JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
GEOTECHNICAL ENGINEERING CHAIR

UTILIZATION OF WHEAT STRAW FIBER AND CEMENT AS SOIL STABILIZER FOR EXPANSIVE SOIL: - A CASE OF ROBE TOWN

A thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Civil Engineering (Geotechnical Engineering)

By
Engda Birhanu Tefera

February 2022
Jimma, Ethiopia

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Engda Birhanu Tefera

Advisor: Dr. Jemal J. Muhammed

Co-Advisor: Ms. Ruhama Beyene

February 2022
Jimma, Ethiopia

APPROVAL SHEET

I, the undersigned certify that the thesis entitled: **"Utilization of Wheat Straw Fiber and Cement as Soil Stabilizer For Expansive Soil:- A Case Of Robe Town"** is the work of Engda Birhanu Tefera and has been accepted and submitted for examination with my approval as university advisor in partial fulfillment of the requirements for degree of Master of Science in Geotechnical Engineering.

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As member of Board of Examiners of the MSc Thesis Open Defense Examination, We certify that we have read, evaluated the thesis prepared by Engda Birhanu Tefera and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Geotechnical Engineering.

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DECLARATION

I declare that this research entitled **"**Utilization of Wheat Straw Fiber and Cement as Soil Stabilizer For Expansive Soil: - A Case Of Robe Town" is my original work and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Engda Birhanu Tefera	____________	______
NAME	SIGNATURE	DATE

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Engda Birhanu Tefera entitled "UTILIZATION OF WHEAT STRAW FIBER AND CEMENT AS SOIL STABILIZER FOR EXPANSIVE SOIL: - A CASE OF ROBE TOWN" and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Geotechnical Engineering.

Advisor: Dr. Jemal J. Muhammed	____________	______
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ABSTRACT

A large surface area of Robe town is covered by expansive soils which has a tendency to undergo volume change due to seasonal moisture variation. This study focused on providing an alternative solution for the disposal of agricultural waste wheat straw fiber (WSF) by using it as a reinforcement of expansive soil and again to reduce the amount and cost of cement used for stabilization of expansive soil in case of Robe town. To achieve the objectives of this study, the soils found in Robe town were studied in the field and representative soil samples were collected from different locations at 1.5m and 3m depth below the ground surface. Six undisturbed and six disturbed samples were collected from three test pits for different laboratory tests and each samples were determined according to American Society of Testing Materials (ASTM) and Ethopian Roads Authority (ERA) manual. The laboratory tests which were carried out include Natural Moisture Content, Grain Size Analysis, Atterberg Limit, Specific Gravity, Free Swell, Linear Shrinkage, Compaction, California Bearing Ratio (CBR) and CBR Swell, Unconfined Compression Strength (UCS) and X-Ray Diffraction (XRD). Wheat straw fiber were collected from around study area and choosen for reinforcement and randomly included at different percentage of fiber that is 1%, 2%, 3%, 4%, 4.5% and 5% with length of 1.5cm by weight of raw soil and different percentage of cement studied by different researchers including 8%, 7%, 6%, 4%, 3% was used to control the swell and shrink behavior of expansive soil. According to Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) the test results indicate that natural soils collected from study area were categorized as fair to poor performing soil groups interms of as a subgrade material. In addition, the soil stabilization was done after knowing the type and property of the soil. Relative to the natural soil the maximum dry density and strength of the stabilized soil was increased in the presence of wheat straw fiber and cement. But as amount of cement decreasing while increasing wheat straw fiber beyond 4% the improvement was lower. And also before utilization of wheat straw fiber as reinforcement of soil different pretreatment including 3% of sodium hydroxide (NaOH) and Hot Water(30min) was used to improve the bonding quality, to improve degradation property with time and extraction of certain amount of chemical constituents. For this study (3%WSF + 7Cement) was an optimum ratio by considering safety in addition to economy and which achieves by improving most of the geotechnical properties of soils of Robe town.

KEYWORDS:- *Expansive Soils, Wheat Straw Fiber, Cement, Reinforcement, Stabilization*

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Finally, I would like to offer my special acknowledgement to my family member for their endless effort to have a meaningful life. And also I would like extend my heartfelt gratitude for those who participate directly or indirectly in this research work to be excellent.

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ABBREVIATIONS

AASHTO	American Association State of Highway and Transportation Officials
ASTM	American Society of Testing Materials
BRTC	Bale Robe Teachers College
CBR	California Bearing Ratio
CEC	Cation Exchange Capacity
CSA	Central Statistics Agency of Ethiopia
FAA	Federal Aviation Exchange
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
JIT	Jimma Institute Technology
LL	Liquid Limit
MDD	Maximim Dry Density
MWU	Madda Walabu University
MWPS	Madda Walabu Primary School
OMC	Optimum Moisture Content
PI	Plastic Index
PL	Plastic Limit
SP	Swelling Potential
USA	United State of America
USCS	Unified Soil Classification System
WSF	Wheat Straw Fiber

CHAPTER 1
INTRODUCTION

1.1 Background

Most of engineering structure having shallow foundation are built on the soil. So the soil on which the structures to be built should be capable of withstanding the load imposed on it. Of course there exist problematical soils to be used as foundation or construction materials such as expansive soil (Ikeagwuani and Nwonu, 2019). Expansive soils have low bearing capacity or low shear strength and due to these structures constructed on these kinds of soils subjected to different damages such as crack and settlement (Madurwar, Dahale and Burile, 2013). These damages are due to swell and shrink behaivor of expansive soil. These swelling and shrinking behaivior can be minimized by stabilizing the soil by adding different admixtures to change the physical as well as chemical properties of the soil (Jones, Survey and Jefferson, 2012).

Stabilization is achieved through enhancing soil shear strength as well as its overall bearing capacity. Once stabilized a hard monolith material forms which limits permeability and thus shrink/swell potential as well as the reducing consequences of freeze/thaw cycles. Stabilized soils also provide a stable working platform laying the groundwork for the rest of the project. And weak soils can be altered by the establishment of permanent pozzolanic reactions after stabilizing procedures. Cement and lime are the major common materials which are used to strengthen the weak soil but these materials are very costly (Firoozi *et al.*, 2017).

The use of randomly distributed fibers to reinforce soil dates back over 5000 years and this technology is still a hot research topic today with a growing range of applications (Wang *et al.*, 2019). Wheat straw, coir reeds, hemp, sisal, grass, bamboo chips, palm and willow branches have all been utilized as soil reinforcement in the past and have recently gotten a lot of attention (Li *et al.*, 2012). Wheat straw is an agricultural waste and locally available material normally used for feeding the animals (Kumar, Gautam and Chaturvedi, 2018). Especially in Bale Zone the availability of wheat straw is very high. The use of agriculture waste such as wheat straw fiber as a reinforcement and other substantially reduce the cost of construction material and also reduce the environment risk which caused by cement or lime. Soil reinforcement by treated wheat straw fiber is considered as nice ground improvement technique since the availability of this material is high. Wheat straw fiber reinforcements also have a noticeable improvement on geotechnical properties. Increases in compressive, shear and tensile strength, as well as a reduction in the swelling potential of expansive soil are all examples of this improvement (Wang *et al.*, 2019). Furthermore due to its relatively cheap, lightweight nature and not harmful to environmentally there is high chance for using wheat straw fiber to reinforce soil.

1.2 Statement of problem

Globally there is huge amount of annual maintenance cost for different structure constructed on expansive soils. This is due to the undesirable volume instability (i.e. swell and shrink behavior) of expansive soil. These volume changes causes different problems such as great distress and serious structural damage to light-weight structures (especially road and airfield infrastructures as they covers large areas) built on it (Selvakumar and Soundara, 2020).

In a country like Ethiopia which is developing at high growth rate many construction works are undergoing at present and will be done in the future. Due to these, geotechnical analysis of soil is critical as datas are crucial for civil engineers in the preliminary design and design of foundations, pavements, retaining structures and other structures for future construction projects in the country. Comparatively with other countries large areas in Ethiopia are covered with expansive clay soils. These soils have caused persistent difficulties in building, road and airfield construction due to their swelling and shrinking behavior. Due to these negative engineering characteristics of expansive soils they have become problematic soils in the areas where they exist and their use have been limited (Jayalath, 2016).

Many researches were done and there are ongoing researches in most big cities of the country like Addis Ababa, Bahir Dar, Mekele, Hawassa, etc. However, the engineering property of the soil in Bale Robe town had not been studied widely. Robe Town, which is Capital of Bale Zone it had been noticed that expansive soils covers large parts of the town where recent constructions are carried out. During the past decades rapid expansion of the town and population growth due to migration from different parts of the small town and villages led to the construction of various structures particularly low-cost buildings and many feeder roads. But the existence of expansive soils in the Robe town has induced structural damages on light-weight buildings ,asphalt road pavement and utility lines under ground (Mahmud.M, 2018). But town municipals, planners and engineers did not appear to pay attention to the problems associated with expansive soil during site selection and construction of low-rise and low-cost buildings.

But there is plenty of wheat available in Bale Zone which can be used for construction purpose if the property of this material is carefully investigated and again which will be used to reduce the amount and cost of cement needed for soil stabilization. So this work was brought to evaluate the characteristics of expansive soils by mixing with waste wheat straw fiber as a reinforcement and cement for possible improvement on their geotechnical characteristics and provide the opportunity to use the expansive soil for construction purpose instead of remove or cart away. Again different researchers used wheat straw ash for stabilization of expansive soils which may cause environmental pollution but in this study the researcher was used treated wheat straw fiber by physical and chemical treatment which reduce environmental impact.

1.3 Research Questions

1. What are the geotechnical properties of natural expansive soil of Robe town?
2. Does wheat straw fiber and cement-soil composite improve soil strength and performance?
3. What is the optimum percentage of wheat straw fiber and cement to improve the performance and strength of the soil?

1.4 Objectives

1.4.1 General objective

The main objective of this research was to use agricultural waste wheat straw fiber and cement as a expansive soil stabilizer for the case of Robe Town.

1.4.2 Specific objective

- To determine the geotechnical properties of natural expansive soil for the case of Robe town.

- To evaluate improvement of expansive soil by using wheat straw fiber and cement as admixture for the case of Robe town.
- To determine the optimum percentage of wheat straw fiber and cement to be used during stabilization of soil for the case of Robe town.

1.5 Scope of study

In this research an attempt were made to consider the expansive soil on the different site of the Robe town such as Maddawalabu Unversity Campus, Maddawalabu Primary School, and Bale Robe Teachers College. For this anticipated purpose disturbed and undisturbed samples were collected from different locations of the town which was confirmed by different investigators to be covered by expansive soils.

Also different Laboratory tests were done such as Compaction test (i.e. to determine Maximum Dry Density, Optimum Moisture Content), Atterberg Limit test (i.e. Liquid Limit, Plastic Limit), Plasticity index, Linear Shrinkage, Specific Gravity, Free Swell test, Unconfined Compression Strength test, XRD, CBR and CBR Swell test were conducted. The swelling tests were performed using free swell test. Moreover, due to the limitation in financial resource and time this research was more limited to the investigation of soils on specific site, and specific soil sample and limited number of tests were considered especially around MWU, MWPS and BRTC. From visual observation of the site soil, expansive soil-related cracks, recent research work and discussion with residents the soil in these areas are expansive soil.

1.6 Significance of The research

For Robe Town the findings of this study provide useful information to a variety of stakeholders including the Town Administration as a source of information for determining adequate structural design that accommodates differential soil movement without undue distress and a foundation for the construction industry that can help to reduce the time and cost of laboratory tests. For construction sector (i.e. contractor, consultant) this study used as the source of information to avoid the potential hazards posed due to the presence of swelling soils during the construction and operational phase of any structures in the town. For next year students who need more information about improvement of expansive soil properties by wheat straw fiber this study can be used as a reference. For the researcher who can use this study as the empirical data it will be used to support the research which will be conducted in the future.

1.7 Justification of the study

The reasoning for conducting this study were to provide the reference under which the engineering property of expansive soil is improved by using wheat straw fiber as a reinforcement and small amount of cement to reduce the cost of construction material by using local material. Again the goal of this study was to reduce engineering structural damage caused by expansive soil. So there will be a chance to fix these problems because Robe Town is heavily covered with expansive soil, but it will require distinct research and experimental analysis.

1.8 Organization of the research

This thesis has a total of five Chapters. Chapter one deals with the general introduction which gives a brief description of the thesis background, statement of problem, objectives, scope, significance and justification of the study. The second chapter is entirely devoted to the literature reviewed on expansive soils, soil stabilization and wheat production around the world, on the continent and in our own country. The third Chapter gives description of study area, materials and methods used in this particular study. Again under this chapter experimental set up and testing procedure used also included. Chapter four presents the experimental results of tests on soil samples collected from Madda Walabu University, Madda Walabu Primary School and Bale Robe Teachers Collage which includes grain size analysis, atterberg limits, specific gravity, free swell, linear shrinkage, compaction, CBR, CBR swell, unconfined compressive strength and XRD test results for natural and stabilized soil with wheat straw fiber and cement. This chapter also includes a discussion for all respective test results mentioned above. Chapter five is the final chapter of the thesis, integrating both conclusions and recommendations as output of this particular work. Reference and appendix placed at the end of the thesis respectively.

CHAPTER 2
LITERATURE REVIEW

2.1 Origins of Expansive Soils

The origin of expansive soil is linked with variation of conditions and process that results in the formation of clay minerals having a particular chemical and mineral composition. There are two types of parent materials assoiciated with expansive soil. The first group is basic igneous rocks which are contain low silica. Again rocks which are rich in metalic base such as gabbros, basalts and volcanic glass are grouped into this category. The second group is sedimentary rocks which contain montimorillonite including shale and clay stones. Limestone and marls also fall within this category but they are rich in magnesium (Chen, 2012).

2.2 Characteristics of expansive soils

Expansive soils owe their characteristics to the presence of swelling and shrinking clay minerals. Whithin the intake of water molecules clay minerals will expand and conversely with lose of water molecules they will shrink which lead to damage and deformation of the building (Jones, Survey and Jefferson, 2012). If any type of soil contain more than 5 percent clay they will show swell and shrink behaivor. Most of the time soil contain montimorillonite exhibit more swelling characteristics than soils contain other minerals such as kaolinite and illite (Shi *et al.*, 2002).

Subsequent swelling and shrinkage of this soils due to change in moisture cause damages to civil engineering structures, particularly light weight structures which could not balance the swelling pressure of the soil (Jayalath, 2016).

2.3 Distribution of Expansive soil

Potentially expansive soils can be found anywhere in the world. In the underdeveloped countries much of the expansive soil related problems may not have been recognized. It is to be anticipated that more expansive regions will be discovered each year as the amount of construction increase. The countries where the expansive soil were reported are Argentina, Kenya, Australia, Burma, Japan, Canada, Cuba, Ethiopia, Ghana, India, Israel, Iran, Mexico, Morocco, Rhodesia, China, South Africa, Romania, Spain, Egypt, Turkey, Saudi Arabia, U.S.A and Venezuela. Expansive soils are in abundance where desiccation phenomenon is common i.e., where the annual evaporation exceeds the precipitation. The problem of expansive soil is widespread throughout the six continents except Antarctica (Elshater, 2019).

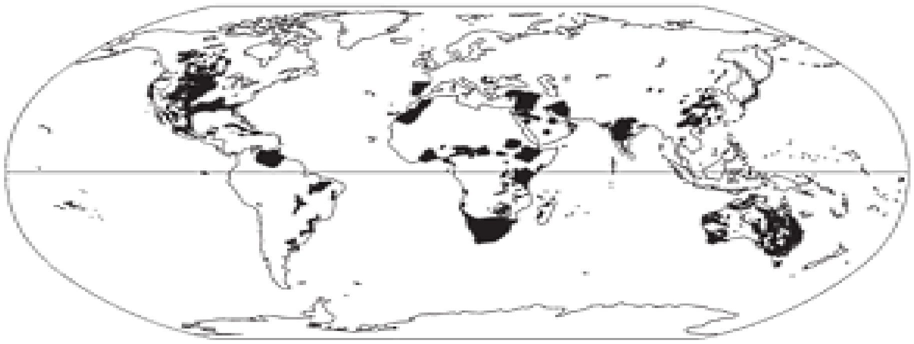

Figure 2.1 Global distribution of expansive soil (Nelson *et al.*, 2015).

2.4 Identification of Expansive Soils

2.4.1 Field identification

Nowadays it is evident that soil deposits can be recognized in the field through visual inspection. Important observations include wide or deep shrinkage cracks, high dry strength and low wet strength, stickiness, low traffic ability when wet, cut surfaces having shiny appearance, appearance of cracks in nearby structures, they usually have a color of black or gray and as a rough guide the presence of distinct cracks on light weight buildings (Musso, 2014).

Figure 2.2 Cracks in dry season (Musso, 2014)

2.4.2 Laboratory identifications

There are three different method of identifying potentially expansive soils in the laboratory.

i. Mineralogical Identification

Mineralogical identification can be useful in the evaluation of the material but it's not sufficient when dealing with natural soils. The techniques which may be used for mineralogical identification are X-ray diffraction, Differential thermal analysis, Dye adsorption, Chemical analysis and Electron microscope resolution (Asuri and Keshavamurthy, 2016).

ii, Indirect methods

This method includes the use of index properties (i.e. Atterberg limit, Grain size analysis), Cation Exchange Capacity (CEC), Potential Volume Change (PVC) test and activity method which are valuable tools in evaluating swelling property (Asuri and Keshavamurthy, 2016).

ii, Direct measurement

Direct measurement of expansive soils can be achieved by the use of conventional one-dimensional consolidometer and Free swell which is available in most soil mechanics laboratories (Asuri and Keshavamurthy, 2016).

2.5 Classification of expansive soils

A soil can be categorized into groups and sub-groups by using different systematic method based on their engineering behavior. The unified soil classification system (USCS), the American Association of State Highway and Transportation Officials (AASHTO), the Pedologic soil classification system, the US public roads administration (PRA) system, the Federal Aviation Agency (FAA) system and the textural classification system are all examples of soil classification systems. Currently, the USCS and the AASHTO system are in use in civil engineering practice (Keaton, Wheeler and Angeles, 2018).

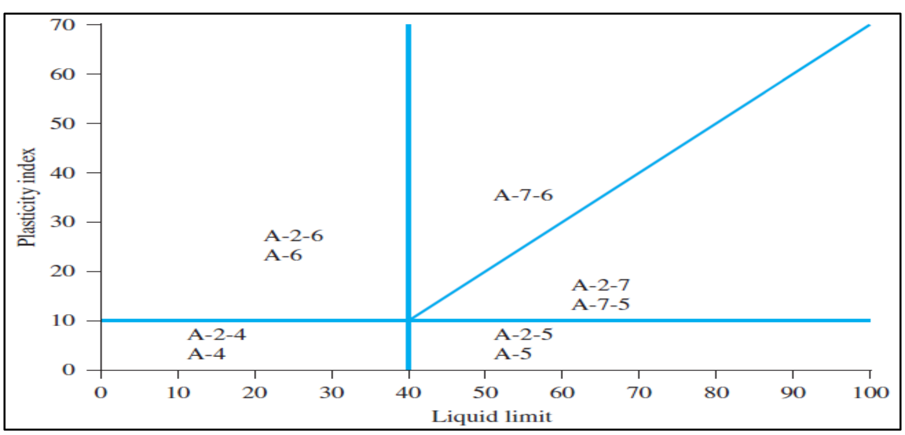

Figure 2.3 Chart for use in AASHTO soil classification system (Das, 2010).

A review of the identification and classification systems for expansive soil that appear in the technical literature follows:

a) Skempton

Activity (A), defined as the ratio of the plasticity index to the percent clay (% < 2 μm), was first defined and used by Skempton (Özdemir and Gülser, 2017). Table 2-1 below shows the relation between activity and swelling potential which had been used by different investigators during their study to classify the soils with regard to potential of expansion.

Table 2-1 Relationship between Potential expansion and Activity

A=PI/%<2μm	
Activity, A	Rating potential expansion
<0.75	Low
0.75-1.25	Medium
>1.25	High

b) Index tests

From laboratory index tests especially Atterberg Limits (i.e. liquid limit, plastic limit and plasticity index) we can classify expansive soil in terms of its swelling potential.

Table 2-2 Relationship between Swelling potential and Plasticity index

Swelling potential(Sp)	Plasticity index(PI)	Sp=0.23(PI)-3.12
Low	20	1.5
Medium	20-31	1.5-4.0
High	31-39	4.0-6.0
Very High	>39	6

2.6 Mechanics of swelling

Swelling is the process of absorbing water to cause an increase in soil volume until the pore water pressure increases to an equilibrium determined by the environment. The amount of swell required to achieve pore pressure equilibrium is determined by the vertical loading magnitude as well as soil variables such as soil composition, natural water content, density (or unit weight) and soil structure. The rate of swell can be related to coefficient of permeability (K), thickness of the soil, percent of clay in a given soil, amount of gravel and surcharge (Nagaraj, Munnas and Sridharan, 2010).

Swelling of expansive soils is due environmental change which can consists of pressure release due to excavation, density of the soil and volume increase because of the introduction of moisture. The volumetric expansion or increase in volume is related to potential gradient, which can cause water migration and continuous passage for water to transfer through the soil (Chen, 2012).

2.7 Soil Stabilization

Soil stabilization is the process of improving original properties of problematic soil to achieve desired specification for construction purpose (Firoozi *et al.*, 2017). The purpose of soil stabilization is to increase the bearing capacity, to improve the permeability and water absorption, to increase volume stability (i.e. by controlling the swelling and shrinking behavior), to increase the workability, to reduce the settlement, to increase the shear strength and durability of a given soil (Afrin, 2017). Stabilization of the soil started 5000 years ago from now. Stabilization of earth roads were started in ancient civilized countries such as Mesopotamia, Egypt, Romans and Greek. Again United State of America was the first country where stabilization test performed for the first time in 1915. Once more for the first time cement introduced to stabilize road construction in Sarasota, Florida (Firoozi *et al.*, 2017).

2.7.1 Types of Soil Stabilization

2.7.1.1 Mechanical Stabilization

Mechanical stabilization is the process altering the stability, durability, workability and strength characteristics of the given soil by mixing different gradation and without changing the chemical properties of the soil. Mechanical stabilization includes compaction, blasting, blending with non expansive and application of geo-reinforcement. Mechanical stabilization is more suitable for coarse grained soil than fine grained soil (Afrin, 2017).

Among mechanical stabilization now adays the use of fibers as soil stabilization is common due to its low cost compared to other types of stabilization materials. Fibers have high resistance to chemical and biological degradation and also they do not cause leaching if properly treated. If we add more fiber into the soil and especially as the length of the fiber increases the maximum dry density decrease due to its low weight. But the shear strength, tensile strength and unconfined compression strength of the soil increased (Firoozi *et al.*, 2017). When the fiber length is between 15 and 25 mm, the highest increase in strength is noticed. Again, the introduction or addition of fiber to the soil can increase the bearing capacity of the soil and it also reduce the settlement. This kind good opportunity happen when the researcher used coir fiber to reinforce tropical soil. In this study due the addition of coir fiber into the soil maximum strength gain (stiffness increment) and the immediate settlement of the soil reduced (Cristelo *et al.*, 2015).

2.7.1.2 Chemical Stabilization

Chemical stabilization is mixing of the soil with different admixtures such as cement, lime, fly ash, potassium chloride, sodium chloride, bitumen and calcium chloride to improve the strength, volume instability and durability of the the soil (Radhakrishnan, Kumar and Raju, 2014). Chemical stabilization is more effective for fine grained soils such as clay. Most of the time cation or ion exchange, flocculation-agglomeration and cementation reactions are the three basic reaction involved in chemical stabilization (Ismaiel, 2006). In this kind of soil stabilization due to the reaction between siliceous and aluminous material with calcium hydroxide ($Ca(OH)_2$) cementitious compound formed and when the soil exchange free cations in exchange location cation exchange occurs (Firoozi *et al.*, 2017).

i) Stabilization using Cement

Cement stabilization is a type chemical stabilization which is applicable to a wide range of soils and situations to reduce moisture induced volume instability. Due to the binding nature of cement it increase the inter-particle bond between granular materials and then increase the strength and elastic modulus of the soil (Mahmud Hasan Mamun, 2016). Stabilization of soil with cement is to form a product name known as soil-cement and it’s a mixture of soil, cement and water to be compacted to the desired density. This kind stabilization method used in different engineering structures such as embankment slope, pavement, building foundation, parking lots…etc. Due to cement addition, different soil properties are modified this include strength, volume stability and durability of soil (Estabragh, Bordbar and Javadi, 2013). The percentage of cement used in soil stabilization depend on type of soil, environment, purpose of service. When cement mixed with water and soil after few hours hydration occurs. During hydration process different compound C-S-H and C-A-H formed and $Ca(OH)_2$ released (Parsons, R.L. and Milburn, 2003). Soil stabilization with cement can reduce plasticity of soils (i.e. increase plastic limit), reduce frost heave, increase maximum dry density, reduce liquid limit, reduce shrinkage and swell, increase shear strength, reduce freeze and thaw. Cement stabilization can be used for any type of soil but its not recommended for soil contain organic matter more than 2%. Addition of cement on granular soil produce promise result due to smaller amount of cement required to stabilize this kind of soil (Firoozi, Taha and Firoozi, 2014).

ii) Stabilization using Lime

There are three kind of lime produced from broken down of limestone these are quiklime, hydrated lime and hydrated slurry lime. The difference between these three types of lime is for instance if quick lime is used for soil stabilization hydration occurs immediately after the addition of water and heat released which leads to drying of soil and evaporation of additional water. However, if hydrated lime or hydrated slurry lime is utilized for soil stability, the soil will dry out due to chemical changes (Louafi, Hadef and Bahar, 2015). Lime is one of an effective stabilizing agent for fine grained soils to improve plasticity, workability, volume instability, durability and strength. But they are not suitable for coarse grained soils without additions of fine pozzolanic additives (Sirivitmaitrie *et al.*, 2011). The process of flocculation and agglomeration occurs when the soil become friable and granural which lead to reduction in plasticity index of the soil. These process to be happened, the soil mineral silica and alumina are released and react with calcium from lime to form permanent, impermeable, durable, layer that is firm and flexible. The formation of this kind of strong material occurs slowly and depend on clay mineral present, amount of lime used, curing time, temperature and compaction effort and from 1 to 4 days required to have homogeneous mixture. The pozzolanic or cementing process is also influenced by climatic conditions (Solanki, Zaman and Dean, 2010).

$$\mathrm{Ca^{2+} + OH^{-} + Soluble\ Clay\ silica \rightarrow Calcium\ silicate\ hydrate\ (CSH)}$$

$$\mathrm{Ca^{2+} + OH^{-} + Soluble\ Clay\ alumina \rightarrow Calcium\ alumina\ hydrate\ (CAH)}$$

iii) Stabilization using Bitumen

Bitumen stabilization is used to stabilize cohensionless materials to increase cohesion property and also used to stabilize cohesive materials to act as water proofing agent. Both effects are due to formation of bitumen film around soil particles to prevent the absorption of water (i.e. prevent water from entering the soil mass). During mix design more care is necessary to achieve satisfactory result, so it's not used widely as cement and lime (Afrin, 2017).

iv) Stabilization using Fly Ash

Burning of coal combustion product produce Class C and Class F fly ash. Class C fly ash produced from burning of lignite and subbituminous and whereas Class F fly ash produced from burning of anthracite. Again Fly Ash particles consist of silicon, iron oxides and aluminum (Bose, 2012). Fly ash can reduce liquid limit, reduce plascticity index, increase CBR and increase UCS of the soil. Fly ash can be used by combined with other material such as lime to stabilize silty and sandy soil for increasing the soil stiffness (Radhakrishnan, Kumar and Raju, 2014). The addition of fly ash to the soil for stabilization also reduce the required base layer thickness for flexible pavement construction. So its effective in stabilizing coarse to medium grained soil (Li *et al.*, 2008).

2.8 Wheat Straw Fiber

2.8.1 Wheat production in the world

Wheat is grown every year on more than 200 million hectares around the world from Scandinavia to South America to Africa and across Asia, making it more widely grown and used than any other agricultural food crop (Asia *et al.*, 2014). Especially Agriculture is backbone or key to Africa's current and future economy. In Africa half the production is employed under the agricultural sector and it is one of the largest contributor to gross domestic product of the continent. But still Africa produce little food and low value added products. Now adays most of low income countries in Africa make necessary headway towards stuctural transformation from agricultural growth to manufacturing, industry to reduce poverty and hunger (Anteneh and Asrat, 2020). Presently more than 2.5 billion people and around 89 countries consume wheat in their day to day life. Again nearly $50 billion –worth of wheat is traded around the world every year. Due to the urbanization, increase human income and working women the world wheat consumption is rapidly increased (Asia *et al.*, 2014).

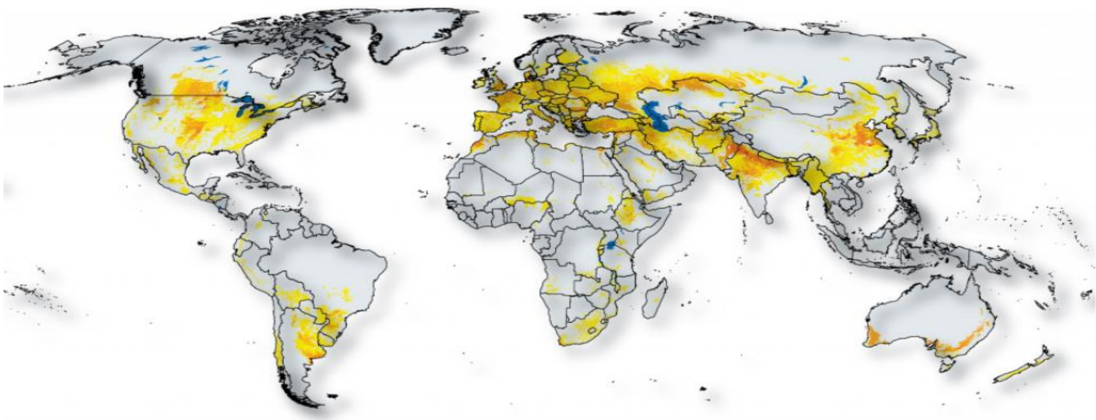

Figure 2.4 Global wheat cultivation **(Fritz, S Guo, Z See, 2014)**

2.8.2 Wheat Production in Ethiopia and Bale zone

Agriculture is also the key to Ethiopian economy, because more than 85% of National GDP of our country derived from agricultural sector. Crop production such as coffee, sugarcane, vegetable, cereals, oil seeds, pulses, potatoes are the major contributor to Gross Domestic, accounting 28 percent from subsector of agriculture. Wheat, teff, maize and barley occupy ¾ of total area cultivated and people spend 40% of their total food budget on these cereals. Ethiopia ranks 31st in the world with 4.2 million quintals produced on 1.7 million hectares of land and Ethiopia is one of the leading wheat producer in Africa especially below sub-saharan countries and third in the continent next to Egypt and Morocco (Anteneh and Asrat, 2020).

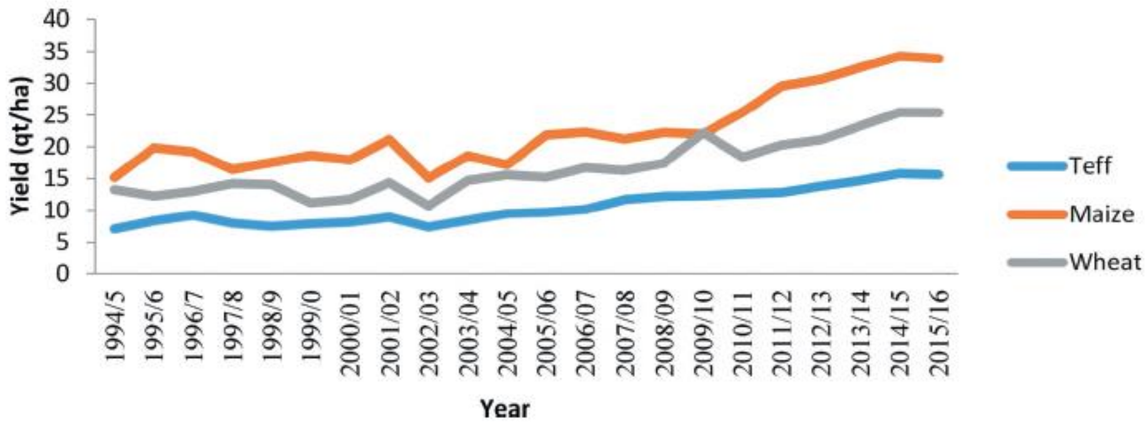

Figure 2.5 Yield status of wheat, maize and teff from 1994 to 2016 (source: PARI, 2015)

Again also our country produces totally about 3 million tones of wheat which is nearly 13 percent in all Africa. Most of the time the wheat production in Ethiopia is bread wheat. In the past decades all wheat production in our country predominantly produced by small-scale farmers, but currently a few government companies owned large-scale farms (FAO, 2014).

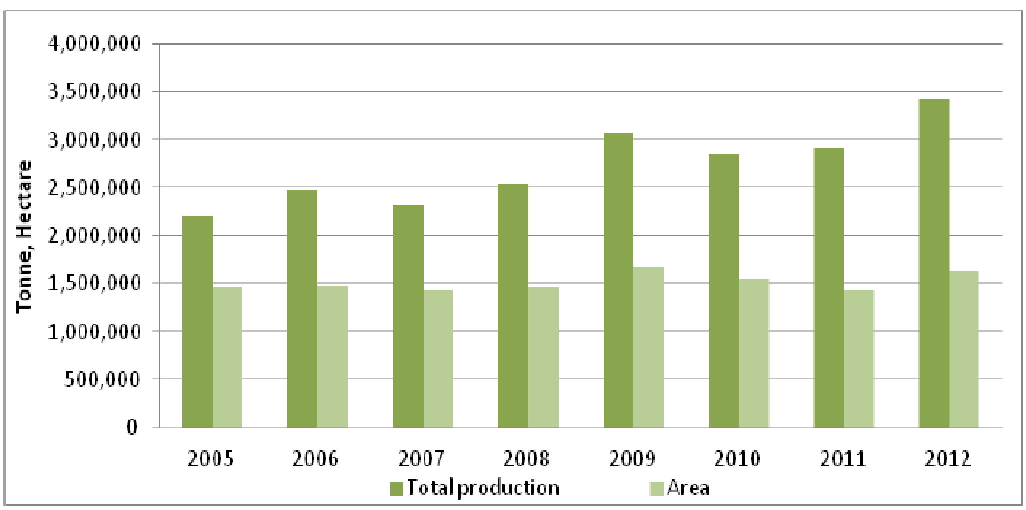

Figure 2.6 Trend of Quantity of Wheat Produced and Area in Ethiopia, 2005-2012 (Tonnes/hectare) [Source: CSA data, 2011/12]

In 2014/2015 GC the total cereal production reached around 270.4 million quintals. Again in 2015/2016 GC the total cereal production in our country increased by 2.41% from the 2014/2015 GC total cereal production. FAOSTAT indicates average wheat production and total areas coverage increased from 2000 GC to 2017 GC. But sometimes there is also decrease rate of wheat production during 2002 GC to 2004 GC due to rainfall variation (Anteneh and Asrat, 2020).

Table 2-3 Trend of wheat in area coverage, production and yield by region in Ethiopia

Region	2016/2017GC production season			2016/2017GC production season		
	Area(ha)	Production(qt)	Yield(qt/ha)	Area(ha)	Production(qt)	Yield(qt/ha)
Oromia	898.46	26640.24	29.65	898.68	26699.18	29.71
Amhara	554.28	13190.62	23.8	554.66	14047.07	25.33
SNNP	127.21	3287.59	25.84	127.25	3391.96	26.66
Tigray	107.72	2128.67	19.76	107.93	2140.03	19.83
Benishangulgumz	2.08			2.46	59.08	24.06

Wheat is grown in highlands of south eastern, central and northwest part of Ethiopia at altitude ranging from 1500 to 3000 meter above seal level. Regionally the percentage of wheat production indicates Oromia (57.4%), Amhara (27%), South Nation and Nationalities of Peoples (8.2%), and Tigray (6.2%) are where wheat comes from. There are 4.7 million farmers who produce and sell wheat in our country. Among these farmers 78% of these live in Oromia and Amhara regions (Anteneh and Asrat, 2020). Again relative to other regional states the average wheat area for production per farm is also largest in Oromia regional state of the country where farmers plant on average of 0.43 hectares per farm. The major crop season are known as “meher” from September to December. Among different Zones in Oromia Region, Bale and Arsi Zone is especially know for its high wheat production sometimes known as a **wheat belt** in our country (Usman, 2016).

Figure 2.7 Wheat production in Bale zone

Wheat has many uses such as in preparation of different traditional and modern processed food and these includes injera, pasta, macaroni and bread. Again wheat straw used as roof covering, bio-biased technology, superplasticizer (i.e admixture for concrete work), as building material and feed for animals. So wheat is an important production which should get emphasis on both its production and marketing. Besides this wheat is an important cereal crops in increase farmers income, employment, food security and again its useful in increasing National Gross domestic product of our country. But production and marketing of wheat in our country challenged by different factors such as diseases and pests, shortage of agricultural inputs, shortage of storage materials, shortage of infrastructures, product quality, low selling price and price cheating. However to negotiate these challenges, different opportunities including government policy, market expansion, demand increment for wheat encourage wheat producers and sellers to engage in wheat production and marketing. However to increase the demand of wheat throughout the world government should give attention by working together with large to medium scale commercial investors and farmers (Anteneh and Asrat, 2020).

In Bale Zone there is also high production of different food crops but for this particular study the researcher select wheat straw fiber as a reinforcement within the idea of using locally available material for construction purpose and to reduce the amount and cost cement used for soil stabilization.

2.8.3 Wheat Straw Fiber as a Reinforcement of Expansive Soil

Currently utilization of different crop straw such as wheat straw, rice straw and barley as reinforcement is gaining momemtum due their cost efficiency, availability, light weight and low environmental impact. Wheat straw is renewable which can replace wood in various application (Chougan *et al.*, 2020).

2.8.4 Wheat straw treatment to avoid biodegradation

The chemical constituents of wheat straw is similar to that of wood. These chemical constituents are cellulose, lignin and hemicellulose (Zheng *et al.*, 2018). Due to this different pre-treatment has been used to improve the surface compatability and to reduce biodegradation properties of wheat straw fiber. These pretreatment can be classified into physical and chemical treatment.

i) **Physical pretreatment: -** are steam cooking, hot water, steam explosion, liquid plasma and ozonation.

ii) **Chemical pretreatment: -**are submerging wheat straw into acetic anhydrayide, sulfuric acid, sodium hydroxide, sodium chlorite, hydrogen peroxide, modified polyvinyl alcohol(SH) and sodium carbonate**.**

Chemical pretreament increase hydrophobicity of these material. In general pretreatment is used to increase tensile strength, durability, elastic modulus and toughness of wheat straw fiber. Again pretreatment also used to improve surface of straw by removal and degradation of some chemical constituent which made it more hydrophobic and more compatible (Chougan *et al.*, 2020).

CHAPTER 3
MATERIALS AND METHODS

3.1 Introduction

The research methodology of this study contain the laboratory testing program which focused on improvement of the expansive soil by using wheat straw fiber as a reinforcement and cement. Again this chapter correctly gave detailed methods in terms of their procedures. The chosen methods were firmly assumed to be suitable for contributing to knowledge.

In general this chapter describes the approaches and techniques the researcher used to collect data and in order to solve the research problem. It also includes the description of Research Area, Materials, Type of Research Design selected, Study Variables, Population and Sampling Method, Sources of Data, Data Collection and Procedure.

3.2 Study/Research Area

Robe Town, more commonly known as **Bale Robe** is a town found in Bale Zone, Oromia Region and separate Woreda in south-central Ethiopia. The geographical location of Robe town is approximately between $7^{0}7'00''$ N latitude and $40^{0}0'00''$ E longitude with an elevation of 2,492 metres (8,176 ft) above sea level. In relative reference Robe town is located 430km in the South East direction from Ethiopia's capital city Addis Ababa (Finfine).

