. of Dry soil(g)	9.63	8.33	10.83	13.6	17.88	10.22
Moisture Content(%)	57.22	63.99	71.65	78.70	43.29	47.65
				AV. Plas. Lim.	45.5	

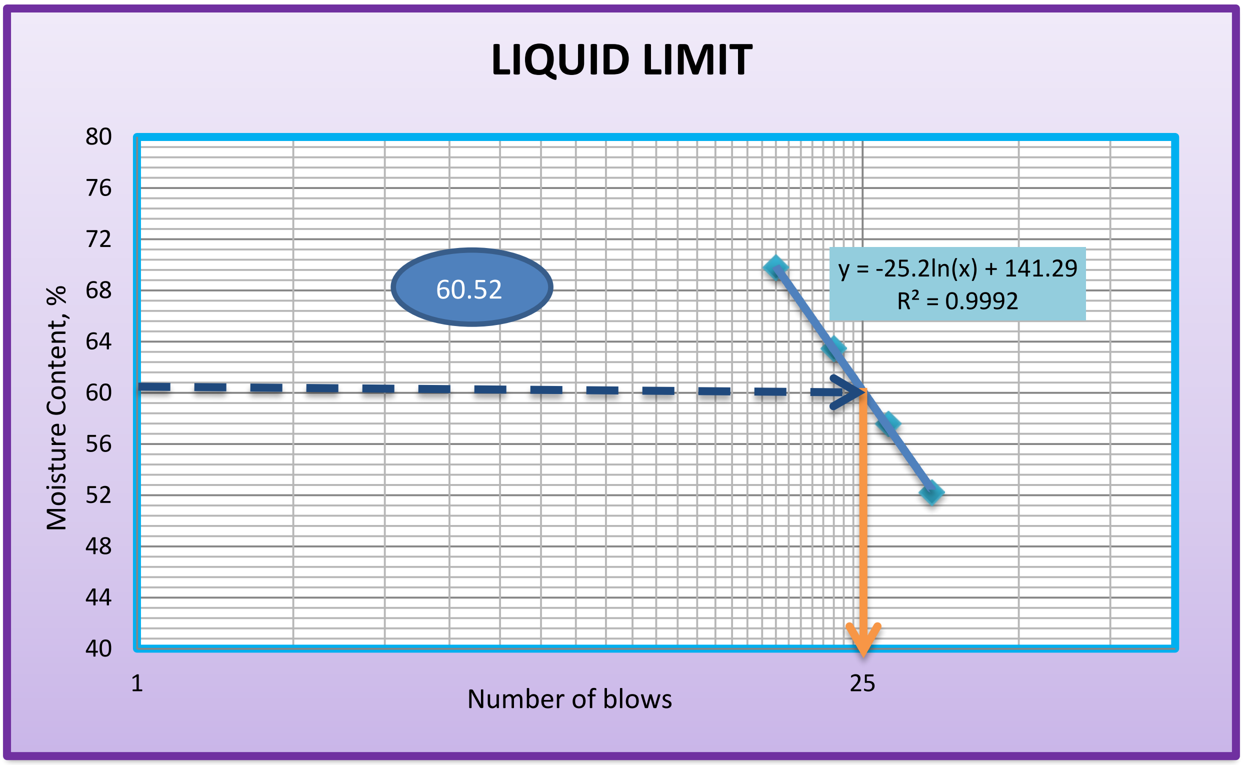
LIQUIDLIMIT	LL	67.05
PLASTIC LIMIT	PL	45.47
PLASTICITY INDEX =	LL-PL	21.58



2.9) 40% CA

	Liquid Limit				Plastic Limit	
No of blows	34	28	22	17		
Container No	D3	C7	T-2	C9	2	TD
Wt. of Container+Wet soil(g)	22.61	37.48	35.29	29.16	28.73	30.96
Wt. of Container+Dry soil(g)	16.85	30.08	30.09	19.78	21.12	22.95
Wt. of Container(g)	5.82	17.23	17.86	6.34	5.73	6.50
Wt. of Moisture(g)	5.76	7.4	7.76	9.38	7.61	8.01
Wt. of Dry soil(g)	11.03	12.85	12.23	13.4	15.39	16.45
Moisture Content(%)	52.22	57.59	63.45	69.79	49.45	48.69

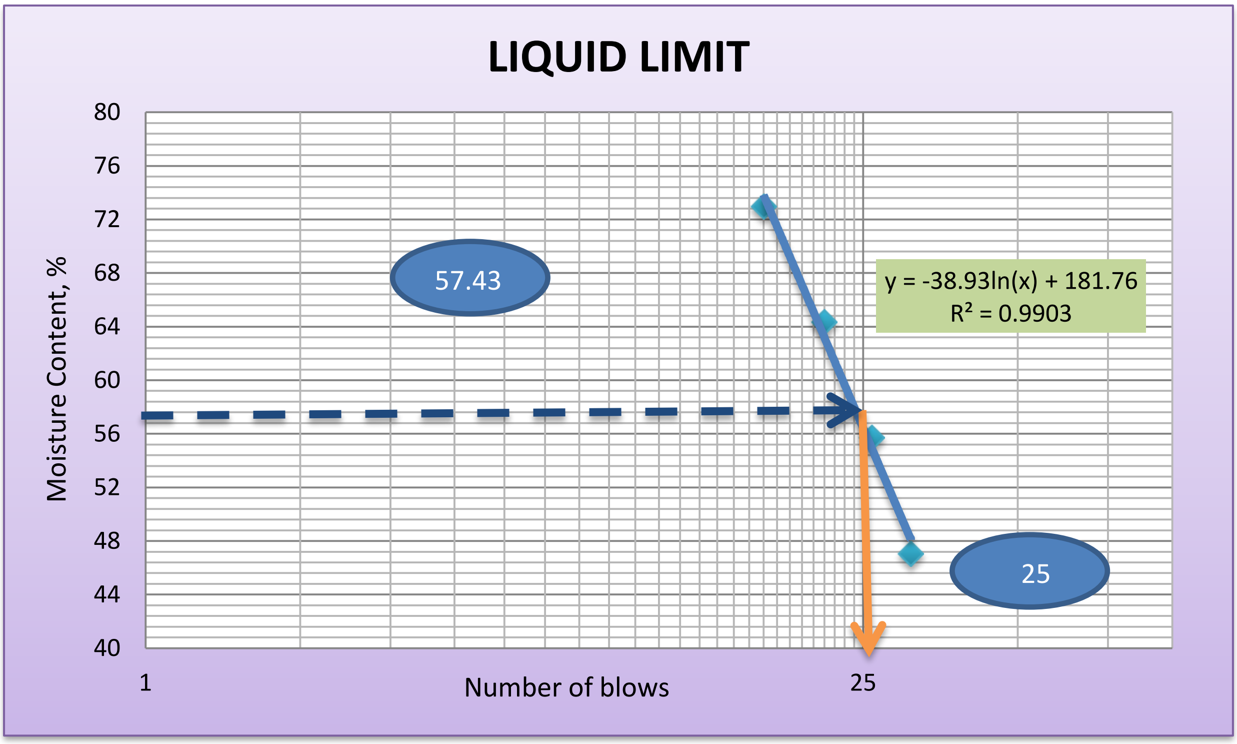
LIQUIDLIMIT	LL	**60.52**	AV. Plas. Lim.	49.1
PLASTIC LIMIT	PL	**49.07**		
PLASTICITY INDEX =	LL-PL	**11.45**		



2.10) 50% CA

	Liquid Limit				Plastic Limit	
No of blows	31	26	21	16		
Container No	C15	B-3	O2	A12	T69	N4
Wt. of Container+Wet soil(g)	29.76	20.04	37.46	38.01	20.22	22.81
Wt. of Container+Dry soil(g)	26.73	14.82	29.38	28.75	15.36	17.22
Wt. of Container(g)	20.29	5.45	17.32	16.06	5.85	5.91
Wt. of Moisture(g)	3.03	5.2	7.76	9.26	4.86	5.59
Wt. of Dry soil(g)	6.44	9.37	12.06	12.7	9.51	11.31
Moisture Content(%)	47.05	55.71	64.34	72.97	51.10	49.43

LIQUIDLIMIT	LL	57.43	AV. Plas. Lim.	50.3
PLASTIC LIMIT	PL	50.26		
PLASTICITY INDEX =	LL-PL	7.17		



3) CBR Laboratory test result

3.1) 1% BF

		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		P85	P85	C50	C50	D10	D10
Mass of soil + Mould	g	11026.5	11185.7	10754.6	10914.3	10782.2	10956.3
Mass Mould	g	7056.5	7056.5	6605.1	6605.1	6756.3	6756.3
Mass of Soil	g	3970	4129.2	4149.5	4309.2	4025.9	4200
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.869	1.944	1.954	2.029	1.895	1.977
Dry density of soil	g/cc	1.638	1.630	1.570	1.535	1.496	1.479

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G19	P65	A22	T4	R45	A50
Mass of wet soil + Container	g	125.60	172.36	98.63	109.86	126.70	176.31
Mass of dry soil + Container	g	114.24	150.23	83.64	91.53	108.73	141.37
Mass of container	g	33.59	35.40	22.36	34.50	41.50	37.60
Mass of water	g	11.36	22.13	14.99	18.33	17.97	34.94
Mass of dry soil	g	80.65	114.83	61.28	57.03	67.23	103.77
Moisture content	%	14.09	19.27	24.46	32.14	26.73	33.67

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.427		0.64	0.384		0.64	0.306	
1.27	0.509		1.27	0.457		1.27	0.371	
1.91	0.557		1.91	0.489		1.91	0.406	
2.54	0.584	4.38	2.54	0.517	3.88	2.54	0.432	3.24
3.81	0.614		3.81	0.554		3.81	0.467	
5.08	0.634	3.17	5.08	0.591	2.96	5.08	0.487	2.44
7.62	0.654		7.62	0.637		7.62	0.516	

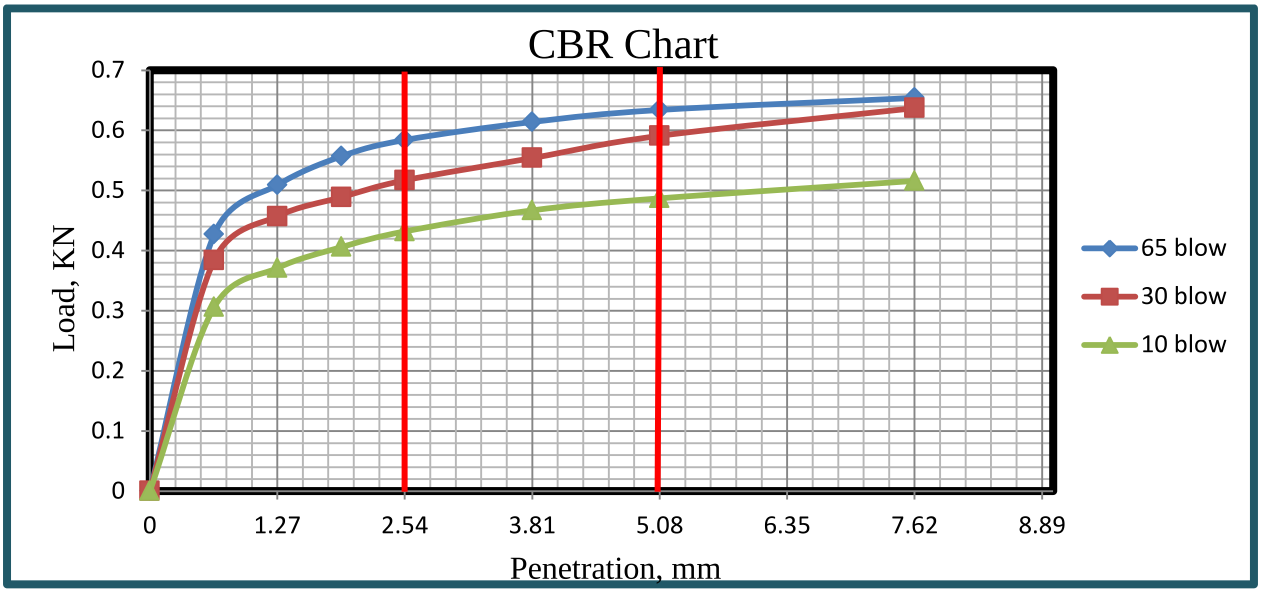
Modified Max.Dry Density g/cc	1.590	OMC %	28.6

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.10	1.77	3.14	2.30	4.95	2.49
01/03/2013	Final	6.16		5.82		7.85	

		Dry Density at 95% of MDD:		1.511
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	26.7	1.496	3.24	94
30	24.5	1.570	3.89	99
65	14.1	1.638	4.39	103

CBR % at 95 % MDD	3.4	Swell %	2.30



3.2) 1.5% BF

		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		AS6	AS6	P7	P7	K64	K64
Mass of soil + Mould	g	11278.96	11249.67	11179.83	11226.49	10904.6	10984.36
Mass Mould	g	6923.5	6923.5	6887.9	6887.9	6897.2	6897.2
Mass of Soil	g	4355.46	4326.17	4291.93	4338.59	4007.4	4087.16
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	2.051	2.037	2.021	2.043	1.887	1.924
Dry density of soil	g/cc	1.712	1.638	1.558	1.521	1.432	1.405

Moisture Determination

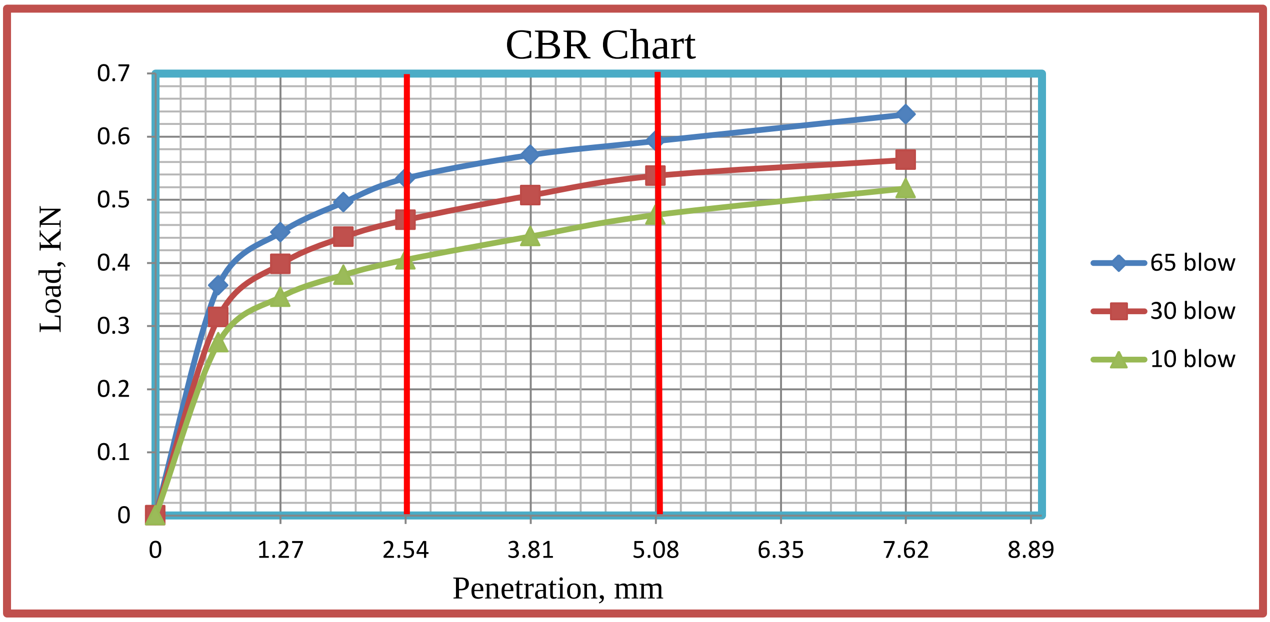
MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		A15	KI06	W56	C05	A154	AR36
Mass of wet soil + Container	g	159.73	167.43	186.61	128.93	172.39	187.96
Mass of dry soil + Container	g	139.62	140.83	152.60	105.95	141.28	147.68
Mass of container	g	38.05	31.49	37.96	38.94	43.20	38.76
Mass of water	g	20.11	26.60	34.01	22.98	31.11	40.28
Mass of dry soil	g	101.57	109.34	114.64	67.01	98.08	108.92
Moisture content	%	19.80	24.33	29.67	34.29	31.72	36.98

CBR Penetration Determination								
Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.364		0.64	0.314		0.64	0.274	
1.27	0.448		1.27	0.398		1.27	0.346	
1.91	0.496		1.91	0.441		1.91	0.381	
2.54	0.534	4.00	2.54	0.468	3.51	2.54	0.405	3.04
3.81	0.571		3.81	0.507		3.81	0.442	
5.08	0.593	2.97	5.08	0.538	2.69	5.08	0.476	2.38
7.62	0.635		7.62	0.563		7.62	0.518	

Modified Max.Dry Density g/cc	1.770	OMC %	15.2

Swell Determination							
Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.10	1.77	3.24	1.87	4.95	1.98
01/03/2013	Final	6.16		5.42		7.25	

Dry Density at 95% of MDD:				1.682
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	31.7	1.432	3.04	81
30	29.7	1.558	3.52	88
65	19.8	1.712	4.02	97
CBR % at 95 % MDD			3.9	Swell % 1.87



3.3) 2% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		A-50	A-50	KN	KN	TP01	TP01
Mass of soil + Mould	g	11097.3	11342.1	10427.5	10763.2	10506.3	10847.3
Mass Mould	g	7012.6	7012.6	6535	6535	6785.6	6785.6
Mass of Soil	g	4084.7	4329.5	3892.5	4228.2	3720.7	4061.7
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.923	2.038	1.833	1.991	1.752	1.912
Dry density of soil	g/cc	1.644	1.584	1.525	1.590	1.353	1.364