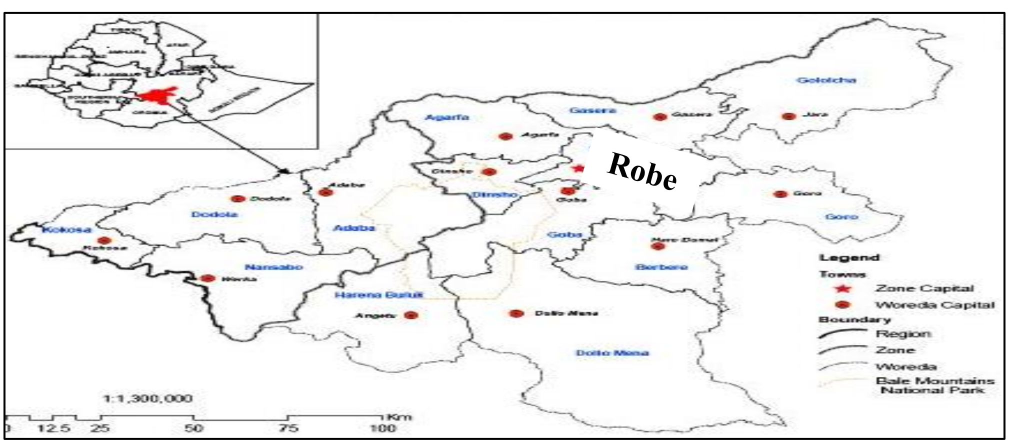

Figure 3.1 Bale zone map(Towns *et al.*, 2014)

Robe town is a zonal town with the 2nd grade of administrative status. According to the municipality's records, the town used to have 10 urban kebeles. In addition to these 10 urban kebeles, the town has now grown outwards to encompass a number of farmers' kebeles, such as Harawa Sinja in the northeast and Ali in the southeast. Robe town is currently undergoing development with the construction of new buildings, roads and enterprises. The town still has a lot of room for investment expansion, owing to its proximity to Adama, the capital of the Oromia Region. The town's relative location is depicted in figure 3.2.

Figure 3.2 Location of Robe town (Google Earth Pro, 2021).

Robe town shares Robe Airport with neighboring Goba town. Ethiopian Airlines operates a four-times-weekly, connecting Robe town, the capital Addis Ababa and the southern city Arba Minch. The primary market day is Thursday, with secondry market operating at a different location in the town on Tuesday and Sunday. Notable tourist attractions around Bale Robe town include the Sof Omar Caves, Dire sheikh Hussein Stone, Dinsho National park and so on.

Figure 3.3 Tourist attraction place around Bale Robe town (Source:- (Bale Zone culture and tourism, 2017).

Robe town had a total population of 44,382 people according to the 2007 national census, with 22,543 males and 21,839 women. The majority of the population claimed to be Muslim, with 48.08 percent claiming to follow this religion, while 45.02 percent claimed to follow Ethiopian Orthodox Christianity and 6.13 percent claimed to be Protestant. Again, the mean minimum, mean maximum and mean average monthly temperatures at Bale Robe town, which is located at an altitude of 2400-2500 meters above mean sea level, are 15°C, 24.9°C, and 19.95°C, respectively. The months of December, January, February and March have the highest temperatures. April and May are the coldest months of the year. The months of June and July are warm and sunny. The rainy season occurs every year in August, September, October and November. Temperatures range from 14°C to 26°C on a monthly basis. This demonstrates that the temperature does not remain consistent throughout the year.

3.3 Materials

I. Natural (Expansive) Soil

The weak expansive soil samples used for this research work were collected from different locations of study area. These locations were MWU (7°8'32.38''N, and 40°0'8.86''E) MWPS (7°7'31.07''N, and 40°0'26.55''E) and BRTC (7°6'46.07''N, and 40°0'3.42''E). For all test pit and depth the soil is Dark gray in color. The samples were undisturbed and disturbed collected at a depth of about 1.5m and 3m.

II. Wheat Straw Fiber (WSF)

The wheat straw fiber used for this study were collected from different villages around Bale Robe town after the harvest season and the wheat straw fiber were sun dried. The collected wheat straw fiber were then grinded into length of 15mm. After grinding wheat straw fiber into this size it was treated by submerging into 3% of Sodium hydroxide(NaOH) solution and Hot water up to 30minutes to minimize degradation characteristics of wheat straw fiber with time.

Figure 3.4 Collection and preparation of wheat straw fiber (WSF)

III. Cement

Different types of cement are available, but Dangote Ordinary Portland Cement (OPC) of grade 42.5R was chosen for this investigation because it have a high sulfate resistance capacity and is readily available in Ethiopia. Laboratory work was carried out at Madda Walabu University, Paragon Engineering Consultant PLC and Jimma Institute of Technology University, Geotechnical and Material Engineering laboratory.

3.4 Research Design

A study design/frame/strategy is the process that guides researchers on how to collect, analyze and interpret observations (Marczyk, G.R., DeMatteo, D. and Festinger, 2010). Therefore, the objective of this research were achieved in accordance with the methodology outlined below. Relevant literatures concerning expansive soils were reviewed. The research design was based on a purposive sampling selection. The excavation sites were chosen based on secondary data obtained from various organizations and earlier study on the engineering properties of the soil collected from Robe town. In order to achieve the objectives of the research, the following methodologies and procedures were adopted:

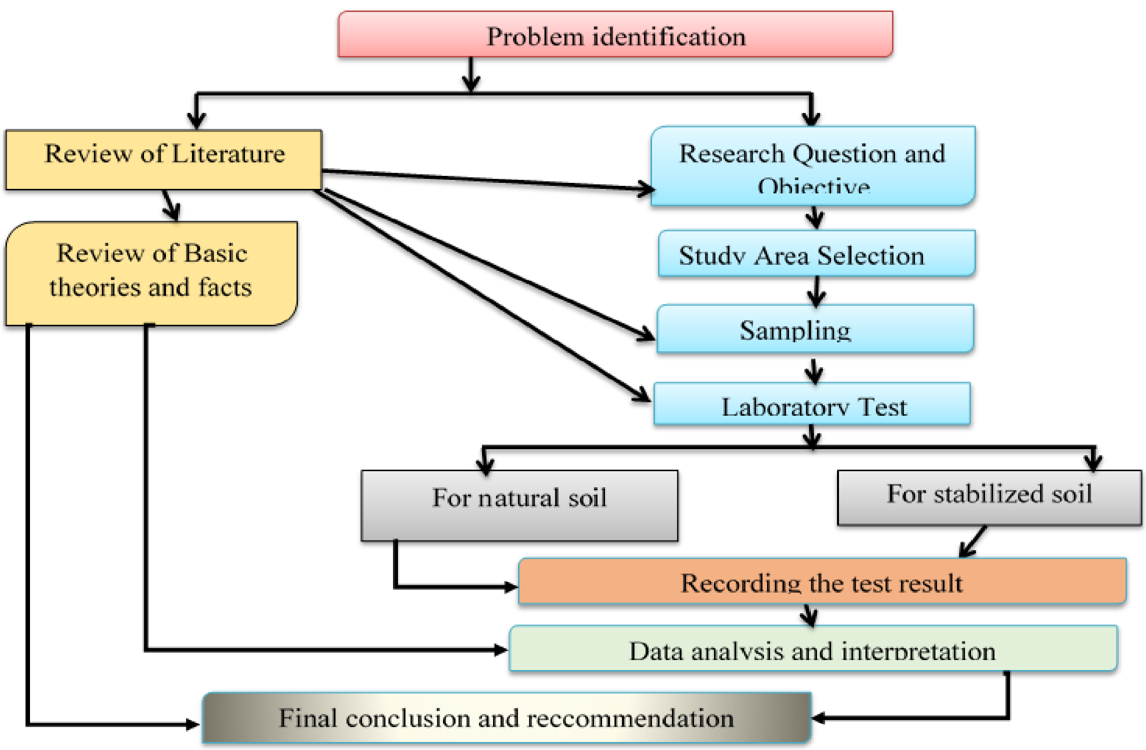

Figure 3.5 Flow chart showing about framework of the study

- ✓ Visual inspections for the soil were made and the study areas were identified and selected for further investigations. The exact location of sampling site were not accurately identified at this point. However, after field visits to the sites the sampling sites were decided.
- ✓ The number and size of the sample were depends on the similarity of the soil type in the study area.
- ✓ For the selected areas, different samples were taken and laboratory tests were performed accordingly.
- ✓ The wheat straw fiber collected from around Robe Town and grinded into length of 15mm.
- ✓ Again the wheat straw fiber used for reinforcement were treated by hot water and sodium hydroxide (NaOH) before utilization, But first the wheat straw were cleaned and sun or oven dried at 100 ± 5℃.
- ✓ The samples were tested in MWU Civil Engineering Laboratory, Paragon Engineering Consultant PLC Laboratory and JIT Geotechnical Engineering Laboratory.

3.5 Study Variables

In this research two variables were considered namely;-

- ✓ Independent variable
- ✓ Dependent variable

3.5.1 Independent Variable

The independent variables for this particular study includes:-

- ❖ Mixing proportion/ percent of treated wheat straw fiber
- ❖ Amount of cement added to the mix

3.5.2 Dependent Variable

For the purpose of this study dependent variable were Engineering Properties of Reinforced and Stabilized Expansive soil (i.e. Maximum dry density, Optimum Moisture Content, Undrained Shear Strength, CBR and CBR Swell… etc).

3.6 Population and Sampling Method

3.6.1 Population

At an early stage in the planning of any investigation decisions must be made concerning the study population. That is, concerning the population of individual units to be investigated. According to this research, the study population were concern improvement occurred due to the addition of wheat straw fiber and cement to expansive soils taken from 3 (three) test pits around study area/Robe town. Again, the geology, climate condition and the topography of the surrounding study area were considered as the study population which were used as source of data for sampling and collection process.

The population is too large for me to consider during data collection process from all test pits. Instead the researcher select samples individually from each test pits that the sample must be representative of the population. That means, each samples were taken from each test pits (population) for data collection and analysis.

3.6.2 Sample size determination

According to (Taherdoost, 2020) the sample is the group of participants whom the researcher actually examines in an empirical investigation. The research of the entire population is impossible due to expense, time and other constraints. As a result, before organizing any investigation, a choice must be made on how many samples must be examined in order to meet the study objectives. If the sample size is too small, it is possible that crucial effects goes undetected or that effects will be estimated too imprecisely. If the sample is too large then there is wastage of resources.

For the purpose of this study 6(Six) samples which are 6(six) undisturbed sample and 6(six) disturbed sample were collected from 3(three) test pits for different laboratory tests in which the sample size and selection procedures of each samples were determined according to ASTM Standard Test Manual.

3.6.3 Sampling Method and procedures

A. Sampling Method

To achieve the objectives of this research, the representative soil sample that represents the particular study area were collected to analyses and describe the typical index and engineering properties of expansive soil for a particular site by having purposive sampling techniques. Three test pits were excavated from open excavation (i.e. test pits) using local labor and all samples were collected from each test pits at 1.5m and 3m depths from different parts of Robe Town.

B. Sampling procedure

The location of test pits were selected, so that it can well represent the soil types (visually) found in the Robe town. Once the locations of the test pits are selected the next procedure was follows:-

- Excavating the test pits representative of the particular study area using proper excavating techniques up to 3m depth.
- Taking both undisturbed and disturbed samples for each test pit using proper sampling techniques.
- Properly labeling (coding) of each sample test pit to indicate the number of test pits and depth at which the samples were taken.
- Properly packing the samples in plastic bags or wooden boxes to preserve the loss of moisture content especially for undisturbed sample.
- Properly transport the samples to the laboratory for testing with no vibration to be free from disturbance as much as possible.
- Conducting laboratory test for the individual collected sample.

3.7 Sources of Data

For this particular study the researcher were use two kinds of sources which are primary sources and secondary sources.

Primary Sources include Field notes, Field/Soil Survey, new photographs, laboratory notebooks.

Secondary Sources include:-

- Reference books, including dictionaries, encyclopedias and atlases
- Magazines articles, Journals articles, Manuals
- Literature reviews(from Previous findings such as thesis, websites…)

3.8 Data Collection Procedure

A set of the procedure is followed to get the desired data or information from the fieldwork in order to process and analysis the facts in a logical and scientific manner. In order to proceed the data collection process permission from the relevant authorities, individuals and the community in the study area were obtained. For the aim of this study, an authorized supportive letter from Jimma University, Jimma Institute of Technology was produced for the Robe administrative town in order to gather data from the defined study region.

3.8.1 Field Survey

The Field Survey consists locating where soil samples were gathered in order to obtain information about the sources of data that would allow the researcher to conduct laboratory tests and identify the soil for sampling. A preliminary survey or visual inspection of the study area was conducted and the location of the soil sample was determined and chosen for this study.

3.8.2 Soil Sample Collection

For the purpose of this research the representative soil samples (disturbed/undisturbed) were collected from different locations in Robe town. After the selection of sample locations from the study area, as expressed under sample size from all three test pits the soil samples were collected at depth of 1.5m and 3m below ground surface by excluding roots, organic material and also by considering economy.

Figure 3.6 Soil sample collection from study area

3.8.3 Laboratory tests

Different laboratory test were done to have the index and engineering properties of expansive soil in Robe town from site located around Madda Walabu University Campus, Madda Walabu Primary School and Bale Robe Teachers Collage as I have said before. The laboratory test which were conducted include Grain size analysis, Natural Moisture content, Atterberg limit (liquid limit and plastic limit), Linear Shrinkage test, Free swell test, Compaction test, Specific gravity, Unconfined Compression Strength test, CBR and CBR Swell test, XRD and so on to attain the objective of this study.

a) Grain Size Analysis Test

Since grain size analysis is one of the index property tests, the soil of the study area were examined for its grain size distribution. For sieve analysis the site samples were air dried before a representative sample taken. And then 500gm of natural subgrade soil was obtained and washed on a sieve size of 75µm to measure the distribution of coarser particles. Mechanical sieve was done on samples of soil retained on sieve No. 200, after oven drying it for 24 hours. On 50gm of soil sample that passes sieve No.200, a hydrometer test is performed. For 24 hours, the soil sample was immersed in a chemical solution (Sodium hexa-meta phosphate). The mixture of soil, chemical and distilled water is then placed into a 1000ml cylinder and turned upside down for 1 minute while covered with the hand palm. For 0.25, 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240, 480, 1440 minutes the hydrometer and test temperature reading were taken. Sieve analysis test for course grained soil were conducted in the laboratory of JIT and hydrometer test for fine grained soil were conduct in the laboratory of Madda Walabu University.

Figure 3.7 Grain size (Sieve and Hydrometer) test in JiT and MWU Geotechnical Engineering Laboratory

b) Natural Moisture Content Test

Moisture content (w) is defined as the ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles (Muni Budhu, 2011). The degree of swelling and shrinking of expansive soil mostly related to change in moisture content. So since the moisture content has an influence on the swelling characteristics of expansive soils, this test were conducted.

Figure 3.8 Natural moisture content determination in MWU Civil Engineering Laboratory

c) Atterberg Limit Test

i) Liquid limit test

The liquid limit is the moisture content at which soil begins to behave as a liquid material and begins to flow on the application of a very small shearing force (Muni Budhu, 2011). There is a relationship between liquid limit and plasticity index hence there is a relationship between liquid limit and swelling behavior of expansive soil.

Figure 3.9 Liquid Limit determination in JIT Geotechnical Engineering laboratory

ii) Plastic limit test

The plastic limit (PL) of a soil is the water content at the boundary between the plastic and semisolid state. The water content at this boundary is arbitrarily defined as the water content at which soil begins to crumble when rolled into threads of specified size 3.2mm (Das, B.M. and Sivakugan, 2018).

Figure 3.10 Plastic Limit determination in JIT Geotechnical Engineering laboratory

iii) **Plasticity Index**

Plasticity index (PI) is defined the range of water content over which the soil behaves plastically or it's the difference between liquid limit and plastic limit (Muni Budhu, 2011). From the Atterberg limit values, it is possible to determine plasticity index using the formula: Plasticity index, PI(%) = LL – PL

d) Linear Shrinkage test

Linear shrinkage refers to how much a sample shrinks linearly after drying, represented as a percentage of its original length. The method involves taking linear measurements on a bar of soil to determine the overall percentage of linear shrinkage of the soil sample that passes through a 425μm sieve. Water content equal to liquid limit were used during conducting linear shrinkage test (Bhavsar and Patel, 2014).

Figure 3.11 Linear shrinkage determination in MWU Civil Engineering Laboratory

e) Free Swell test

The free swell of expansive soil, also termed as a free swell index, is the increase in the volume of soil without any external constraint when subjected to submergence in water (Prakash and Sridharan, 2004). Soils having free swell index of more than 100 can cause damage, whereas soils with a free swell index of less than 100 can cause significant damage to light-loaded structures and soils with a free swell index of less than 50 percent rarely demonstrate appreciable volume change even under light loads (Ranjan, G. and Rao, 2007).

Figure 3.12 Free swell determination in JIT Geotechnical Engineering laboratory

f) Specific Gravity test

Knowledge about specific gravity is essential in relation to other soil tests. Particularly important when gradation and compaction characteristics of the soil being investigated. For this particular study specific gravity test were done using Pcynometer method in the Laboratory of JIT Geotechnical Engineering.

Figure 3.13 Specific gravity determination in JIT Geotechnical Engineering Laboratory

g) Compaction test

Compaction test were done to determine the Optimum Moisture Content (OMC) and Maximum dry density (MDD), of a given soil. OMC is the water content at which the soil can be compacted to maximum unit weight and MDD is the peak value of compaction curve (Aysen, 2002). Investigation revealed that expansive soil expand very little when compacted to low density and high moisture content and vice versa.

Figure 3.14 MDD and OMC determination in MWU Civil Engineering Laboratory

h) Unconfined Compression test

Undisturbed sample were collected to determine the unconfined compressive strength of a given natural soil. But for other sample which were mixed with wheat straw fiber and cement remolded type of sample were used. The test was carried out in accordance with the AASHTO T-208 standard. After the specimen was made, the Shelby tube sampler extruded it from the compaction mold and sliced it to a height-to-diameter ratio of 2 to 2.5. The mass of the specimen, its height and the diameter of the specimen at mid-height were all measured and documented. After determining the specimens mass and dimensions they were loaded into the loading apparatus.

Figure 3.15 UCS determination in JIT Geotechnical Engineering laboratory

i) CBR test

The CBR value is expressed as a percentage of the actual load causing the penetrations of 2.54 mm or 5.08 mm to the standard loads 13.7 for 2.54mm and 20.55 for 5.08mm. Soil passing no 4 (4.75mm) sieve was mixed with wheat straw fiber and cement at optimum moisture content and compacted in CBR molds at maximum dry density. The soil material was mixed with wheat straw fiber and cement in the laboratory and soaked in water for 96 hours. Starting with the initial swelling measurement, the soil specimen was swelled after four days of soaking and then the final swelling value was obtained. Then also penetration process was done by using CBR machine to determine the CBR value of soil samples.

Figure 3.16 CBR and CBR Swell determination in Paragon Engineering Consultant PLC Laboratory

j) X-ray Diffaction test

XRD Test was done to determine crstallinity and chemical composion of wheat straw fiber in Jimma institute of technology, Material Engineering laboratory by using XRD equipment. The XRD was done on wheat straw powder that had not been treated and that had been treated with sodium hydroxide (NaOH) and Hot water for 30minutes. Using an XRD 7000 diffractometer, the analysis was carried out to determine the variations in chemical constituent due to pretreatment in the samples. The samples were scanned at a 2theta angle, with ranges between 10 and 60 to provide enough X-ray diffraction peaks and to identify the most common chemical constituents in wheat straw. The data from the diffractometer was analyzed using X-Pert Highscore and Match-3 Software.

Figure 3.17 XRD analysis in JIT Material Engineering laboratory

CHAPTER 4

RESULTS AND DISCUSSION

This chapter discusses the study findings and gives the results of laboratory tests. Both natural and stabilized soil samples were examined independently to determine appropriate engineering property of the soil. The laboratory test result and discussion presented under this chapter include Natural moisture content, Grainsize analysis, Atterberg limits, Free swell index, Specific gravity, Linear shrinkage, Compaction, CBR, CBR Swell, UCS and XRD Analysis test.

4.1 Properties of Natural Expansive soil used in this study

4.1.1 Natural Moisture Content

The natural moisture content tests were performed for three test pits at depth of 1.5m and 3m following ASTM D2216-98. Natural moisture content of soil of the study area ranges from 36.5%-45.58%. The summary of natural moisture content test results for the soils are depicted in the figure 4.1.

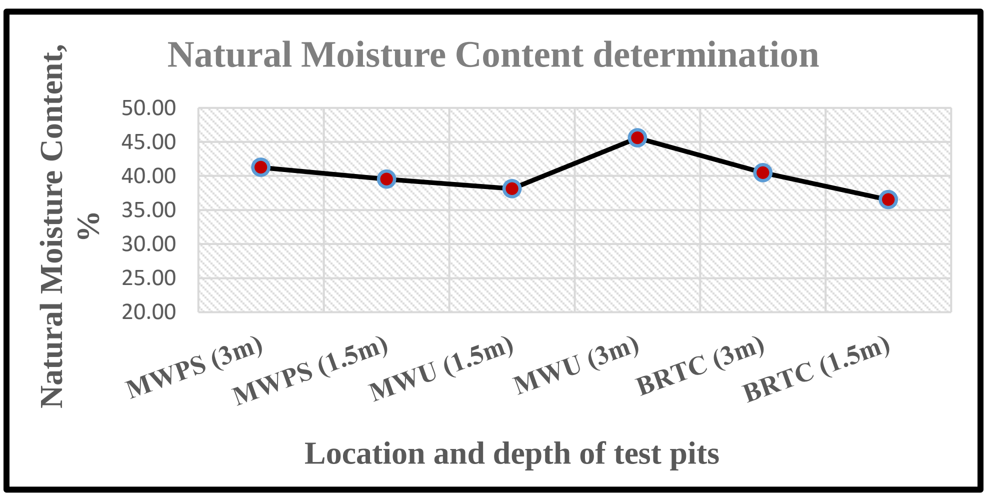

Figure 4.1 Natural Moisture content value for soil sample collected from study area

From field visual classification of soils most of the soil samples taken from study area were gray in color, odorless, dry to moist moisture condition, major and minor soil constituents were fine-grained and sand respectively. Again these soils had a medium dry strength (the specimen broken into pieces with modest finger pressure) and high plasticity (a significant amount of time was required to reach the plastic limit). So the soil samples for this investigation can be visually categorized as gray silty clay, trace fine sand, high plasticity and dry to moist.

4.1.2 Particle size distribution

Following the AASHTO T88 Test Method for Particle-Size Analysis of Soils, Wet sieve analysis was used to evaluate the grain size distribution of soil samples. The distribution of particle sizes bigger than 0.075mm (No. 200 sieve) is determined by sieving, whereas the distribution of particle sizes smaller than 0.075mm is determined by a sedimentation process (hydrometer test). As a result, the soil samples collected from different locations of Robe town such as Madda Walabu University, Madda Walabu Primary School and Bale Robe Teachers College were dark gray in color and almost 98% of the soil are passing through No.200 sieve at both 1.5m and 3m depth.

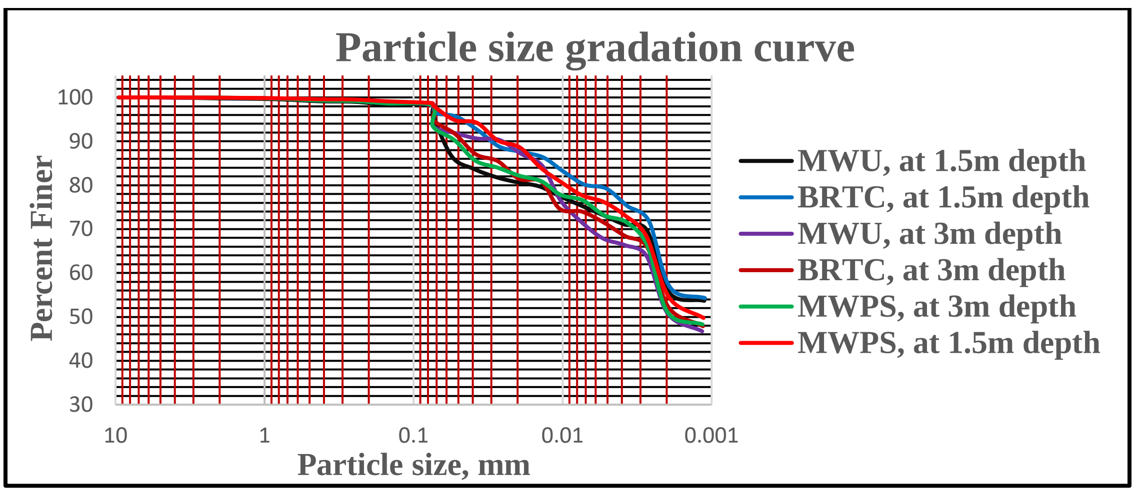

Figure 4.2 Grain size distribution curve for different samples collected from the study area

The gradation of soils in the study area varies considerably as shown above in the figure 4.2. The results obtained from the wet sieve analysis and hydrometer indicate that the dominant proportion of soil particle in the study area are silt and clay. From the particle size distribution curve/results, it is observed that there is a range of variation of the particle sizes. The Grain Size Analysis test result show that the soil in the study area contain clay 50.77%-56.74%, silt fraction 30.304%-47.364%, sand fraction 1.283%-1.865% and gravel content 0%. Again, according to AASHTO soil classification the soils are categorized as silty-clay materials if 35 percent or more of a soil sample passes sieve no.200. Since minimum percent pass sieve no.200 for the soil sample taken from the study area were 98% and so the soils are categorized as poor subgrade soil.

4.1.3 Atterberg limit test on natural soil

The AASHTO T 89 and 90 standard test methods were used to determine the Atterberg limits (liquid limit and plastic limit). The air-dried soil sample was prepared by spreading the material out in the lab and exposing it to the air for at least 6-10 days. The portion of sample for this test was prepared using the sections of the samples that passed the No. 40 (0.425mm) sieve. Figure 4.3 shows a summary of the Atterberg limit test results for soil samples collected from MWU test pit and others provided in appendix section.

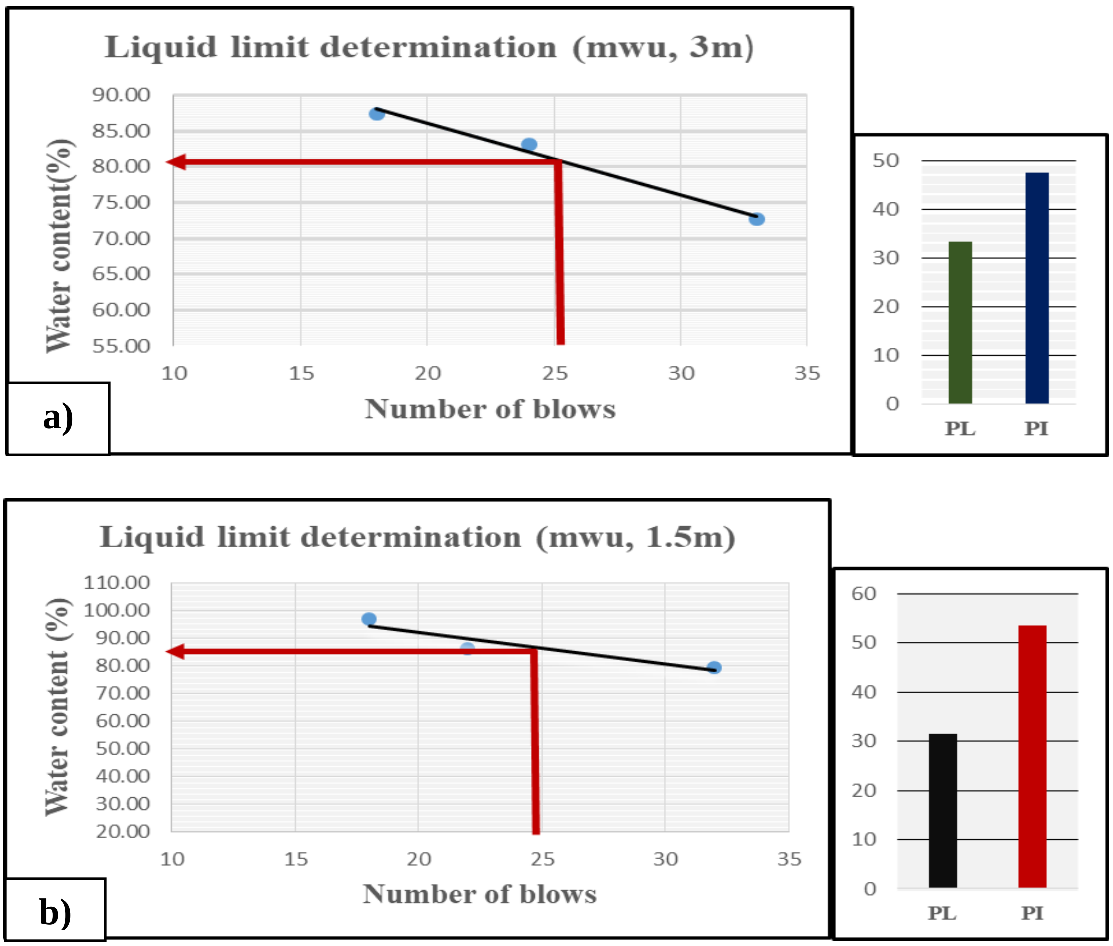

Figure 4.3 Liquid limit value for soil samples collected from MWU. a) MWU at 3m depth, b) MWU at 1.5m depth

According to Atterberg limit test results as shown in the figure 4.4 the soil sample collected from MWU, MWPS and BRTC changed from liquid state to plastic state and with an average liquid limit of 80.7%, 82.4%, and 82.9% respectively at 3m depth and 85.1%, 84.6%, and 85.4% respectively at 1.5m depth. The given soil sample translate from plastic state to semisolid state and with an average plastic limit of 33.34%, 34.15%, and 33.56% respectively at 3m depth and 31.47%, 31.36%, and 32.1% respectively at 1.5m depth. At this state the soil rolled into threads. The difference between the liquid limit and plastic limit is called Plastic Index. The soil sample collected from study area also has Plastic Index of 47%, 48.25%, and 49.34% respectively at 3m depth and 53.63%, 52.6%, and 53.30% respectively at 1.5m depth. The Atterberg limit tabular data provided in full in the appendix section.

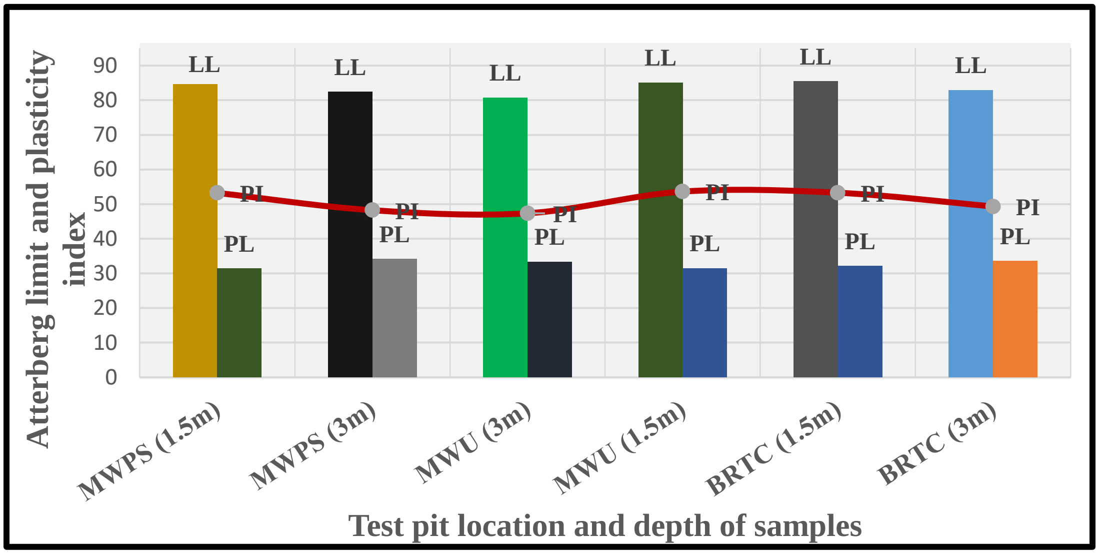

Figure 4.4 Atterberg limit and plasticity index value for soil sample from study area

Again the Atterberg limits test results for soil of study area showed that the liquid limit ranges from 80.7%-85.4%, plastic limit ranges from 31.36%-34.15% and plastic index ranges from 47%-53.63%. The test results in the figure 4.4 showed that soils of the study area are highly plasticity soils with high plasticity index values. As result of high plasticity index it indicates that all the native subgrade soil samples have poor quality for sub grade material unless it's treated.

4.1.4 Soil Classification

4.1.4.1 AASHTO Classification system

The AASHTO system employs identical procedures as that of USCS system, however the dividing line is defined by the equation PI=LL-30. It divides soil into two types, which are granular material and silt-clay material. The granular material is further separated into three categories: A-1, A-2, and A-3. The silt-clay material is then separated into four categories: A-4, A-5, A-6, and A-7. The materials classified as A-7-5 and A-7-6 are generally regarded as the worst performers in terms of roadway building, however they can be used as sub-grade material. The plasticity chart, as shown in the figure 4.5, is based on the AASHTO classification system.

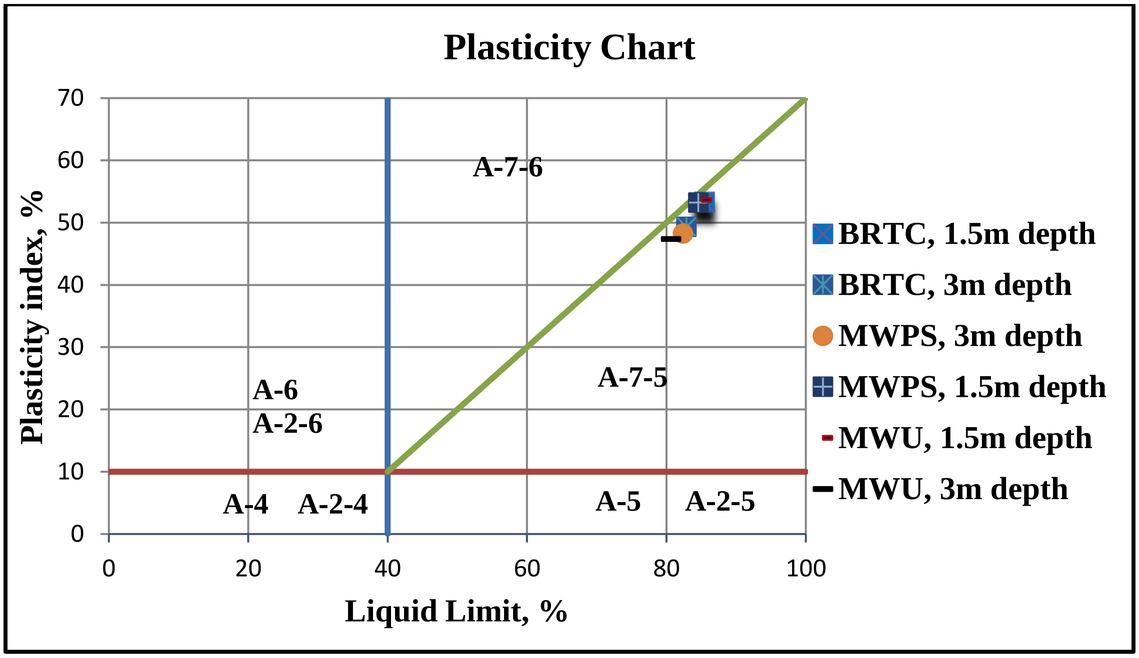

Figure 4.5 Soil classification for soil sample collected from study area according to AASHTO

As results of atterberg limit test results all soils samples has different liquid limit and plastic index. However according to AASHTO soil classification system all soil samples classified under group A-7-5 with rating Fair-to- Poor to be used as a subgrade material. As a result, without specific upgrading measures, natural subgrade material is unsuited for use as a subgrade material.

More over group index values of soil samples are calculated, indicating that all soil samples may require stabilization measures before being used as construction material. For all samples, the GI values are greater than 20, indicating that the fraction of fine particles (#200) are high and the soils are very plastic as mentioned before. The group index of the soil samples are calculated in the table 4.1 as follow.

$$GI = (F_{200} - 35)\big(0.2 + 0.005(LL - 40)\big) + 0.01(F_{200} - 15)(PI - 10)$$

Table 4-1 Group index value for soil sample collected from study area

Location of test pit	Depth(m)	F_{200}	LL	PI	GI
BRTC	1.5	98.549	85.4	53.30	63.3
BRTC	3	98.354	82.9	49.34	59.1
MWPS	3	98.210	82.4	48.25	57.9
MWPS	1.5	98.717	84.6	53.24	63.2
MWU	1.5	98.401	85.1	53.63	63.4
MWU	3	98.135	80.7	47.36	56.5

4.1.4.2 Unified soil classification (USCS) system

The USCS is based on recognition of the type and predominance of the constituents considering grain size, gradation and plasticity. According to this classification system coarse-grained soils, fine-grained soils and highly organic (peat) soils are the three major divisions. For engineering reasons, this system describes also a system for classifying minerals and organo-mineral soils. In the laboratory, the Grain-Size curve and the Atterberg limits can be used. The peat soils are readily identified by color, odor, spongy feel and fibrous texture. The classification of the soils in study area according to USCS is presented below in the figure 4.6.

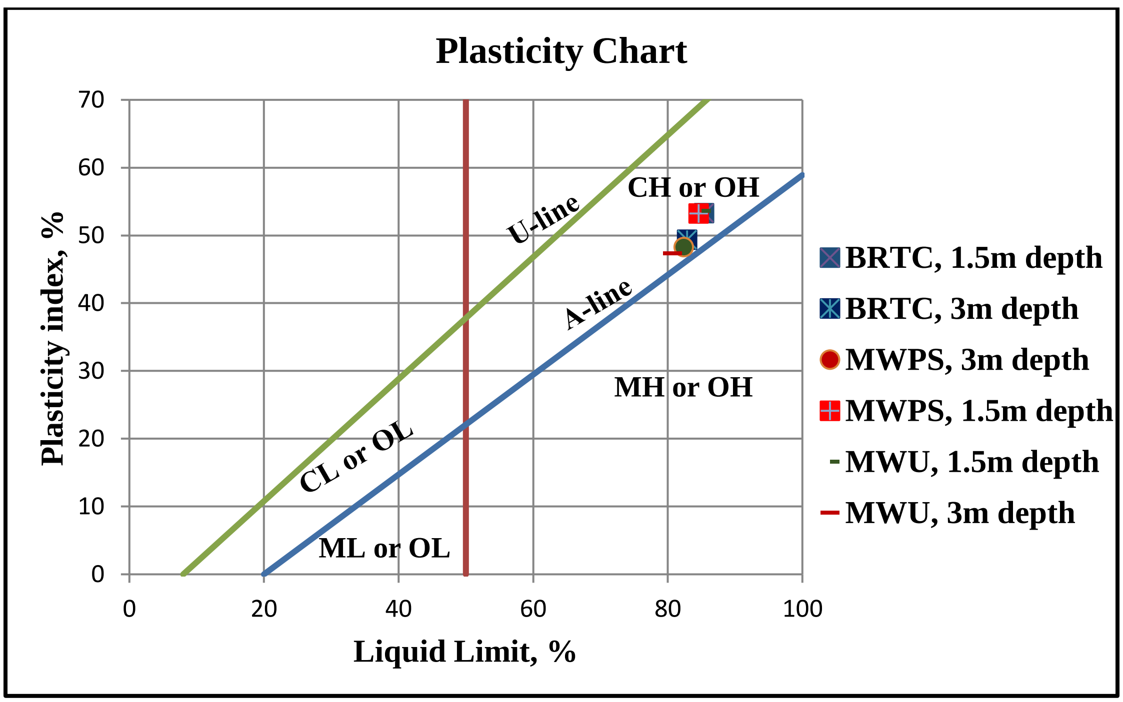

Figure 4.6 Soil classification for soil sample collected from study area according to USCS

According to USCS, if the Liquid limit are greater or equal to 50% the soil can be classified as clay, silt, or organic depends on whether the soil coordinates plot above or below the A line. Since all soil sample taken from study area has Liquid limit more than 50%, but ploted above A-Line, so they are classified under high plasticity clay (CH).

4.1.4.3 Mineralogical Identification using indirect method

There is no commonly accepted straightforward approach for identifying expansive soil at this time. Despite the fact that there are numerous precise laboratory techniques for identifying expansive and non-expansive clay minerals, but these techniques are not applicable to practicing engineers. The mineralogy of natural soil samples was determined using indirect methods such as the plastic index and the liquid limit chart, as discussed in this report's literature review and showed below in figure 4.7.