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		C4	A45	D21	EP12	50K	CD1
Mass of wet soil + Container	g	187.60	108.90	128.76	151.34	119.00	128.30
Mass of dry soil + Container	g	165.30	89.32	110.23	129.65	100.50	102.40
Mass of container	g	33.74	21.15	18.46	43.56	37.81	38.00
Mass of water	g	22.30	19.58	18.53	21.69	18.50	25.90
Mass of dry soil	g	131.56	68.17	91.77	86.09	62.69	64.40
Moisture content	%	16.95	28.72	20.19	25.19	29.51	40.22

CBR Penetration Determination

Penetration after 96 hrs Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.426		0.64	0.412		0.64	0.383	
1.27	0.534		1.27	0.527		1.27	0.451	
1.91	0.602		1.91	0.571		1.91	0.491	
2.54	0.637	4.78	2.54	0.597	4.48	2.54	0.518	3.88
3.81	0.671		3.81	0.631		3.81	0.551	
5.08	0.698	3.49	5.08	0.657	3.29	5.08	0.574	2.87
7.62	0.721		7.62	0.694		7.62	0.596	

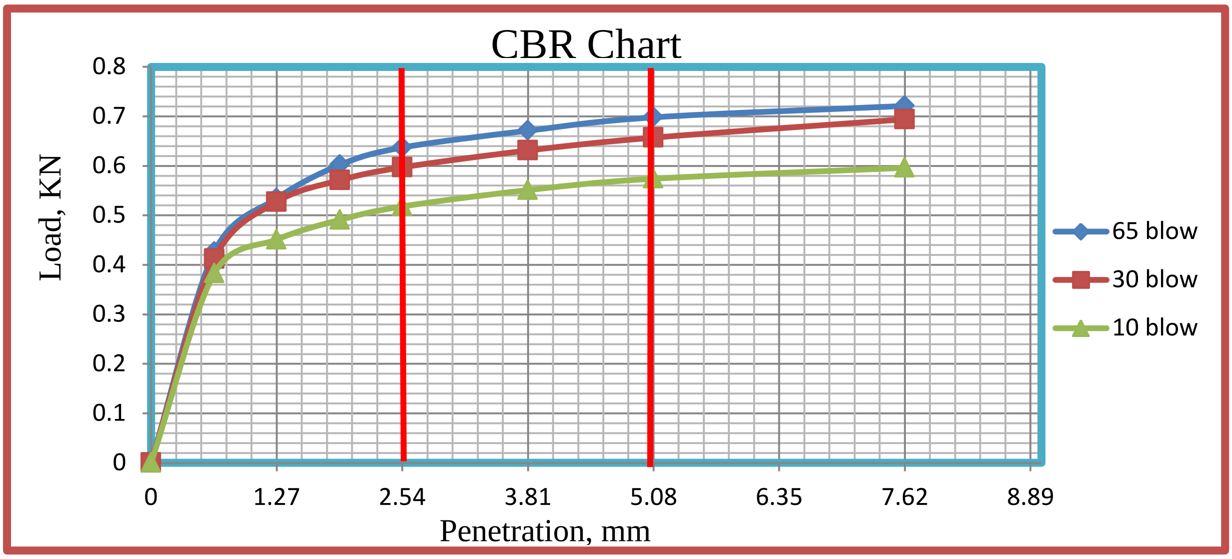
Modified Max.Dry Density g/cc	1.690	OMC %	31.2

Swell Determination

Date		65 Blows Gauge rdg mm	65 Blows Swell in %	30 Blows Gauge rdg mm	30 Blows Swell in %	10 Blows Gauge rdg mm	10 Blows Swell in %
27/02/2013	Initial	3.45	0.61	4.51	1.31	3.14	1.77
01/03/2013	Final	4.16		6.03		5.20	

`Dry Density at 95% of MDD:				1.606
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction

10	29.5	1.353	3.88	80
30	20.2	1.525	4.49	90
65	17.0	1.644	4.79	97
CBR % at 95 % MDD		**4.7**	**Swell %**	**1.31**



3.4) 2.5% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		XS-6	XS-6	YF-7	YF-7	FG-3	FG-3
Mass of soil + Mould	g	11034.6	11136.4	10778.61	11013.6	10534.37	10705.4
Mass Mould	g	6705.3	6705.3	6542.3	6542.3	6437.6	6437.6
Mass of Soil	g	4329.3	4431.1	4236.31	4471.3	4096.77	4267.8
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	2.038	2.086	1.994	2.105	1.929	2.009
Dry density of soil	g/cc	1.583	1.593	1.497	1.520	1.432	1.500

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		E-35	C-24	WX-4	E12	4AA	F22
Mass of wet soil + Container	g	109.30	118.70	150.74	168.97	144.79	138.79
Mass of dry soil + Container	g	88.70	99.65	121.43	132.55	117.48	113.50
Mass of container	g	17.00	38.17	33.20	37.90	38.81	39.10
Mass of water	g	20.60	19.05	29.31	36.42	27.31	25.29
Mass of dry soil	g	71.70	61.48	88.23	94.65	78.67	74.40
Moisture content	%	28.73	30.99	33.22	38.48	34.71	33.99

CBR Penetration Determination								
Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.659		0.64	0.634		0.64	0.586	
1.27	0.807		1.27	0.781		1.27	0.701	
1.91	0.865		1.91	0.843		1.91	0.756	
2.54	0.901	6.75	2.54	0.874	6.55	2.54	0.795	5.96
3.81	0.946		3.81	0.911		3.81	0.831	
5.08	0.976	4.88	5.08	0.936	4.68	5.08	0.853	4.27
7.62	1.020		7.62	0.974		7.62	0.884	

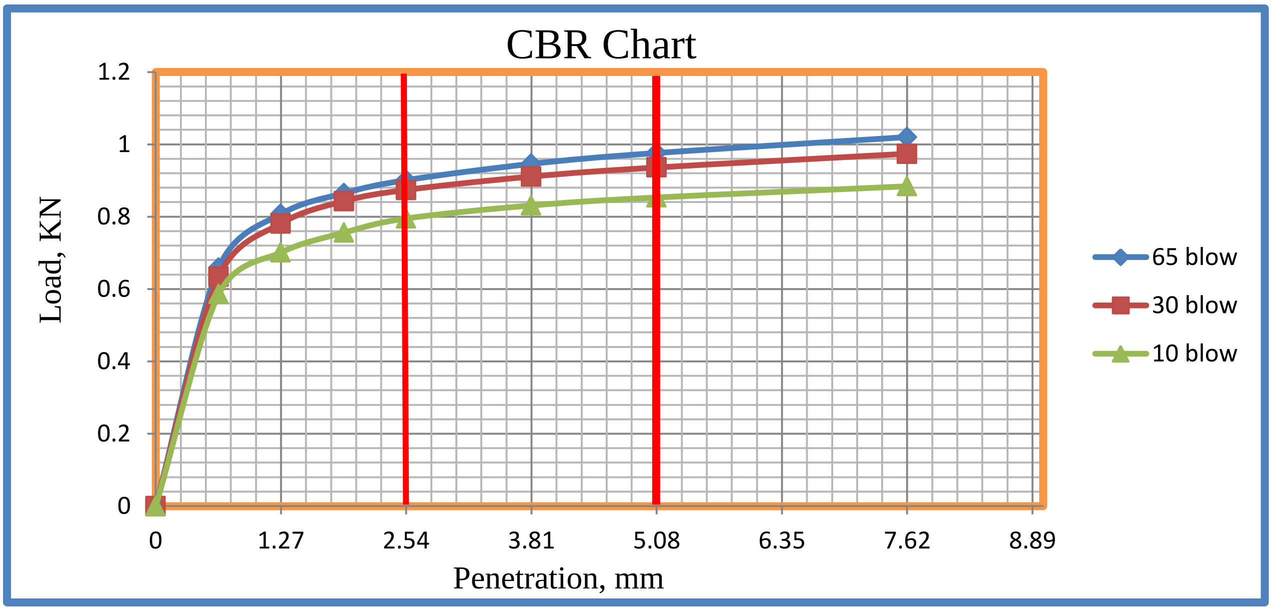
Modified Max.Dry Density g/cc	1.520	OMC %	20.2

E-35

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.21	0.83	5.3	1.14	3.08	1.58
01/03/2013	Final	5.18		6.63		4.92	

Dry Density at 95% of MDD:				1.444
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	34.7	1.432	5.96	94
30	33.2	1.497	6.57	98
65	28.7	1.583	6.77	104

CBR % at 95 % MDD	6.1	Swell %	1.14



3.5) 3% BF

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		L8	L8	KL8	KL8	D40	D40
Mass of soil + Mould	g	11012.6	11124.3	10896.3	10976.4	10623	10904.3
Mass Mould	g	6652.4	6652.4	6742.3	6742.3	6523.4	6523.4
Mass of Soil	g	4360.2	4471.9	4154	4234.1	4099.6	4380.9
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	2.053	2.105	1.956	1.993	1.930	2.063
Dry density of soil	g/cc	1.654	1.632	1.543	1.508	1.451	1.505