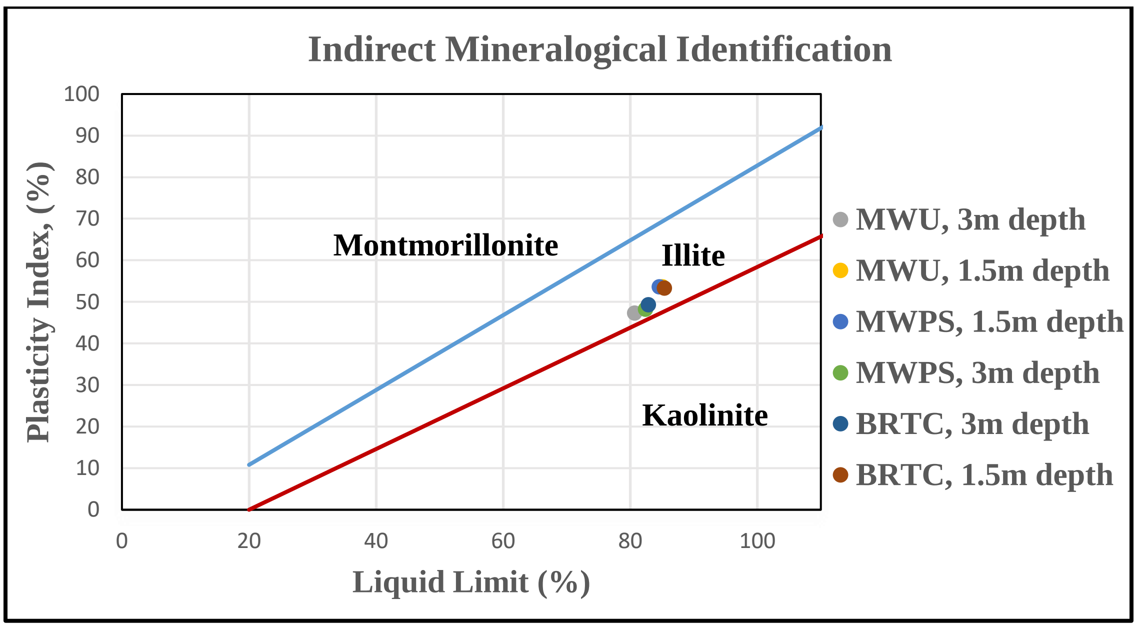

Figure 4.7 Minerological Identification using indirect method for soil sample from study area

4.1.5 Specific Gravity of natural soil

The specific gravity values showed that there is small variation within a limited range of depths and at similar locations. The variations may be due to the size range and the type of clay minerals. The specific gravity may have lower value due to the presence of the high organic content, whereas the presence of heavy minerals may lead to higher values. This test was conducted on fined grained particles used for the study and summary of the test results are shown below.

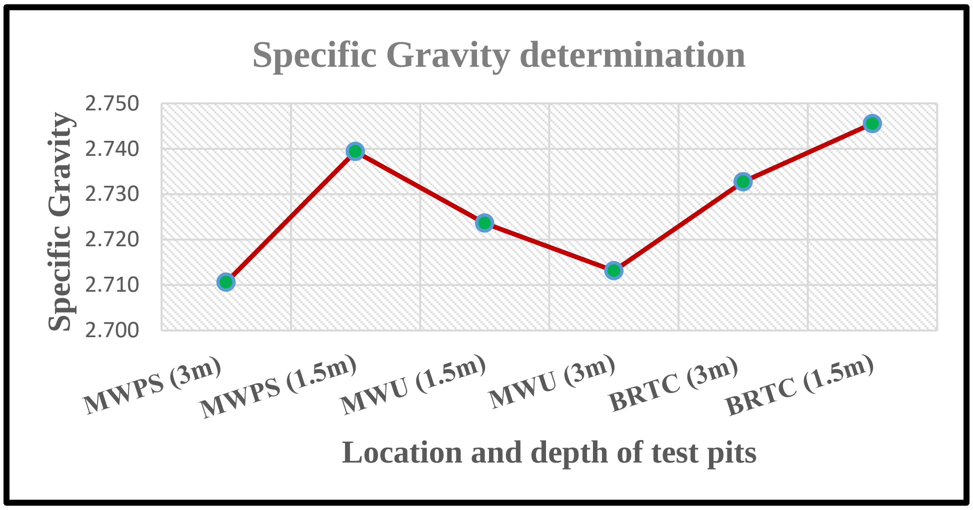

Figure 4.8 Specific gravity value of soil sample collected from all test pits and depth

As figure 4.8 showed the soil sample collected from MWU, MWPS and BRTC soil sample has an average specific gravity of 2.713, 2.711, and 2.733 respectively at 3m depth and 2.724, 2.739, and 2.746 respectively at 1.5m depth. The specific gravity of solid particles for most soils ranges from 2.5 to 2.9, as we all know. For most computations, specific gravity (Gs) of 2.65 for Cohesion-less soils and 2.70 for clay soils can be assumed. As a result of these tests, the specific gravity of all samples ranges from 2.7 to 2.75, as seen in the figure above. This indicates that all soil samples were classified as clay soil.

4.1.6 Free swell index of natural soil

This test aims to provide a reasonable estimate of a soil sample's degree of expansiveness. Soils with a free swell of less than 50% are unlikely to be expansive, however soils with free swells more than 50% can cause swell problems for light-weight structures. Values of 100% or more are associated with soil contain high percentage of clay which could swell considerably. The free swell test results of soil taken from study area exceeds 50% in all soil samples (specimens), so such soils has high expansive nature and undergo volumetric changes leading to pavement distortion, cracking and general unevenness due to seasonal wetting and drying which has then some impact on construction of structures.

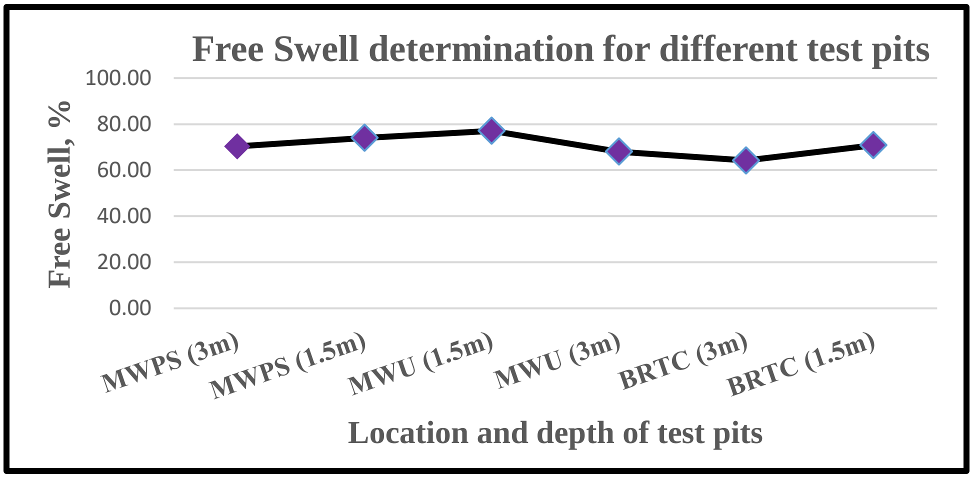

Figure 4.9 Free index value of soil sample collected from all test pits and depth

The free swell test value of sample collected from MWU, MWPS and BRTC showed in figure 4.9 indicates that 68%, 70.34%, and 64.22% respectively at 3m depth and 77.06%, 74%, and 70.83% respectively at 1.5m depth. From the free swell test results we can understand that the soil must cut out or treated.

4.1.7 Linear shrinkage test result

The total linear shrinkage of a soil samples passing a 425µm sieve can be calculated using linear measurements on a bar of soil fraction. Even more than 48 hours of air drying may be required for extremely plastic soils. The moisture content equivalent to the liquid limit was used during conduction of the linear shrinkage test. It's best that if the sample should not be placed in the oven too early.

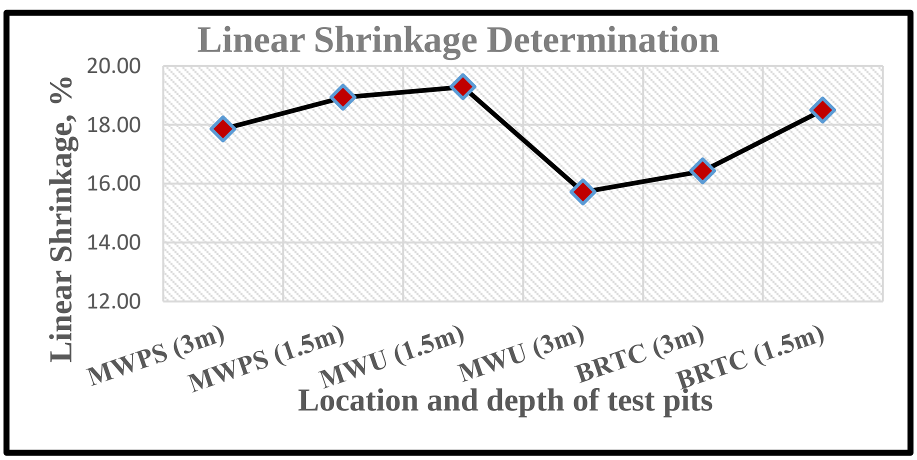

Figure 4.10 Linear shrinkage value of soil sample collected from study area

As result the linear shrinkage test value of soil sample collected from MWU, MWPS and BRTC indicates that 15.71%, 17.86%, and 16.43% respectively at 3m depth and 19.29%, 18.93%, and 18.50% respectively at 1.5m depth. Again, the results of the linear shrinkage test show that the soils collected from the study area has a high shrinking nature and undergo volumetric changes, resulting in pavement distortion, cracking and general unevenness as a result of seasonal wetting and drying, which poses a problem for structural construction.

4.2 Effect of Wheat straw fiber and Cement on Geotechnical properties of natural soil

4.2.1 The effect of adding WSF and cement on Compaction characteristics of natural soil

Modified Proctor compaction tests were conducted on natural and stabilized soil to determine the relationship between the moisture content and dry density for specific compaction effort according to AASHTO T99-94 testing procedures. The soil samples collected from MWU, MWPS and BRTC has optimum moisture content of 27.97%, 34.55%, and 32.51% respectively at 3m depth and 31.58%, 32.22%, and 35.90% respectively at 1.5m depth. Again on the other hand the soil samples has maximum dry density of 1.425gm/cm3, 1.404gm/cm3, and 1.447gm/cm3 respectively at 3m depth and 1.373gm/cm3, 1.39gm.cm3, and 1.394gm/cm3 respectively at 1.5m depth. But after stabilization the value of MDD and OMC are different. From the test results in the stabilization part the MDD value become increased and OMC decreased which is presented in the next pages.

The percentage of mixing/proportion includes Soil+0%WSF, Soil+1%WSF(1.5cm)+0%C, Soil+2%WSF(1.5cm)+8%C, Soil+3%WSF(1.5cm)+7%C, Soil+4%WSF(1.5cm)+6%C, Soil +4.5%WSF(1.5cm)+4%C, Soil+5%WSF(1.5cm)+3%C. Moisture content versus dry density graph is plotted and the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are determined from the graph. The details of the test results are attached in Appendix part.

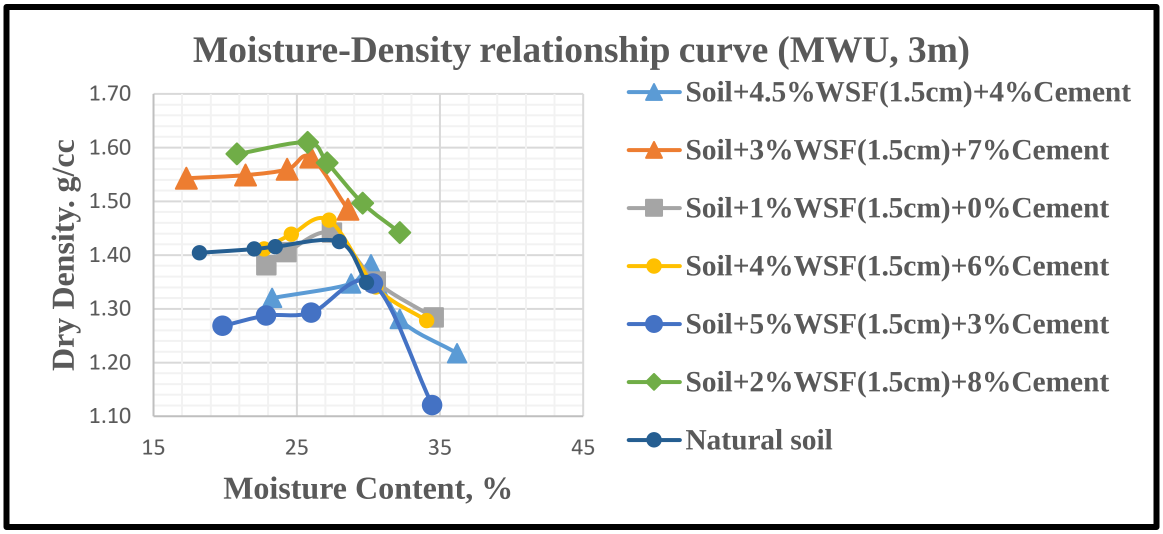

Figure 4.11 Moisture density relation ship curve for test pit located at MWU(3m depth)

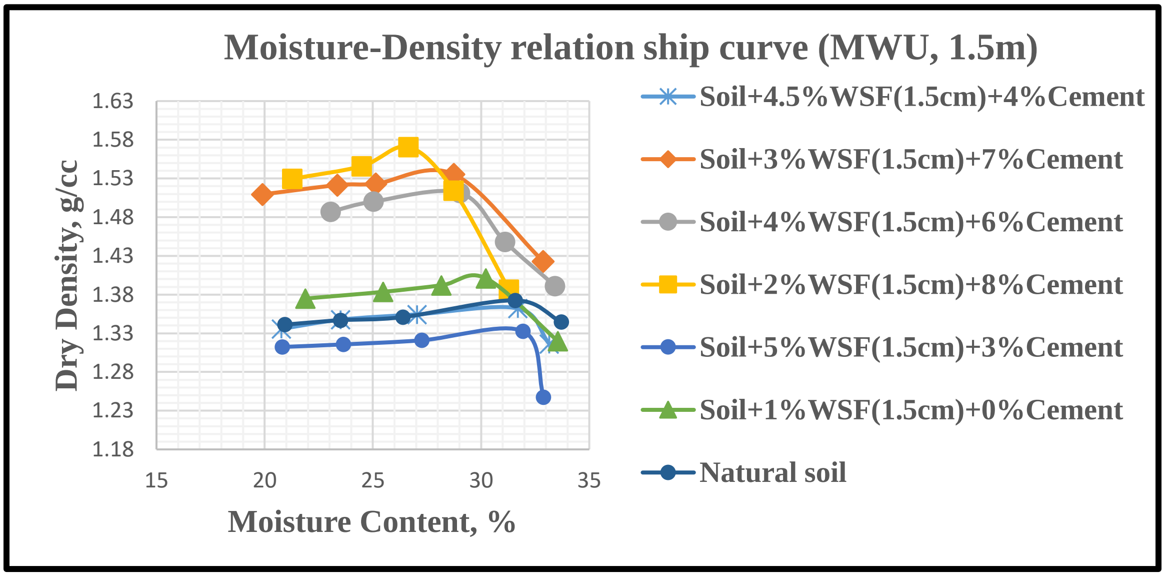

Figure 4.12 Moisture density relation ship curve for test pit located at MWU(1.5m depth)

From the test results the Maximum dry density (MDD) for site located at MWU increase from 1.425g/cm3 at Soil+0%WSF(1.5cm)+0%Cement to 1.582g/cm3 at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and from 1.373g/cm3 at Soil+0% WSF(1.5cm)+0% Cement to 1.535g/cm3 at Soil+3%WSF(1.5cm)+7%Cement at the depth of 1.5m. But the optimum moisture content (OMC) decrease from 27.97% at Soil+0%WSF(1.5cm)+0%Cement to 25.98% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and from 31.58% at Soil+0%WSF(1.5cm)+0%Cement to 28.75% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m. As we seen from the graph the maximum dry density increased as the amount of cement increased, this is due to cement has high pozzolanic property than wheat straw fiber and the maximum dry density decreased as the percentage of wheat straw fiber increased. The reduction of MDD is greatest when the soil is stabilized with wheat straw fiber with a percentage greater than 4%. This is owing to the low unit weight of wheat straw fiber, which leads to a drop in density by creating a wide void space between soil particles. So reinforcing soil with wheat straw fiber had a significant impact on dry density, but had minimal effect on water content.

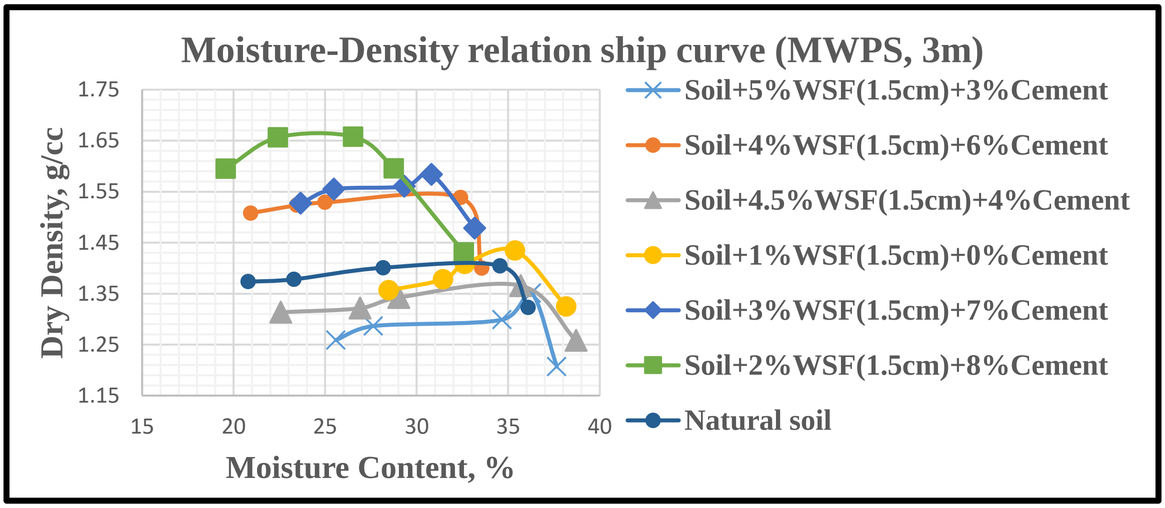

Figure 4.13 Moisture density relation ship curve for test pit located at MWPS(3m depth)

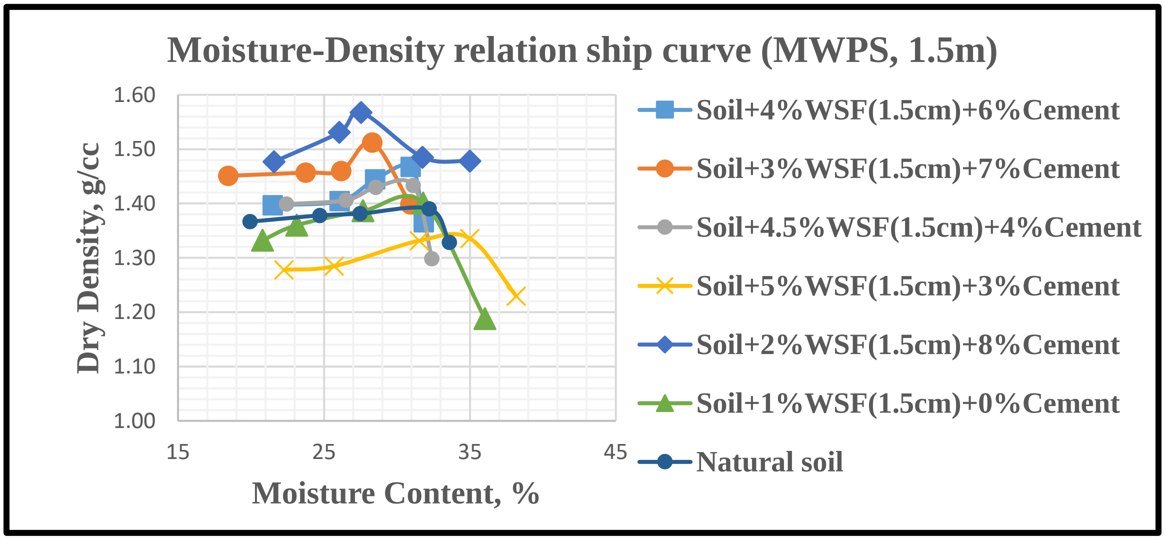

Figure 4.14 Moisture density relation ship curve for test pit located at MWPS(1.5m depth)

The Maximum dry density (MDD) for site located at MWPS increase from 1.404g/cm3 at Soil+0%WSF(1.5cm)+0%Cement to 1.583g/cm3 at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and from 1.390g/cm3 at Soil+0%WSF(1.5cm)+0% Cement to 1.512g/cm3 at Soil+3%WSF(1.5cm)+7%Cement at the depth of 1.5m. But the optimum moisture content (OMC) decrease from 34.55% at Soil+0%WSF(1.5cm)+0%C to 30.81% at Soil+3%WSF(1.5cm)+7%C at the depth of 3m, and from 32.22% at Soil+0%WSF(1.5cm) to 28.32% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m. Chemical reactions in the soil-wheat straw fiber mixtures could be the cause of the slight rise in MDD. These reactions may have made it easier for the treated specimens to compress easily and resulting in an increase in dry density. Again as we seen from the graph the maximum dry density increased as the amount of cement increased and decreased as the percentage of wheat straw fiber increased as mentioned earlier. Again because of the less friction between soil particles and wheat straw, using a higher percentage of WSF can prevent soil particles from approaching each other (overlapping of WSF) and lower the average unit weight.

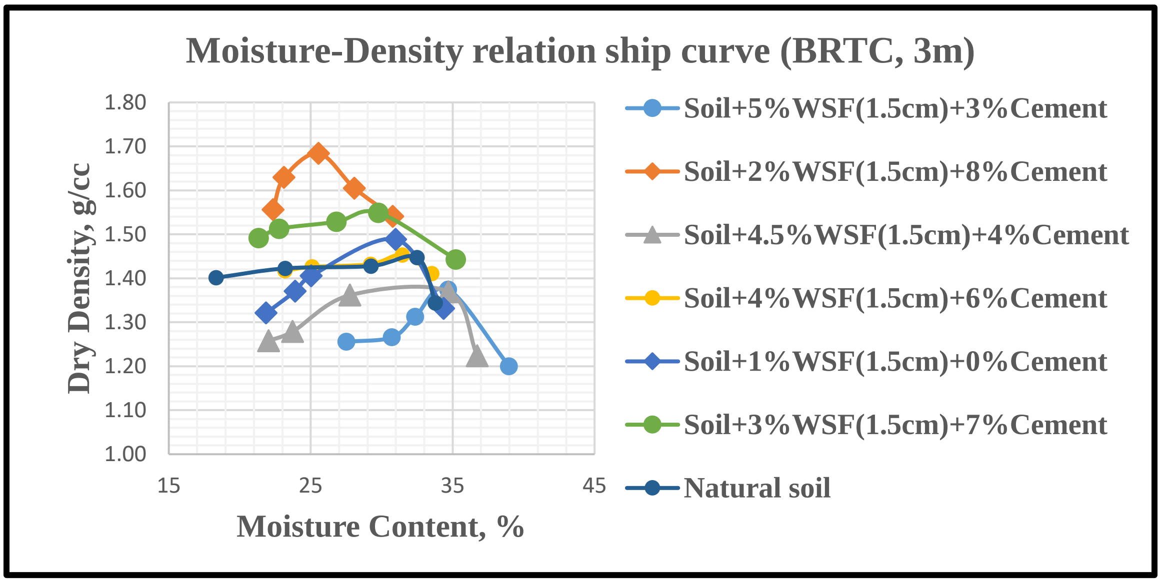

Figure 4.15 Moisture density relation ship curve for test pit located at BRTC(3m depth)

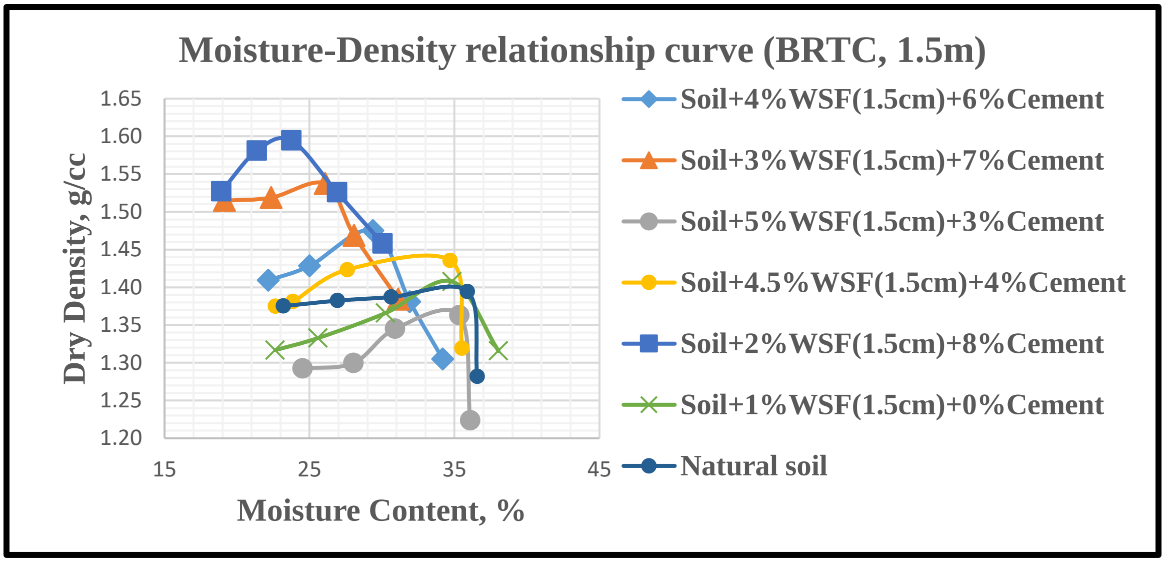

Figure 4.16 Moisture density relation ship curve for test pit located at BRTC(1.5m depth)

The Maximum dry density (MDD) for site located at BRTC increase from 1.447g/cm3 at Soil+0%WSF(1.5cm)+0%Cement to 1.549g/cm3 at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and from 1.394g/cm3 at Soil+0% WSF(1.5cm)+0%Cement to 1.537g/cm3 at Soil+3%WSF(1.5cm)+7%Cement at the depth of 1.5m. But the optimum moisture content of the specimens decrease from 32.51% at Soil+0%WSF(1.5cm)+0%Cement to 29.78% at Soil+3%WSF(1.5cm)+7%Cement at the depth of 3m, and from 35.90% at Soil+0%WSF(1.5cm)+0%Cement to 26.10% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m. Again as we seen from the graph maximum dry density increased as the amount of cement increased this is due to cement has high pozzolanic property than wheat straw fiber and the maximum dry density decreased as the percentage of wheat straw fiber increased. But as the dry density decreases, it implies that it will require less compactive energy to reach the required dry density and which is also economical interms of cost of compaction.

4.2.2 The effect of adding WSF and cement on CBR and CBR Swell of natural soil

The value of CBR for all samples was determined for normal and stabilized soil using AASHTO T193-93 procedure. According to the soaked CBR test, natural subgrade soil had a low CBR value and all natural soil samples do not meet the minimal requirements as sub-grade material, according to the ERA manual 2002. CBR swell values are also over the specified maximum value of 2%, indicating that this soil should be treated before use.

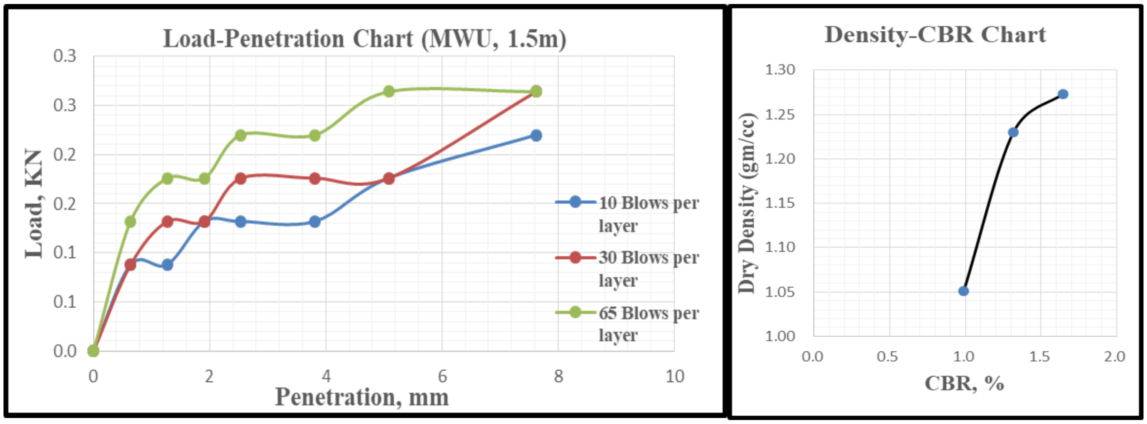

Figure 4.17 Load-Penetration and Density-CBR chart for sample collected from MWU at 1.5m depth (i.e. Soil+0%WSF)

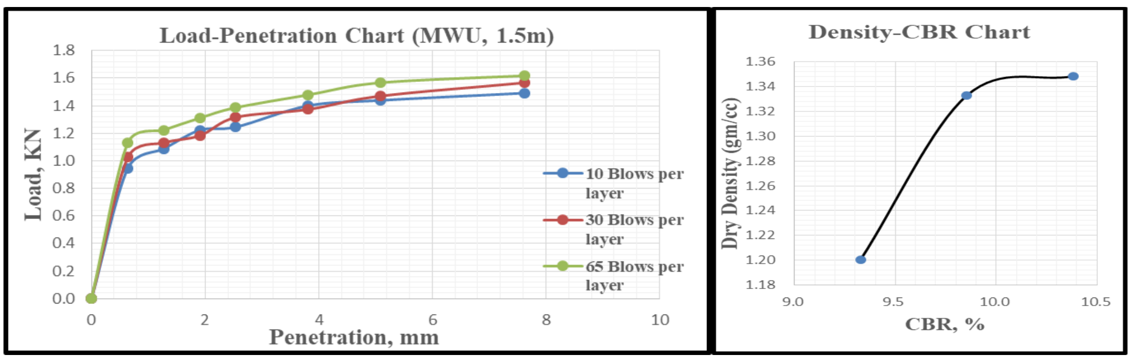

Figure 4.18 Load-Penetration and Density-CBR chart for sample collected from MWU at 1.5m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

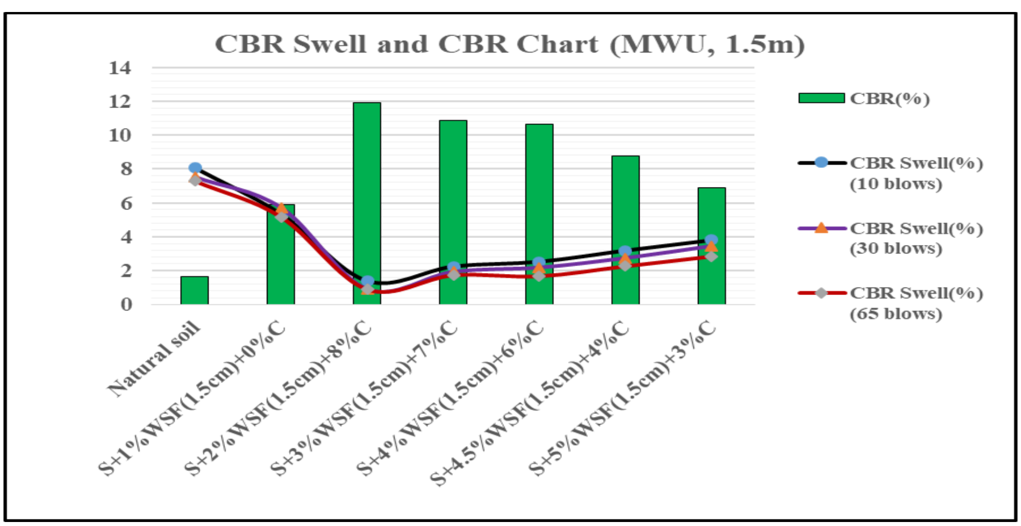

Figure 4.19 CBR and CBR Swell for sample collected from MWU at 1.5m depth and stabilized with WSF&C

However in comparison to natural soil, higher CBR value for stabilized soil was achieved. Depending upon the ERA subgrade manual the soil stabilized with WSF and cement becomes S4 subgrade strength. The California Bearing Ratio (CBR) for site located at MWU increase from 1.63% at Soil+0%WSF(1.5cm)+0%Cement to 10.85% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m, and the percentage of CBR Swell decrease drastically as number blows increase and as percentage of cement increased. Even though CBR value increases, the rate of increment is not as high as the percent of wheat straw fiber increment in the soil-wheat straw fiber mix. The subgrade strength of the sample shows insignificant increment with wheat straw fiber treatment alone and had almost small effect on the soaked CBR values. The minor improvement in strength may be owing to insufficient levels of CaO in the oxides that make up wheat straw fiber, prevent or hinder the development of stable calcium silicate hydrate (CSH) and calcium aluminate hydrates (CAH), which provide long-term strength.

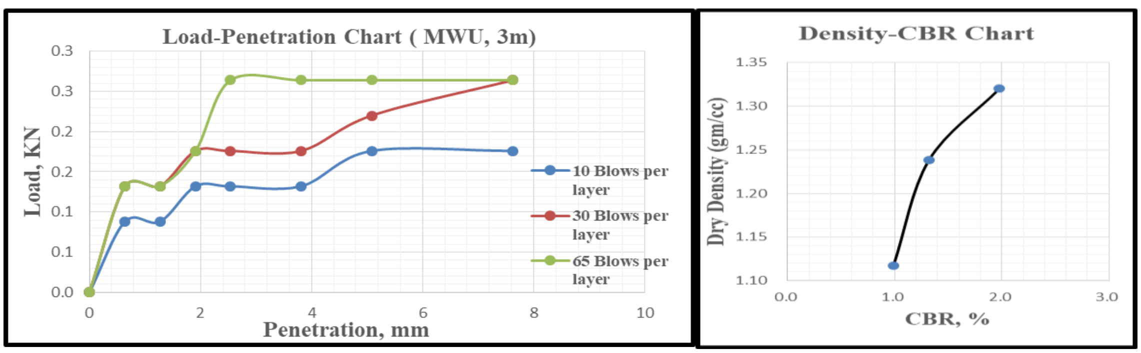

Figure 4.20 Load-Penetration and Density-CBR chart for sample collected from MWU at 3m depth (i.e. Soil+0%WSF)

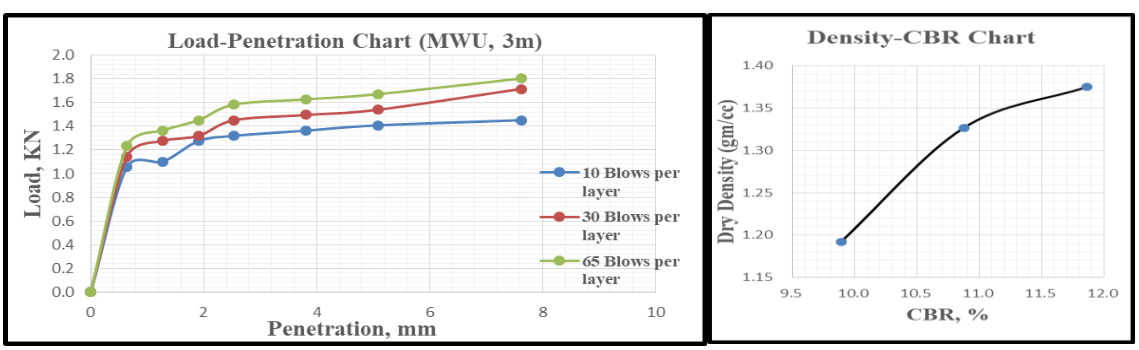

Figure 4.21 Load-Penetration and Density-CBR chart for sample collected from MWU at 3m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

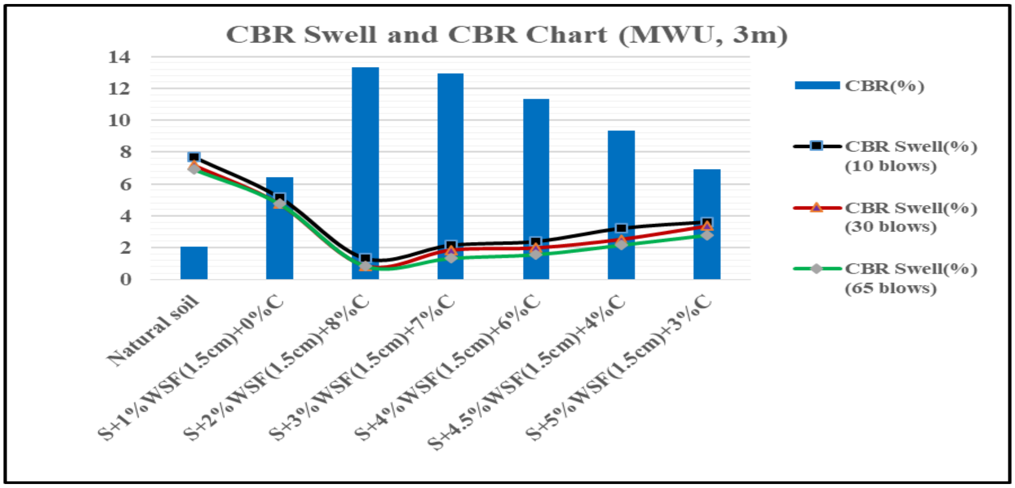

Figure 4.22 CBR and CBR Swell for sample collected from MWU at 3m depth and stabilized with WSF&C

The California Bearing Ratio (CBR) for site located at MWU increase from 2.04% at Soil+0%WSF(1.5cm)+0%Cement to 12.92% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and the percentage of CBR Swell decrease drastically as number blows and percentage of cement increases. The addition of wheat straw fiber and cement makes the specimen more firm. Especially this is due to hydration of cement with age makes the sample become harder to be penetrated by CBR machine. But the CBR value decreased and CBR Swell increased as the amount of cement decreased due to the reaction between soil, wheat straw fiber, water is slower than the reaction between soil, wheat straw fiber, cement and water. The CBR values for natural soil, soil+WSF and soil+WSF+cement mixtures provided in full in the appendix section.