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		85K	74K	C41	F12	C90	AB30
Mass of wet soil + Container	g	101.30	107.23	161.10	181.30	184.36	134.68
Mass of dry soil + Container	g	87.54	91.64	134.60	144.76	143.50	108.73
Mass of container	g	30.50	37.90	35.51	31.40	19.62	38.60
Mass of water	g	13.76	15.59	26.50	36.54	40.86	25.95
Mass of dry soil	g	57.04	53.74	99.09	113.36	123.88	70.13
Moisture content	%	24.12	29.01	26.74	32.23	32.98	37.00

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.387		0.64	0.315		0.64	0.312	
1.27	0.548		1.27	0.482		1.27	0.453	
1.91	0.653		1.91	0.567		1.91	0.528	
2.54	0.714	5.35	2.54	0.634	4.75	2.54	0.573	4.30
3.81	0.791		3.81	0.716		3.81	0.626	
5.08	0.846	4.23	5.08	0.786	3.93	5.08	0.671	3.36
7.62	0.923		7.62	0.864		7.62	0.749	

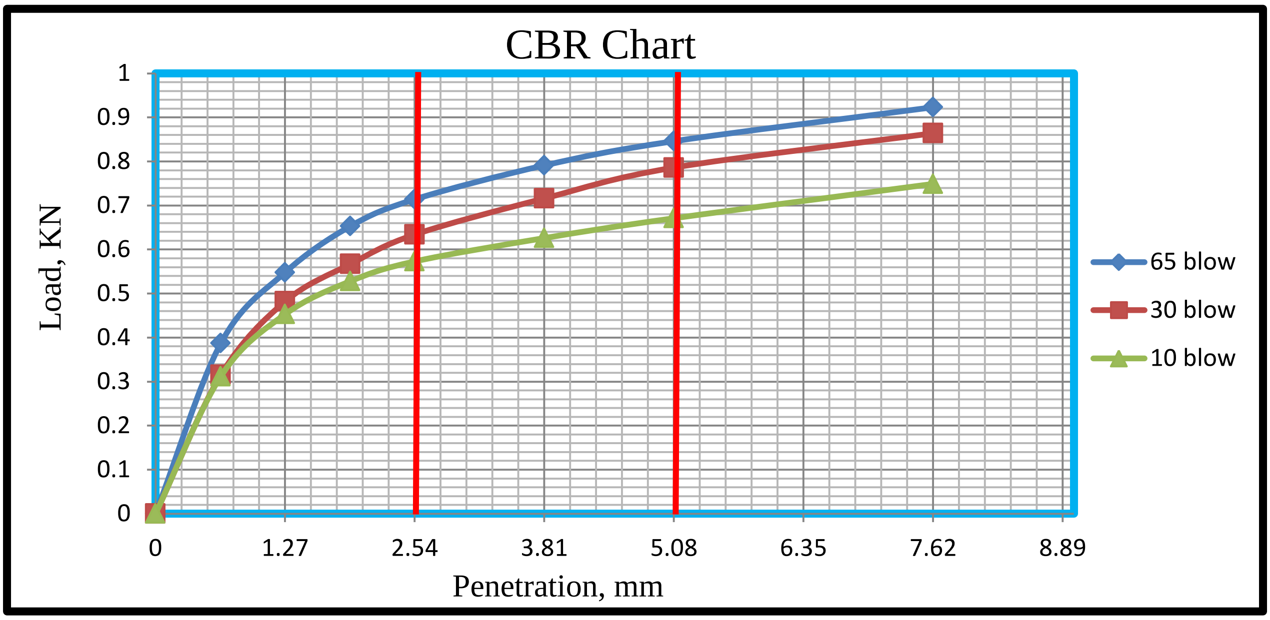
Modified Max.Dry Density g/cc	1.690	OMC %	31.2

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	4.01	1.66	3.25	1.86	3.08	2.71
01/03/2013	Final	5.94		5.42		6.23	

		Dry Density at 95% of MDD:		1.606
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	33.0	1.451	4.30	86
30	26.7	1.543	4.77	91
65	24.1	1.654	5.37	98

CBR % at 95 % MDD	5.1	Swell %	1.86



3.6) 2% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		T8	T8	N12	N12	T4	T4
Mass of soil + Mould	g	10795.2	10903.5	10766.9	10900.9	10681.3	10846.9
Mass Mould	g	6960.6	6960.6	7033.6	7033.6	7020.8	7020.8
Mass of Soil	g	3834.6	3942.9	3733.3	3867.3	3660.5	3826.1
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.805	1.856	1.758	1.821	1.723	1.801
Dry density of soil	g/cc	1.656	1.448	1.556	1.393	1.476	1.336

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G-53	G19	A-3	A-13	10G	A-16
Mass of wet soil + Container	g	180.86	194.26	198.80	205.64	175.01	154.24
Mass of dry soil + Container	g	169.41	159.82	181.23	169.81	154.21	118.94
Mass of container	g	42.39	37.54	45.46	53.2	30.26	17.6
Mass of water	g	11.45	34.44	17.57	35.83	20.80	35.30
Mass of dry soil	g	127.03	122.28	135.78	116.61	123.96	101.34
Moisture content	%	9.01	28.16	12.94	30.73	16.78	34.83

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %

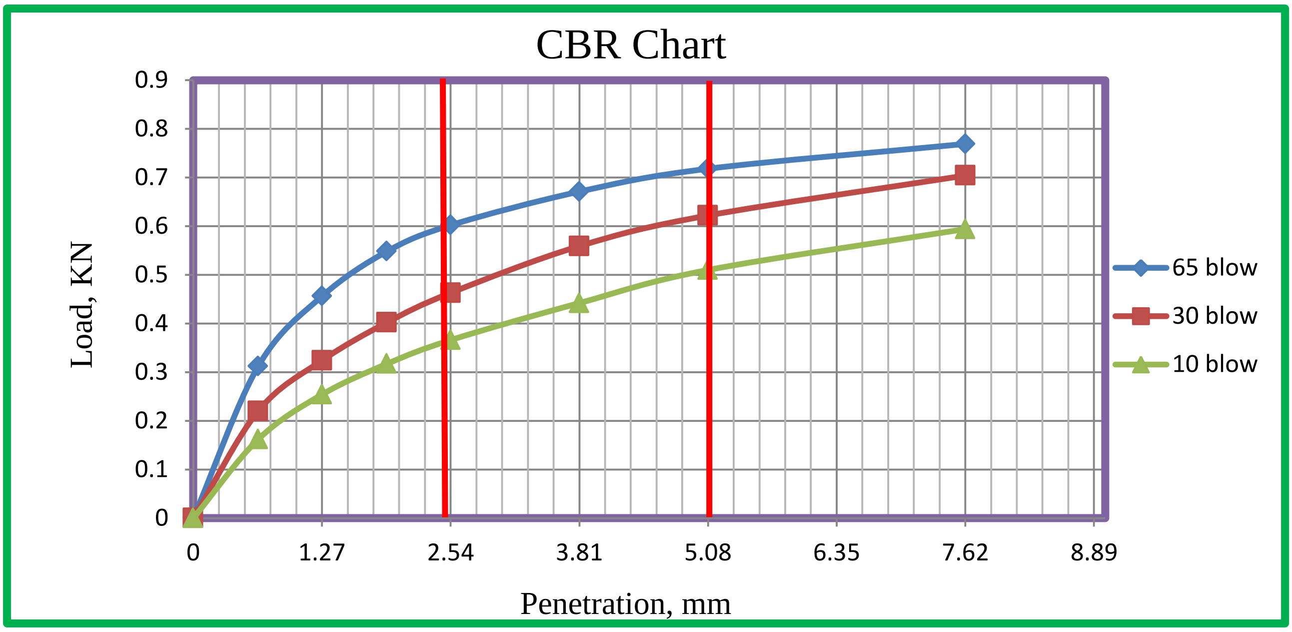
0.00	0.000		0.00	0.000		0.00	0.00	
0.64	0.312		0.64	0.220		0.64	0.162	
1.27	0.456		1.27	0.324		1.27	0.254	
1.91	0.548		1.91	0.402		1.91	0.317	
2.54	0.602	4.51	2.54	0.463	3.47	2.54	0.366	2.74
3.81	0.671		3.81	0.559		3.81	0.442	
5.08	0.718	3.59	5.08	0.622	3.11	5.08	0.510	2.55
7.62	0.769		7.62	0.704		7.62	0.594	

Modified Max.Dry Density g/cc	1.620	OMC %	21.29

Swell Determination							
Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	5.56	1.59	7.32	1.75	9.45	2.10
01/03/2013	Final	7.41		9.36		11.89	

Dry Density at 95% of MDD:				1.539
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**16.8**	**1.476**	**2.74**	**91**
30	**12.9**	**1.556**	**3.48**	**96**
65	**9.0**	**1.656**	**4.53**	**102**

CBR % at 95 % MDD	3.3	Swell %	1.75



3.8) 6% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		T2	T2	N6	N6	T5	T5
Mass of soil + Mould	g	10826	10981.6	10755.5	10867.1	10691.9	10835.9
Mass Mould	g	6945.4	6945.4	6972.6	6972.6	6992.7	6992.7
Mass of Soil	g	3880.6	4036.2	3782.9	3894.5	3699.2	3843.2
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.827	1.900	1.781	1.834	1.742	1.809
Dry density of soil	g/cc	1.521	1.485	1.479	1.384	1.422	1.235

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		WE	G19	A-3	E-12	SX	2Q
Mass of wet soil + Container	g	194.96	164.78	158.60	174.06	197.21	187.19
Mass of dry soil + Container	g	171.21	135.88	137.21	139.07	167.32	139.94
Mass of container	g	53.35	32.57	32.58	31.29	34.31	38.31
Mass of water	g	23.75	28.90	21.39	34.99	29.89	47.25
Mass of dry soil	g	117.86	103.31	104.63	107.78	133.01	101.63
Moisture content	%	20.15	27.97	20.44	32.46	22.47	46.49

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.00	
0.64	0.401		0.64	0.318		0.64	0.362	
1.27	0.584		1.27	0.524		1.27	0.512	
1.91	0.687		1.91	0.648		1.91	0.608	
2.54	0.754	5.65	2.54	0.724	5.43	2.54	0.674	5.05
3.81	0.838		3.81	0.812		3.81	0.739	
5.08	0.894	4.47	5.08	0.861	4.31	5.08	0.786	3.93
7.62	0.964		7.62	0.906		7.62	0.861	

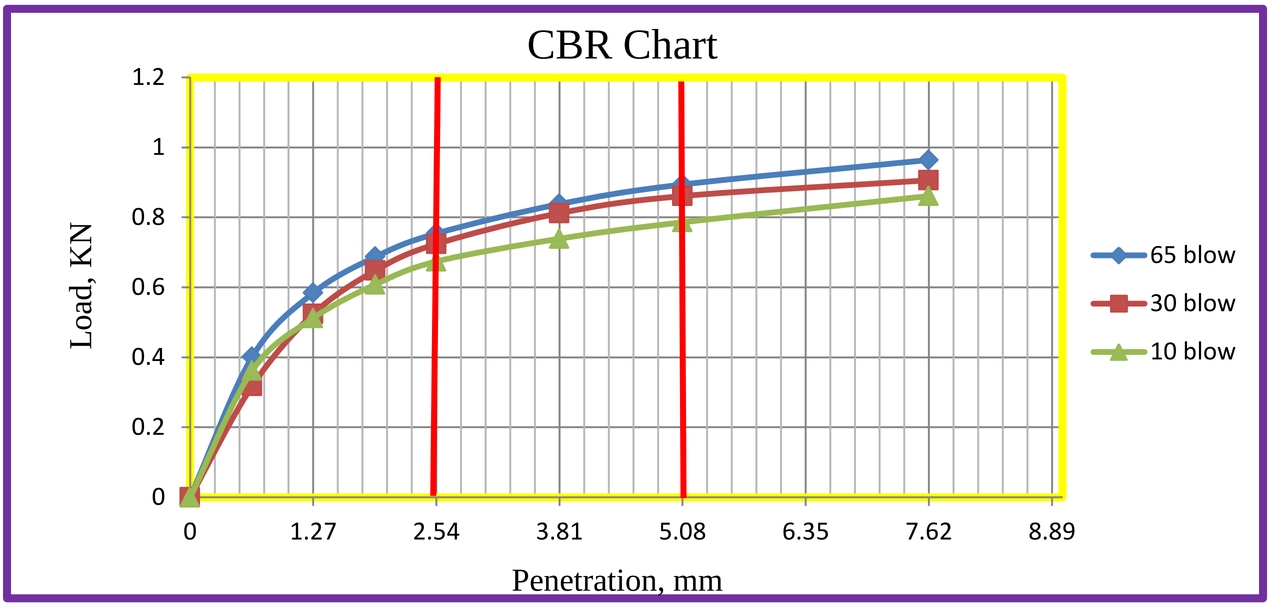
Modified Max.Dry Density g/cc	1.510	OMC %	25.7

Swell Determination

Date		65 Blows Gauge rdg mm	65 Blows Swell in %	30 Blows Gauge rdg mm	30 Blows Swell in %	10 Blows Gauge rdg mm	10 Blows Swell in %
27/02/2013	Initial	3.26	0.96	4.11	1.16	5.21	1.25
01/03/2013	Final	4.38		5.46		6.66	

Dry Density at 95% of MDD:				1.435
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**22.5**	**1.422**	**5.05**	**94**
30	**20.4**	**1.479**	**5.44**	**98**
65	**20.2**	**1.521**	**5.67**	**101**

CBR % at 95 % MDD	5.1	Swell %	1.16



3.9) 8% GSA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		T8	T8	N12	N12	T4	T4
Mass of soil + Mould	g	10811.5	10917.4	10715.7	10839.3	10635.7	10780.4
Mass Mould	g	6957.2	6957.2	6963.7	6963.7	6965.6	6965.6
Mass of Soil	g	3854.3	3960.2	3752	3875.6	3670.1	3814.8
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.815	1.865	1.766	1.825	1.728	1.796
Dry density of soil	g/cc	1.473	1.422	1.384	1.361	1.290	1.315
Moisture Determination							
MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		W12	E11	G-67	P21	G19	A4
Mass of wet soil + Container	g	188.25	157.21	218.92	181.06	217.51	167.83
Mass of dry soil + Container	g	159.87	128.23	178.97	143.26	171.29	132.98
Mass of container	g	37.67	35.21	34.40	32.29	35.20	37.66
Mass of water	g	28.38	28.98	39.95	37.80	46.22	34.85
Mass of dry soil	g	122.20	93.02	144.57	110.97	136.09	95.32
Moisture content	%	23.22	31.15	27.63	34.06	33.96	36.56

CBR Penetration Determination

Penetration after 96 hrs Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.00	

0.64	0.395		0.64	0.322		0.64	0.308	
1.27	0.603		1.27	0.501		1.27	0.436	
1.91	0.764		1.91	0.642		1.91	0.511	
2.54	0.873	6.54	2.54	0.745	5.58	2.54	0.573	4.30
3.81	0.999		3.81	0.856		3.81	0.641	
5.08	1.074	5.37	5.08	0.921	4.61	5.08	0.698	3.49
7.62	1.174		7.62	1.043		7.62	0.794	

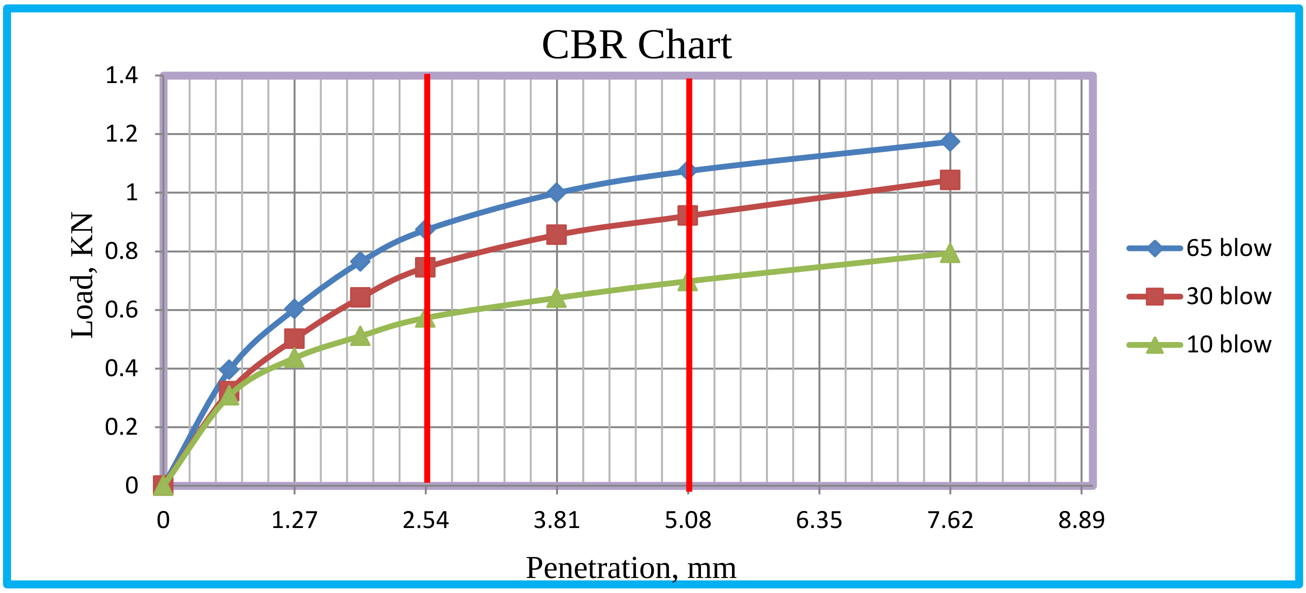
Modified Max.Dry Density g/cc	1.490	OMC %	31.25

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	3.12	0.89	4.25	1.02	4.75	1.31
01/03/2013	Final	4.16		5.44		6.28	

Dry Density at 95% of MDD:				1.416
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	34.0	1.290	4.30	87
30	27.6	1.384	5.60	93
65	23.2	1.473	6.56	99