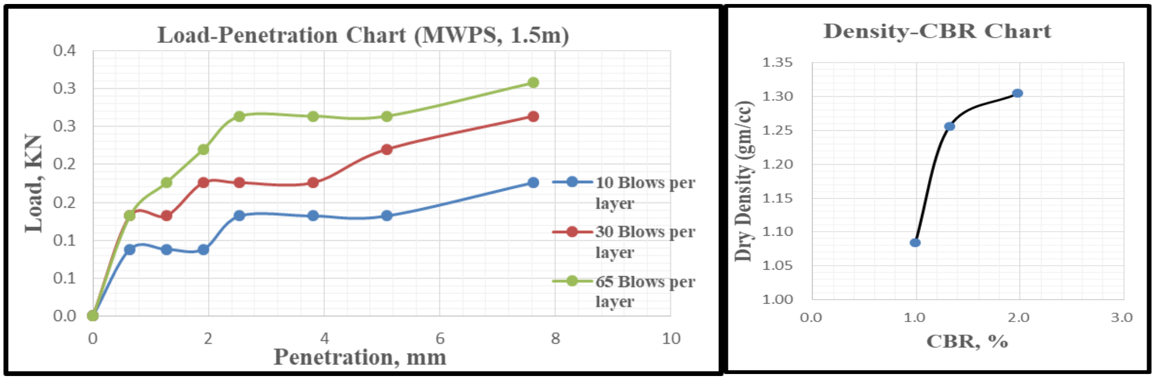

Figure 4.23 Load-Penetration and Density-CBR chart for sample collected from MWPS at 1.5m depth (i.e. Soil+0%WSF)

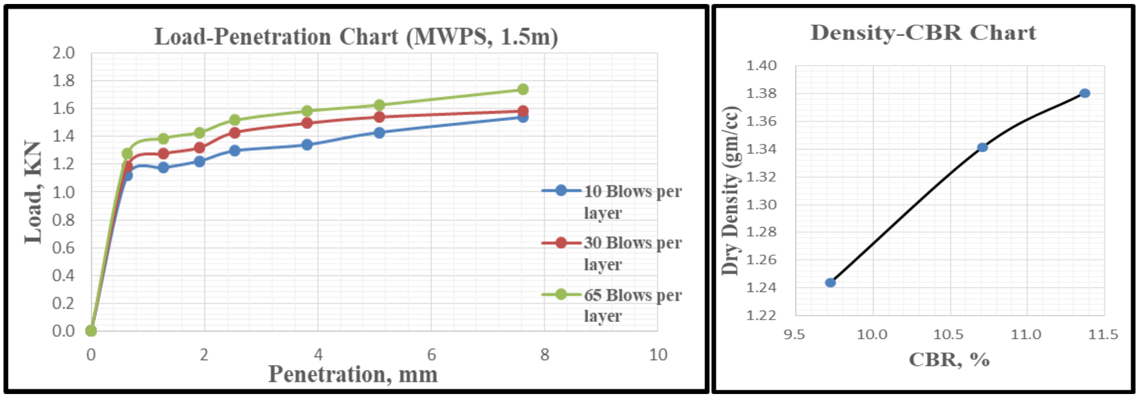

Figure 4.24 Load-Penetration and Density-CBR chart for sample collected from MWPS at 1.5m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

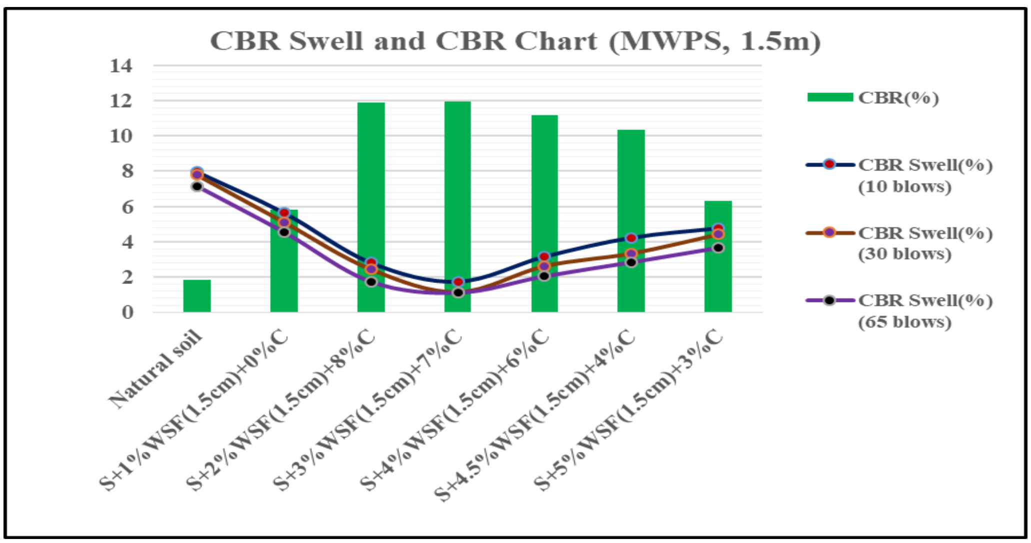

Figure 4.25 CBR and CBR Swell for sample collected from MWPS at 1.5m depth and stabilized with WSF&C

The California Bearing Ratio (CBR) for site located at MWPS increase from 1.83% at Soil+0%WSF(1.5cm)+0%Cement to 11.92% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m, and the percentage of CBR Swell decrease drastically as number blows increase. The CBR Swell, on the other hand, decreases when the cement component in the soil-WSF and cement mix increases for soil samples collected from the study area. The formation of a cementitious matrix that resists volumetric expansions, as well as the calcium saturated clay's decreased affinity for water are the reason to these reduced swell properties.

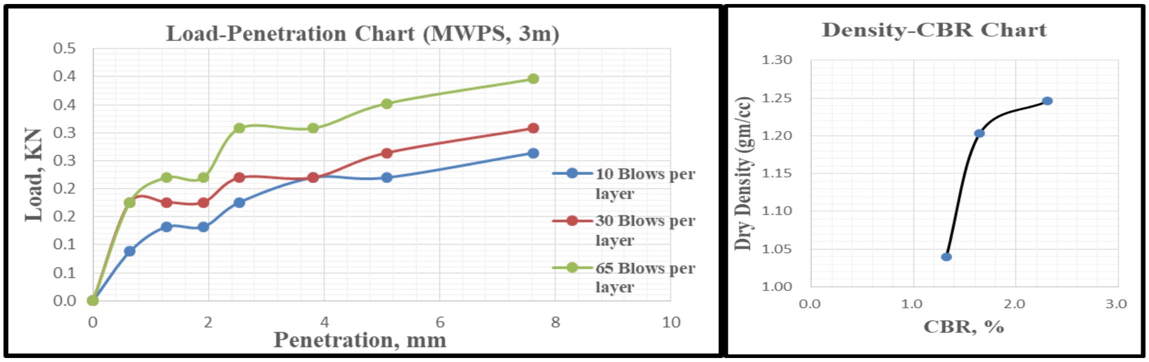

Figure 4.26 Load-Penetration and Density-CBR chart for sample collected from MWPS at 3m depth (i.e. Soil+0%WSF)

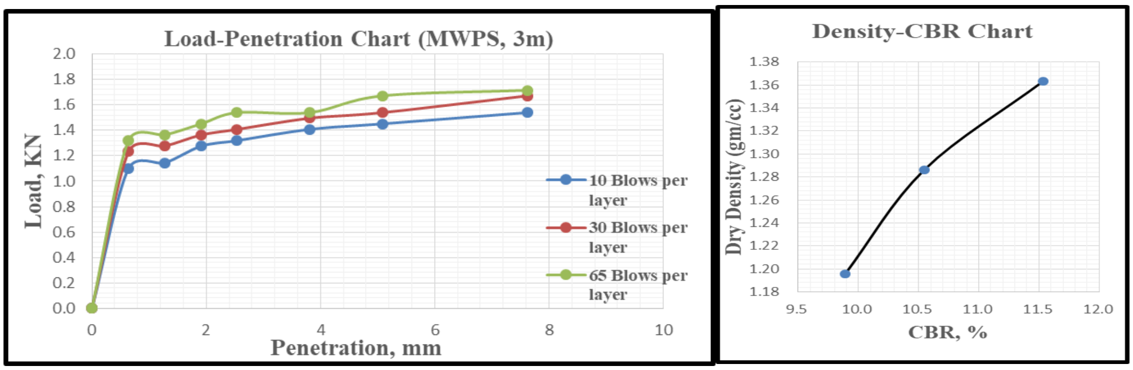

Figure 4.27 Load-Penetration and Density-CBR chart for sample collected from MWPS at 3m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

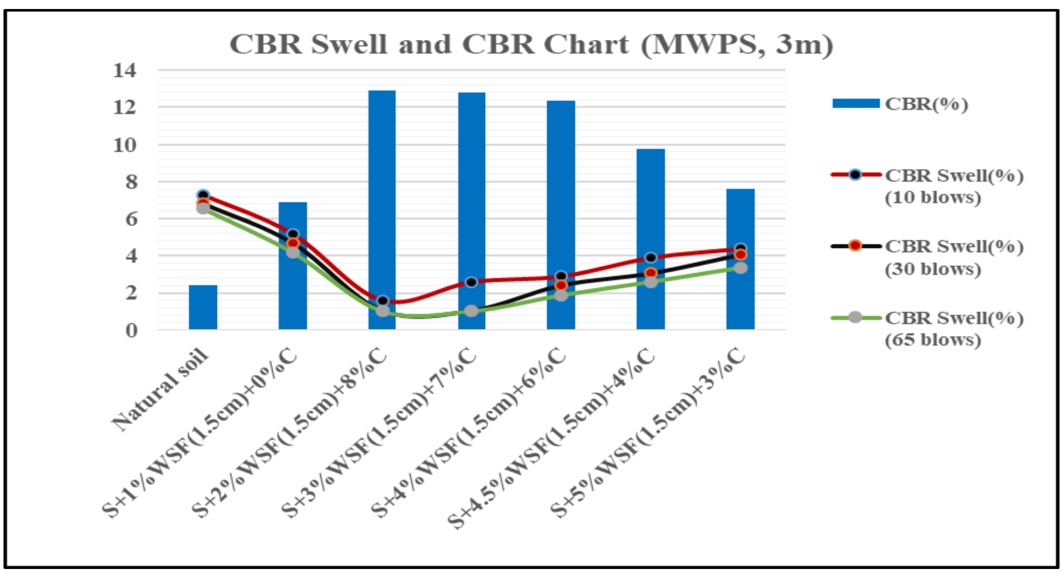

Figure 4.28 CBR and CBR Swell for sample collected from MWPS at 3m depth and stabilized with WSF&C

The California Bearing Ratio (CBR) for site located at MWPS increase from 2.43% at Soil+0%WSF(1.5cm)+0%Cement to 12.79% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and the percentage of CBR Swell decrease drastically as number blows increase. When compared to an untreated soil sample, the CBR test result for treated soil showed a considerable increase in strength. The CBR values of treated soils with WSF-cement mix increases as the amount of cement increases rather than wheat straw fiber, according to the findings. The CBR values of treated soil with wheat straw fiber alone, on the other hand, meet the ERA pavement design manual specification as a subgrade material.

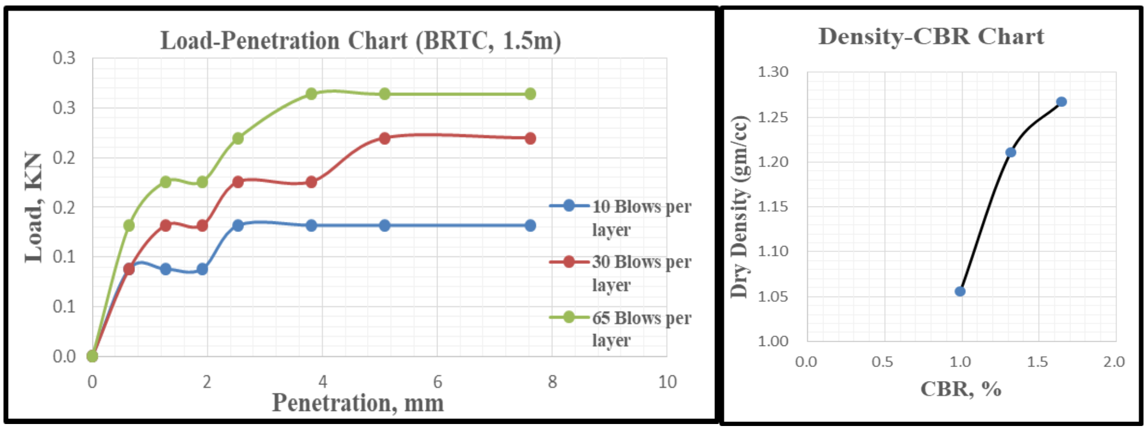

Figure 4.29 Load-Penetration and Density-CBR chart for sample collected from BRTC at 1.5m depth (i.e. Soil+0%WSF)

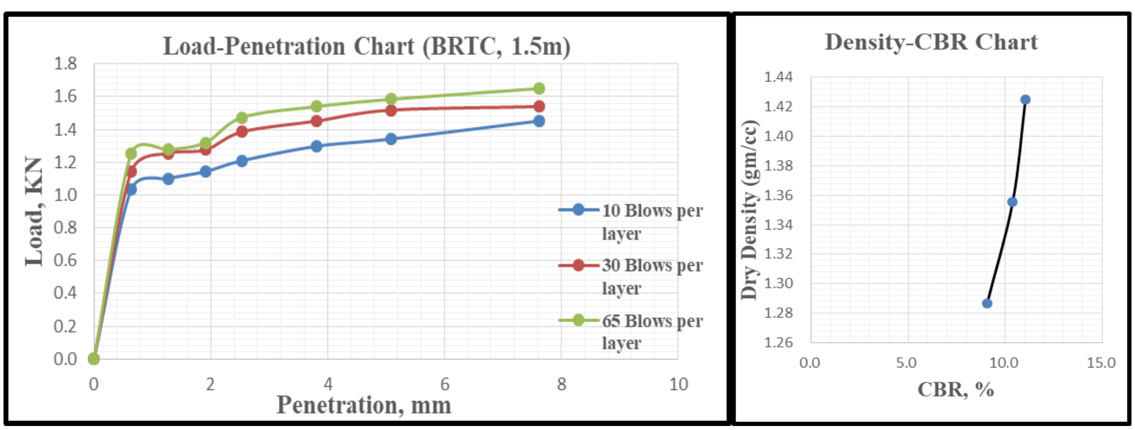

Figure 4.30 Load-Penetration and Density-CBR chart for sample collected from BRTC at 1.5m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

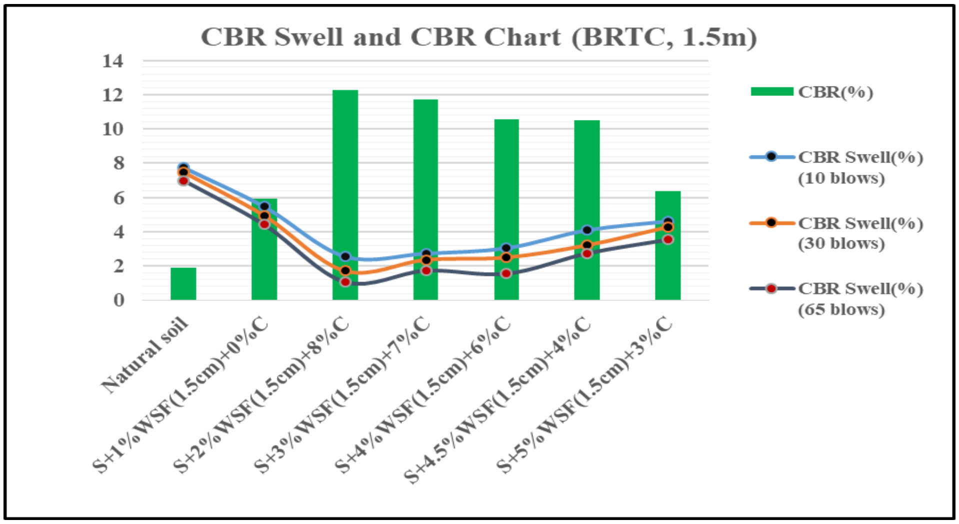

Figure 4.31 CBR and CBR Swell for sample collected from BRTC at 1.5m depth and stabilized with WSF&C

The California Bearing Ratio (CBR) for site located at BRTC increase from 1.90% at Soil+0%WSF(1.5cm)+0%Cement to 11.70% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 1.5m, and the percentage of CBR Swell decrease drastically as number blows increase. Again the addition of wheat straw fiber and cement makes the specimen more firm due to hydration of cement with age makes the sample become harder to be penetrated by CBR machine. But the CBR value decreased and CBR Swell increased as the amount of cement decreased due the reaction between soil, wheat straw fiber, water is slower than the reaction between soil, wheat straw fiber, cement and water.

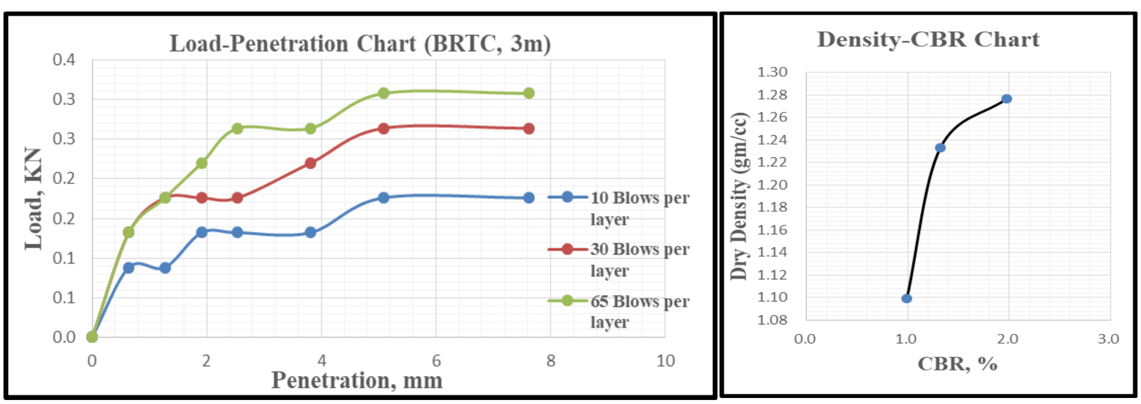

Figure 4.32 Load-Penetration and Density-CBR chart for sample collected from BRTC at 3m depth (i.e. Soil+0%WSF)

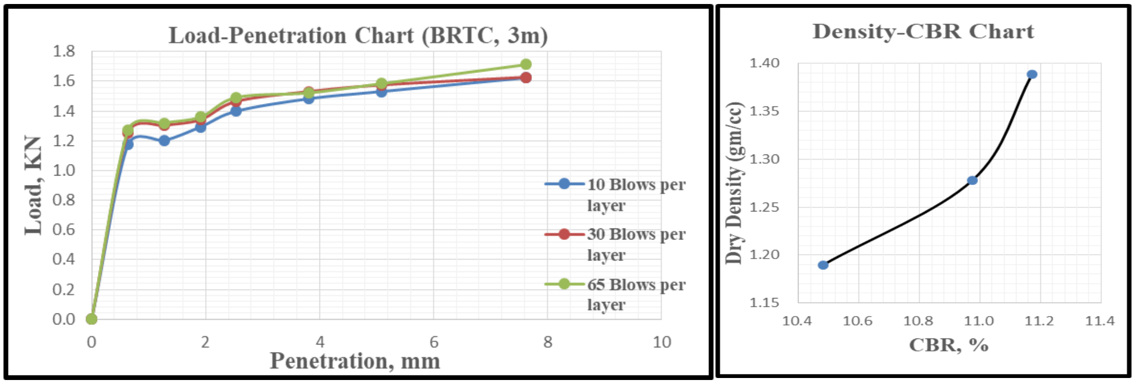

Figure 4.33 Load-Penetration and Density-CBR chart for sample collected from BRTC at 3m depth (i.e. Soil+3%WSF(1.5cm)+7%C)

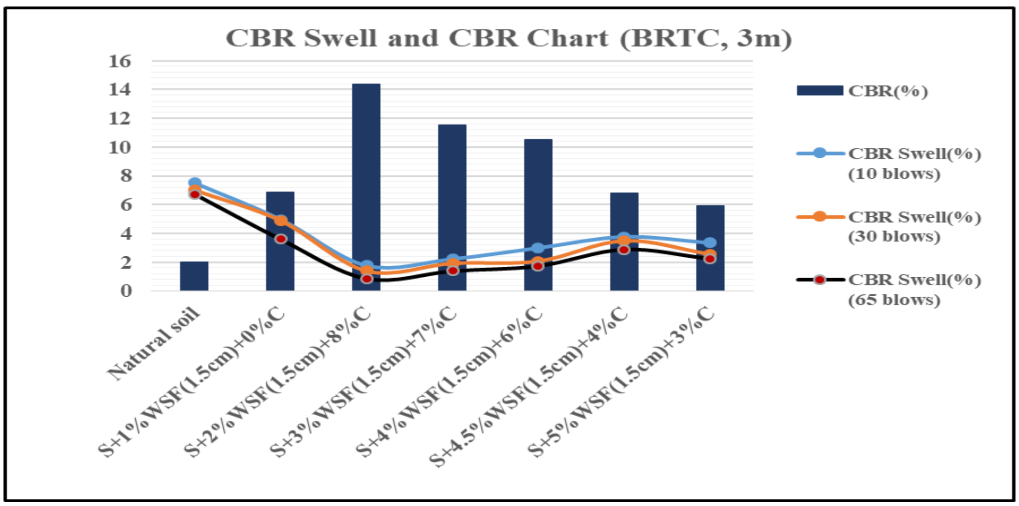

Figure 4.34 CBR and CBR Swell for sample collected from BRTC at 3m depth and stabilized with WSF&C

The California Bearing Ratio (CBR) for site located at BRTC increase from 2.02% at Soil+0%WSF(1.5cm)+0%Cement to 11.51% at Soil+3% WSF(1.5cm)+7%Cement at the depth of 3m, and the percentage of CBR Swell decrease drastically as number blows increase. Due to the formation of a cementitious gel between the wheat straw fiber, soil and the calcium in the cement, adding cement to the soil–wheat straw fiber combination improves the soaked CBR value.

4.2.3 The effect of adding WSF and cement on UCS of natural soil

This test was conducted to determine the UCS of the Natural soil, Soil+WSF and Soil+WSF+Cement specimens prepared by mixing, compacting at different percentage. The sample for this test was prepared using the Optimum Moisture Content and Maximum

Dry Density obtained from compaction test and remolded using the modified proctor compaction mold then extruded by shelby tube sampler. The test was performed on undisturbed and remolded samples for the natural soil and for the Soil-WSF and Cement mixture respectively.

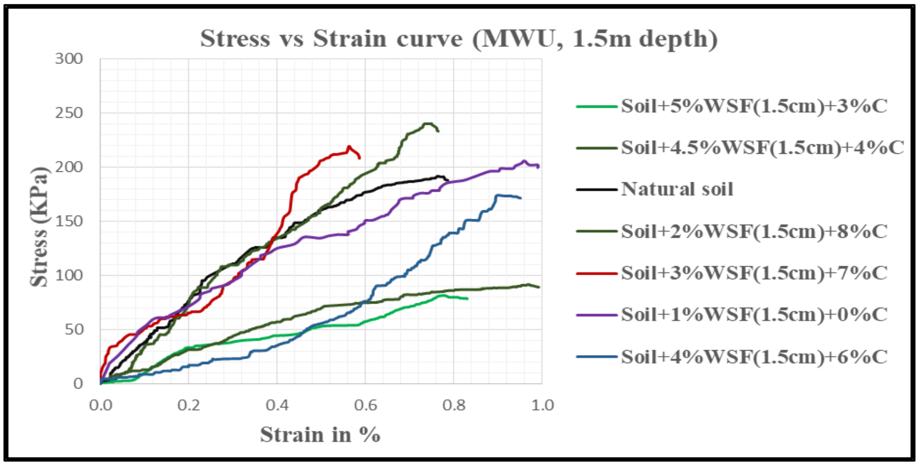

Figure 4.35 UCS value for varied percentage of WSF and Cement mixed with soil sample from MWU at 1.5m depth

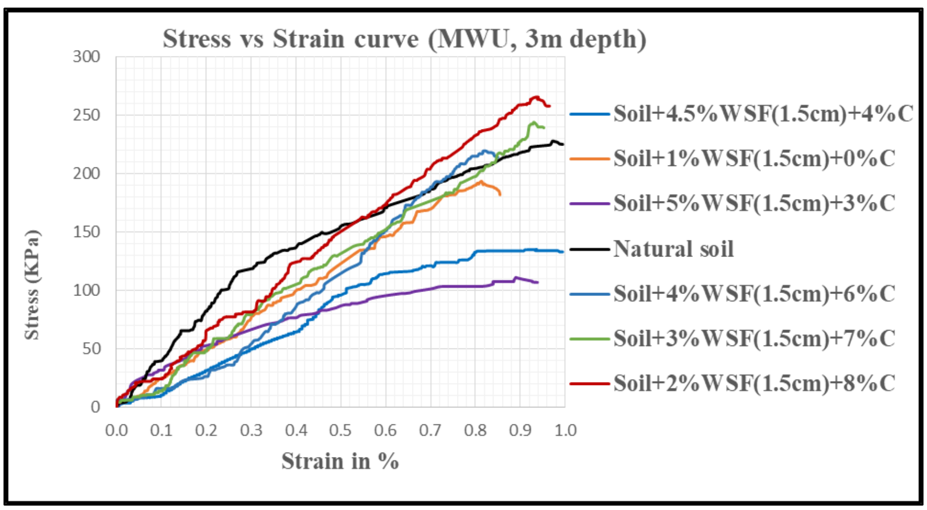

Figure 4.36 UCS value for varied percentage of WSF and Cement mixed with soil sample from MWU at 3m depth

Figures 4.35 and 4.36 shows the stress-strain behavior of natural soil and WSF-Cement treated soil with different mixing ratio. Initially the stress is gradually increases with the increase of strain. After attaining the peak stress, it decreases with the increase of strain for all mixing ratios of wheat straw fiber, cement and soil. Again the Unconfined compression strength for site located at MWU increases from 191.85Kpa at Soil+0%WSF(1.5cm) to

219.46KPa at Soil+3%WSF(1.5cm)+7%Cement, and then after decreases to 81.66Kpa at Soil+5%WSF+3%Cement for sample collected at 1.5m depth. In addition the Unconfined Compression Strength increase from 227.63KPa at Soil+0%WSF(1.5cm) to 243.60KPa at Soil+3%WSF(1.5cm)+7%C, and decrease to 110.95Kpa at Soil+5%WSF+3%Cement for sample collected at 3m depth.

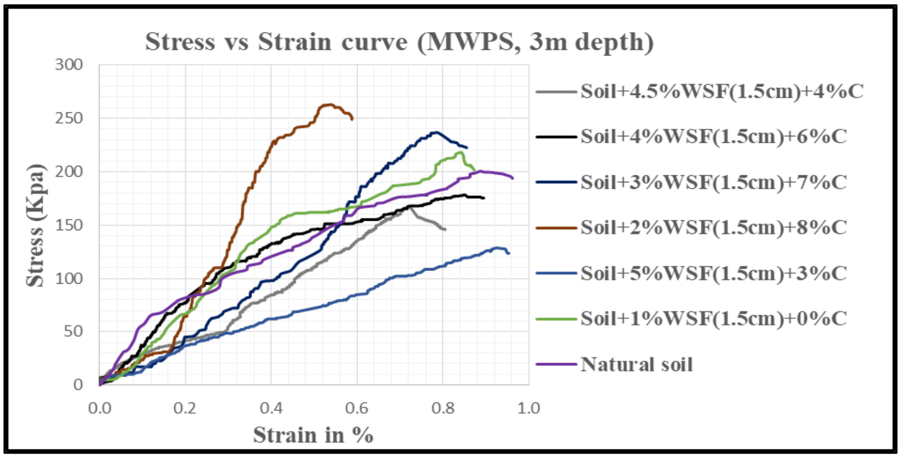

Figure 4.37 UCS value for varied percentage of WSF and Cement mixed with soil sample from MWPS at 3m depth

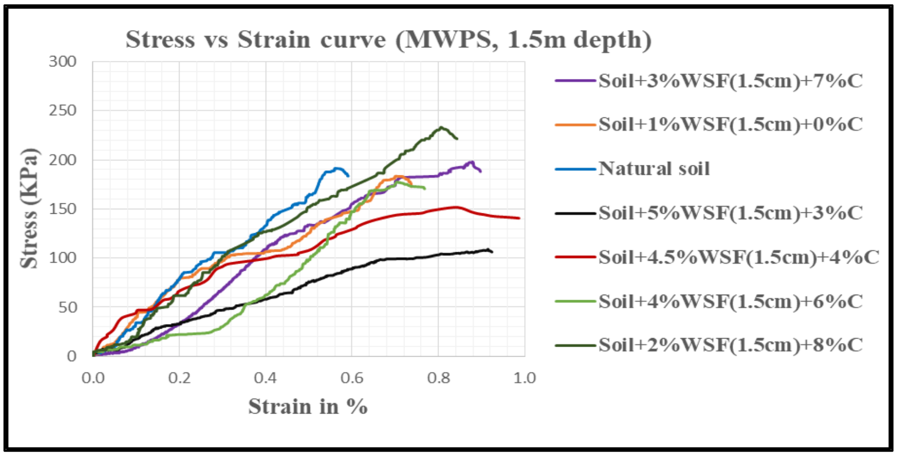

Figure 4.38 UCS value for varied percentage of WSF and Cement mixed with soil sample from MWPS at 1.5m depth

As we seen from figure 4.37 and figure 4.38 the Unconfined compression strength (UCS) for site located at MWPS increase from 191.51KPa at Soil+0%WSF(1.5cm)+0%Cement to 198.07KPa at Soil+3%WSF(1.5cm)+7%Cement, and decrease to 109.11Kpa at Soil+5%WSF+3%Cement for sample collected at 1.5m depth. Again the Unconfined Compression Strength increase from 200.60KPa at Soil+0%WSF(1.5cm)+0%Cement to

236.43KPa at Soil+3%WSF(1.5cm)+7%Cement, and then decrease to 128.72Kpa at Soil+5%WSF+3%Cement for sample collected at 3m depth. The improvement at lower reinforcing percentages are because of the confining pressure created due friction between WSF and soil particles. The reason for the decrease of the unconfined compressive strength of the soil-wheat straw fiber at higher mix ratio (i.e as the amount of the wheat straw fiber is increasing while amount of soil and cement decreasing) is because of the addition of more cohesion less material to the clay soil reduce its natural cohesive force between the clay soil particles. Therefore, at higher percentage of wheat straw fiber the Unconfined compressive strength value of the treated soil gets lower and lower. But the addition of wheat straw fiber at small mixed ratio in the soil increase the strain at failure and make the stabilized soil more ductile.

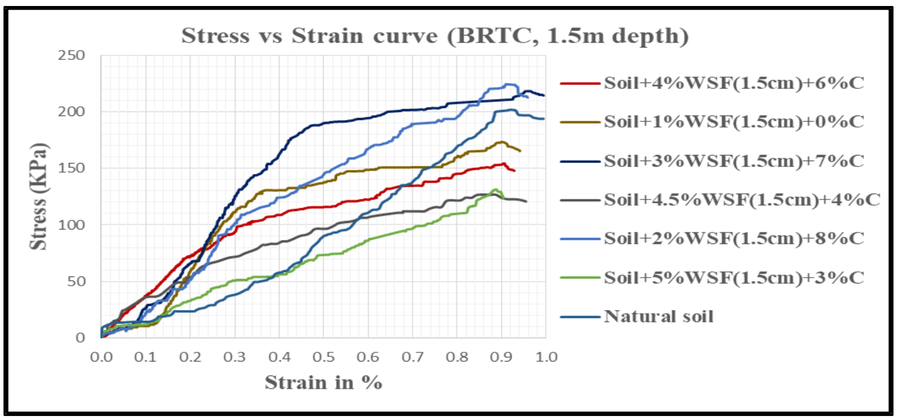

Figure 4.39 UCS value for varied percentage of WSF and Cement mixed with soil sample from BRTC at 1.5m depth

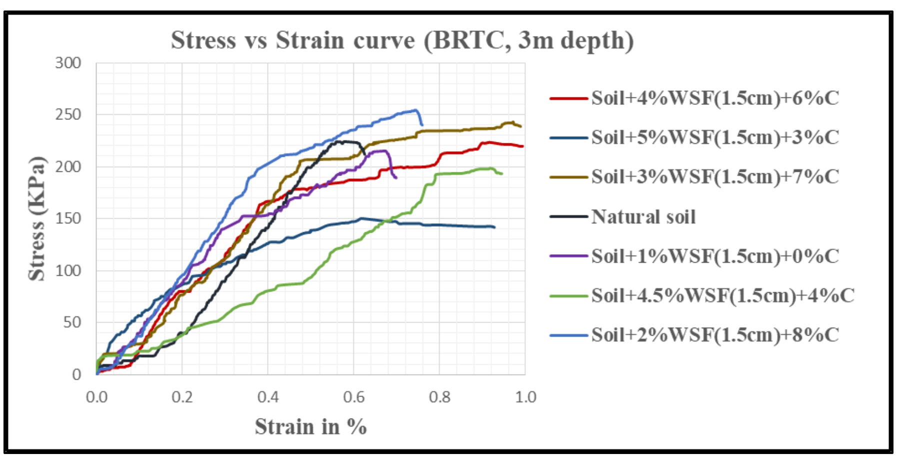

Figure 4.40 UCS value for varied percentage of WSF and Cement mixed with soil sample from BRTC at 3m depth

The Unconfined compression strength for site located at BRTC increase from 202.10KPa at Soil+0%WSF(1.5cm)+0%Cement to 218.48KPa at Soil+3%WSF(1.5cm)+7%Cement, and decrease to 131.37Kpa at Soil+5%WSF+3%Cement for sample collected at 1.5m depth. Again the Unconfined Compression Strength (UCS) increase from 224KPa at Soil+0%WSF(1.5cm)+0%Cement to 242.96KPa at Soil+3% WSF(1.5cm)+7%Cement, and decrease to 150.18Kpa at Soil+5%WSF+3%Cement for sample collected at 3m depth as showed above in figure 4.39 and figure 4.40. The reinforced soil samples fail at a greater strain, implying that fiber reinforced soil can withstand a greater load and will fail at a higher deformation than unreinforced soil, because the fibers close the shear failure plane. Another factor contributing to the reduction of UCS could be, the molding water used in sample preparation for high percentage of wheat straw fiber was high.

4.3 Effect of the sodium hydroxide(NaOH) and hot water on chemical properties of wheat straw fiber

Wheat straw has similar chemical constituted to those of wood such as hemicellulose, cellulose, lignin and extractives. And also wheat straw have high amount of hydrophobic waxy cuticle and inorganic silica (Li *et al.*, 2012). Different pretreatment were applied to improve the bonding quality, tensile strength, enlongation and extraction of certain amount of chemical constituents. The powder X-ray diffraction was performed to investigate the changes in the crystalline structure of two powdered samples of untreated wheat straw and treated wheat straw with sodium hydroxide(NaOH) and hot water employing XRD machine, at 2theta of 10-60 degree, at 40kv and 40mA.

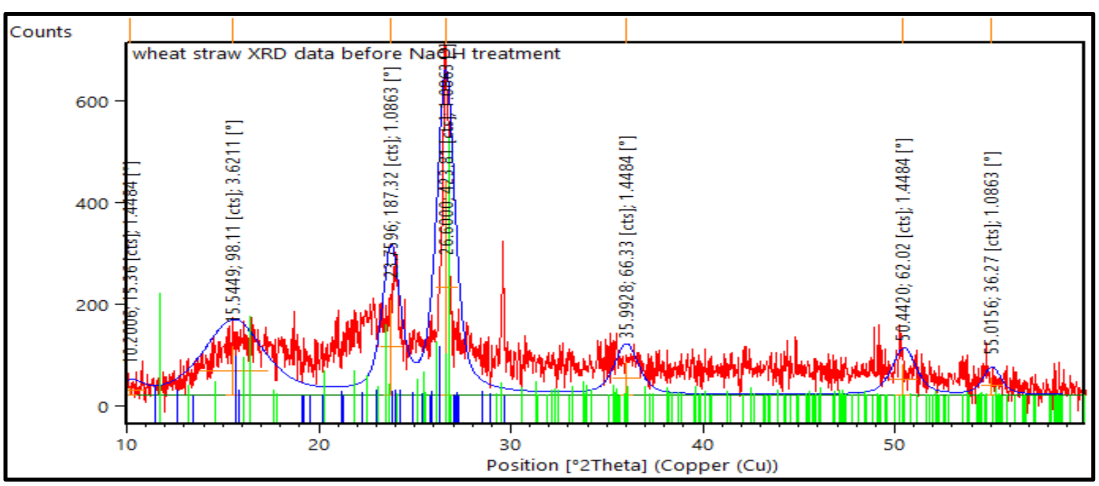

Figure 4.41 XRD Analysis for untreated wheat straw

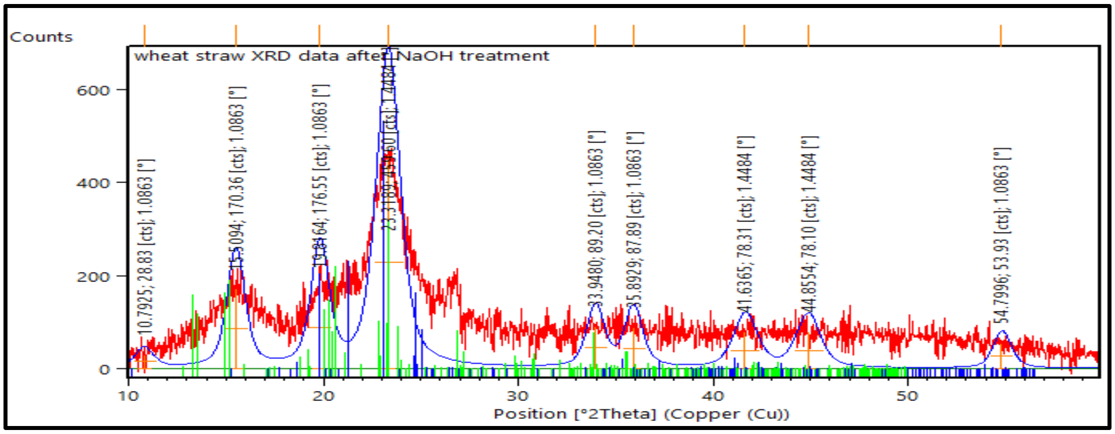

Figure 4.42 XRD Analysis for treated wheat straw with sodium hydroxide(NaoH) and Hot water

There is increased in crystallinity index after treatment with sodium hydroxide and hot water, this indicate that the strength improvement of pretreated sample due to the preserve of more stable cellulose chains in their structures. Comparing figure 4.41 and figure 4.42, the pre-treatment raises the peak intensity, peak height and crystallinity (i.e. 61.43A for untreated and 70.56A for treated wheat straw) of this material. The reaction between wheat straw contents and chemicals could account for the difference in XRD pattern and peak height between treated and untreated wheat straw. Chemical pre-treatments has been more effective in removing and extracting a certain proportion of hemicellulose, waxy and resulting in better-purified lignin and cellulose. And also the chemical pretreatment reduce water absorption as a result of a reaction of acetyl groups with hydroxyl groups. However chemical pretreatments, have a lower cost-effectiveness in large-scale production and have negative environmental consequences, which limit their utilization in comparison to physical pretreatments such as hot water.

Moreover the smooth surface of raw WSF reduces the bonding between WSF and soil, whereas treated WSF with a rough surface can help to alleviate this problem. When the mechanics of treated WSF are higher than those of raw WSF, the use of treated WSF as a reinforcing material is favorable even when the water content is high. The manner in which cement chemically stabilized the soil made the fiber reinforcing effect more effective and cement stabilization development was accelerated by the water channel running through the surface and honey comb pore of the wheat straw. Again, soil treated just with cement alone is brittle, thus it is preferable to modify with the reinforcement.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this research, the experimental works were carried out to evaluate the type and engineering behavior of the natural soil and after stabilization for the soil samples taken from MWU, MWPS and BRTC at the depth of 1.5m and 3m. Based on results obtained from Atterberg limit, Sieve and Hydrometer analysis, Free Swell, Compaction, Linear Shrinkage, Unconfined Compression Strength, XRD, CBR and CBR Swell tests the following conclusion are made.

- The Grain Size Distribution (wet sieve and hydrometer test) for all test pit, depth and locations indicates that majority of soil samples are silty-clay material.
- The Specific gravity of the soil samples taken from study area was ranging from 2.70 to 2.75 for both 1.5m and 3m depth and locations. Therefore these soil samples grouped under clay soil.
- Free swell and Linear shrinkage test results indicates that most of the soils collected from study areas exhibit swelling and shrinking nature.
- The Atterberg limit test results showed that, all soil specimens are highly plastic having high atterberg limit values with the average liquid limit ranges from 80.7%-85.4%, plastic limit ranges from 31.36%-34.15% and plastic index ranges from 47%-53.63%.
- According to AASHTO and USCS soil classification system most soils of study areas categorized under A-7-5 and CH respectively. Therefore these soils have poor quality with regard to roadway construction, but can be utilized as sub-grade material.
- The MDD and OMC of all soil samples treated with wheat straw fiber alone reveal a minor increase in maximum dry density and a small decrease in optimum moisture content. But cement addition has resulted higher increment in maximum dry density and decrement in optimum moisture content when we compare with stabilization of soil by wheat straw fiber alone. This is due to

wheat straw fiber has low pozzolanic nature, low unit weight than cement and creating void space between soil particles.

- The value of CBR for natural soils are grouped under S1, but after stabilization of natural soil with wheat straw fiber and cement the soil becomes S4 subgrade class. Again, all mix ratios with wheat straw fiber alone satisfied the minimum requirements of CBR value >3% as per ERA specification to be used as a road subgrade material. The CBR swell for natural soils was very high, which is higher than the ERA manual's recommended maximum of 2%, but with the addition of wheat straw fiber and cement, the CBR swell for all soil samples were significantly reduced.
- For treated soil the Unconfined Compression Strength (UCS) dropped as the amount of wheat straw fiber increased and the amount of cement decreased, owing to the fact that adding more cohesion-less material to the clay soil reduces the natural cohesive force between the particles of clay soil. However, the findings of UCS show that combining physical and chemical treatments can improve soil strength and anti-deformation while also overcoming the brittleness associated with cement soil mixtures.
- The XRD results indicate that after treating wheat straw with sodium hydroxide and hot water, there is a difference in peak intensity, indicating that the strength of the pretreated sample has improved due to the preservation of more stable cellulose chains in their structures.
- Under this study the maximum results were achieved at 2%WSF+8%C for most tests. But by considering safety as well as economy 3%WSF+7%Cement is considered as optimum percentage and which achieves by improving most of the geotechnical properties of soils of Robe town.

5.2 Recommendations

- By doing different laboratory tests such as tensile strength test, permeability test, the property of the soil sample stabilized with wheat straw fiber and cement should be determined and in-depth investigation should be done for the future.
- This study was carried out by combining soil, wheat straw fiber (15mm) and cement at various percentages of mixing ratio. It is suggested that the next

investigator should conduct experiments at another percentages and length of wheat straw fiber by considering different parameters such as the effect of curing time, temperature to have realistic result. Again also durability of stabilized soil, as well as wetting-drying and leaching effects, require further investigation.