CBR % at 95 % MDD	5.9	Swell %	1.02



3.10) 10% GSA

COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.	N10	N10	I65	I65	N2	N2

Mass of soil + Mould	g	10803.5	10903	10727.4	10847.6	10667.4	10819.7
Mass Mould	g	6948.5	6948.5	6975.3	6975.3	6995.8	6995.8
Mass of Soil	g	3855	3954.5	3752.1	3872.3	3671.6	3823.9
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.815	1.862	1.767	1.823	1.729	1.800
Dry density of soil	g/cc	1.463	1.446	1.378	1.391	1.316	1.325

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G-53	G19	A-3	A-13	10G	A-16
Mass of wet soil + Container	g	121.23	168.14	143.43	129.72	154.42	174.05
Mass of dry soil + Container	g	101.10	138.98	115.76	103.12	124.87	137.25
Mass of container	g	17.41	37.49	17.74	17.45	30.58	34.78
Mass of water	g	20.13	29.16	27.67	26.60	29.55	36.80
Mass of dry soil	g	83.70	101.49	98.02	85.67	94.30	102.47
Moisture content	%	24.05	28.73	28.23	31.05	31.33	35.91

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — **Surcharge Weight:-4.55 KG**

65 Blows			30 Blows			10 Blows		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.00	
0.64	0.376		0.64	0.414		0.64	0.321	
1.27	0.548		1.27	0.546		1.27	0.482	
1.91	0.664		1.91	0.618		1.91	0.561	
2.54	0.736	5.52	2.54	0.671	5.03	2.54	0.613	4.60
3.81	0.813		3.81	0.730		3.81	0.664	
5.08	0.857	4.29	5.08	0.771	3.86	5.08	0.701	3.51
7.62	0.901		7.62	0.843		7.62	0.764	

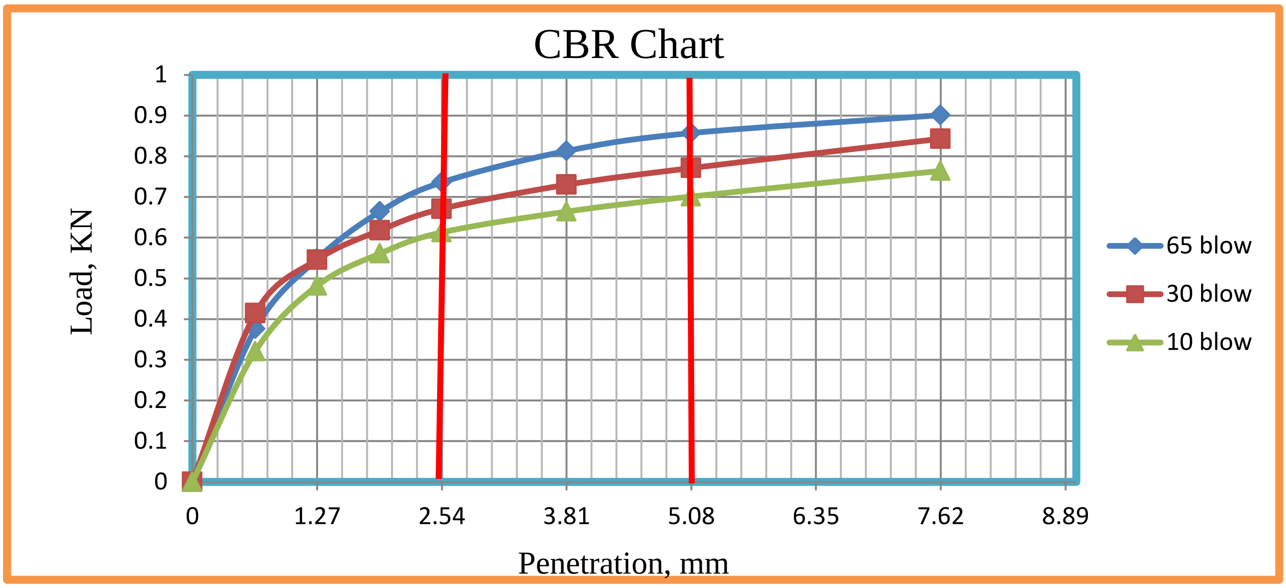
Modified Max.Dry Density g/cc	**1.470**	**OMC %**	**26.54**

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	5.01	1.49	7.46	1.80	8.12	2.08
01/03/2013	Final	6.74		9.56		10.54	

Dry Density at 95% of MDD:				**1.397**
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**31.3**	**1.316**	**4.60**	**90**
30	**28.2**	**1.378**	**5.05**	**94**
65	**24.1**	**1.463**	**5.53**	**100**

CBR % at 95 % MDD	**5.2**	**Swell %**	**1.80**



3.11) 10% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		P7	P7	MN8	MN8	A-50	A-50
Mass of soil + Mould	g	10921.6	11124.3	10857.6	11053.7	10739.7	10990.4
Mass Mould	g	6887.9	6887.9	7041.2	7041.2	7012.6	7012.6
Mass of Soil	g	4033.7	4236.4	3816.4	4012.5	3727.1	3977.8
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.899	1.995	1.797	1.889	1.755	1.873
Dry density of soil	g/cc	1.561	1.586	1.402	1.440	1.310	1.364

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		A154	C90	D21	P65	C4	G40
Mass of wet soil + Container	g	189.37	132.49	175.26	180.49	151.29	153.68
Mass of dry soil + Container	g	163.34	109.36	144.25	146.58	121.48	119.50
Mass of container	g	43.20	19.62	34.20	37.81	33.74	27.81
Mass of water	g	26.03	23.13	31.01	33.91	29.81	34.18
Mass of dry soil	g	120.14	89.74	110.05	108.77	87.74	91.69
Moisture content	%	21.67	25.77	28.18	31.18	33.98	37.28

CBR Penetration Determination

Penetration after 96 hrs Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.337		0.64	0.351		0.64	0.357	
1.27	0.441		1.27	0.452		1.27	0.448	
1.91	0.505		1.91	0.503		1.91	0.498	

2.54	0.551	4.13	2.54	0.538	4.03	2.54	0.531	3.98
3.81	0.609		3.81	0.584		3.81	0.578	
5.08	0.651	3.26	5.08	0.615	3.08	5.08	0.608	3.04
7.62	0.703		7.62	0.648		7.62	0.652	

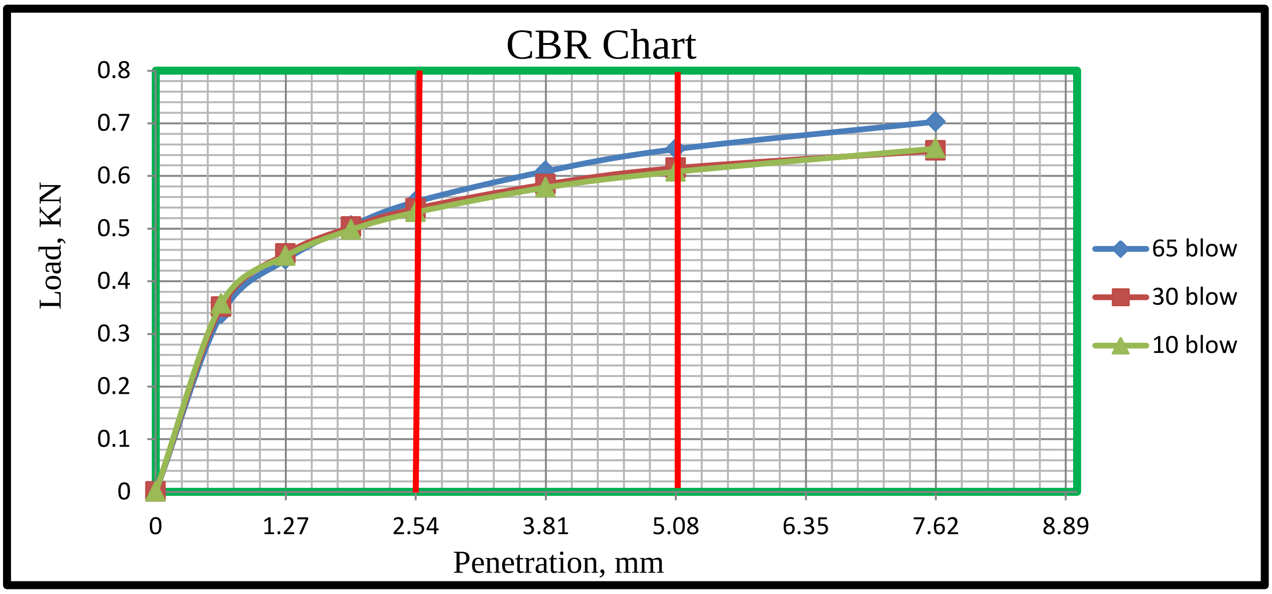
Modified Max.Dry Density g/cc	1.610	OMC %	22.1

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	1.25	1.83	1.48	1.92	1.86	2.00
01/03/2013	Final	3.38		3.71		4.19	

Dry Density at 95% of MDD:				1.530
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	34.0	1.310	3.98	81
30	28.2	1.402	4.05	87
65	21.7	1.561	4.14	97

CBR % at 95 % MDD	4.1	Swell %	1.92



3.12) 20% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		XS-6	XS-6	P7	P7	D40	D40
Mass of soil + Mould	g	11226.5	11478.6	11210.9	11425.7	11198.7	11389.7
Mass Mould	g	6705.3	6705.3	6887.9	6887.9	6523.4	6523.4

Mass of Soil	g	4521.2	4773.3	4323	4537.8	4675.3	4866.3
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	2.129	2.247	2.035	2.136	2.201	2.291
Dry density of soil	g/cc	1.598	1.643	1.460	1.502	1.343	1.370

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		G40	R45	AR36	C05	E-35	WX-4
Mass of wet soil + Container	g	144.25	174.25	159.61	167.83	113.25	139.29
Mass of dry soil + Container	g	115.24	138.53	125.45	129.58	75.73	96.63
Mass of container	g	27.81	41.50	38.76	38.94	17.00	33.20
Mass of water	g	29.01	35.72	34.16	38.25	37.52	42.66
Mass of dry soil	g	87.43	97.03	86.69	90.64	58.73	63.43
Moisture content	%	33.18	36.81	39.40	42.20	63.89	67.26

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period — Surcharge Weight:-4.55 KG

65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.286		0.64	0.367		0.64	0.376	
1.27	0.478		1.27	0.513		1.27	0.504	
1.91	0.613		1.91	0.598		1.91	0.576	
2.54	0.697	5.22	2.54	0.662	4.96	2.54	0.628	4.71
3.81	0.788		3.81	0.748		3.81	0.698	
5.08	0.847	4.24	5.08	0.801	4.01	5.08	0.746	3.73
7.62	0.934		7.62	0.887		7.62	0.834	

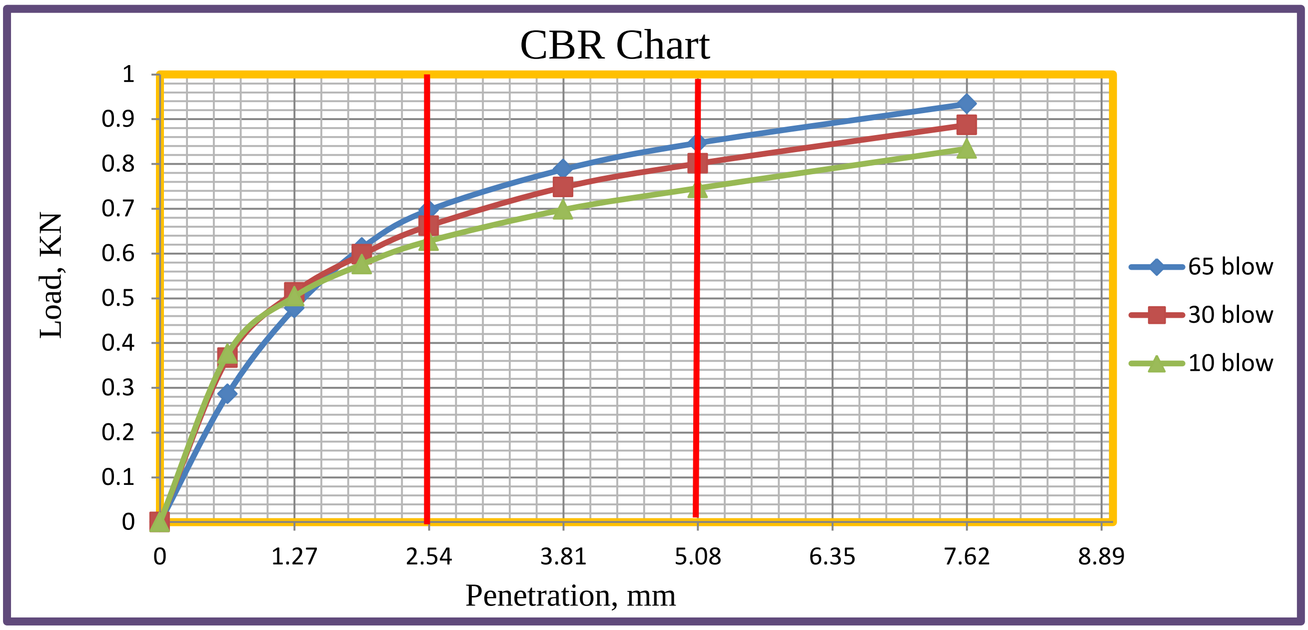
Modified Max.Dry Density g/cc	1.544	OMC %	24.6

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	0.00	1.00	0.00	1.71	0.00	2.05
01/03/2013	Final	1.16		1.99		2.39	

Dry Density at 95% of MDD:				1.467
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**63.9**	**1.343**	**4.71**	**87**
30	**39.4**	**1.460**	**4.98**	**95**
65	**33.2**	**1.598**	**5.24**	**104**

CBR % at 95 % MDD	5.0	Swell %	1.71



3.13) 30% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		N5	N5	N12	N12	N10	N10
Mass of soil + Mould	g	10943.59	11228.39	10789.61	10976.41	10417.98	10708.51
Mass Mould	g	6931.5	6931.5	7006.1	7006.1	6950.1	6950.1
Mass of Soil	g	4012.09	4296.89	3783.51	3970.31	3467.88	3758.41
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.889	2.023	1.781	1.869	1.633	1.769
Dry density of soil	g/cc	1.574	1.650	1.378	1.422	1.238	1.303

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		K-20	C-54	AB	B	G4	P22
Mass of wet soil + Container	g	153.74	168.91	149.83	187.96	163.83	146.88
Mass of dry soil + Container	g	133.26	143.68	122.94	151.26	131.53	116.35
Mass of container	g	31.02	32.15	31.05	34.50	30.15	31.07
Mass of water	g	20.48	25.23	26.89	36.70	32.30	30.53
Mass of dry soil	g	102.24	111.53	91.89	116.76	101.38	85.28
Moisture content	%	20.03	22.62	29.26	31.43	31.86	35.80

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	

0.64	0.471		0.64	0.573		0.64	0.549	
1.27	0.701		1.27	0.743		1.27	0.714	
1.91	0.814		1.91	0.824		1.91	0.799	
2.54	0.887	6.65	2.54	0.867	6.50	2.54	0.853	6.39
3.81	0.974		3.81	0.928		3.81	0.908	
5.08	1.041	5.21	5.08	0.968	4.84	5.08	0.957	4.79
7.62	1.154		7.62	1.046		7.62	1.029	

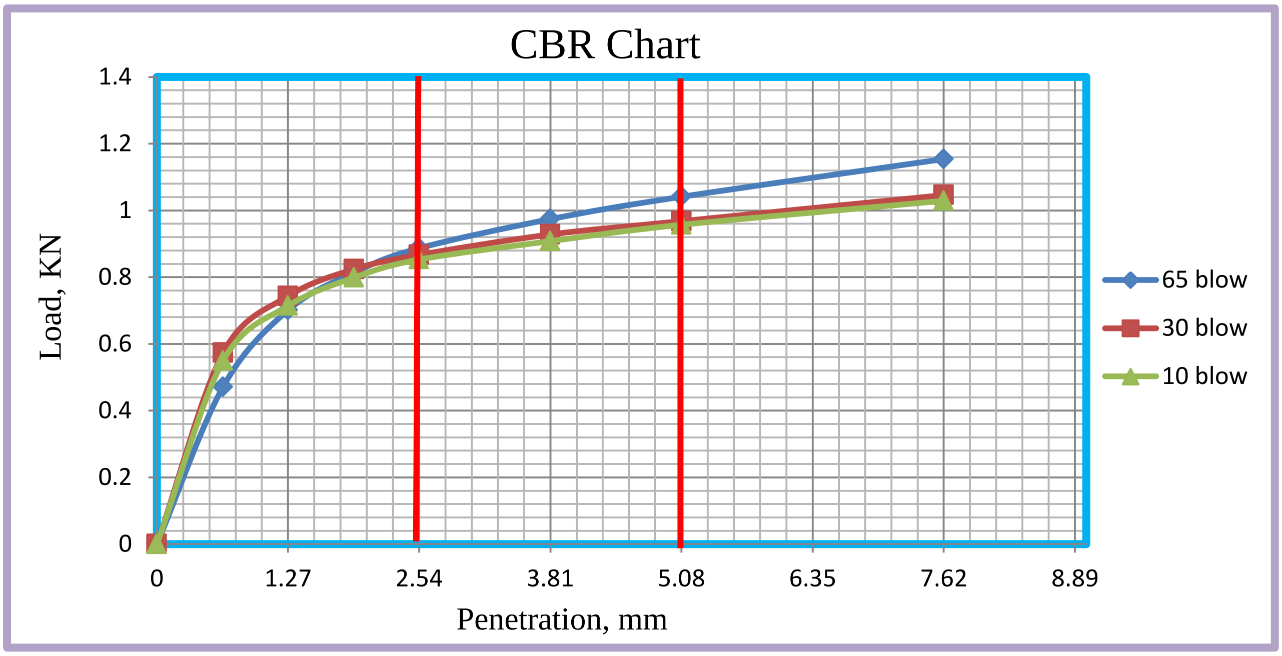
Modified Max.Dry Density g/cc	**1.491**	**OMC %**	**25.9**