- Grinding or cutting of wheat straw fiber into various lengths by hand takes a long time and is inaccurate, so an electrical machine or tool is advised. This technology creates doors for small-scale entrepreneurs that don't need a lot of money or experience. The accessory which is used in grinding or cutting of wheat straw fiber can be manufactured in local work-shop by small business groups (entrepreneurs).

From the test results soil stabilization with cement was better than soil stabilization with wheat straw fiber alone in improving sub grade soil properties. However, due to its maximum optimal ratio and current market cost when compared to the cost of agricultural waste wheat straw fiber, employing cement alone is not cost effective. A mixture of wheat straw fiber and cement, which is less expensive than using cement alone can be utilized to improve soil with similar geotechnical properties and making them more suitable for construction.

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APPENDIX

Appendix 1 Soil Classification System Tables

a) The American Association of State Highway and Transportation Officials (AASHTO) System

Table 1.7 AASHTO Soil Classification System

General classification	Granular materials (35% or less of total sample passing No. 200 sieve)						
	A-1			A-2			
Group classification	**A-1-a**	**A-1-b**	**A-3**	**A-2-4**	**A-2-5**	**A-2-6**	**A-2-7**
Sieve analysis (% passing)							
No. 10 sieve	50 max						
No. 40 sieve	30 max	50 max	51 min				
No. 200 sieve	15 max	25 max	10 max	35 max	35 max	35 max	35 max
For fraction passing No. 40 sieve							
Liquid limit (LL)				40 max	41 min	40 max	41 min
Plasticity index (PI)	6 max		Nonplastic	10 max	10 max	11 min	11 min
Usual type of material	Stone fragments, gravel, and sand		Fine sand	Silty or clayey gravel and sand			
Subgrade rating	Excellent to good						

General classification	Silt–clay materials (More than 35% of total sample passing No. 200 sieve)			
Group classification	**A-4**	**A-5**	**A-6**	**A-7**
				A-7-5[a] A-7-6[b]
Sieve analysis (% passing)				
No. 10 sieve				
No. 40 sieve				
No. 200 sieve	36 min	36 min	36 min	36 min
For fraction passing No. 40 sieve				
Liquid limit (LL)	40 max	41 min	40 max	41 min
Plasticity index (PI)	10 max	10 max	11 min	11 min
Usual types of material	Mostly silty soils		Mostly clayey soils	
Subgrade rating	Fair to poor			

[a]If $PI \leq LL - 30$, the classification is A-7-5.

[b]If $PI > LL - 30$, the classification is A-7-6.

b) The Unified Soil Classification System (USCS)

Table 1.8 Unified Soil Classification Chart (after ASTM, 2009) (ASTM D2487-98: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification). Copyright ASTM INTERNATIONAL. Reprinted with permission.)

Criteria for assigning group symbols and group names using laboratory tests[a]				Soil classification: Group symbol	Soil classification: Group name[b]
Coarse-grained soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[c]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[e]	GW	Well-graded gravel[f]
			$C_u < 4$ and/or $1 > C_c > 3$[e]	GP	Poorly graded gravel[f]
		Gravels with Fines More than 12% fines[c]	Fines classify as ML or MH	GM	Silty gravel[f,g,h]
			Fines classify as CL or CH	GC	Clayey gravel[f,g,h]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[d]	$C_u \geq 6$ and $1 \leq C_c \leq 3$[e]	SW	Well-graded sand[i]
			$C_u < 6$ and/or $1 > C_c > 3$[e]	SP	Poorly graded sand[i]
		Sand with Fines More than 12% fines[d]	Fines classify as ML or MH	SM	Silty sand[g,h,i]
			Fines classify as CL or CH	SC	Clayey sand[g,h,i]
Fine-grained soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[j]	CL	Lean clay[k,l,m]
			PI < 4 or plots below "A" line[j]	ML	Silt[k,l,m]
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$	OL	Organic clay[k,l,m,n] / Organic silt[k,l,m,o]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay[k,l,m]
			PI plots below "A" line	MH	Elastic silt[k,l,m]
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$	OH	Organic clay[k,l,m,p] / Organic silt[k,l,m,q]
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

[a]Based on the material passing the 75-mm. (3-in) sieve.
[b]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[c]Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt; GW-GC well-graded gravel with clay; GP-GM poorly graded gravel with silt; GP-GC poorly graded gravel with clay.
[d]Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt; SW-SC well-graded sand with clay; SP-SM poorly graded sand with silt; SP-SC poorly graded sand with clay.

[e]$C_u = D_{60}/D_{10}$ $\quad C_c = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$
[f]If soil contains ≥15% sand, add "with sand" to group name.
[g]If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
[h]If fines are organic, add "with organic fines" to group name.
[i]If soil contains ≥15% gravel, add "with gravel" to group name.
[j]If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[k]If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.
[l]If soil contains ≥30% plus No. 200, predominantly sand, add "sandy" to group name.
[m]If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[n]PI ≥ 4 and plots on or above "A" line.
[o]PI < 4 or plots below "A" line.
[p]PI plots on or above "A" line.
[q]PI plots below "A" line.

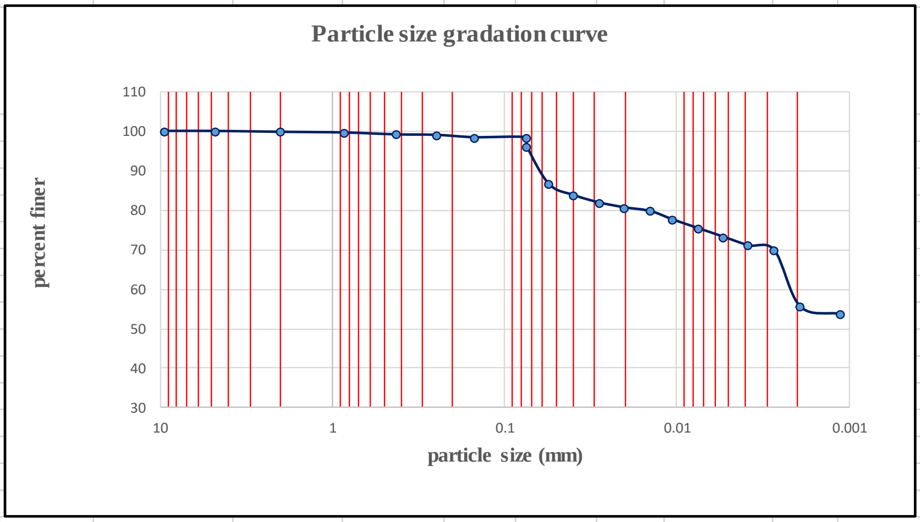
Appendix 2 Grain Size Analysis Test Result

a) Grain Size Analysis (wet sieve and hydrometer test) for MWU at 1.5m depth

Grain Size Analysis (wet sieve analysis)				
Madda Walabu University, 1.5m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle(passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	1.095	0.219	0.219	99.781
0.85	0.874	0.1748	0.3938	99.6062
0.425	2.381	0.4762	0.87	99.13
0.25	0.568	0.1136	0.9836	99.0164
0.15	2.996	0.5992	1.5828	98.4172
0.075	0.081	0.0162	1.599	98.401

HYDROMETER ANALYSIS						Mass of Sample = 50g				Location -MWU at 1.5m depth		
Madda Walabu University 1.5m depth						Specific gravity=2.724				Hydrometer type-151H		
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
19/10/2013EC	2:30AM	0.25	20	1.032	-0.001	1.031	7.84	0.0133	0.074	31	98.05	96.165
	2:30	0.5	20	1.029	-0.001	1.028	8.66	0.0133	0.055	27.9	88.24	86.5485
	2:31	1	20	1.028	-0.001	1.027	8.89	0.0133	0.04	27	85.4	83.7566
	2:32	2	20	1.027	-0.001	1.026	9.05	0.0133	0.028	26.4	83.5	81.8954
	2:34	4	20	1.027	-0.001	1.026	9.15	0.0133	0.02	26	82.23	80.6545
	2:38	8	20	1.027	-0.001	1.026	9.23	0.0133	0.014	25.7	81.28	79.7239
	2:45	15	20	1.026	-0.001	1.025	9.41	0.0133	0.011	25	79.07	77.5524
	3:00	30	20	1.025	-0.001	1.024	9.60	0.0133	0.008	24.3	76.86	75.381
	3:30AM	60	20	1.025	-0.001	1.024	9.78	0.0133	0.005	23.6	74.64	73.2095
	4:30	120	20	1.024	-0.001	1.023	9.97	0.0133	0.004	22.9	72.43	71.038
	6:30	240	20	1.024	-0.001	1.023	10.07	0.0133	0.003	22.5	71.16	69.7972
	10:30	480	21	1.023	-0.005	1.018	10.23	0.01319	0.002	17.9	56.61	55.5275
20/10/2013 EC	2:30	1440	21	1.022	-0.005	1.017	10.38	0.01319	0.001	17.3	54.72	53.6663

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100
2	99.781
0.85	99.606
0.425	99.130
0.25	99.016
0.15	98.417
0.075	98.401
0.0745	96.165
0.0553	86.548
0.0397	83.757
0.0283	81.895
0.0201	80.655
0.0143	79.724
0.0105	77.552
0.0075	75.381
0.0054	73.209
0.0038	71.038
0.0027	69.797
0.0019	55.528
0.0011	53.666



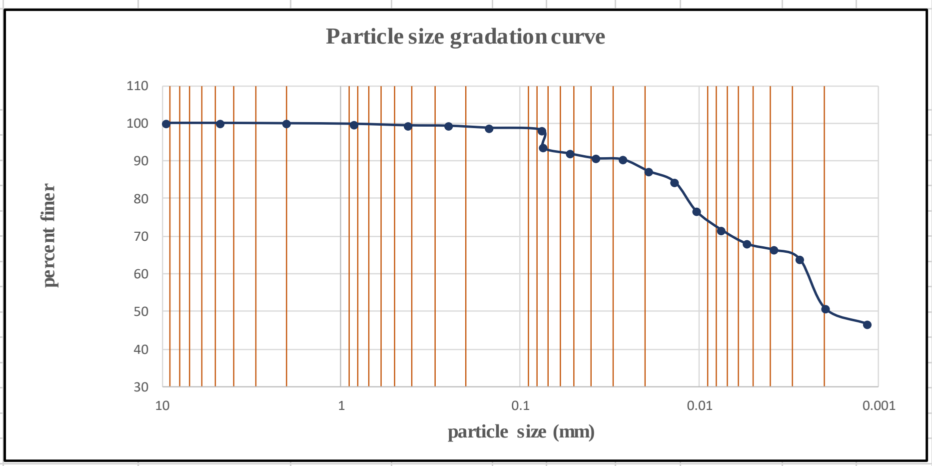
Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.599	42.873	55.528		

b) Grain Size Analysis (wet sieve and hydrometer test) for MWU at 3m depth

Grain Size Analysis (wet sieve analysis)				
Madda Walabu University, 3m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle (passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	0.408	0.0816	0.0816	99.9184
0.85	0.713	0.1426	0.2242	99.7758
0.425	2.036	0.4072	0.6314	99.3686
0.25	0.56	0.112	0.7434	99.2566
0.15	2.618	0.5236	1.267	98.733
0.075	2.99	0.598	1.865	98.135

HYDROMETER ANALYSIS						Mass of Sample = 50g				Location -MWU at 3m depth		
Madda Walabu University 3m depth						Specific gravity=2.713				Hydrometer type-151H		
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
18/10/2013EC	2:30AM	0.25	20	1.031	-0.001	1.030	8.10	0.013	0.074	30	95.026	93.4441
	2:30	0.5	20	1.031	-0.001	1.030	8.24	0.013	0.0528	29.5	93.442	91.8867
	2:31	1	20	1.030	-0.001	1.029	8.34	0.013	0.0375	29.1	92.175	90.6408
	2:32	2	20	1.030	-0.001	1.029	8.37	0.013	0.0266	29	91.859	90.3293
	2:34	4	20	1.029	-0.001	1.028	8.63	0.013	0.0191	28	88.691	87.2145
	2:38	8	20	1.028	-0.001	1.027	8.87	0.013	0.0137	27.1	85.84	84.4112
	2:45	15	20	1.026	-0.001	1.025	9.52	0.013	0.0104	24.6	77.922	76.6241
	3:00	30	20	1.024	-0.001	1.023	9.94	0.013	0.0075	23	72.853	71.6405
	3:30AM	60	20	1.023	-0.001	1.022	10.25	0.013	0.0054	21.8	69.052	67.9027
	4:30	120	20	1.022	-0.001	1.021	10.38	0.013	0.0038	21.3	67.469	66.3453
	6:30	240	20	1.022	-0.001	1.021	10.59	0.013	0.0027	20.5	64.935	63.8535
	10:30	480	21	1.021	-0.005	1.016	10.65	0.0132	0.002	16.3	51.631	50.7713
19/10/2013 EC	2:30	1440	21	1.020	-0.005	1.015	11.00	0.0132	0.0012	15	47.513	46.722

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100
2	99.918
0.85	99.776
0.425	99.369
0.25	99.257
0.15	98.733
0.075	98.135
0.0740	93.444
0.0528	91.887
0.0375	90.641
0.0266	90.329
0.0191	87.214
0.0137	84.411
0.0104	76.624
0.0075	71.640
0.0054	67.903
0.0038	66.345
0.0027	63.853
0.0020	50.771
0.0012	46.722



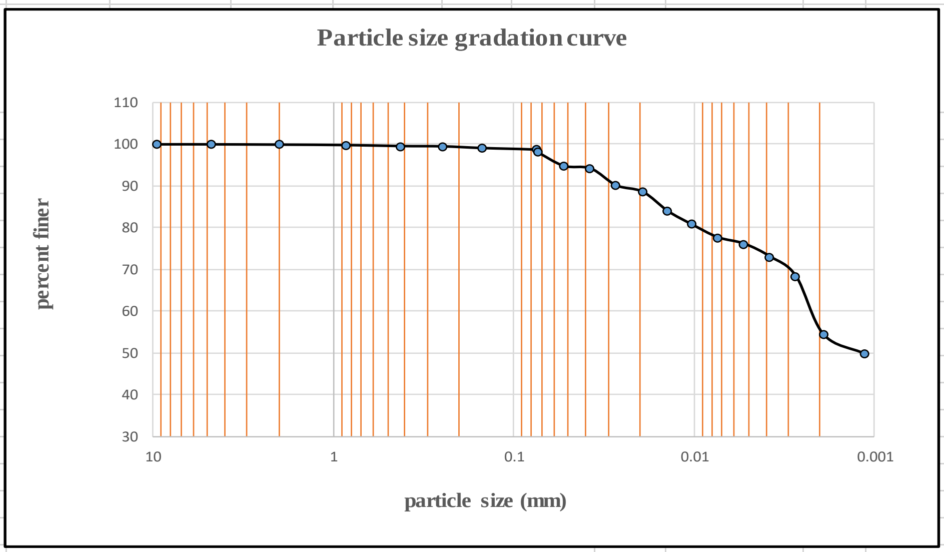
Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.865	47.364	50.771		

c) Grain Size Analysis (wet sieve and hydrometer test) for MWPS at 1.5m depth

Grain Size Analysis (wet sieve analysis)				
Madda Walabu Primary School, 1.5m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle (passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	0.341	0.0682	0.0682	99.9318
0.85	0.519	0.1038	0.172	99.828
0.425	1.189	0.2378	0.4098	99.5902
0.25	0.342	0.0684	0.4782	99.5218
0.15	2.027	0.4054	0.8836	99.1164
0.075	1.996	0.3992	1.2828	98.7172

HYDROMETER ANALYSIS Madda Walabu Primary School at 1.5m depth						Mass of Sample = 50g				Location -MWPS at 1.5m depth		
						Specific gravity=2.739				Hydrometer type-151H		
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
16/10/2013EC	2:30AM	0.25	20	1.033	-0.001	1.032	7.69	0.01329	0.074	31.55	99.39	98.110
	2:30	0.5	20	1.032	-0.001	1.031	7.97	0.01329	0.053	30.5	96.08	94.845
	2:31	1	20	1.031	-0.001	1.030	8.03	0.01329	0.038	30.3	95.45	94.223
	2:32	2	20	1.030	-0.001	1.029	8.37	0.01329	0.027	29	91.35	90.181
	2:34	4	20	1.030	-0.001	1.029	8.50	0.01329	0.019	28.5	89.78	88.626
	2:38	8	20	1.028	-0.001	1.027	8.89	0.01329	0.014	27	85.05	83.961
	2:45	15	20	1.027	-0.001	1.026	9.15	0.01329	0.01	26	81.9	80.852
	3:00	30	20	1.026	-0.001	1.025	9.41	0.01329	0.007	25	78.75	77.742
	3:30AM	60	20	1.026	-0.001	1.025	9.55	0.01329	0.005	24.5	77.18	76.187
	4:30	120	20	1.025	-0.001	1.024	9.81	0.01329	0.004	23.5	74.03	73.077
	6:30	240	20	1.023	-0.001	1.022	10.20	0.01329	0.003	22	69.3	68.413
	10:30	480	21	1.023	-0.005	1.018	10.34	0.01313	0.002	17.5	55.13	54.419
17/10/2013 EC	2:30	1440	21	1.021	-0.005	1.016	10.72	0.01313	0.001	16	50.4	49.755

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100
2	99.932
0.85	99.828
0.425	99.590
0.25	99.522
0.15	99.116
0.075	98.717
0.0737	98.110
0.0531	94.845
0.0377	94.223
0.0272	90.181
0.0194	88.626
0.0140	83.961
0.0104	80.852
0.0074	77.742
0.0053	76.187
0.0038	73.077
0.0027	68.413
0.0019	54.419
0.0011	49.755



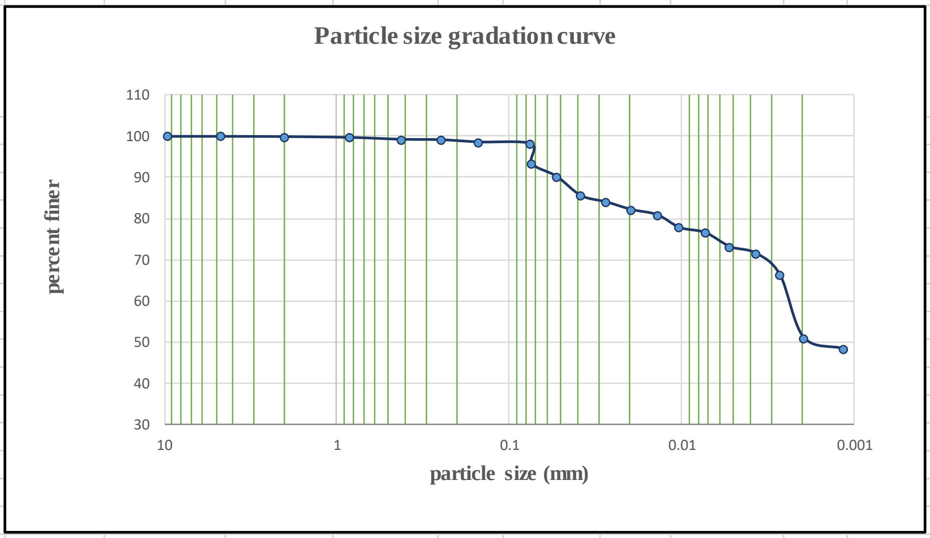
Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.283	30.304	54.419		

d) Grain Size Analysis (wet sieve and hydrometer test) for MWPS at 3m depth

Grain Size Analysis (wet sieve analysis)				
Madda Walabu Primary School, 3m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle (passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	0.281	0.0562	0.0562	99.9438
0.85	0.936	0.1872	0.2434	99.7566
0.425	2.299	0.4598	0.7032	99.2968
0.25	0.559	0.1118	0.815	99.185
0.15	2.702	0.5404	1.3554	98.6446
0.075	2.172	0.4344	1.7898	98.2102

HYDROMETER ANALYSIS						Mass of Sample = 50g				Location -MWPS at 3m depth			
Madda Walabu Primary School 3m depth						Specific gravity=2.711				Hydrometer type-151H			
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
18/10/2013EC	2:30AM	0.25	20	1.031	-0.001	1.030	8.10	0.013	0.074	30	95.07	93.3656
	2:30	0.5	20	1.030	-0.001	1.029	8.37	0.013	0.0532	29	91.9	90.2534
	2:31	1	20	1.029	-0.001	1.028	8.76	0.013	0.0385	27.5	87.14	85.5851
	2:32	2	20	1.028	-0.001	1.027	8.89	0.013	0.0274	27	85.56	84.029
	2:34	4	20	1.027	-0.001	1.026	9.04	0.013	0.0195	26.4	83.66	82.1617
	2:38	8	20	1.027	-0.001	1.026	9.15	0.013	0.0139	26	82.39	80.9169
	2:45	15	20	1.026	-0.001	1.025	9.42	0.013	0.0103	25	79.22	77.8047
	3:00	30	20	1.026	-0.001	1.025	9.52	0.013	0.0073	24.6	77.96	76.5598
	3:30AM	60	20	1.025	-0.001	1.024	9.81	0.013	0.0053	23.5	74.47	73.1364
	4:30	120	20	1.024	-0.001	1.023	9.94	0.013	0.0037	23	72.88	71.5803
	6:30	240	20	1.022	-0.001	1.021	10.38	0.013	0.0027	21.3	67.5	66.2896
	10:30	480	21	1.021	-0.005	1.016	10.62	0.013238	0.002	16.4	51.97	51.0399
19/10/2013 EC	2:30	1440	21	1.021	-0.005	1.016	10.86	0.013238	0.0011	15.51	49.15	48.27

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100
2	99.944
0.85	99.757
0.425	99.297
0.25	99.185
0.15	98.645
0.075	98.210
0.0740	93.366
0.0532	90.253
0.0385	85.585
0.0274	84.029
0.0195	82.162
0.0139	80.917
0.0103	77.805
0.0073	76.560
0.0053	73.136
0.0037	71.580
0.0027	66.290
0.0020	51.040
0.0011	48.270



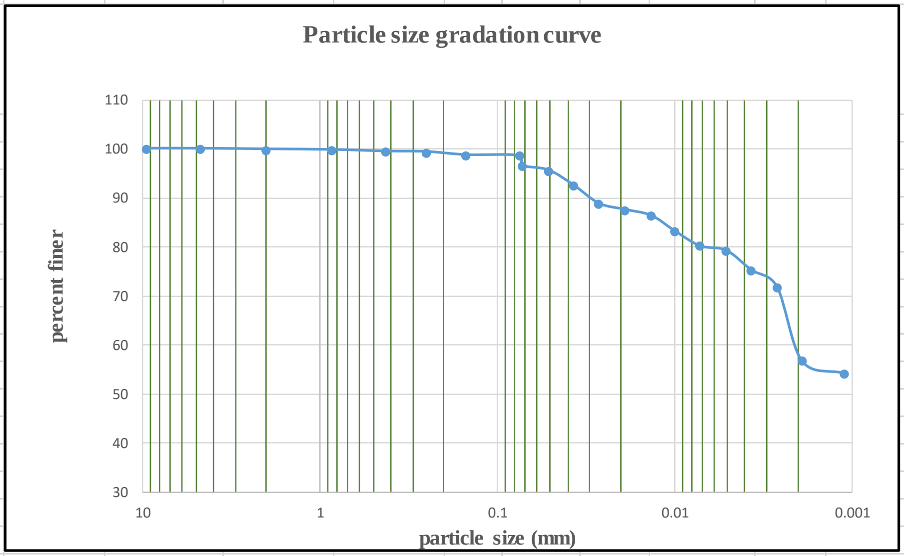
Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.790	47.170	51.040		

e) Grain Size Analysis (wet sieve and hydrometer test) for BRTC at 1.5m depth

Grain Size Analysis (wet sieve analysis)				
Bale Robe Teachers Collage, 1.5m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle (passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	0.631	0.1262	0.1262	99.87
0.85	0.627	0.1254	0.2516	99.7484
0.425	1.546	0.3092	0.5608	99.4392
0.25	0.516	0.1032	0.664	99.336
0.15	3.173	0.6346	1.2986	98.7014
0.075	0.763	0.1526	1.4512	98.5488

HYDROMETER ANALYSIS						Mass of Sample = 50g				Location -BRTC at 1.5m depth		
Bale Robe Teachers Collage 1.5m depth						Specific gravity=2.746				Hydrometer type-151H		
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
20/10/2013EC	2:30AM	0.25	20	1.032	-0.001	1.031	7.76	0.013	0.072	31.3	98.453	96.5227
	2:30	0.5	20	1.032	-0.001	1.031	7.84	0.013	0.051	31	97.51	95.5976
	2:31	1	20	1.031	-0.001	1.030	8.10	0.013	0.037	30	94.364	92.5138
	2:32	2	20	1.030	-0.001	1.029	8.42	0.013	0.027	28.8	90.59	88.8132
	2:34	4	20	1.029	-0.001	1.028	8.52	0.013	0.019	28.4	89.332	87.5797
	2:38	8	20	1.029	-0.001	1.028	8.63	0.013	0.014	28	88.073	86.3462
	2:45	15	20	1.028	-0.001	1.027	8.89	0.013	0.010	27	84.928	83.2624
	3:00	30	20	1.027	-0.001	1.026	9.15	0.013	0.007	26	81.782	80.1786
	3:30AM	60	20	1.027	-0.001	1.026	9.23	0.013	0.005	25.7	80.839	79.2535
	4:30	120	20	1.025	-0.001	1.024	9.57	0.013	0.004	24.4	76.75	75.2445
	6:30	240	20	1.024	-0.001	1.023	9.86	0.013	0.003	23.3	73.29	71.8524
	10:30	480	21	1.023	-0.005	1.018	10.10	0.0131	0.002	18.4	57.877	56.7418
21/10/2013 EC	2:30	1440	21	1.023	-0.005	1.018	10.30	0.0131	0.001	17.6	55.36	54.2747

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100.000
2	99.874
0.85	99.748
0.425	99.439
0.25	99.336
0.15	98.701
0.075	98.549
0.0724	96.523
0.0515	95.598
0.0370	92.514
0.0267	88.813
0.0190	87.580
0.0135	86.346
0.0100	83.262
0.0072	80.179
0.0051	79.253
0.0037	75.245
0.0026	71.852
0.0019	56.742
0.0011	54.275



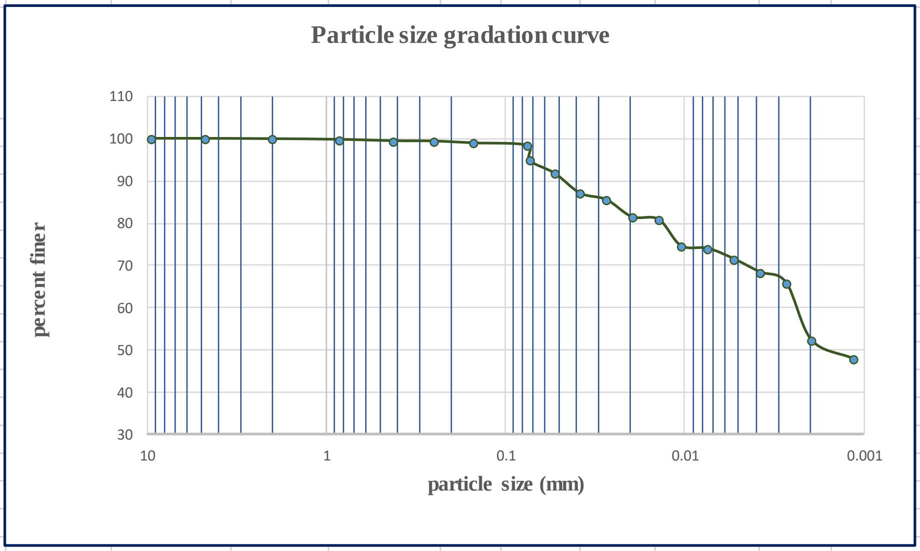
Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.451	26.696	56.742		

f) Grain Size Analysis (wet sieve and hydrometer test) for BRTC at 3m depth

Grain Size Analysis (wet sieve analysis)				
Bale Robe Teachers Collage, 3m(depth)				
Sieve size (mm)	Mass retained(gm)	% of Retained	% of Cumulative Retained	% of Finer Particle (passing)
9.5	0	0	0	100
4.75	0	0	0	100
2	0.396	0.0792	0.0792	99.9208
0.85	0.781	0.1562	0.2354	99.7646
0.425	1.624	0.3248	0.5602	99.4398
0.25	0.396	0.0792	0.6394	99.3606
0.15	2.153	0.4306	1.07	98.93
0.075	2.881	0.5762	1.6462	98.3538

HYDROMETER ANALYSIS						Mass of Sample = 50g				Location -BRTC at 3m depth		
Bale Robe Teachers Collage 3m depth						Specific gravity=2.733				Hydrometer type-151H		
Date	Time	Elapsed Time(min)	Temp °C	Actual Hydrometer Reading Ra	Composite Correction	Corrected Hydrometer Reading	L	K	D(mm)	Corrected Hydrometer Reading Rc	% Finer P	% Adjusted Finer PA
17/10/2013EC	2:30AM	0.25	20	1.032	-0.001	1.031	7.97	0.013	0.073	30.5	96.199	94.8078
	2:30	0.5	20	1.031	-0.001	1.030	8.24	0.013	0.053	29.5	93.045	91.6994
	2:31	1	20	1.029	-0.001	1.028	8.63	0.013	0.038	28	88.314	87.0367
	2:32	2	20	1.029	-0.001	1.028	8.76	0.013	0.027	27.5	86.737	85.4825
	2:34	4	20	1.027	-0.001	1.026	9.10	0.013	0.020	26.2	82.637	81.4415
	2:38	8	20	1.027	-0.001	1.026	9.15	0.013	0.014	26	82.006	80.8198
	2:45	15	20	1.025	-0.001	1.024	9.68	0.013	0.010	24	75.698	74.6029
	3:00	30	20	1.025	-0.001	1.024	9.73	0.013	0.007	23.8	75.067	73.9812
	3:30AM	60	20	1.024	-0.001	1.023	9.94	0.013	0.005	23	72.544	71.4944
	4:30	120	20	1.023	-0.001	1.022	10.20	0.013	0.004	22	69.389	68.386
	6:30	240	20	1.022	-0.001	1.021	10.41	0.013	0.003	21.2	66.866	65.8992
	10:30	480	21	1.022	-0.005	1.017	10.52	0.0132	0.002	16.8	52.988	52.222
18/10/2013 EC	2:30	1440	21	1.020	-0.005	1.015	10.88	0.0132	0.001	15.4	48.573	47.8702

Sieve size (mm)	**% of Finer Particle(passing)**
9.5	100
4.75	100
2	99.921
0.85	99.765
0.425	99.440
0.25	99.361
0.15	98.930
0.075	98.354
0.0734	94.808
0.0528	91.699
0.0382	87.037
0.0272	85.482
0.0196	81.441
0.0139	80.820
0.0104	74.603
0.0074	73.981
0.0053	71.494
0.0038	68.386
0.0027	65.899
0.0019	52.222
0.0011	47.870



Subgrade Soil Classification				AASHTO	USCS
%Gravel	%Sand	%Silt	%Clay	A-7-5	CH
0	1.646	46.132	52.222		

Appendix 3 Natural Moisture Content Test Result

a) Natural Moisture Content Determination

Natural moisture content determinationn				Natural moisture content determinationn			
Madda walabu university 3m				**Madda walabu university 1.5m**			
Determination No	Obs. 1	Obs. 2	Obs. 3	Determination No	Obs. 1	Obs. 2	Obs. 3
Container number	I	II	III	Container number	I	II	III
Weight of container (g)	23	23	21	Weight of container (g)	24	24	24
Weight of container + wet soil (g)	94	93	94	Weight of container + wet soil (g)	86	88	90
Weight of container + dry soil (g)	72	71	71	Weight of container + dry soil (g)	69	70	72
Weight of water (Ww) (g)	22	22	23	Weight of water (Ww) (g)	17	18	18
Weight of dry soil (Ws) (g)	49	48	50	Weight of dry soil (Ws) (g)	45	46	48
Water content (w) %	44.90	45.83	46.00	Water content (w) %	37.78	39.13	37.50
Average water content (w) %	45.58			Average water content (w) %	38.14		

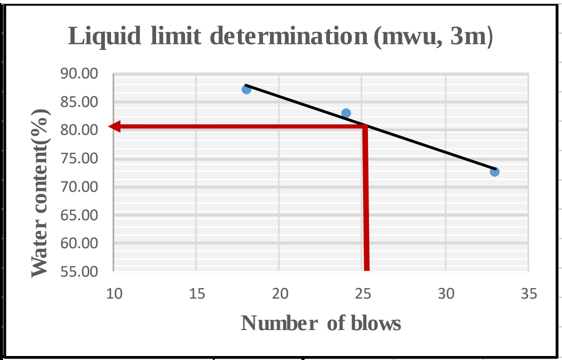
Natural moisture content determinationn				Natural moisture content determinationn			
Madda walabu primary school 3m				**Madda walabu primary school 1.5m**			
Determination No	Obs. 1	Obs. 2	Obs. 3	Determination No	Obs. 1	Obs. 2	Obs. 3
Container number	I	II	III	Container number	I	II	III
Weight of container (g)	24	22	24	Weight of container (g)	24	24	24
Weight of container + wet soil (g)	95	73	74	Weight of container + wet soil (g)	76	81	81
Weight of container + dry soil (g)	75	58	59	Weight of container + dry soil (g)	61	65	65
Weight of water (Ww) (g)	20	15	15	Weight of water (Ww) (g)	15	16	16
Weight of dry soil (Ws) (g)	51	36	35	Weight of dry soil (Ws) (g)	37	41	41
Water content (w) %	39.22	41.67	42.86	Water content (w) %	40.54	39.02	39.02
Average water content (w) %	41.25			Average water content (w) %	39.53		

Natural moisture content determinationn				Natural moisture content determinationn			
Bale Robe Teachers college 3m				**Bale Robe Teachers college 1.5m**			
Determination No	Obs. 1	Obs. 2	Obs. 3	Determination No	Obs. 1	Obs. 2	Obs. 3
Container number	I	II	III	Container number	I	II	III
Weight of container (g)	24	23	23	Weight of container (g)	23	24	23
Weight of container + wet soil (g)	86	73	74	Weight of container + wet soil (g)	91	92	78
Weight of container + dry soil (g)	68	59	59	Weight of container + dry soil (g)	73	74	63
Weight of water (Ww) (g)	18	14	15	Weight of water (Ww) (g)	18	18	15
Weight of dry soil (Ws) (g)	44	36	36	Weight of dry soil (Ws) (g)	50	50	40
Water content (w) %	40.91	38.89	41.67	Water content (w) %	36	36	37.5
Average water content (w) %	40.49			Average water content (w) %	36.50		

Appendix 4 Atterberg Limit Test Result

a) Atterberg limit determination for soil sample from MWU at 1.5m and 3m depth

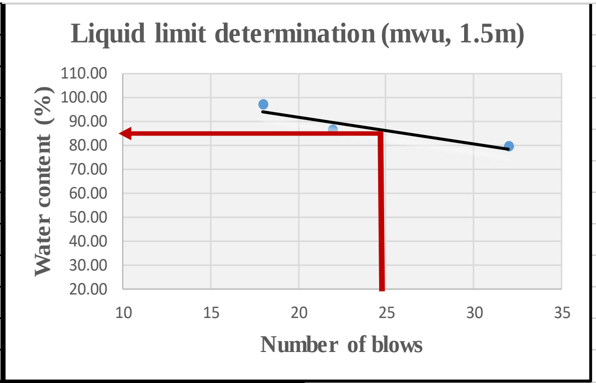
Liquid limit determination			
Madda Walabu University 3m (depth)			
Trial Number	1	2	3
Can Number	[2]	G21	1A
A. Weight of Wet Soil + can	52.809	68.019	68.433
B. Weight of Dry Soil + can	38.313	45.185	45.8
C. Weight of Water(A-B)	14.496	22.834	22.633
D. Weight of can	18.378	17.723	19.919
E. Weight of Dry Soil(B-D)	19.935	27.462	25.881
Water Content (C/E x 100) %	72.72	83.15	87.45
Number of Blows	33	24	18
Liquid Limit %			



Liquid Limit, LL(%)	80.7
Plastic Limit, PL (%)	33.34
Plasticity Index, PI (%)	47

Plastic limit determination		
Madda Walabu University 3m (depth)		
Trial Number	1	2
Can Number	FT-10	G-2
F. Weight of Wet Soil + Can	24.983	24.157
G. Weight of Dry Soil + Can	23.11	22.46
H. Weight of Water(F-G)	1.873	1.697
I. Weight of Can	17.659	17.208
J. Weight of Dry Soil(G-I)	5.451	5.252
Water Content (H/J x 100)%	34.36	32.31
Plastic Limit %(Average)	33.34	

Liquid limit determination			
Madda Walabu University 1.5m (depth)			
Trial Number	1	2	3
Can Number	P66	A3	P1
A. Weight of Wet Soil + can	52.971	65.057	43.329
B. Weight of Dry Soil + can	37.305	52.238	30.882
C. Weight of Water(A-B)	15.666	12.819	12.447
D. Weight of can	17.624	37.413	18.038
E. Weight of Dry Soil(B-D)	19.681	14.825	12.844
Water Content (C/E x 100) %	79.60	86.47	96.91
Number of Blows	32	22	18
Liquid Limit %			

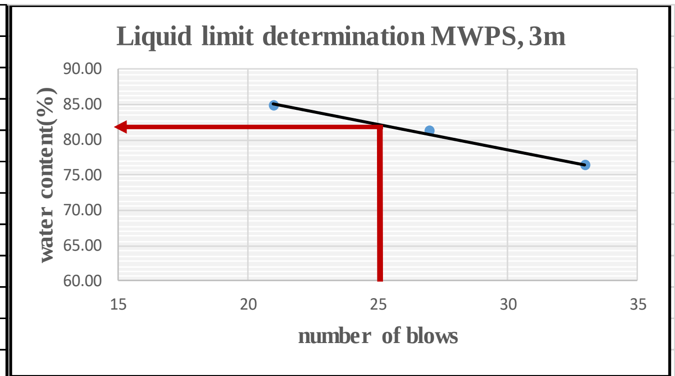


Liquid Limit, LL(%)	85.1
Plastic Limit, PL(%)	31.47
Plasticity Index, PI(%)	53.63

Plastic limit determination		
Madda Walabu University 1.5m (depth)		
Trial Number	1	2
Can Number	I	II
F. Weight of Wet Soil + Can	27.986	12.525
G. Weight of Dry Soil + Can	26.142	10.903
H. Weight of Water(F-G)	1.844	1.622
I. Weight of Can	20.204	5.817
J. Weight of Dry Soil(G-I)	5.938	5.086
Water Content (H/J x 100)%	31.05	31.89
Plastic Limit %(Average)	31.47	

b) Atterberg limit determination for soil sample from MWPS at 1.5m and 3m depth

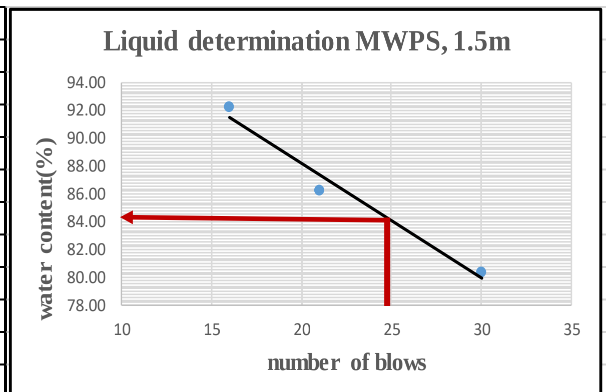
Liquid limit determination			
Madda Walabu primary school 3m (depth)			
Trial Number	1	2	3
Can Number	2-3M	SSB	G-3
A. Weight of Wet Soil + can	60.59	49.011	46.312
B. Weight of Dry Soil + can	42.015	35.171	32.943
C. Weight of Water(A-B)	18.575	13.84	13.369
D. Weight of can	17.65	18.114	17.193
E. Weight of Dry Soil(B-D)	24.365	17.057	15.75
Water Content (C/E x 100) %	76.24	81.14	84.88
Number of Blows	33	27	21
Liquid Limit %			



Plastic limit determination		
Madda Walabu primary school 3m (depth)		
Trial Number	1	2
Can Number	I	II
F. Weight of Wet Soil + Can	25.646	23.214
G. Weight of Dry Soil + Can	24.021	21.399
H. Weight of Water(F-G)	1.625	1.815
I. Weight of Can	19.329	16.009
J. Weight of Dry Soil(G-I)	4.692	5.39
Water Content (H/J x 100)%	34.63	33.67
Plastic Limit %(Average)	34.15	

Liquid Limit, LL(%)	82.4
Plastic Limit, PL(%)	34.15
Plasticity Index, PI(%)	48.25

Liquid limit determination			
Madda Walabu primary school 1.5m (depth)			
Trial Number	1	2	3
Can Number	G-5	P5	SSB
A. Weight of Wet Soil + can	54.309	79.982	55.437
B. Weight of Dry Soil + can	38.17	59.909	37.652
C. Weight of Water(A-B)	16.139	20.073	17.785
D. Weight of can	18.079	36.639	18.379
E. Weight of Dry Soil(B-D)	20.091	23.27	19.273
Water Content (C/E x 100) %	80.33	86.26	92.28
Number of Blows	30	21	16
Liquid Limit %			

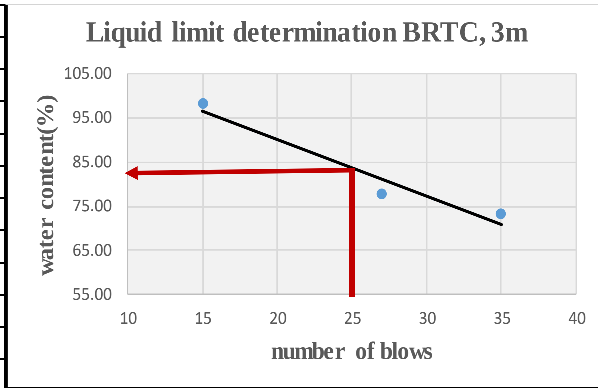


Plastic limit determination		
Madda Walabu primary school 1.5m (depth)		
Trial Number	1	2
Can Number	P8	2-3M
F. Weight of Wet Soil + Can	26.208	23.281
G. Weight of Dry Soil + Can	24.518	21.595
H. Weight of Water(F-G)	1.69	1.686
I. Weight of Can	19.326	16.005
J. Weight of Dry Soil(G-I)	5.192	5.59
Water Content (H/J x 100)%	32.55	30.16
Plastic Limit %(Average)	31.36	

Liquid Limit, LL(%)	84.6
Plastic Limit, PL(%)	31.36
Plasticity Index, PI(%)	53.2

c) Atterberg limit determination for soil sample from BRTC at 1.5m and 3m depth

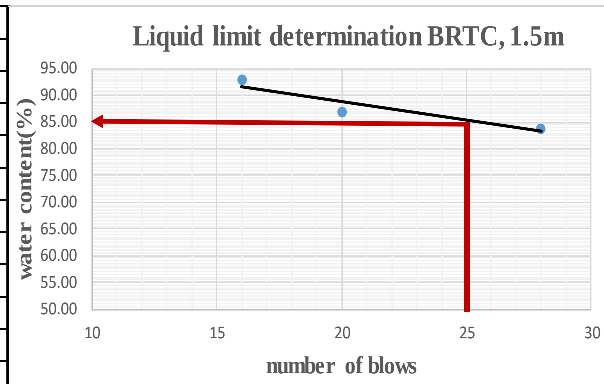
Liquid limit determination			
Bale Robe Teachers collage 3m (depth)			
Trial Number	1	2	3
Can Number	HC11	H2-3	GT3-2
A. Weight of Wet Soil + can	35.236	33.641	32.124
B. Weight of Dry Soil + can	27.81	27.969	25.099
C. Weight of Water(A-B)	7.426	8	7.025
D. Weight of can	17.639	17.652	17.932
E. Weight of Dry Soil(B-D)	10.171	10.317	7.167
Water Content (C/E x 100) %	73.01	77.54	98.02
Number of Blows	35	27	15
Liquid Limit %			



Plastic limit determination		
Bale Robe Teachers collage 3m (depth)		
Trial Number	1	2
Can Number	G21	G-4
F. Weight of Wet Soil + Can	26.308	27.813
G. Weight of Dry Soil + Can	24.692	25.909
H. Weight of Water(F-G)	1.616	1.904
I. Weight of Can	19.911	20.194
J. Weight of Dry Soil(G-I)	4.781	5.715
Water Content (H/J x 100)%	33.80	33.32
Plastic Limit %(Average)	33.56	

Liquid Limit, LL(%)	82.9
Plastic Limit, PL(%)	33.56
Plasticity Index, PI(%)	49.34

Liquid limit determination			
Bale Robe Teachers collage 1.5m (depth)			
Trial Number	1	2	3
Can Number	P5	J41	A3
A. Weight of Wet Soil + can	34.103	53.993	35.567
B. Weight of Dry Soil + can	26.399	43.825	26.9
C. Weight of Water(A-B)	7.704	10.168	8.667
D. Weight of can	17.206	32.127	17.565
E. Weight of Dry Soil(B-D)	9.193	11.698	9.335
Water Content (C/E x 100) %	83.80	86.92	92.84
Number of Blows	28	20	16
Liquid Limit %			



Plastic limit determination		
Bale Robe Teachers collage 1.5m (depth)		
Trial Number	1	2
Can Number	G2	C10
F. Weight of Wet Soil + Can	12.12	43.983
G. Weight of Dry Soil + Can	10.598	41.91
H. Weight of Water(F-G)	1.522	2.073
I. Weight of Can	5.812	35.513
J. Weight of Dry Soil(G-I)	4.786	6.397
Water Content (H/J x 100)%	31.80	32.41
Plastic Limit %(Average)	32.10	

Liquid Limit, LL(%)	85.4
Plastic Limit, PL(%)	32.10
Plasticity Index, PI(%)	53.30

Appendix 5 Linear Shrinkage and Free Swell Test Result

a) Linear shrinkage and free swell determination for all soil samples collected from study area

Linear Shrinkage Determination	
Location and depth:- Madda Walabu University 1.5m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.3
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	19.29

Free swell determination	
Location-Madda walabu university 1.5m(depth)	
depth	1.5m
initial volume of soil, ml	10.9
final volume of soil, ml	19.3
free swell, %	77.06

Linear Shrinkage Determination	
Location and depth:- Madda Walabu University 3m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.8
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	15.71

Free swell determination	
Location-Madda walabu university 3m(depth)	
depth	3m
initial volume of soil, ml	10
final volume of soil, ml	16.8
free swell, %	68

Linear Shrinkage Determination	
Location and depth:- Madda Walabu Primary School 1.5m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.35
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	18.93

Free swell determination	
Location-Madda walabu primary school 1.5m(depth)	
depth	1.5m
initial volume of soil, ml	10
final volume of soil, ml	17.4
free swell, %	74

Linear Shrinkage Determination	
Location and depth:- Madda Walabu Primary School 3m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.5
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	17.86

Free swell determination	
Loction-Madda walabu primary school 3m(depth)	
depth	3m
initial volume of soil, ml	11.8
final volume of soil, ml	20.1
free swell, %	70.34

Linear Shrinkage Determination	
Location and depth:- Bale Robe Teachers Collage 1.5m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.41
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	18.50

Free swell determination	
Location-Bale Robe Teachers college 1.5m(depth)	
depth	1.5m
initial volume of soil, ml	12
final volume of soil, ml	20.5
free swell, %	70.83

Linear Shrinkage Determination	
Location and depth:- Bale Robe Teachers Collage 3m(depth)	
Initial Length(L) of sample, in mm	14
Final length(Lf) of sample, in mm	11.7
$\textbf{Linear Shrinkage (LS) in \%} = \frac{L - L_f}{L} * 100$	16.43

Free swell determination	
Location-Bale Robe Teachers college 3m(depth)	
depth	3m
initial volume of soil, ml	10.9
final volume of soil, ml	17.9
free swell, %	64.22

Appendix 6 Specific Gravity Test Result

a) Specific gravity determination

Specific gravity determination			
Madda Walabu University 1.5m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	18.947	15.567	17.219
Weight of Pycnometer +soil Wps (g)	29.583	25.496	27.318
Weight of Pycnometer +soil + Water, Wpws (g)	51.91	47.99	55.159
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	45.185	41.6961	48.7542
Weight of solids, Ws (g)	10.636	9.929	10.099
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of water (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.715	2.727	2.729
Average	2.724		

Specific gravity determination			
Madda Walabu University 3m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	18.867	19.466	16.015
Weight of Pycnometer +soil Wps (g)	28.378	30.626	26.274
Weight of Pycnometer +soil + Water, Wpws (g)	50.389	53.19	47.31
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	44.3674	46.0828	40.8877
Weight of solids, Ws (g)	9.511	11.16	10.259
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of soil (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.721	2.749	2.669
Average	2.713		

Specific gravity determination			
Madda Walabu primary school 1.5m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	30.337	18.399	18.514
Weight of Pycnometer +soil Wps (g)	42.225	28.459	28.679
Weight of Pycnometer +soil + Water, Wpws (g)	132.284	52.55	73.289
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	124.736	46.1782	66.8002
Weight of solids, Ws (g)	11.888	10.06	10.165
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of soil (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.735	2.723	2.760
Average	2.739		

Specific gravity determination			
Madda Walabu primary school 3m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	21.187	16.297	17.241
Weight of Pycnometer +soil Wps (g)	31.33	26.443	27.314
Weight of Pycnometer +soil + Water, Wpws (g)	83.11	49.68	57.439
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	76.6544	43.2996	51.0959
Weight of solids, Ws (g)	10.143	10.146	10.073
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of soil (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.746	2.690	2.696
Average	2.711		

Specific gravity determination			
Bale Robe Teachers college 1.5m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	27.552	16.015	16.759
Weight of Pycnometer +soil Wps (g)	37.998	28.091	26.887
Weight of Pycnometer +soil + Water, Wpws (g)	85.149	49.293	87.179
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	78.5348	41.6483	80.6689
Weight of solids, Ws (g)	10.446	12.076	10.128
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of soil (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.722	2.721	2.795
Average	2.746		

Specific gravity determination			
Bale Robe Teachers college 3m (depth)			
Trial	1	2	3
Weight of Pycnometer (g)	26.501	18.177	20.531
Weight of Pycnometer +soil Wps (g)	37.998	28.109	30.667
Weight of Pycnometer +soil + Water, Wpws (g)	84.349	51.339	65.453
Weight of Pycnometer + Water at Tx, Wpw(at Tx) (g)	77.011	45.0736	59.0175
Weight of solids, Ws (g)	11.497	9.932	10.136
Temperature, Ti (0C)	25	25	25
D Ti = Relative density of water(g/ml)	0.99708	0.99708	0.99708
Temperature, Tx (0C)	27	27	27
D Tx = Relative density of soil (g/ml)	0.99655	0.99655	0.99655
Coversion factor, k	0.9983	0.9983	0.9983
Specific gravity, $G_s = \frac{kW_s}{W_s + W_{pw}(\text{at Tx}) - W_{pws}}$	2.760	2.704	2.734
Average	2.733		

Appendix 7 MDD, OMC, CBR and CBR Swell Test Result

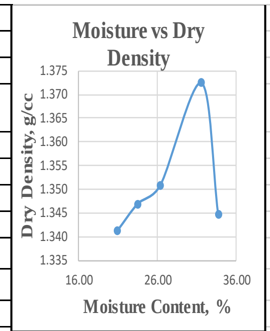
a) Determination of MDD, OMC, CBR and CBR Swell

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

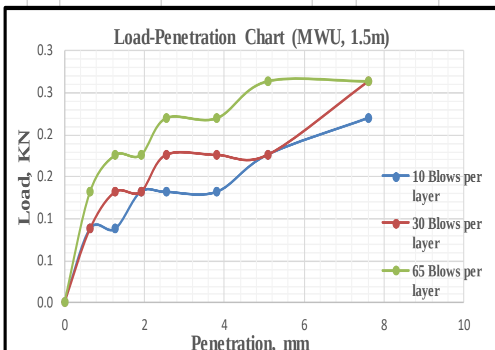
Madda Walabu University at 1.5m depth

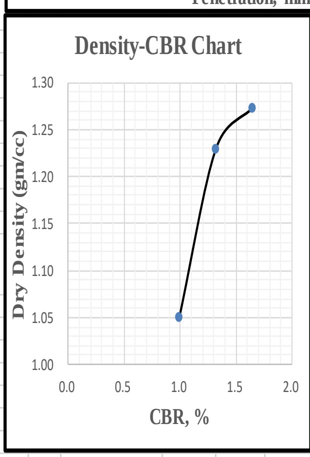
BLOWS PER LAYER	56	No. OF LAYER	5		Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Material Description- Natural Soil+0%WSF	Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8526.4		8611.4		8701.1		8903.2		8886.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3325.4		3410.4		3500.1		3702.2		3685.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.622		1.664		1.707		1.806		1.798	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		45	68	52	199	43	336	314	216	38	42
G	Weight of container (gm)		16.05	16.24	16.11	15.27	16.54	16.18	16.12	15.8	17.08	16.24
H	Weight of container +wet soil(gm)		89.45	78.77	91.12	98.67	60.61	79.11	74.28	102.1	83.78	99.37
I	Weight of container +dry soil(gm)		77.13	67.61	76.67	82.98	50.78	66.9	60.19	81.58	66.89	78.5
J	Weight of water(gm)	H-I	12.32	11.16	14.45	15.69	9.83	12.21	14.09	20.52	16.89	20.87
K	Weigth of dry soil(gm)	I-G	61.08	51.37	60.56	67.71	34.24	50.72	44.07	65.78	49.81	62.26
L	Moisture content%	J/K	20.17	21.72	23.86	23.17	28.71	24.07	31.97	31.19	33.91	33.52
M	Average moisture content(%)		20.95		23.52		26.39		31.58		33.71	
N	Dry density(Kg/m3)		1.341		1.347		1.351		1.373		1.345	



Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+0%WSF





Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9800	10170	10289	10500	10403	10608
Wt.of mold, g	W2	6749		6733		6711	
Wt.of wet sample, g	W3 = W1 - W2	3051	3421	3556	3767	3692	3897
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.45	1.63	1.69	1.79	1.75	1.85
Dry unit weight, g/cc	γw /(1+ W8/100)	1.05	1.05	1.23	1.17	1.27	1.24
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	505.8	543.4	484.6	432.9	465.1	499.7
Wt. of dry sample + cont., g	W4	389.5	380.7	375.2	312.5	360.7	362.0
Wt. of water, g	W5 = W3 - W4	116.3	162.7	109.42	120.41	104.42	137.67
Wt. of container, g	W6	82.37	81.04	81.88	84.23	83.86	81.09
Wt. of dry sample, g	W7 = W4 - W6	307.1	299.69	293.31	228.26	276.82	280.94
Moisture Content, %	W8 = W5/W7*100	37.9	54.3	37.3	52.8	37.7	49.0

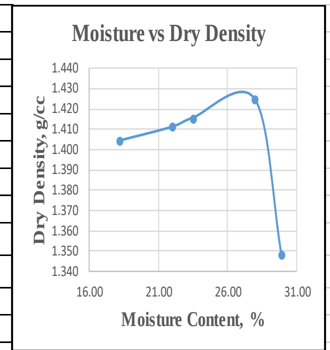
SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	9.35	9.35	8.06	0	8.74	8.74	7.53	0	8.45	8.45	7.28

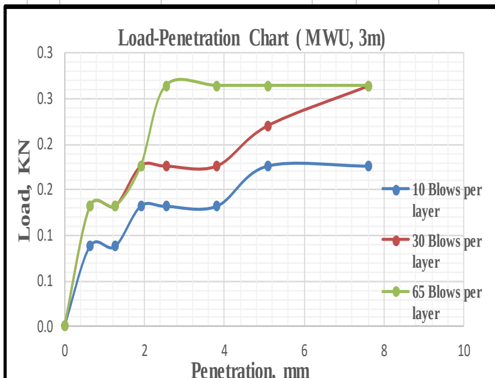
CBR DATA (4 days Soaked)

Ring factor		0.044	kN/div									
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			2	0.1			3	0.1		
1.27		2	0.1			3	0.1			4	0.2		
1.91		3	0.1			3	0.1			4	0.2		
2.54	13.35	3	0.1	0.13	1.0	4	0.2	0.18	1.3	5	0.2	0.22	1.6
3.81		3	0.1			4	0.2			5	0.2		
5.08	20	4	0.2	0.18	0.9	4	0.2	0.18	0.9	6	0.3	0.26	1.3
7.62		5	0.2			6	0.3			6	0.3		
Soaked CBR, %		1.0				1.3				1.6			
Dry Density, g/cc		1.05				1.23				1.27			
Swell, %		8.06				7.53				7.28			
Density Requirement:		95%		Target Density:				1.30		CBR		1.63	

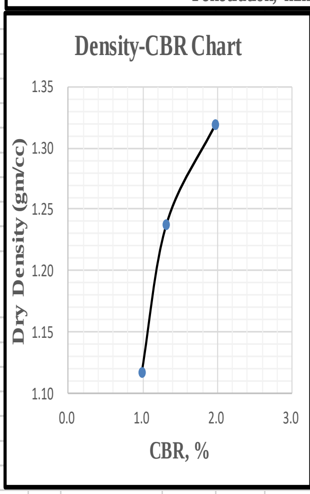
	Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
	Madda Walabu University at 3m depth											
	BLOWS PER LAYER	56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold		116mm	Soil+0%WSF		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8603.9		8731.1		8784.9		8938.2		8791.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3402.9		3530.1		3583.9		3737.2		3590.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.660		1.722		1.748		1.823		1.752	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		30	322	12	67	41	23	43	21	40	202
G	Weight of container (gm)		17.06	17.25	15.98	16.95	17.16	17.22	16.97	16.99	17.86	17.05
H	Weight of container +wet soil(gm)		70.01	80.57	75.64	62.36	73.62	88.80	85.42	87.75	75.86	81.25
I	Weight of container +dry soil(gm)		62.14	70.48	64.57	54.39	62.85	75.21	69.45	73.36	62.22	66.8
J	Weight of water(gm)	H-I	7.87	10.09	11.07	7.97	10.77	13.59	15.97	14.39	13.64	14.44
K	Weigth of dry soil(gm)	I-G	45.0775	53.23	48.59	37.44	45.693	57.99	52.482	56.37	44.36	49.8
L	Moisture content%	J/K	17.47	18.95	22.78	21.29	23.57	23.44	30.42	25.52	30.74	29.02
M	Average moisture content(%)		18.21		22.03		23.51		27.97		29.88	
N	Dry density(Kg/m3)		1.404		1.411		1.416		1.425		1.349	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+0%WSF



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9841	10214	10211	10509	10406	10668
Wt.of mold, g	W2	6638		6654		6621	
Wt.of wet sample, g	W3 = W1 - W2	3203	3576	3557	3855	3785	4047
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.52	1.70	1.69	1.83	1.80	1.92
Dry unit weight, g/cc	γw /(1+ W8/100)	1.12	1.15	1.24	1.24	1.32	1.36
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	451.1	404.1	411.9	420.0	408.1	462.2
Wt. of dry sample + cont., g	W4	352.8	300.0	323.6	311.4	321.9	350.0
Wt. of water, g	W5 = W3 - W4	98.3	104.04	88.33	108.51	86.2	112.14
Wt. of container, g	W6	81.02	83.36	81.57	84.94	83.9	81.62
Wt. of dry sample, g	W7 = W4 - W6	271.8	216.65	242.02	226.5	238.03	268.39
Moisture Content, %	W8 = W5/W7*100	36.2	48.0	36.5	47.9	36.2	41.8

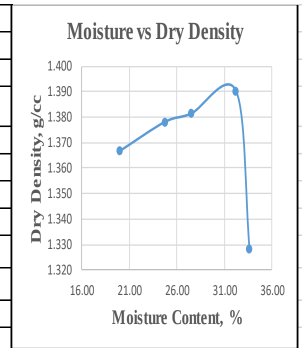


SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	8.91	8.91	7.68	0	8.32	8.32	7.17	0	8.01	8.01	6.91

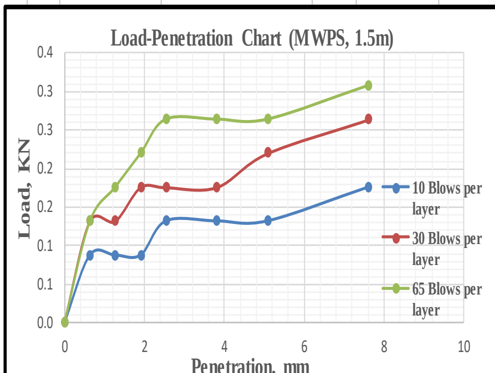
CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			3	0.1			3	0.1		
1.27		2	0.1			3	0.1			3	0.1		
1.91		3	0.1			4	0.2			4	0.2		
2.54	13.35	3	0.1	0.13	1.0	4	0.2	0.18	1.3	6	0.3	0.26	2.0
3.81		3	0.1			4	0.2			6	0.3		
5.08	20	4	0.2	0.18	0.9	5	0.2	0.22	1.1	6	0.3	0.26	1.3
7.62		4	0.2			6	0.3			6	0.3		
Soaked CBR, %		1.0				1.3				2.0			
Dry Density, g/cc		1.12				1.24				1.32			
Swell, %		7.68				7.17				6.91			
Density Requirement:			95%		Target Density:			1.35		CBR		2.04	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)						
Madda Walabu Primary School at 1.5m depth						
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+0%WSF	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

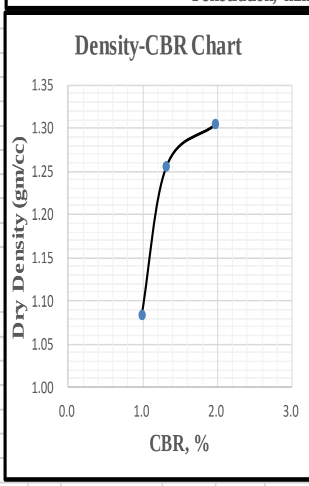
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8561.4		8724.7		8810.9		8968.5		8839.1	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3360.4		3523.7		3609.9		3767.5		3638.1	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.639		1.719		1.761		1.838		1.775	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		38	288	340	30	55	67	202	214	58	326
G	Weight of container (gm)		16.78	17.11	15.49	16.32	17.27	16.74	15.51	17.01	16.38	15.94
H	Weight of container +wet soil(gm)		71.28	106.92	89.14	96.49	74.84	67.54	84.5	87.36	71.91	78.58
I	Weight of container +dry soil(gm)		62.04	92.27	75.07	80.02	62.09	56.89	67.32	70.6	57.73	63.06
J	Weight of water(gm)	H-I	9.24	14.65	14.07	16.47	12.75	10.65	17.18	16.76	14.18	15.52
K	Weigth of dry soil(gm)	I-G	45.26	75.16	59.58	63.70	44.82	40.15	51.81	53.59	41.35	47.12
L	Moisture content%	J/K	20.42	19.49	23.62	25.86	28.45	26.53	33.16	31.27	34.29	32.94
M	Average moisture content(%)		19.95		24.74		27.49		32.22		33.61	
N	Dry density(Kg/m3)		1.367		1.378		1.381		1.390		1.328	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+0%WSF



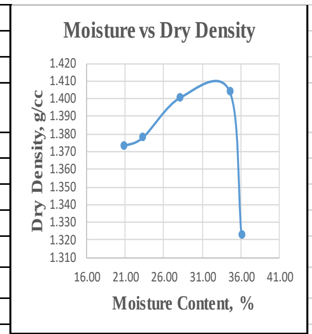
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9812	10198	10293	10491	10429	10635
Wt.of mold, g	W2	6652		6627		6628	
Wt.of wet sample, g	W3 = W1 - W2	3160	3546	3666	3864	3801	4007
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.50	1.68	1.74	1.84	1.81	1.90
Dry unit weight, g/cc	γw /(1+ W8/100)	1.08	1.11	1.26	1.26	1.30	1.32
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	434.1	442.5	396.3	414.0	475.4	453.3
Wt. of dry sample + cont., g	W4	336.9	319.5	309.2	309.2	366.3	339.1
Wt. of water, g	W5 = W3 - W4	97.2	123.02	87.12	104.76	109.03	114.19
Wt. of container, g	W6	84.38	81.77	83.94	82.34	82.3	83.01
Wt. of dry sample, g	W7 = W4 - W6	252.5	237.73	225.27	226.88	284.04	256.11
Moisture Content, %	W8 = W5/W7*100	38.5	51.7	38.7	46.2	38.4	44.6



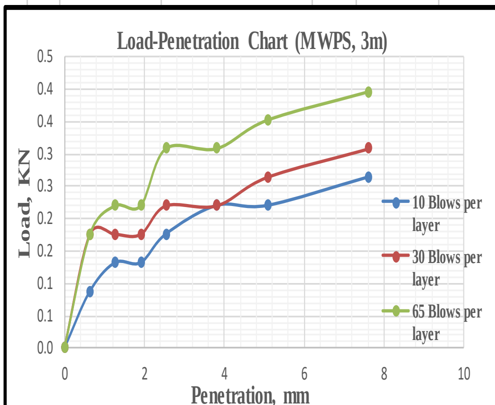
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	9.22	9.22	7.95	0	9.03	9.03	7.78	0	8.29	8.29	7.15

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			3	0.1			3	0.1		
1.27		2	0.1			3	0.1			4	0.2		
1.91		2	0.1			4	0.2			5	0.2		
2.54	13.35	3	0.1	0.13	1.0	4	0.2	0.18	1.3	6	0.3	0.26	2.0
3.81		3	0.1			4	0.2			6	0.3		
5.08	20	3	0.1	0.13	0.7	5	0.2	0.22	1.1	6	0.3	0.26	1.3
7.62		4	0.2			6	0.3			7	0.3		
Soaked CBR, %		1.0				1.3				2.0			
Dry Density, g/cc		1.08				1.26				1.30			
Swell, %		7.95				7.78				7.15			
Density Requirement:			95%	Target Density:				1.32		CBR		1.83	

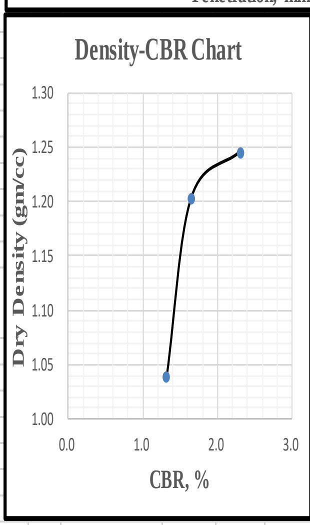
	Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
	Madda Walabu Primary School at 3m depth											
	BLOWS PER LAYER	56	No. OF LAYER		5	Material Description-Soil+0%WSF		Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8601.6		8683.9		8881.2		9074.7		8891.9	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3400.6		3482.9		3680.2		3873.7		3690.9	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.659		1.699		1.795		1.890		1.801	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		55	67	340	288	214	38	326	202	58	21
G	Weight of container (gm)		17.14	17.53	16.69	15.72	16.29	17.22	16.08	17.82	15.67	16.73
H	Weight of container +wet soil(gm)		72.37	57.31	95.26	68.06	74.57	76.35	77.87	81.31	84.9	79.72
I	Weight of container +dry soil(gm)		63.26	50.18	79.7	58.66	61.61	63.51	62.03	64.98	66.54	63.01
J	Weight of water(gm)	H-I	9.11	7.13	15.56	9.4	12.96	12.84	15.84	16.33	18.36	16.71
K	Weight of dry soil	I-G	46.12	32.7	63.01	42.94	45.32	46.29	45.95	47.16	50.87	46.28
L	Moisture content%	J/K	19.75	21.84	24.69	21.89	28.60	27.74	34.47	34.63	36.09	36.11
M	Average moisture content(%)		20.80		23.29		28.17		34.55		36.10	
N	Dry density(Kg/m3)		1.373		1.378		1.401		1.404		1.323	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+0%WSF



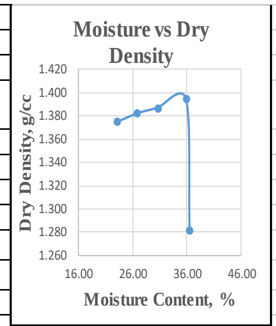
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9802	10188	10287	10443	10377	10609
Wt.of mold, g	W2	6745		6758		6749	
Wt.of wet sample, g	W3 = W1 - W2	3057	3443	3529	3685	3628	3860
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.45	1.64	1.68	1.75	1.72	1.83
Dry unit weight, g/cc	γw /(1+ W8/100)	1.04	1.08	1.20	1.19	1.25	1.28
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	427.2	472.9	437.4	445.3	436.3	423.9
Wt. of dry sample + cont., g	W4	329.6	338.7	337.1	330.0	338.3	319.7
Wt. of water, g	W5 = W3 - W4	97.6	134.18	100.28	115.36	97.95	104.22
Wt. of container, g	W6	83.53	81.22	81.99	83.13	82.79	81.19
Wt. of dry sample, g	W7 = W4 - W6	246.1	257.52	255.12	246.83	255.54	238.49
Moisture Content, %	W8 = W5/W7*100	39.7	52.1	39.3	46.7	38.3	43.7



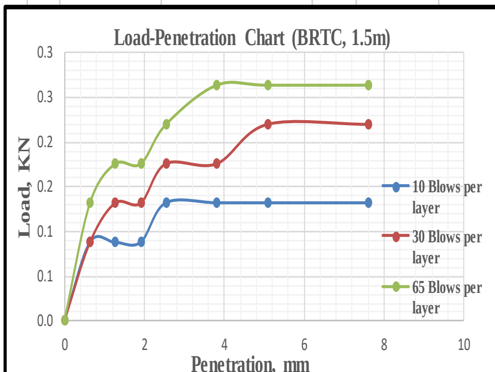
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	8.46	8.46	7.29	0	7.91	7.91	6.82	0	7.59	7.59	6.54

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			4	0.2			4	0.2		
1.27		3	0.1			4	0.2			5	0.2		
1.91		3	0.1			4	0.2			5	0.2		
2.54	13.35	4	0.2	0.18	1.3	5	0.2	0.22	1.6	7	0.3	0.31	2.3
3.81		5	0.2			5	0.2			7	0.3		
5.08	20	5	0.2	0.22	1.1	6	0.3	0.26	1.3	8	0.4	0.35	1.8
7.62		6	0.3			7	0.3			9	0.4		
Soaked CBR, %		1.3				1.6				2.3			
Dry Density, g/cc		1.04				1.20				1.25			
Swell, %		7.29				6.82				6.54			
Density Requirement:		95%		Target Density:			1.33			CBR		2.43	

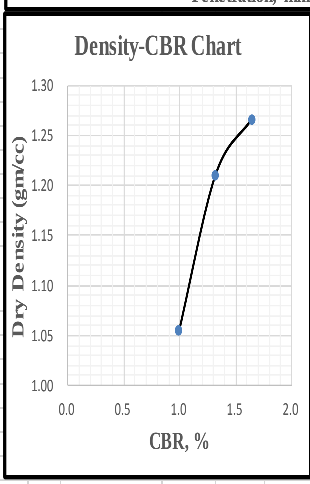
	Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
	Bale Robe Teachers Collage at 1.5m depth											
	BLOWS PER LAYER	56	No. OF LAYER		5	Material Description-Soil+0%WSF		Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8673.7		8797.9		8915.1		9085.6		8789.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3472.7		3596.9		3714.1		3884.6		3588.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.694		1.755		1.812		1.895		1.751	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		28	277	202	337	21	58	30	324	214	36
G	Weight of container (gm)		17.09	16.82	17.15	15.2	16.41	16.07	17.55	17.63	16.71	16.14
H	Weight of container +wet soil(gm)		76.95	85.31	77.3	88.93	69.54	55.97	62.69	70.35	78.1	63.34
I	Weight of container +dry soil(gm)		65.68	72.41	64.67	73.12	57.14	46.57	50.5	56.74	62.03	50.42
J	Weight of water(gm)	H-I	11.27	12.9	12.63	15.81	12.4	9.4	12.19	13.61	16.07	12.92
K	Weigth of dry soil(gm)	I-G	48.59	55.59	47.52	57.92	40.73	30.5	32.95	39.11	45.32	34.28
L	Moisture content%	J/K	23.19	23.21	26.58	27.30	30.44	30.82	37.00	34.80	35.46	37.69
M	Average moisture content(%)		23.20		26.94		30.63		35.90		36.57	
N	Dry density(Kg/m3)		1.375		1.382		1.387		1.394		1.282	



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+0%WSF



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9837	10230	10245	10478	10400	10633
Wt.of mold, g	W2	6788		6730		6741	
Wt.of wet sample, g	W3 = W1 - W2	3049	3442	3515	3748	3659	3892
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.45	1.64	1.67	1.78	1.74	1.85
Dry unit weight, g/cc	γw /(1+ W8/100)	1.06	1.07	1.21	1.20	1.27	1.27
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	427.6	442.5	496.9	514.3	452.2	431.2
Wt. of dry sample + cont., g	W4	334.1	319.6	383.4	373.2	351.7	322.9
Wt. of water, g	W5 = W3 - W4	93.6	122.94	113.56	141.11	100.41	108.26
Wt. of container, g	W6	82.68	84.43	83.31	82.93	81.72	82.41
Wt. of dry sample, g	W7 = W4 - W6	251.4	235.17	300.06	290.23	270.02	240.49
Moisture Content, %	W8 = W5/W7*100	37.2	52.3	37.8	48.6	37.2	45.0



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	8.99	8.99	7.75	0	8.68	8.68	7.48	0	8.12	8.12	7.00

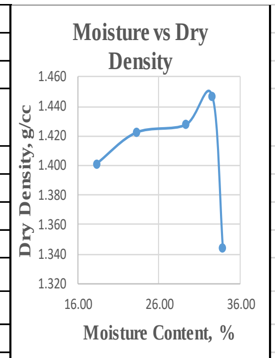
CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			2	0.1			3	0.1		
1.27		2	0.1			3	0.1			4	0.2		
1.91		2	0.1			3	0.1			4	0.2		
2.54	13.35	3	0.1	0.13	1.0	4	0.2	0.18	1.3	5	0.2	0.22	1.6
3.81		3	0.1			4	0.2			6	0.3		
5.08	20	3	0.1	0.13	0.7	5	0.2	0.22	1.1	6	0.3	0.26	1.3
7.62		3	0.1			5	0.2			6	0.3		
Soaked CBR, %		1.0				1.3				1.6			
24		1.06				1.21				1.27			
Swell, %		7.75				7.48				7.00			
Density Requirement:		95%		Target Density:			1.38			CBR		1.90	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

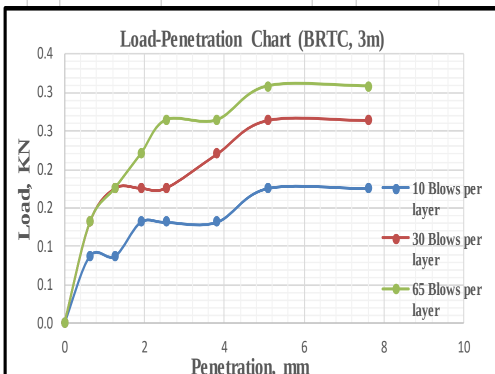
Bale Robe Teachers Collage at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description- Soil+0%WSF	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8600.3		8793.9		8984.1		9131.7		8887.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3399.3		3592.9		3783.1		3930.7		3686.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.658		1.753		1.846		1.918		1.798	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		25	58	329	321	78	333	54	202	337	40
G	Weight of container (gm)		16.46	17.73	16.81	15.89	16.52	16.4	17.22	17.08	15.61	16.39
H	Weight of container +wet soil(gm)		59.44	78.12	62.41	65.53	72.28	65.89	82.02	103.5	86.12	90.42
I	Weight of container +dry soil(gm)		52.59	69.03	54.08	55.9	60.05	54.35	66.14	82.27	68.48	71.54
J	Weight of water(gm)	H-I	6.85	9.09	8.33	9.63	12.23	11.54	15.88	21.23	17.64	18.88
K	Weigth of dry soil(gm)	I-G	36.13	51.3	37.27	40.01	43.53	37.95	48.92	65.19	52.87	55.15
L	Moisture content%	J/K	18.96	17.72	22.35	24.07	28.10	30.41	32.46	32.57	33.36	34.23
M	Average moisture content(%)		18.34		23.21		29.25		32.51		33.80	
N	Dry density(Kg/m3)		1.401		1.423		1.428		1.447		1.344	

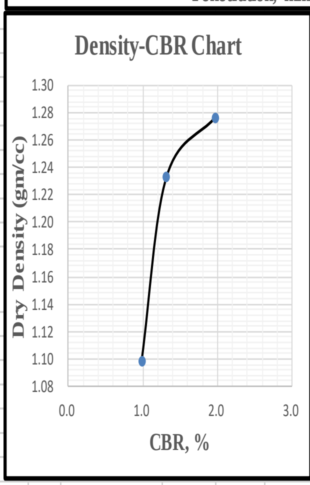


Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+0%WSF



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9850	10205	10298	10496	10418	10629
Wt.of mold, g	W2	6647		6694		6674	
Wt.of wet sample, g	W3 = W1 - W2	3203	3558	3604	3802	3744	3955
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.52	1.69	1.71	1.81	1.78	1.88
Dry unit weight, g/cc	γw /(1+ W8/100)	1.10	1.12	1.23	1.24	1.28	1.31
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	427.2	510.1	461.7	443.2	496.8	459.9
Wt. of dry sample + cont., g	W4	331.4	365.0	356.1	330.3	380.0	346.0
Wt. of water, g	W5 = W3 - W4	95.8	145.07	105.62	112.95	116.8	113.88
Wt. of container, g	W6	82.23	81.95	84.21	84.36	82.66	83.93
Wt. of dry sample, g	W7 = W4 - W6	249.2	283.08	271.88	245.92	297.29	262.08
Moisture Content, %	W8 = W5/W7*100	38.4	51.2	38.8	45.9	39.3	43.5



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	8.7	8.70	7.50	0	8.12	8.12	7.00	0	7.79	7.79	6.72

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

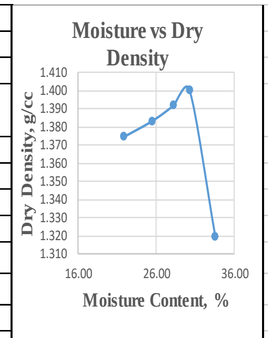
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		2	0.1			3	0.1			3	0.1		
1.27		2	0.1			4	0.2			4	0.2		
1.91		3	0.1			4	0.2			5	0.2		
2.54	13.35	3	0.1	0.13	1.0	4	0.2	0.18	1.3	6	0.3	0.26	2.0
3.81		3	0.1			5	0.2			6	0.3		
5.08	20	4	0.2	0.18	0.9	6	0.3	0.26	1.3	7	0.3	0.31	1.5
7.62		4	0.2			6	0.3			7	0.3		
Soaked CBR, %		1.0				1.3				2.0			
24		1.10				1.23				1.28			
Swell, %		7.50				7.00				6.72			
Density Requirement:		95%		Target Density:			1.33			CBR		2.02	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

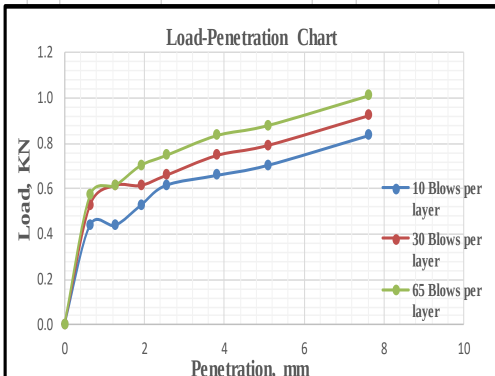
Madda Walabu University at 1.5m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+1%WSF(1.5cm)+0%C	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8636.3		8759.9		8858.8		8940.8		8814.1	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3435.3		3558.9		3657.8		3739.8		3613.1	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.676		1.736		1.784		1.824		1.763	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		58	202	21	38	89	336	341	30	214	277
G	Weight of container (gm)		17.53	16.01	17.8	15.72	16.82	16.04	15.95	16.88	15.29	17.73
H	Weight of container +wet soil(gm)		82.93	94.34	71.89	81.78	83.98	95.53	71.35	81.17	107.75	93.03
I	Weight of container +dry soil(gm)		71.23	80.22	60.82	68.47	69.06	78.24	58.58	66.14	84.67	73.99
J	Weight of water(gm)	H-I	11.7	14.12	11.07	13.31	14.92	17.29	12.77	15.03	23.08	19.04
K	Weigth of dry soil(gm)	I-G	53.70	64.21	43.02	52.75	52.24	62.20	42.63	49.26	69.38	56.26
L	Moisture content%	J/K	21.79	21.99	25.73	25.23	28.56	27.80	29.96	30.51	33.27	33.84
M	Average moisture content(%)		21.89		25.48		28.18		30.23		33.55	
N	Dry density(Kg/m3)		1.375		1.384		1.392		1.401		1.320	