Swell Determination

Date		**65 Blows Gauge rdg mm**	**65 Blows Swell in %**	**30 Blows Gauge rdg mm**	**30 Blows Swell in %**	**10 Blows Gauge rdg mm**	**10 Blows Swell in %**
27/02/2013	Initial	2.39	0.48	2.84	0.77	3.11	0.82
01/03/2013	Final	2.95		3.74		4.06	

Dry Density at 95% of MDD:				**1.416**
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**31.9**	**1.238**	**6.39**	**83**
30	**29.3**	**1.378**	**6.52**	**92**
65	**20.0**	**1.574**	**6.67**	**106**

CBR % at 95 % MDD	**6.5**	**Swell %**	**0.77**



3.14) 40% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		K64	K64	N2	N2	N7	N7
Mass of soil + Mould	g	11028.7	11279.6	10964.8	11175.8	10844.3	11084.4
Mass Mould	g	6897.2	6897.2	6935.6	6935.6	6965.7	6965.7
Mass of Soil	g	4131.5	4382.4	4029.2	4240.2	3878.6	4118.7
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.945	2.063	1.897	1.996	1.826	1.939
Dry density of soil	g/cc	1.593	1.652	1.479	1.526	1.377	1.436

Moisture Determination

MOISTURE CONTENT DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		P65	49K	G3T3	A	U10	C86
Mass of wet soil + Container	g	143.29	176.89	147.83	184.35	167.83	151.39
Mass of dry soil + Container	g	123.74	148.73	123.56	149.63	133.74	121.71
Mass of container	g	35.40	35.53	37.70	37.03	29.16	36.90
Mass of water	g	19.55	28.16	24.27	34.72	34.09	29.68
Mass of dry soil	g	88.34	113.20	85.86	112.60	104.58	84.81
Moisture content	%	22.13	24.88	28.27	30.83	32.60	35.00

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			30 Blows			10 Blows		
Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %	Pen.mm	Load, KN	CBR %
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.649		0.64	0.617		0.64	0.612	
1.27	0.851		1.27	0.823		1.27	0.826	
1.91	0.964		1.91	0.938		1.91	0.927	
2.54	1.029	7.71	2.54	1.008	7.56	2.54	0.994	7.45
3.81	1.124		3.81	1.113		3.81	1.085	
5.08	1.203	6.02	5.08	1.173	5.87	5.08	1.146	5.73
7.62	1.309		7.62	1.264		7.62	1.241	

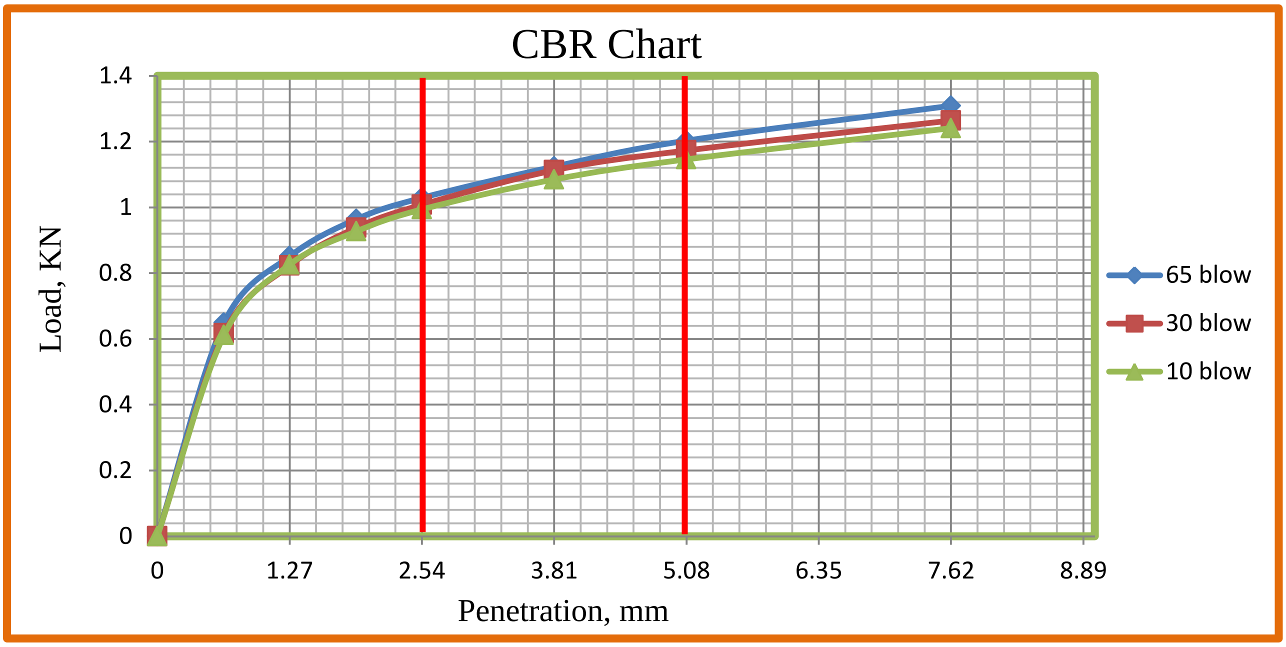
Modified Max.Dry Density g/cc	1.474	OMC %	29.8

Swell Determination

Date		65 Blows		30 Blows		10 Blows	
		Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %	Gauge rdg mm	Swell in %
27/02/2013	Initial	1.39	0.70	1.79	1.07	1.96	1.92
01/03/2013	Final	2.21		3.04		4.19	

Dry Density at 95% of MDD:				1.400
No.of blows	MCBS %	DDBS g/cm3	Correcrt CBR %	% OF Compaction
10	32.6	1.377	7.45	93
30	28.3	1.479	7.58	100
65	22.1	1.593	7.74	108

CBR % at 95 % MDD	7.5	Swell %	1.07



3.15) 50% CA

COMPACTION DATA		65 Blows		30 Blows		10 Blows	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.		T4	T4	KL8	KL8	AS6	AS6
Mass of soil + Mould	g	10946.8	11236.4	10904.6	11214.2	10874.9	11173.5
Mass Mould	g	6950	6950	6742.3	6742.3	6923.5	6923.5
Mass of Soil	g	3996.8	4286.4	4162.3	4471.9	3951.4	4250
Volume of Mould	g	2124	2124	2124	2124	2124	2124
Wet density of soil	g/cc	1.882	2.018	1.960	2.105	1.860	2.001
Dry density of soil	g/cc	1.586	1.641	1.416	1.501	1.313	1.377
Moisture Determination							
MOISTURE CONTENT DATA		**65 Blows**		**30 Blows**		**10 Blows**	
		Before soak	After soak	Before soak	After soak	Before soak	After soak
Container no.		43-K	A22	CD1	C4	85K	KI06
Mass of wet soil + Container	g	151.21	142.93	183.69	168.53	156.38	171.26
Mass of dry soil + Container	g	132.58	120.41	143.26	129.85	119.34	127.71
Mass of container	g	32.84	22.36	38.00	33.74	30.50	31.49
Mass of water	g	18.63	22.52	40.43	38.68	37.04	43.55
Mass of dry soil	g	99.74	98.05	105.26	96.11	88.84	96.22
Moisture content	%	18.68	22.97	38.41	40.25	41.69	45.26

CBR Penetration Determination

Penetration after 96 hrs. Soaking Period			Surcharge Weight:-4.55 KG					
65 Blows			**30 Blows**			**10 Blows**		
Pen.mm	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**	**Pen.mm**	**Load, KN**	**CBR %**
0.00	0.000		0.00	0.000		0.00	0.000	
0.64	0.574		0.64	0.542		0.64	0.429	
1.27	0.781		1.27	0.711		1.27	0.618	
1.91	0.894		1.91	0.798		1.91	0.715	

2.54	0.943	7.07	2.54	0.853	6.39	2.54	0.788	5.91
3.81	1.097		3.81	0.924		3.81	0.887	
5.08	1.184	5.92	5.08	0.994	4.97	5.08	0.957	4.79
7.62	1.307		7.62	1.089		7.62	1.022	

Modified Max.Dry Density g/cc	**1.440**	**OMC %**	**27.4**

Swell Determination

Date		**65 Blows**		**30 Blows**		**10 Blows**	
		Gauge rdg mm	**Swell in %**	**Gauge rdg mm**	**Swell in %**	**Gauge rdg mm**	**Swell in %**
27/02/2013	Initial	0.99	1.17	1.26	1.49	1.72	1.97
01/03/2013	Final	2.35		2.99		4.01	

Dry Density at 95% of MDD:				**1.368**
No.of blows	**MCBS %**	**DDBS g/cm3**	**Correcrt CBR %**	**% OF Compaction**
10	**41.7**	**1.313**	**5.91**	**91**
30	**38.4**	**1.416**	**6.41**	**98**
65	**18.7**	**1.586**	**7.09**	**110**

CBR % at 95 % MDD	**6.2**	**Swell %**	**1.49**