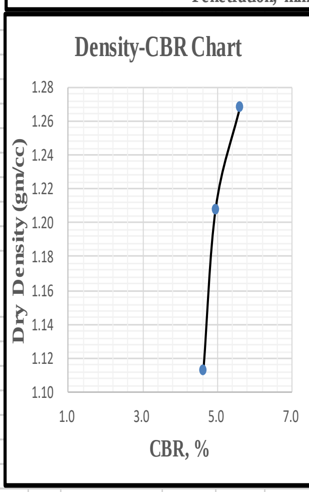


Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9931	10234	10256	10467	10343	10580
Wt.of mold, g	W2	6672		6758		6647	
Wt.of wet sample, g	W3 = W1 - W2	3259	3562	3498	3709	3696	3933
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.55	1.69	1.66	1.76	1.76	1.87
Dry unit weight, g/cc	γw /(1+ W8/100)	1.11	1.16	1.21	1.22	1.27	1.33
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	454.9	468.4	482.9	479.3	493.7	501.3
Wt. of dry sample + cont., g	W4	350.5	347.7	373.3	356.8	379.7	379.9
Wt. of water, g	W5 = W3 - W4	104.4	120.67	109.55	122.5	114.06	121.42
Wt. of container, g	W6	83.22	81.42	81.28	83.34	82.75	82.42
Wt. of dry sample, g	W7 = W4 - W6	267.3	266.27	292.02	273.43	296.93	297.48
Moisture Content, %	W8 = W5/W7*100	39.1	45.3	37.5	44.8	38.4	40.8



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	6.18	6.18	5.33	0	6.64	6.64	5.72	0	5.98	5.98	5.16

CBR DATA (4 days Soaked)

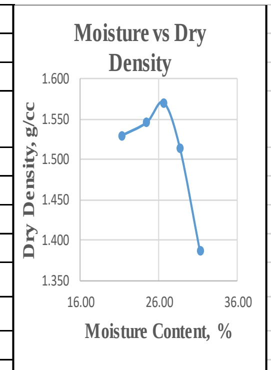
Ring factor 0.044 kN/div

Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		10	0.4			12	0.5			13	0.6		
1.27		10	0.4			14	0.6			14	0.6		
1.91		12	0.5			14	0.6			16	0.7		
2.54	13.35	14	0.6	0.62	4.6	15	0.7	0.66	4.9	17	0.7	0.75	5.6
3.81		15	0.7			17	0.7			19	0.8		
5.08	20	16	0.7	0.70	3.5	18	0.8	0.79	4.0	20	0.9	0.88	4.4
7.62		19	0.8			21	0.9			23	1.0		

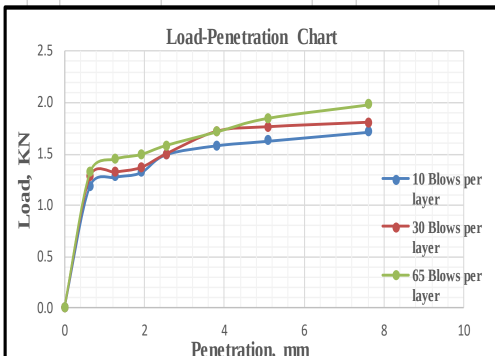
Soaked CBR, %	4.6	4.9	5.6
24	1.11	1.21	1.27
Swell, %	5.33	5.72	5.16

Density Requirement:	95%	Target Density:	1.33	CBR	5.87

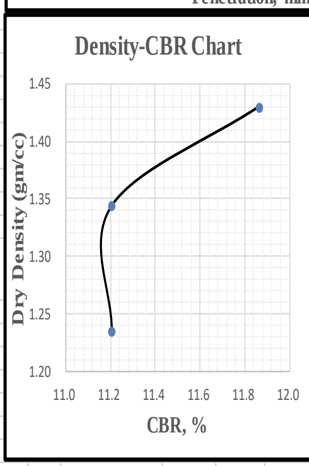
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu University at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-Soil+2%WSF(1.5cm)+8%C		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		9003.6		9146.3		9278.8		9197.5		8932.2	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3802.6		3945.3		4077.8		3996.5		3731.2	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.855		1.925		1.989		1.950		1.820	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		89	21	336	341	43	38	202	30	58	214
G	Weight of container (gm)		16.8	16.3	17.8	17.48	15.02	16.93	15.09	16.14	17.04	15.46
H	Weight of container +wet soil(gm)		70.74	77.38	84.65	92.6	67.37	78.54	89.01	86.75	73.7	80.62
I	Weight of container +dry soil(gm)		61.54	66.37	71.68	77.62	56.29	65.65	72.53	70.97	60.16	65.13
J	Weight of water(gm)	H-I	9.2	11.01	12.97	14.98	11.08	12.89	16.48	15.78	13.54	15.49
K	Weigth of dry soil(gm)	I-G	44.74	50.07	53.88	60.14	41.27	48.72	57.44	54.83	43.12	49.67
L	Moisture content%	J/K	20.56	21.99	24.07	24.91	26.85	26.46	28.69	28.78	31.40	31.19
M	Average moisture content(%)		21.28		24.49		26.65		28.74		31.29	
N	Dry density(Kg/m3)		1.530		1.546		1.571		1.514		1.386	



Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10010	10315	10386	10555	10613	10845
Wt.of mold, g	W2	6622		6693		6681	
Wt.of wet sample, g	W3 = W1 - W2	3388	3693	3693	3862	3932	4164
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.61	1.75	1.75	1.83	1.87	1.98
Dry unit weight, g/cc	γw /(1+ W8/100)	1.24	1.29	1.34	1.35	1.43	1.49
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	405.7	431.3	458.4	487.3	396.7	421.7
Wt. of dry sample + cont., g	W4	330.5	339.0	370.2	381.2	323.6	338.5
Wt. of water, g	W5 = W3 - W4	75.2	92.31	88.18	106.14	73.17	83.24
Wt. of container, g	W6	81.93	83.85	81.46	82.03	84.61	82.19
Wt. of dry sample, g	W7 = W4 - W6	248.6	255.1	288.78	299.12	238.94	256.28
Moisture Content, %	W8 = W5/W7*100	30.2	36.2	30.5	35.5	30.6	32.5



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	1.61	1.61	1.39	0	1.06	1.06	0.91	0	1.03	1.03	0.89

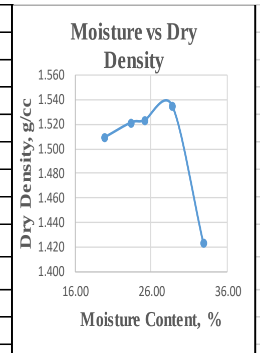
CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		27	1.2			29	1.3			30	1.3		
1.27		29	1.3			30	1.3			33	1.5		
1.91		30	1.3			31	1.4			34	1.5		
2.54	13.35	34	1.5	1.50	11.2	34	1.5	1.50	11.2	36	1.6	1.58	11.9
3.81		36	1.6			39	1.7			39	1.7		
5.08	20	37	1.6	1.63	8.1	40	1.8	1.76	8.8	42	1.8	1.85	9.2
7.62		39	1.7			41	1.8			45	2.0		
Soaked CBR, %		11.2				11.2				11.9			
24		1.24				1.34				1.43			
Swell, %		1.39				0.91				0.89			
Density Requirement:		95%		Target Density:			1.49			CBR		11.93	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)						
Madda Walabu University at 1.5m depth						
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+3%WSF(1.5cm)+7%C	Volume of Mold(mm3)	2049.9

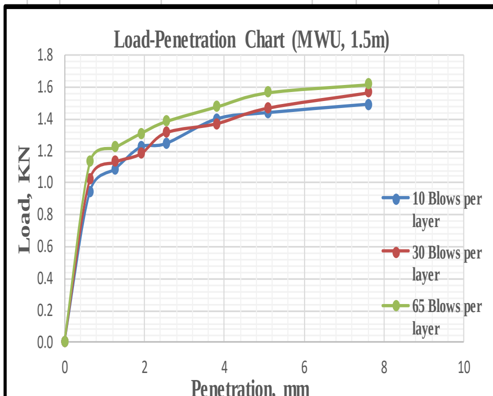
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8911.4	9048.9	9108.3	9253.1	9076.7
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3710.4	3847.9	3907.3	4052.1	3875.7
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.810	1.877	1.906	1.977	1.891

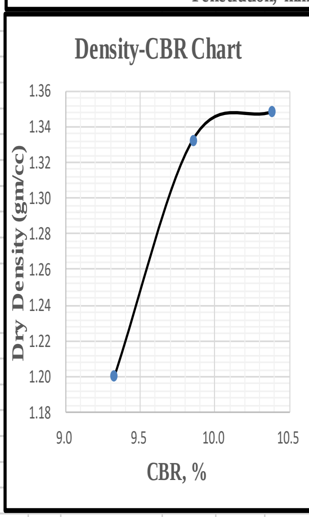
Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		28	277	30	21	337	58	36	53	324	202
G	Weight of container (gm)		17.27	16.96	15.49	15.81	16.66	15.29	17.36	15.47	15.22	17.85
H	Weight of container +wet soil(gm)		97.23	73.56	62.79	77	53.6	65.73	56.11	82.89	70.76	60.4
I	Weight of container +dry soil(gm)		84.14	64.03	53.92	65.29	46.04	55.79	47.56	67.66	56.83	50.02
J	Weight of water(gm)	H-I	13.09	9.53	8.87	11.71	7.56	9.94	8.55	15.23	13.93	10.38
K	Weigth of dry soil(gm)	I-G	66.87	47.07	38.43	49.48	29.38	40.50	30.20	52.19	41.61	32.17
L	Moisture content%	J/K	19.58	20.25	23.08	23.67	25.73	24.54	28.31	29.18	33.48	32.27
M	Average moisture content(%)		19.91		23.37		25.14		28.75		32.87	
N	Dry density(Kg/m3)		1.509		1.521		1.523		1.535		1.423	



Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C





Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9973	10452	10377	10537	10476	10783
Wt.of mold, g	W2	6648		6693		6739	
Wt.of wet sample, g	W3 = W1 - W2	3325	3804	3684	3844	3737	4044
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.81	1.75	1.83	1.78	1.92
Dry unit weight, g/cc	γw /(1+ W8/100)	1.20	1.31	1.33	1.34	1.35	1.44
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	434.7	406.6	418.8	403.6	391.8	426.6
Wt. of dry sample + cont., g	W4	350.4	317.3	339.0	319.1	318.0	340.4
Wt. of water, g	W5 = W3 - W4	84.3	89.35	79.87	84.52	73.89	86.28
Wt. of container, g	W6	83.43	81.52	83.72	82.83	84.49	81.91
Wt. of dry sample, g	W7 = W4 - W6	266.9	235.76	255.25	236.26	233.46	258.44
Moisture Content, %	W8 = W5/W7*100	31.6	37.9	31.3	35.8	31.6	33.4

SWELL DATA (Surcharge Weight 4.54kg)

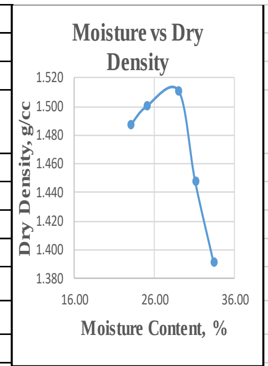
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.61	2.61	2.25	0	2.25	2.25	1.94	0	2.01	2.01	1.73

CBR DATA (4 days Soaked)

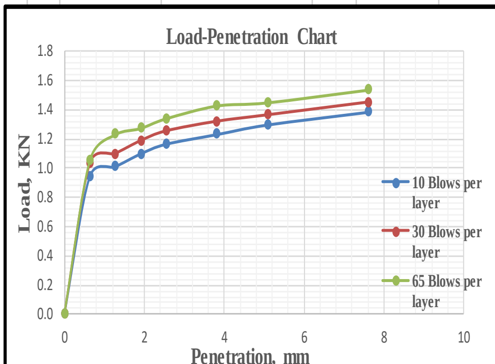
Ring factor 0.044 kN/div

Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		22	0.9			23	1.0			26	1.1		
1.27		25	1.1			26	1.1			28	1.2		
1.91		28	1.2			27	1.2			30	1.3		
2.54	13.35	28	1.2	1.25	9.3	30	1.3	1.32	9.9	32	1.4	1.39	10.4
3.81		32	1.4			31	1.4			34	1.5		
5.08	20	33	1.4	1.44	7.2	33	1.5	1.47	7.3	36	1.6	1.57	7.8
7.62		34	1.5			36	1.6			37	1.6		
Soaked CBR, %		9.3				9.9				10.4			
Dry Density, g/cc		1.20				1.33				1.35			
Swell, %		2.25				1.94				1.73			
Density Requirement:		95%		Target Density:			1.46			CBR		10.85	

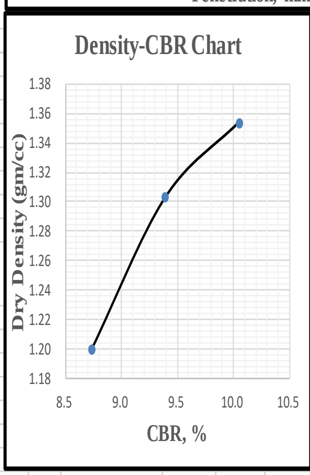
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu University at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description- Soil+4%WSF(1.5cm)+6%C		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8952.5		9046.3		9198.7		9093.1		9005.9	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3751.5		3845.3		3997.7		3892.1		3804.9	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.830		1.876		1.950		1.899		1.856	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		56	321	333	54	25	78	330	329	89	30
G	Weight of container (gm)		16.9	17.04	17.5	15.67	16.08	15.99	16.86	15.2	17.33	16.75
H	Weight of container +wet soil(gm)		104.7	97.37	74.11	62.98	83.67	88.8	103.3	111.5	66.97	94.42
I	Weight of container +dry soil(gm)		88.19	82.35	62.71	53.56	68.34	72.55	83.17	88.23	54.52	74.99
J	Weight of water(gm)	H-I	16.48	15.02	11.4	9.42	15.33	16.25	20.13	23.27	12.45	19.43
K	Weigth of dry soil(gm)	I-G	71.29	65.31	45.21	37.89	52.26	56.56	66.31	73.03	37.19	58.24
L	Moisture content%	J/K	23.12	23.00	25.22	24.86	29.33	28.73	30.36	31.86	33.48	33.36
M	Average moisture content(%)		23.06		25.04		29.03		31.11		33.42	
N	Dry density(Kg/m3)		1.487		1.500		1.511		1.448		1.391	



Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C



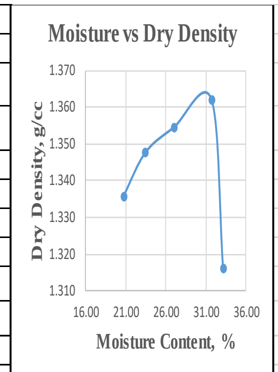
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10158	10457	10412	10689	10526	10883
Wt.of mold, g	W2	6785		6743		6739	
Wt.of wet sample, g	W3 = W1 - W2	3373	3672	3669	3946	3787	4144
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.60	1.74	1.74	1.87	1.80	1.97
Dry unit weight, g/cc	γw /(1+ W8/100)	1.20	1.24	1.30	1.34	1.35	1.45
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	390.5	374.0	415.6	390.5	412.7	443.1
Wt. of dry sample + cont., g	W4	312.9	290.3	331.7	303.1	331.2	348.9
Wt. of water, g	W5 = W3 - W4	77.6	83.66	83.84	87.33	81.47	94.17
Wt. of container, g	W6	81.45	83.82	83.36	81.68	83.25	84.33
Wt. of dry sample, g	W7 = W4 - W6	231.4	206.49	248.35	221.45	247.93	264.6
Moisture Content, %	W8 = W5/W7*100	33.5	40.5	33.8	39.4	32.9	35.6



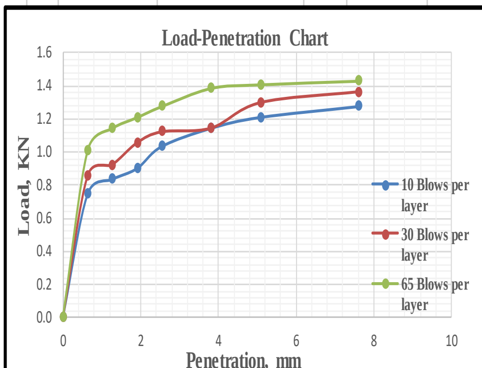
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.94	2.94	2.53	0	2.54	2.54	2.19	0	1.94	1.94	1.67

CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		22	0.9			24	1.0			24	1.1		
1.27		23	1.0			25	1.1			28	1.2		
1.91		25	1.1			27	1.2			29	1.3		
2.54	13.35	27	1.2	1.17	8.7	29	1.3	1.25	9.4	31	1.3	1.34	10.1
3.81		28	1.2			30	1.3			33	1.4		
5.08	20	30	1.3	1.30	6.5	31	1.4	1.36	6.8	33	1.5	1.45	7.3
7.62		32	1.4			33	1.5			35	1.5		
Soaked CBR, %		8.7				9.4				10.1			
Dry Density, g/cc		1.20				1.30				1.35			
Swell, %		2.53				2.19				1.67			
Density Requirement:		95%		Target Density:			1.43			CBR		10.62	

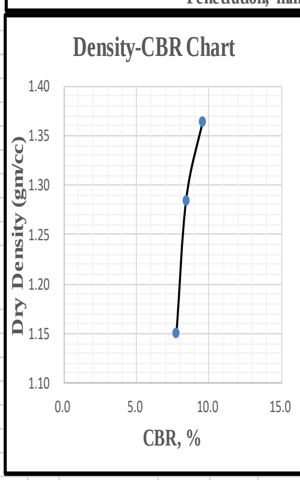
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Madda Walabu University at 1.5m depth											
	BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+4.5%WSF(1.5cm)+4%C		Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold	116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5
A	Weight of mold +wet soil(gm)		8508.1		8612.9		8728.3		8878.4		8793.7
B	Weight of mold(gm)		5201		5201		5201		5201		5201
C	Weight of wet soil(gm)	A-B	3307.1		3411.9		3527.3		3677.4		3592.7
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9
E	Wet density(Kg/ m^3)	C/D	1.613		1.664		1.721		1.794		1.753
Moisture content determination(%)											
	Determiation No.		1		2		3		4		5
F	Container No.		326	21	214	288	336	202	30	26	98	340
G	Weight of container (gm)		16.3	17.83	15.45	16.69	17.35	17.41	15.62	16.55	16.03	15.94
H	Weight of container +wet soil(gm)		55.91	67.82	70.16	69.33	82.03	81.6	70.44	67.8	72.88	57.84
I	Weight of container +dry soil(gm)		48.97	59.38	60.16	58.92	67.91	68.29	57.32	55.39	58.76	47.38
J	Weight of water(gm)	H-I	6.94	8.44	10	10.41	14.12	13.31	13.12	12.41	14.12	10.46
K	Weigth of dry soil(gm)	I-G	32.67	41.55	44.71	42.23	50.56	50.88	41.70	38.84	42.73	31.44
L	Moisture content%	J/K	21.24	20.31	22.37	24.65	27.93	26.16	31.46	31.95	33.04	33.27
M	Average moisture content(%)		20.78		23.51		27.04		31.71		33.16	
N	Dry density(Kg/m3)		1.336		1.348		1.354		1.362		1.316	



Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10001	10234	10425	10635	10585	10798
Wt.of mold, g	W2	6685		6737		6689	
Wt.of wet sample, g	W3 = W1 - W2	3316	3549	3688	3898	3896	4109
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.69	1.75	1.85	1.85	1.95
Dry unit weight, g/cc	γw /(1+ W8/100)	1.15	1.15	1.29	1.28	1.37	1.37
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	415.9	395.1	391.3	439.0	417.1	371.1
Wt. of dry sample + cont., g	W4	326.3	295.5	309.6	328.9	329.0	285.2
Wt. of water, g	W5 = W3 - W4	89.6	99.62	81.71	110.18	88.05	85.94
Wt. of container, g	W6	82.96	84.19	84.53	83.3	81.19	82.53
Wt. of dry sample, g	W7 = W4 - W6	243.4	211.32	225.08	245.56	247.84	202.66
Moisture Content, %	W8 = W5/W7*100	36.8	47.1	36.3	44.9	35.5	42.4



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.7	3.70	3.19	0	3.19	3.19	2.75	0	2.62	2.62	2.26

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		17	0.7			20	0.9			23	1.0		
1.27		19	0.8			21	0.9			26	1.1		
1.91		21	0.9			24	1.1			28	1.2		
2.54	13.35	24	1.0	1.03	7.7	26	1.1	1.12	8.4	29	1.3	1.28	9.6
3.81		26	1.1			26	1.1			32	1.4		
5.08	20	28	1.2	1.21	6.1	30	1.3	1.30	6.5	32	1.4	1.41	7.0
7.62		29	1.3			31	1.4			33	1.4		
Soaked CBR, %		7.7				8.4				9.6			
Dry Density, g/cc		1.15				1.29				1.37			
Swell, %		3.19				2.75				2.26			
Density Requirement:			95%		Target Density:			1.29		CBR		8.77	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

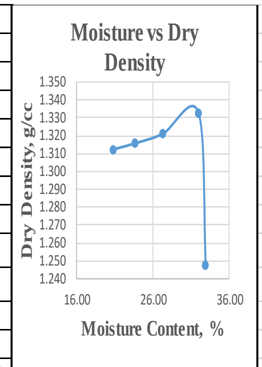
Madda Walabu University at 1.5m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+5%WSF(1.5cm)+3%C	Volume of Mold(mm3)	2049.9

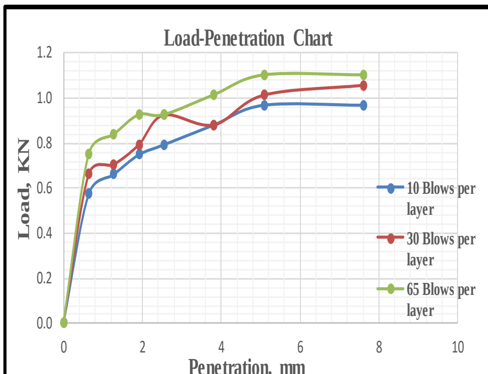
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8451.4	8535.8	8647.3	8805.2	8599.3
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3250.4	3334.8	3446.3	3604.2	3398.3
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.586	1.627	1.681	1.758	1.658

Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		30	214	341	202	43	89	58	21	58	336
G	Weight of container (gm)		17.26	16.82	17.72	15.03	16.86	16.97	17.01	16.92	15.02	17.35
H	Weight of container +wet soil(gm)		61.46	91.93	96.56	93.77	80.46	87.85	90.48	93.19	99.45	102.4
I	Weight of container +dry soil(gm)		54.09	78.57	81.27	78.92	66.47	73.07	72.32	75.12	78.17	81.76
J	Weight of water(gm)	H-I	7.37	13.36	15.29	14.85	13.99	14.78	18.16	18.07	21.28	20.67
K	Weigth of dry soil(gm)	I-G	36.83	61.75	63.55	63.89	49.61	56.10	55.31	58.20	63.15	64.41
L	Moisture content%	J/K	20.01	21.64	24.06	23.24	28.20	26.35	32.83	31.05	33.70	32.09
M	Average moisture content(%)		20.82		23.65		27.27		31.94		32.89	
N	Dry density(Kg/m3)		1.312		1.316		1.321		1.333		1.247	

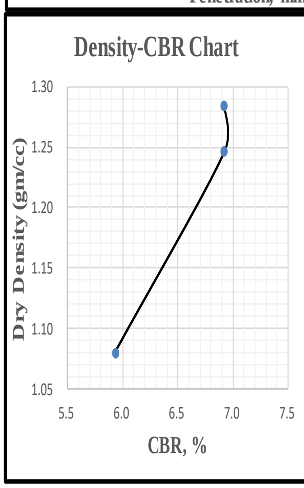


Location and Depth-Madda Walabu University at 1.5m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9915	10288	10389	10549	10457	10658
Wt.of mold, g	W2	6785		6793		6749	
Wt.of wet sample, g	W3 = W1 - W2	3130	3503	3596	3756	3708	3909
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.49	1.66	1.71	1.78	1.76	1.86
Dry unit weight, g/cc	γw /(1+ W8/100)	1.08	1.10	1.25	1.21	1.28	1.28
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	446.5	442.1	417.8	437.6	433.3	428.9
Wt. of dry sample + cont., g	W4	346.7	321.0	327.5	324.2	338.2	320.8
Wt. of water, g	W5 = W3 - W4	99.9	121.06	90.22	113.43	95.09	108.08
Wt. of container, g	W6	81.43	81.9	84.07	83.72	82.1	82.88
Wt. of dry sample, g	W7 = W4 - W6	265.2	239.11	243.47	240.49	256.07	237.96
Moisture Content, %	W8 = W5/W7*100	37.7	50.6	37.1	47.2	37.1	45.4



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.41	4.41	3.80	0	4.01	4.01	3.46	0	3.29	3.29	2.84

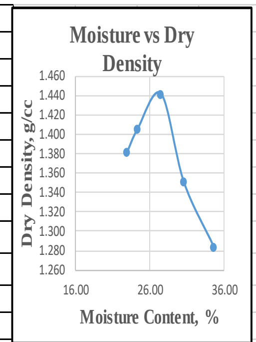
CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

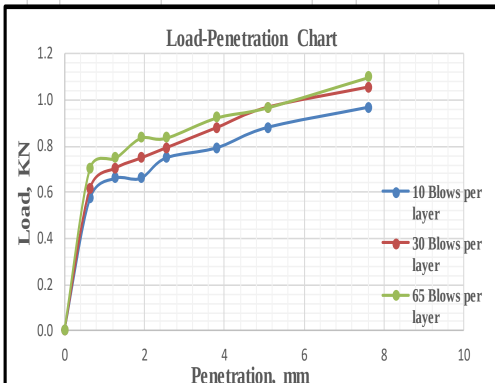
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		13	0.6			15	0.7			17	0.7		
1.27		15	0.7			16	0.7			19	0.8		
1.91		17	0.7			18	0.8			21	0.9		
2.54	13.35	18	0.8	0.79	5.9	21	0.9	0.92	6.9	21	0.9	0.92	6.9
3.81		20	0.9			20	0.9			23	1.0		
5.08	20	22	1.0	0.97	4.8	23	1.0	1.01	5.1	25	1.1	1.10	5.5
7.62		22	1.0			24	1.1			25	1.1		
Soaked CBR, %		5.9				6.9				6.9			
Dry Density, g/cc		1.08				1.25				1.28			
Swell, %		3.80				3.46				2.84			

Density Requirement:	95%	Target Density:	1.26	CBR	6.90

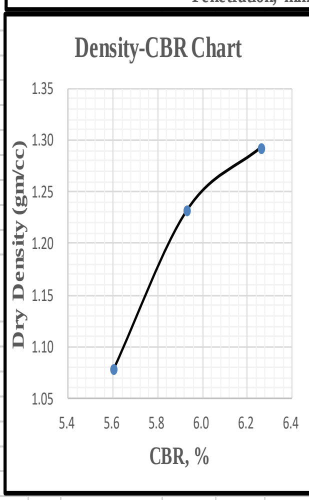
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu University at 3m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm	Soil+1%WSF(1.5cm)+0%C		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8679.5		8781.2		8967.4		8814.4		8741.8	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3478.5		3580.2		3766.4		3613.4		3540.8	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.697		1.747		1.837		1.763		1.727	
Moisture content determination(%)												
	Determination No.		1		2		3		4		5	
F	Container No.		28	47	64	41	218	323	89	105	45	30
G	Weight of container (gm)		16.93	16.08	16.05	16.16	14.97	15.19	16.50	15.89	15.95	15.71
H	Weight of container +wet soil(gm)		82.69	57.63	65.54	88.01	96.81	87.64	110.34	56.98	68.41	91.78
I	Weight of container +dry soil(gm)		70.45	49.89	55.9	73.91	79.32	71.9	88.45	47.34	55.11	71.98
J	Weight of water(gm)	H-I	12.24	7.74	9.64	14.10	17.49	15.74	21.89	9.64	13.30	19.80
K	Weigth of dry soil(gm)	I-G	53.52	33.81	39.85	57.75	64.35	56.71	71.95	31.45	39.16	56.27
L	Moisture content%	J/K	22.87	22.89	24.19	24.41	27.18	27.75	30.43	30.65	33.96	35.19
M	Average moisture content(%)		22.88		24.30		27.47		30.54		34.58	
N	Dry density(Kg/m3)		1.381		1.405		1.441		1.350		1.284	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9938	10164	10315	10548	10465	10654
Wt.of mold, g	W2	6792		6720		6693	
Wt.of wet sample, g	W3 = W1 - W2	3146	3372	3595	3828	3772	3961
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.49	1.60	1.71	1.82	1.79	1.88
Dry unit weight, g/cc	γw /(1+ W8/100)	1.08	1.09	1.23	1.29	1.29	1.35
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	437.7	454.1	488.4	467.9	485.4	503.5
Wt. of dry sample + cont., g	W4	339.4	335.9	375.8	357.0	373.7	383.1
Wt. of water, g	W5 = W3 - W4	98.3	118.21	112.63	110.95	111.66	120.42
Wt. of container, g	W6	84.33	81.01	83.82	83.09	84.72	81.02
Wt. of dry sample, g	W7 = W4 - W6	255.1	254.87	291.93	273.87	289.01	302.08
Moisture Content, %	W8 = W5/W7*100	38.6	46.4	38.6	40.5	38.6	39.9



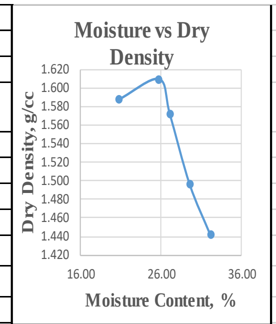
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	5.97	5.97	5.15	0	5.5	5.50	4.74	0	5.01	5.01	4.32

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		13	0.6			14	0.6			16	0.7		
1.27		15	0.7			16	0.7			17	0.7		
1.91		15	0.7			17	0.7			19	0.8		
2.54	13.35	17	0.7	0.75	5.6	18	0.8	0.79	5.9	19	0.8	0.84	6.3
3.81		18	0.8			20	0.9			21	0.9		
5.08	20	20	0.9	0.88	4.4	22	1.0	0.97	4.8	22	1.0	0.97	4.8
7.62		22	1.0			24	1.1			25	1.1		
Soaked CBR, %		5.6				5.9				6.3			
Dry Density, g/cc		1.08				1.23				1.29			
Swell, %		5.15				4.74				4.32			
Density Requirement:			95%		Target Density:			1.37		CBR		6.42	

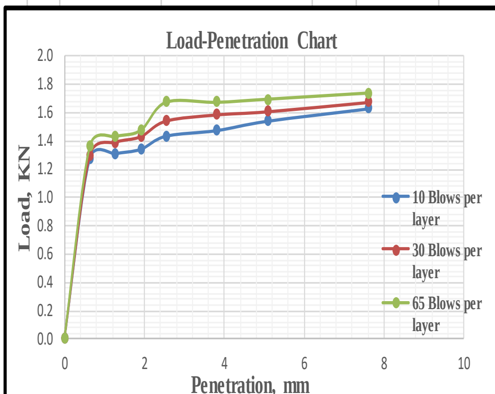
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)								
Madda Walabu University at 3m depth								
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+2%WSF(1.5cm)+8%C	Rammer Weight		4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)		2049.9	

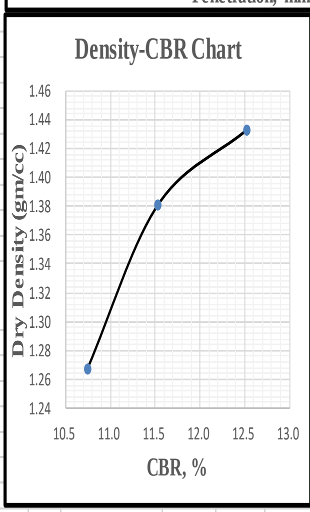
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		9134.3	9350.6	9296.9	9176.6	9107.9
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3933.3	4149.6	4095.9	3975.6	3906.9
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.919	2.024	1.998	1.939	1.906

	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		41	214	28	38	222	336	21	45	35	58
G	Weight of container (gm)		16.03	15.98	15.43	16.39	16.58	17.78	17.31	15.27	15.53	16.48
H	Weight of container +wet soil(gm)		83.17	54.28	98.01	76.41	55.19	101.3	67.18	63.39	112.12	98.41
I	Weight of container +dry soil(gm)		73.85	46.49	81.7	63.68	46.93	83.51	55.93	52.26	88.49	78.53
J	Weight of water(gm)	H-I	9.32	7.79	16.31	12.73	8.26	17.79	11.25	11.13	23.63	19.88
K	Weigth of dry soil(gm)	I-G	57.82	30.51	66.27	47.29	30.35	65.73	38.62	36.99	72.96	62.05
L	Moisture content%	J/K	16.12	25.53	24.61	26.92	27.22	27.07	29.13	30.09	32.39	32.04
M	Average moisture content(%)		20.83		25.77		27.14		29.61		32.21	
N	Dry density(Kg/m3)		1.588		1.610		1.572		1.496		1.442	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C



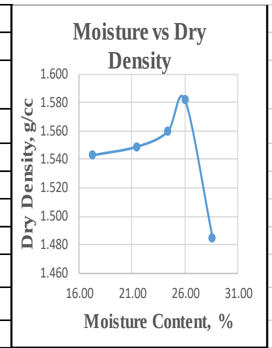


Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10113	10453	10399	10676	10596	10824
Wt.of mold, g	W2	6668		6640		6684	
Wt.of wet sample, g	W3 = W1 - W2	3445	3785	3759	4036	3912	4140
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.64	1.80	1.79	1.92	1.86	1.97
Dry unit weight, g/cc	γw /(1+ W8/100)	1.27	1.32	1.38	1.42	1.43	1.48
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	392.6	411.8	408.5	452.5	424.2	410.6
Wt. of dry sample + cont., g	W4	323.2	325.1	334.7	357.3	346.2	330.0
Wt. of water, g	W5 = W3 - W4	69.5	86.7	73.82	95.22	77.99	80.58
Wt. of container, g	W6	84.67	82.81	82.53	81.87	83.44	82.08
Wt. of dry sample, g	W7 = W4 - W6	238.5	242.26	252.16	275.42	262.74	247.93
Moisture Content, %	W8 = W5/W7*100	29.1	35.8	29.3	34.6	29.7	32.5

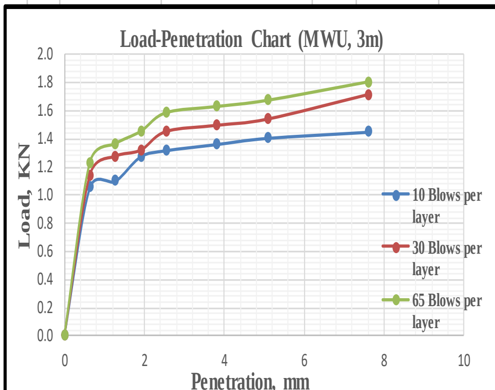
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	1.54	1.54	1.33	0	1.01	1.01	0.87	0	0.98	0.98	0.84

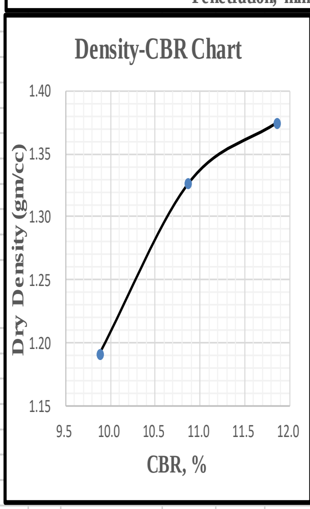
CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penetration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		29	1.3			30	1.3			31	1.4		
1.27		30	1.3			32	1.4			33	1.4		
1.91		31	1.3			33	1.4			34	1.5		
2.54	13.35	33	1.4	1.43	10.7	35	1.5	1.54	11.5	38	1.7	1.67	12.5
3.81		34	1.5			36	1.6			38	1.7		
5.08	20	35	1.5	1.54	7.7	37	1.6	1.61	8.0	39	1.7	1.69	8.5
7.62		37	1.6			38	1.7			40	1.7		
Soaked CBR, %		10.7				11.5				12.5			
Dry Density, g/cc		1.27				1.38				1.43			
Swell, %		1.33				0.87				0.84			
Density Requirement:			95%	Target Density:				1.53		CBR		13.31	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Madda Walabu University at 3m depth											
	BLOWS PER LAYER	56	No. OF LAYER		5	Material Description-Soil+3%WSF(1.5cm)+7%C		Rammer Weight		4.54Kg	
	MOLD DIAMETER	150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9	
	Determination No		1		2		3		4	5	
A	Weight of mold +wet soil(gm)		8911.1		9056.5		9176.4		9286.7	9114.8	
B	Weight of mold(gm)		5201		5201		5201		5201	5201	
C	Weight of wet soil(gm)	A-B	3710.1		3855.5		3975.4		4085.7	3913.8	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9	2049.9	
E	Wet density(Kg/ m^3)	C/D	1.810		1.881		1.939		1.993	1.909	
Moisture content determination(%)											
	Determiation No.		1		2		3		4		5
F	Container No.		55	288	38	21	67	12	326	202	214	340
G	Weight of container (gm)		16.68	15.89	15.4	17.3	16.53	17.11	16.72	16.47	15.31	16.28
H	Weight of container +wet soil(gm)		88.36	81.7	98.42	102.1	54.89	67.28	81.22	84.13	73.21	69.23
I	Weight of container +dry soil(gm)		77.48	72.28	84.37	86.53	47.24	57.64	67.99	70.1	60.83	57.02
J	Weight of water(gm)	H-I	10.88	9.42	14.05	15.57	7.65	9.64	13.23	14.03	12.38	12.21
K	Weigth of dry soil(gm)	I-G	60.8	56.39	68.97	69.23	30.71	40.53	51.27	53.63	45.52	40.74
L	Moisture content%	J/K	17.89	16.71	20.37	22.49	24.91	23.78	25.80	26.16	27.20	29.97
M	Average moisture content(%)		17.30		21.43		24.35		25.98		28.58	
N	Dry density(Kg/m3)		1.543		1.549		1.560		1.582		1.485	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C





Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10017	10301	10423	10665	10481	10767
Wt.of mold, g	W2	6739		6783		6711	
Wt.of wet sample, g	W3 = W1 - W2	3278	3562	3640	3882	3770	4056
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.56	1.69	1.73	1.84	1.79	1.93
Dry unit weight, g/cc	γw /(1+ W8/100)	1.19	1.21	1.33	1.33	1.38	1.42
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	426.1	430.4	469.6	434.8	439.2	443.7
Wt. of dry sample + cont., g	W4	345.9	331.6	379.3	337.2	356.8	349.6
Wt. of water, g	W5 = W3 - W4	80.2	98.87	90.35	97.63	82.39	94.1
Wt. of container, g	W6	84.14	83.98	81.26	82.34	84.37	82.41
Wt. of dry sample, g	W7 = W4 - W6	261.8	247.57	298	254.82	272.45	267.16
Moisture Content, %	W8 = W5/W7*100	30.6	39.9	30.3	38.3	30.2	35.2

SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.49	2.49	2.15	0	2.15	2.15	1.85	0	1.54	1.54	1.33

CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		24	1.1			26	1.1			28	1.2		
1.27		25	1.1			29	1.3			31	1.4		
1.91		29	1.3			30	1.3			33	1.5		
2.54	13.35	30	1.3	1.32	9.9	33	1.5	1.45	10.9	36	1.6	1.58	11.9
3.81		31	1.4			34	1.5			37	1.6		
5.08	20	32	1.4	1.41	7.0	35	1.5	1.54	7.7	38	1.7	1.67	8.4
7.62		33	1.5			39	1.7			41	1.8		
Soaked CBR, %		9.9				10.9				11.9			
24		1.19				1.33				1.38			
Swell, %		2.15				1.85				1.33			
Density Requirement:		95%		Target Density:			1.50			CBR		12.92	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

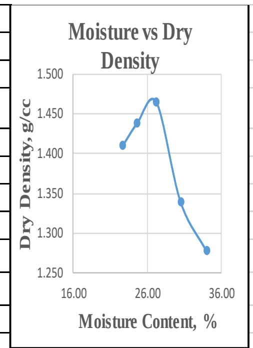
Madda Walabu University at 1.5m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description- Soil+4%WSF(1.5cm)+6%C	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

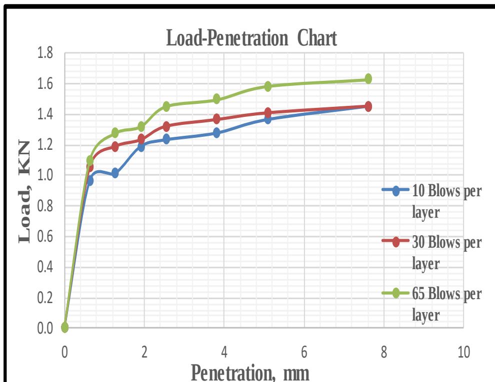
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8751.1	8875.6	9022.3	8786.7	8712.6
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3550.1	3674.6	3821.3	3585.7	3511.6
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.732	1.793	1.864	1.749	1.713

Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		35	56	226	45	214	21	28	38	30	34
G	Weight of container (gm)		15.79	16.92	17.43	15.48	16.39	16.89	17.01	16.35	17.15	16.63
H	Weight of container +wet soil(gm)		51.16	85.09	71.22	67.34	105.54	47.52	59.43	64.33	79.24	106.17
I	Weight of container +dry soil(gm)		44.52	72.64	60.51	57.17	86.76	40.85	49.64	52.96	63.56	83.27
J	Weight of water(gm)	H-I	6.64	12.45	10.71	10.17	18.78	6.67	9.79	11.37	15.68	22.90
K	Weigth of dry soil(gm)	I-G	28.73	55.72	43.08	41.69	70.37	23.96	32.63	36.61	46.41	66.64
L	Moisture content%	J/K	23.11	22.34	24.86	24.39	26.69	27.84	30.00	31.06	33.79	34.36
M	Average moisture content(%)		22.73		24.63		27.26		30.53		34.07	
N	Dry density(Kg/m3)		1.411		1.438		1.465		1.340		1.278	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C

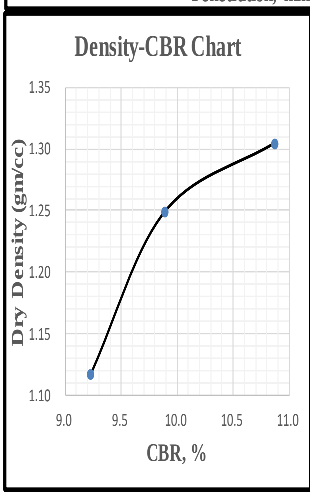


Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9946	10257	10274	10481	10356	10601
Wt.of mold, g	W2	6781		6729		6628	
Wt.of wet sample, g	W3 = W1 - W2	3165	3476	3545	3752	3728	3973
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.50	1.65	1.68	1.78	1.77	1.89
Dry unit weight, g/cc	γw /(1+ W8/100)	1.12	1.13	1.25	1.23	1.30	1.32

Moisture Content Determination

Wt. of wet sample + cont., g	W3	431.2	387.9	444.2	451.0	405.7	399.6
Wt. of dry sample + cont., g	W4	341.6	290.8	350.3	337.9	320.8	303.8
Wt. of water, g	W5 = W3 - W4	89.6	97.09	93.85	113.04	84.86	95.81
Wt. of container, g	W6	81.86	82.24	81.11	84.97	83.44	83.14
Wt. of dry sample, g	W7 = W4 - W6	259.7	208.53	269.2	252.97	237.4	220.61
Moisture Content, %	W8 = W5/W7*100	34.5	46.6	34.9	44.7	35.7	43.4



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample: 116 mm	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
	0	2.77	2.77	2.39	0	2.31	2.31	1.99	0	1.81	1.81	1.56

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		22	1.0			24	1.1			25	1.1		
1.27		23	1.0			27	1.2			29	1.3		
1.91		27	1.2			28	1.2			30	1.3		
2.54	13.35	28	1.2	1.23	9.2	30	1.3	1.32	9.9	33	1.5	1.45	10.9
3.81		29	1.3			31	1.4			34	1.5		
5.08	20	31	1.4	1.36	6.8	32	1.4	1.41	7.0	36	1.6	1.58	7.9
7.62		33	1.5			33	1.5			37	1.6		

	10	30	65
Soaked CBR, %	9.2	9.9	10.9
24	1.12	1.25	1.30
Swell, %	2.39	1.99	1.56

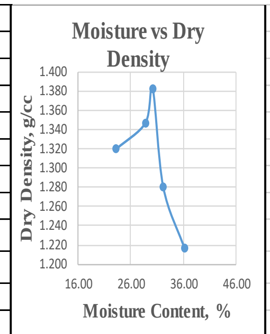
Density Requirement:	95%	Target Density:	1.39	CBR	11.33

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

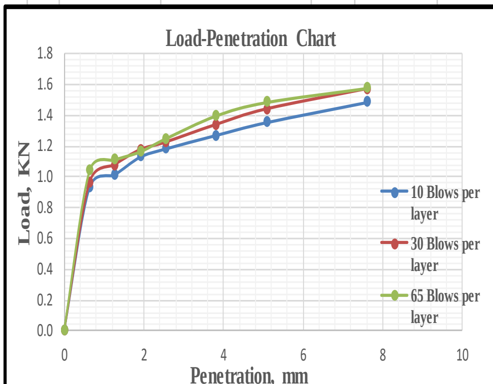
Madda Walabu University at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+4.5%WSF(1.5cm)+4%	Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8536.8		8757.4		8891.4		8671.1		8599.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3335.8		3556.4		3690.4		3470.1		3398.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.627		1.735		1.800		1.693		1.658	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		23	30	341	322	40	30	12	43	67	41
G	Weight of container (gm)		17.17	16.24	16.21	16.32	15.12	15.34	16.67	16.05	16.11	15.87
H	Weight of container +wet soil(gm)		51.51	44.26	74.43	63.78	74.31	58.78	95.53	77.56	69.14	79.47
I	Weight of container +dry soil(gm)		45.12	38.89	61.45	53.13	60.54	48.74	76.83	62.19	54.78	62.89
J	Weight of water(gm)	H-I	6.39	5.37	12.98	10.65	13.77	10.04	18.7	15.37	14.36	16.58
K	Weigth of dry soil(gm)	I-G	27.95	22.65	45.24	36.81	45.42	33.4	60.16	46.14	38.67	47.02
L	Moisture content%	J/K	22.86	23.71	28.69	28.93	30.32	30.06	31.08	33.31	37.13	35.26
M	Average moisture content(%)		23.29		28.81		30.19		32.20		36.20	
N	Dry density(Kg/m3)		1.320		1.347		1.383		1.281		1.217	

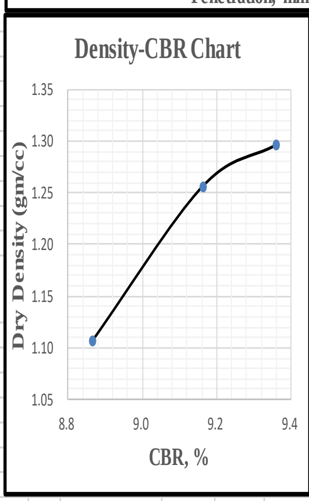


Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9938	10368	10394	10637	10535	10748
Wt.of mold, g	W2	6737		6749		6783	
Wt.of wet sample, g	W3 = W1 - W2	3201	3631	3645	3888	3752	3965
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.52	1.72	1.73	1.85	1.78	1.88
Dry unit weight, g/cc	γw /(1+ W8/100)	1.11	1.16	1.26	1.25	1.30	1.32
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	381.2	418.8	437.1	394.5	397.4	405.8
Wt. of dry sample + cont., g	W4	299.9	308.0	340.2	295.0	311.6	309.1
Wt. of water, g	W5 = W3 - W4	81.3	110.79	96.9	99.46	85.78	96.66
Wt. of container, g	W6	82.36	83.08	83.83	84.92	82.51	82.99
Wt. of dry sample, g	W7 = W4 - W6	217.6	224.88	256.34	210.11	229.11	226.11
Moisture Content, %	W8 = W5/W7*100	37.3	49.3	37.8	47.3	37.4	42.7



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.73	3.73	3.22	0	2.94	2.94	2.53	0	2.5	2.50	2.16

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

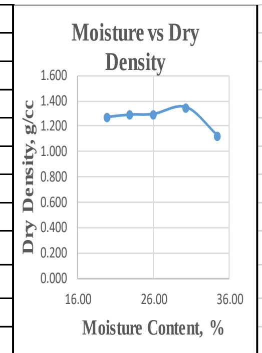
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		21	0.9			22	1.0			24	1.0		
1.27		23	1.0			25	1.1			25	1.1		
1.91		26	1.1			27	1.2			27	1.2		
2.54	13.35	27	1.2	1.18	8.9	28	1.2	1.22	9.2	28	1.2	1.25	9.4
3.81		29	1.3			30	1.3			32	1.4		
5.08	20	31	1.4	1.36	6.8	33	1.4	1.44	7.2	34	1.5	1.49	7.4
7.62		34	1.5			36	1.6			36	1.6		

	10	30	65
Soaked CBR, %	8.9	9.2	9.4
Dry Density, g/cc	1.11	1.26	1.30
Swell, %	3.22	2.53	2.16

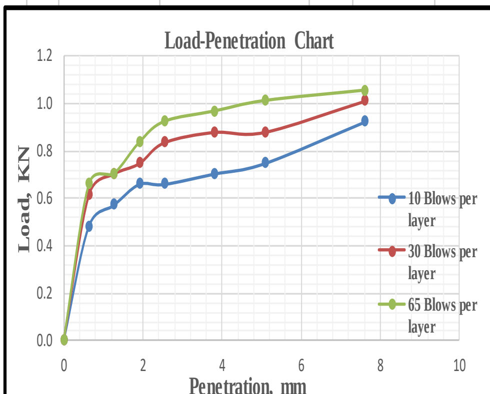
Density Requirement: 95% | Target Density: 1.31 | CBR 9.35

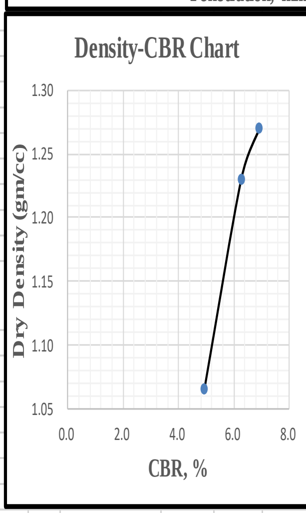
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)							
Madda Walabu University at 1.5m depth							
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-		Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+5%WSF(1.5cm)+3%C		Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8316.2		8443.6		8540.9		8799.4		8289.8	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3115.2		3242.6		3339.9		3598.4		3088.8	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.520		1.582		1.629		1.755		1.507	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		38	21	26	79	29	80	30	38	30	34
G	Weight of container (gm)		16.45	16.22	15.68	16.91	17.34	15.51	17.01	16.48	16.23	17.15
H	Weight of container +wet soil(gm)		67.19	75.34	89.98	65.39	110.23	54.17	78.95	69.15	74.17	52.29
I	Weight of container +dry soil(gm)		58.45	65.96	76.53	56.12	90.71	46.33	64.53	56.9	59.49	43.18
J	Weight of water(gm)	H-I	8.74	9.38	13.45	9.27	19.52	7.84	14.42	12.25	14.68	9.11
K	Weigth of dry soil(gm)	I-G	42.00	49.74	60.85	39.21	73.37	30.82	47.52	40.42	43.26	26.03
L	Moisture content%	J/K	20.81	18.86	22.10	23.64	26.60	25.44	30.35	30.31	33.93	35.00
M	Average moisture content(%)		19.83		22.87		26.02		30.33		34.47	
N	Dry density(Kg/m3)		1.268		1.287		1.293		1.347		1.121	



Location and Depth-Madda Walabu University at 3m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C



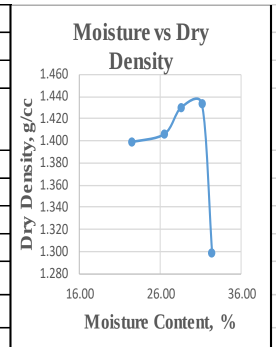


Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9903	10289	10345	10563	10432	10693
Wt.of mold, g	W2	6783		6739		6720	
Wt.of wet sample, g	W3 = W1 - W2	3120	3506	3606	3824	3712	3973
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.48	1.67	1.71	1.82	1.76	1.89
Dry unit weight, g/cc	γw /(1+ W8/100)	1.07	1.11	1.23	1.22	1.27	1.30
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	482.1	505.1	493.3	472.6	442.1	463.2
Wt. of dry sample + cont., g	W4	370.1	363.9	377.5	344.2	341.4	344.4
Wt. of water, g	W5 = W3 - W4	112.1	141.22	115.74	128.4	100.76	118.78
Wt. of container, g	W6	82.18	81.86	82.37	83.3	81.6	81.49
Wt. of dry sample, g	W7 = W4 - W6	287.9	282.06	295.15	260.89	259.76	262.95
Moisture Content, %	W8 = W5/W7*100	38.9	50.1	39.2	49.2	38.8	45.2

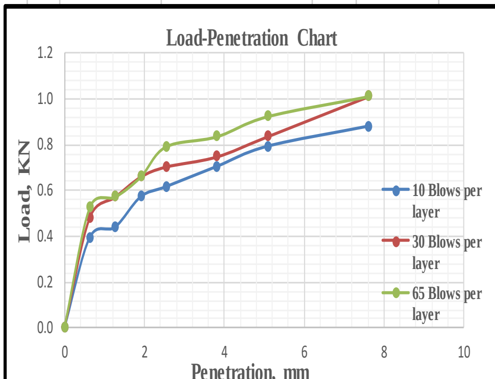
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.2	4.20	3.62	0	3.9	3.90	3.36	0	3.23	3.23	2.78

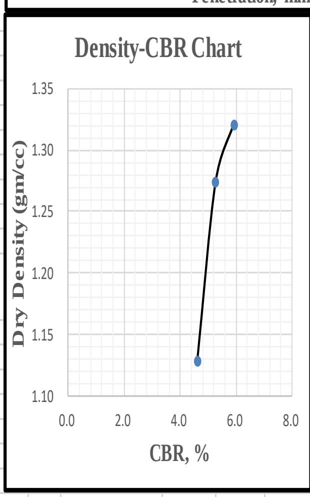
CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		11	0.5			14	0.6			15	0.7		
1.27		13	0.6			16	0.7			16	0.7		
1.91		15	0.7			17	0.7			19	0.8		
2.54	13.35	15	0.7	0.66	4.9	19	0.8	0.84	6.3	21	0.9	0.92	6.9
3.81		16	0.7			20	0.9			22	1.0		
5.08	20	17	0.7	0.75	3.7	20	0.9	0.88	4.4	23	1.0	1.01	5.1
7.62		21	0.9			23	1.0			24	1.1		
Soaked CBR, %	4.9					6.3				6.9			
Dry Density, g/cc	1.07					1.23				1.27			
Swell, %	3.62					3.36				2.78			
Density Requirement:	95%		Target Density:			1.28				CBR		6.90	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Madda Walabu Primary School at 1.5m depth											
BLOWS PER LAYER		56	No. OF LAYER	5	Material Description-Soil+1%WSF(1.5cm)+0%C		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold	116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5
A	Weight of mold +wet soil(gm)		8711.6		8848.4		8969.5		9053.89		8724.8
B	Weight of mold(gm)		5201		5201		5201		5201		5201
C	Weight of wet soil(gm)	A-B	3510.6		3647.4		3768.5		3852.89		3523.8
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9
E	Wet density(Kg/ m^3)	C/D	1.713		1.779		1.838		1.880		1.719
Moisture content determination(%)											
	Determiation No.		1		2		3		4		5
F	Container No.		30	21	336	314	202	58	328	341	38	25
G	Weight of container (gm)		15.78	16.34	16.91	17.59	17.49	16.22	15.57	17.73	16.33	16.21
H	Weight of container +wet soil(gm)		87.56	65.89	98.44	56.1	48.95	114.76	91.57	69.7	59.23	78.69
I	Weight of container +dry soil(gm)		74.48	56.76	81.55	47.93	41.82	93.31	73.63	57.29	48.64	63.53
J	Weight of water(gm)	H-I	13.08	9.13	16.89	8.17	7.13	21.45	17.94	12.41	10.59	15.16
K	Weigth of dry soil(gm)	I-G	58.70	40.42	64.64	30.34	24.33	77.09	58.06	39.56	32.31	47.32
L	Moisture content%	J/K	22.28	22.59	26.13	26.93	29.31	27.82	30.90	31.37	32.78	32.04
M	Average moisture content(%)		22.44		26.53		28.57		31.13		32.41
N	Dry density(Kg/m3)		1.399		1.406		1.430		1.433		1.298



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C



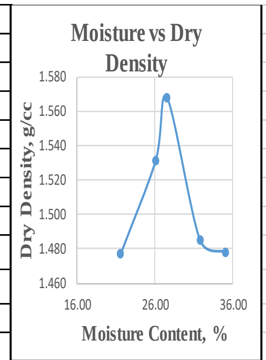


Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9946	10336	10329	10535	10438	10792
Wt.of mold, g	W2	6682		6639		6624	
Wt.of wet sample, g	W3 = W1 - W2	3264	3654	3690	3896	3814	4168
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.55	1.74	1.75	1.85	1.81	1.98
Dry unit weight, g/cc	γw /(1+ W8/100)	1.13	1.17	1.27	1.27	1.32	1.37
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	449.9	404.9	422.8	487.1	399.6	479.8
Wt. of dry sample + cont., g	W4	350.5	299.2	330.0	360.3	313.6	357.4
Wt. of water, g	W5 = W3 - W4	99.5	105.75	92.78	126.85	85.92	122.38
Wt. of container, g	W6	84.18	81.75	83.25	84.43	82.13	82.3
Wt. of dry sample, g	W7 = W4 - W6	266.3	217.4	246.72	275.85	231.51	275.14
Moisture Content, %	W8 = W5/W7*100	37.4	48.6	37.6	46.0	37.1	44.5

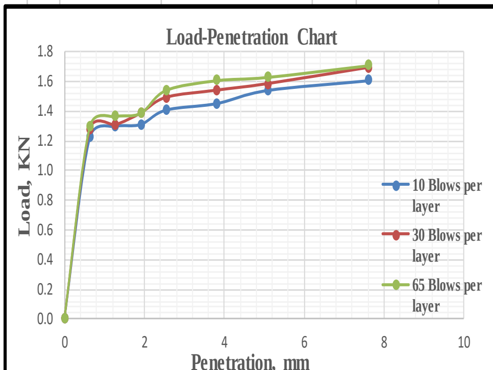
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	6.54	6.54	5.64	0	5.93	5.93	5.11	0	5.28	5.28	4.55

CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		9	0.4			11	0.5			12	0.5		
1.27		10	0.4			13	0.6			13	0.6		
1.91		13	0.6			15	0.7			15	0.7		
2.54	13.35	14	0.6	0.62	4.6	16	0.7	0.70	5.3	18	0.8	0.79	5.9
3.81		16	0.7			17	0.7			19	0.8		
5.08	20	18	0.8	0.79	4.0	19	0.8	0.84	4.2	21	0.9	0.92	4.6
7.62		20	0.9			23	1.0			23	1.0		
Soaked CBR, %		4.6				5.3				5.9			
Dry Density, g/cc		1.13				1.27				1.32			
Swell, %		5.64				5.11				4.55			
Density Requirement:		95%		Target Density:			1.33			CBR		5.83	

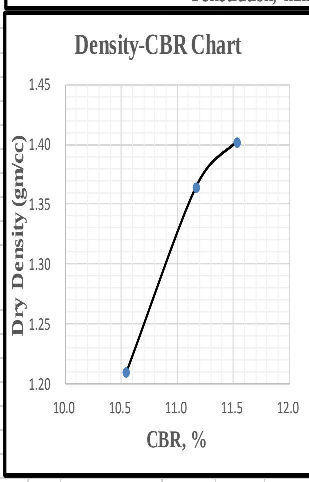
	Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
	Madda Walabu Primary School at 1.5m depth											
	BLOWS PER LAYER	56	No. OF LAYER		5		Material Description-		Rammer Weight		4.54Kg	
	MOLD DIAMETER	150mm	Height of Mold		116mm		Soil+2%WSF(1.5cm)+8%C		Volume of Mold(mm3)		2049.9	
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8881.8		9157.4		9299.9		9212.5		9291.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3680.8		3956.4		4098.9		4011.5		4090.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.796		1.930		2.000		1.957		1.995	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		214	202	288	326	336	21	214	98	340	30
G	Weight of container (gm)		16.37	17.53	17.11	17.64	16.47	15.49	16.37	17.42	17.58	16.9
H	Weight of container +wet soil(gm)		49.56	89.26	57.3	93.75	59.67	91.04	56.7	63.25	78.12	85.3
I	Weight of container +dry soil(gm)		43.78	76.29	48.81	78.36	50.41	74.6	46.87	52.32	62.27	67.73
J	Weight of water(gm)	H-I	5.78	12.97	8.49	15.39	9.26	16.44	9.83	10.93	15.85	17.57
K	Weigth of dry soil(gm)	I-G	27.41	58.76	31.70	60.72	33.94	59.11	30.50	34.90	44.69	50.83
L	Moisture content%	J/K	21.09	22.07	26.78	25.35	27.28	27.81	32.23	31.32	35.47	34.57
M	Average moisture content(%)		21.58		26.06		27.55		31.77		35.02	
N	Dry density(Kg/m3)		1.477		1.531		1.568		1.485		1.478	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C



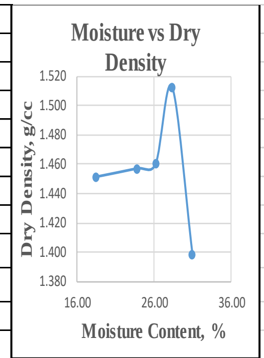
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9995	10401	10386	10653	10525	10789
Wt.of mold, g	W2	6682		6649		6638	
Wt.of wet sample, g	W3 = W1 - W2	3313	3719	3737	4004	3887	4151
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.57	1.77	1.78	1.90	1.85	1.97
Dry unit weight, g/cc	γw /(1+ W8/100)	1.21	1.27	1.36	1.39	1.40	1.47
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	418.9	377.0	414.8	435.8	439.3	395.4
Wt. of dry sample + cont., g	W4	341.5	293.3	337.7	341.6	353.4	315.5
Wt. of water, g	W5 = W3 - W4	77.4	83.66	77.03	94.25	85.84	79.84
Wt. of container, g	W6	83.93	81.73	81.65	84.14	82.62	83.22
Wt. of dry sample, g	W7 = W4 - W6	257.6	211.59	256.07	257.42	270.82	232.29
Moisture Content, %	W8 = W5/W7*100	30.0	39.5	30.1	36.6	31.7	34.4



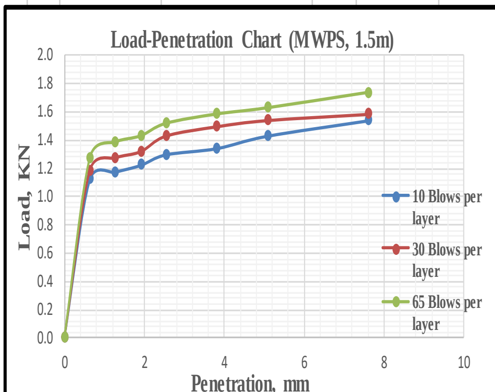
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.26	3.26	2.81	0	2.83	2.83	2.44	0	2.02	2.02	1.74

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		28	1.2			29	1.3			30	1.3		
1.27		30	1.3			30	1.3			31	1.4		
1.91		30	1.3			32	1.4			32	1.4		
2.54	13.35	32	1.4	1.41	10.5	34	1.5	1.49	11.2	35	1.5	1.54	11.5
3.81		33	1.5			35	1.5			37	1.6		
5.08	20	35	1.5	1.54	7.7	36	1.6	1.58	7.9	37	1.6	1.63	8.1
7.62		37	1.6			39	1.7			39	1.7		
Soaked CBR, %		10.5				11.2				11.5			
Dry Density, g/cc		1.21				1.36				1.40			
Swell, %		2.81				2.44				1.74			
Density Requirement:		95%		Target Density:			1.49			CBR		11.89	

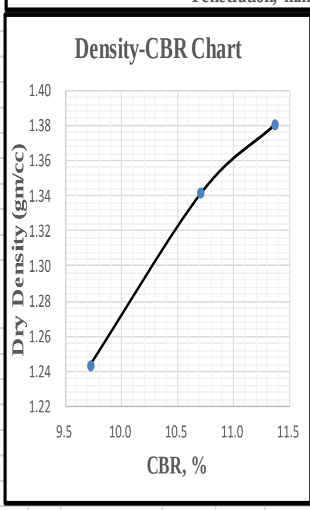
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm	Soil+3%WSF(1.5cm)+7%C		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8724.3		8896.9		8977.7		9179.2		8954.2	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3523.3		3695.9		3776.7		3978.2		3753.2	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.719		1.803		1.842		1.941		1.831	
Moisture content determination(%)												
	Determination No.		1		2		3		4		5	
F	Container No.		56	333	26	78	202	214	329	25	30	21
G	Weight of container (gm)		16.39	15.21	16.03	16.81	17.4	15.1	17.29	16.43	17.9	15.88
H	Weight of container +wet soil(gm)		113.9	95.1	86.17	90.2	100.4	74.14	81.29	88.91	97.11	80.1
I	Weight of container +dry soil(gm)		99.02	82.4	73.01	75.79	83.22	61.85	67.17	72.91	78.42	64.91
J	Weight of water(gm)	H-I	14.88	12.7	13.16	14.41	17.18	12.29	14.12	16	18.69	15.19
K	Weigth of dry soil(gm)	I-G	82.63	67.19	56.98	58.98	65.82	46.75	49.88	56.48	60.52	49.03
L	Moisture content%	J/K	18.01	18.90	23.10	24.43	26.10	26.29	28.31	28.33	30.88	30.98
M	Average moisture content(%)		18.45		23.76		26.20		28.32		30.93	
N	Dry density(Kg/m3)		1.451		1.457		1.460		1.512		1.398	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C



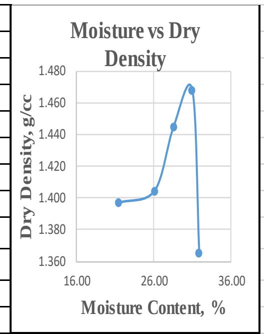
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10234	10472	10438	10683	10578	10891
Wt.of mold, g	W2	6772		6729		6762	
Wt.of wet sample, g	W3 = W1 - W2	3462	3700	3709	3954	3816	4129
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.64	1.76	1.76	1.88	1.81	1.96
Dry unit weight, g/cc	γw /(1+ W8/100)	1.24	1.26	1.34	1.37	1.38	1.45
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	448.0	471.1	433.9	440.9	456.2	432.7
Wt. of dry sample + cont., g	W4	359.2	360.2	350.4	344.1	367.4	340.2
Wt. of water, g	W5 = W3 - W4	88.7	110.93	83.5	96.75	88.89	92.47
Wt. of container, g	W6	83.73	81.35	83.85	82.01	83.39	81.13
Wt. of dry sample, g	W7 = W4 - W6	275.5	278.81	266.5	262.09	283.96	259.1
Moisture Content, %	W8 = W5/W7*100	32.2	39.8	31.3	36.9	31.3	35.7



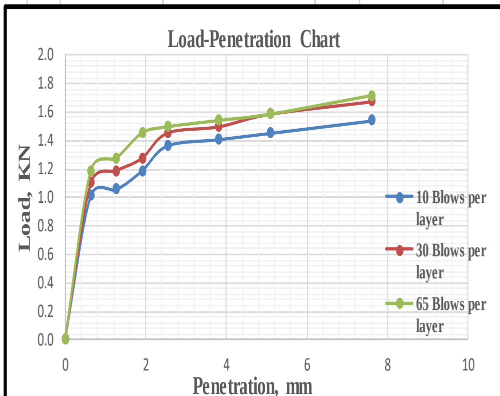
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.02	2.02	1.74	0	1.33	1.33	1.15	0	1.29	1.29	1.11

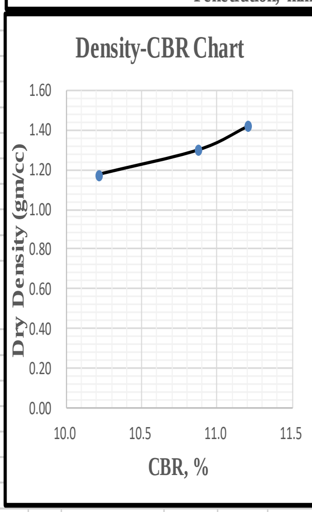
CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		26	1.1			27	1.2			29	1.3		
1.27		27	1.2			29	1.3			32	1.4		
1.91		28	1.2			30	1.3			33	1.4		
2.54	13.35	30	1.3	1.30	9.7	33	1.4	1.43	10.7	35	1.5	1.52	11.4
3.81		31	1.3			34	1.5			36	1.6		
5.08	20	33	1.4	1.43	7.2	35	1.5	1.54	7.7	37	1.6	1.63	8.1
7.62		35	1.5			36	1.6			40	1.7		
Soaked CBR, %		9.7				10.7				11.4			
Dry Density, g/cc		1.24				1.34				1.38			
Swell, %		1.74				1.15				1.11			
Density Requirement:			95%		Target Density:			1.43		CBR		11.92	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm	Soil+4%WSF(1.5cm)+6%C		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8680.3		8830.8		9006.4		9140.8		8891.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3479.3		3629.8		3805.4		3939.8		3690.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.697		1.771		1.856		1.922		1.800	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		36	28	277	358	339	324	337	343	321	53
G	Weight of container (gm)		17.16	16.22	14.56	16.37	16.19	16.34	16.11	15.11	16.54	17.09
H	Weight of container +wet soil(gm)		76.22	109.47	54.04	79.15	65.55	78.87	67.01	79.29	68.09	65.53
I	Weight of container +dry soil(gm)		65.67	93.12	45.59	66.62	54.64	64.94	54.88	64.24	55.9	53.59
J	Weight of water(gm)	H-I	10.55	16.35	8.45	12.53	10.91	13.93	12.13	15.05	12.19	11.94
K	Weigth of dry soil(gm)	I-G	48.51	76.90	31.03	50.25	38.45	48.60	38.77	49.13	39.36	36.50
L	Moisture content%	J/K	21.75	21.26	27.23	24.94	28.37	28.66	31.29	30.63	30.97	32.71
M	Average moisture content(%)		21.50		26.08		28.52		30.96		31.84	
N	Dry density(Kg/m3)		1.397		1.404		1.444		1.468		1.366	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C



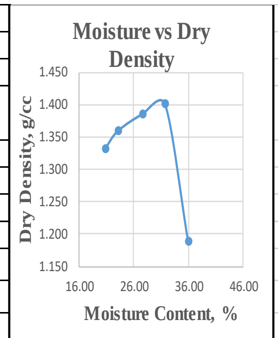


Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10035	10381	10394	10675	10623	10821
Wt.of mold, g	W2	6728		6782		6670	
Wt.of wet sample, g	W3 = W1 - W2	3307	3653	3612	3893	3953	4151
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.57	1.74	1.72	1.85	1.88	1.97
Dry unit weight, g/cc	γw /(1+ W8/100)	1.17	1.26	1.30	1.36	1.42	1.48
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	487.2	511.8	514.4	440.7	463.0	540.4
Wt. of dry sample + cont., g	W4	384.3	394.1	409.7	346.6	370.1	427.2
Wt. of water, g	W5 = W3 - W4	102.8	117.67	104.68	94.13	92.9	113.12
Wt. of container, g	W6	81.1	84.99	83.51	82.54	81.61	84.41
Wt. of dry sample, g	W7 = W4 - W6	303.2	309.1	326.17	264.05	288.48	342.82
Moisture Content, %	W8 = W5/W7*100	33.9	38.1	32.1	35.6	32.2	33.0

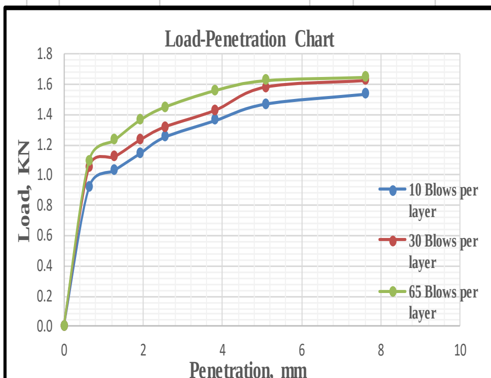
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.66	3.66	3.16	0	3.04	3.04	2.62	0	2.38	2.38	2.05

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		23	1.0			25	1.1			27	1.2		
1.27		24	1.1			27	1.2			29	1.3		
1.91		27	1.2			29	1.3			33	1.5		
2.54	13.35	31	1.4	1.36	10.2	33	1.5	1.45	10.9	34	1.5	1.50	11.2
3.81		32	1.4			34	1.5			35	1.5		
5.08	20	33	1.5	1.45	7.3	36	1.6	1.58	7.9	36	1.6	1.58	7.9
7.62		35	1.5			38	1.7			39	1.7		
Soaked CBR, %		10.2				10.9				11.2			
24		1.17				1.30				1.42			
Swell, %		3.16				2.62				2.05			
Density Requirement:			95%		Target Density:			1.40		CBR		11.16	

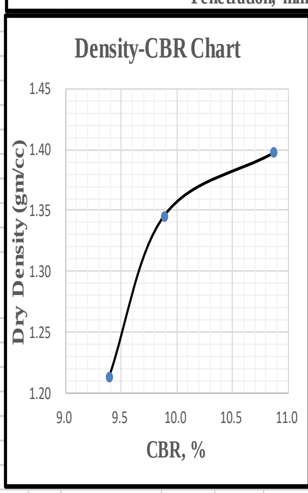
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 1.5m depth												
BLOWS PER LAYER		**56**	**No. OF LAYER**		**5**		**Material Description-Soil+4.5%WSF(1.5cm)+4%C**		**Rammer Weight**		**4.54Kg**	
MOLD DIAMETER		**50mı**	**Height of Mold**		**116mm**				**Volume of Mold(mm3)**		**2049.9**	
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8500.9		8634.1		8830.2		8986.6		8514.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3299.9		3433.1		3629.2		3785.6		3313.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.610		1.675		1.770		1.847		1.616	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		324	337	358	21	53	28	58	277	36	30
G	Weight of container (gm)		16.35	16.62	16.9	15.81	15.3	17.83	16.73	15.26	17.7	16.82
H	Weight of container +wet soil(gm)		72.9	101.3	88.82	63.2	92.62	83.7	113.17	62.72	94.72	73.82
I	Weight of container +dry soil(gm)		63.28	86.52	75.73	54.02	75.73	69.52	90.42	51.01	74.41	58.65
J	Weight of water(gm)	H-I	9.62	14.75	13.09	9.18	16.89	14.18	22.75	11.71	20.31	15.17
K	Weigth of dry soil(gm)	I-G	46.93	69.90	58.83	38.21	60.43	51.69	73.69	35.75	56.71	41.83
L	Moisture content%	J/K	20.50	21.10	22.25	24.03	27.95	27.43	30.87	32.76	35.81	36.27
M	Average moisture content(%)		20.80		23.14		27.69		31.81		36.04	
N	Dry density(Kg/m3)		1.333		1.360		1.386		1.401		1.188	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C



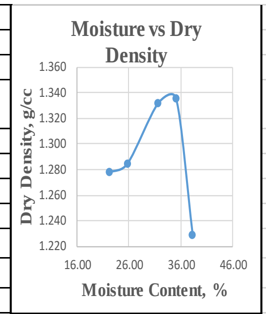
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10111	10267	10462	10677	10579	10808
Wt.of mold, g	W2	6673		6645		6628	
Wt.of wet sample, g	W3 = W1 - W2	3438	3594	3817	4032	3951	4180
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.63	1.71	1.81	1.92	1.88	1.99
Dry unit weight, g/cc	γw /(1+ W8/100)	1.21	1.23	1.35	1.40	1.40	1.47
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	406.3	428.8	418.9	409.2	399.7	421.5
Wt. of dry sample + cont., g	W4	322.9	332.4	332.6	321.3	318.9	333.5
Wt. of water, g	W5 = W3 - W4	83.4	96.41	86.32	87.81	80.72	88.01
Wt. of container, g	W6	81.7	84.64	83.9	81.96	83.34	81.37
Wt. of dry sample, g	W7 = W4 - W6	241.2	247.79	248.66	239.38	235.59	252.13
Moisture Content, %	W8 = W5/W7*100	34.6	38.9	34.7	36.7	34.3	34.9



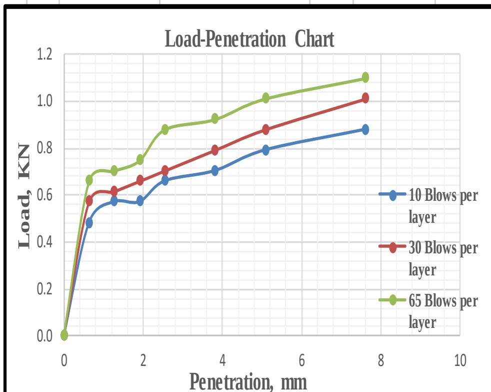
SWELL DATA (Surcharge Weight 4.54kg)											
No. of Blows	10				30				65		
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.91	4.91	4.23	0	3.87	3.87	3.34	0	3.29	3.29	2.84

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	%	Gauge reading	Load kN	Corrected CBR kN	%	Gauge reading	Load kN	Corrected CBR kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		21	0.9			24	1.1			25	1.1		
1.27		24	1.0			26	1.1			28	1.2		
1.91		26	1.1			28	1.2			31	1.4		
2.54	13.35	29	1.3	1.25	9.4	30	1.3	1.32	9.9	33	1.5	1.45	10.9
3.81		31	1.4			33	1.4			36	1.6		
5.08	20	34	1.5	1.47	7.4	36	1.6	1.58	7.9	37	1.6	1.63	8.1
7.62		35	1.5			37	1.6			38	1.7		
Soaked CBR, %		9.4				9.9				10.9			
24		1.21				1.35				1.40			
Swell, %		4.23				3.34				2.84			
Density Requirement:		95%		Target Density:			1.36			CBR		10.34	

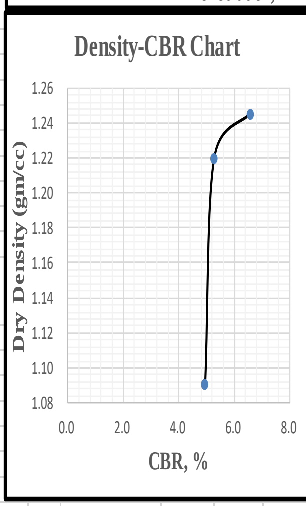
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-Soil+5%WSF(1.5cm)+3%C		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8403.6		8511.6		8791.5		8896.8		8683.5	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3202.6		3310.6		3590.5		3695.8		3482.5	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.562		1.615		1.752		1.803		1.699	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		24	290	275	347	38	354	42	21	222	216
G	Weight of container (gm)		17.65	15.4	16.31	16.15	16.88	17.23	16.47	17.01	16.49	17.29
H	Weight of container +wet soil(gm)		59.62	72.38	120.4	64.67	50.32	94.48	61.57	71.8	81.37	79.3
I	Weight of container +dry soil(gm)		52.36	61.5	99.81	54.43	42.39	75.76	49.99	57.45	63.64	61.97
J	Weight of water(gm)	H-I	7.26	10.88	20.59	10.24	7.93	18.72	11.58	14.35	17.73	17.33
K	Weigth of dry soil(gm)	I-G	34.71	46.10	83.50	38.28	25.51	58.53	33.52	40.44	47.15	44.68
L	Moisture content%	J/K	20.92	23.60	24.66	26.75	31.09	31.98	34.55	35.48	37.60	38.79
M	Average moisture content(%)		22.26		25.70		31.53		35.02		38.20	
N	Dry density(Kg/m3)		1.278		1.285		1.332		1.335		1.229	



Location and Depth-Madda Walabu Primary School at 1.5m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C



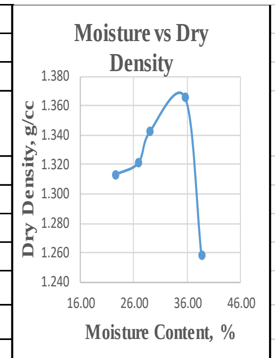
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9920	10223	10341	10550	10431	10667
Wt.of mold, g	W2	6735		6773		6792	
Wt.of wet sample, g	W3 = W1 - W2	3185	3488	3568	3777	3639	3875
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.51	1.66	1.70	1.79	1.73	1.84
Dry unit weight, g/cc	γw /(1+ W8/100)	1.09	1.13	1.22	1.23	1.25	1.27
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	448.1	466.5	461.3	472.0	497.3	486.3
Wt. of dry sample + cont., g	W4	346.8	343.1	355.9	350.0	381.4	361.1
Wt. of water, g	W5 = W3 - W4	101.2	123.42	105.4	122.01	115.89	125.16
Wt. of container, g	W6	84.92	81.18	84.98	82.08	82.49	81.18
Wt. of dry sample, g	W7 = W4 - W6	261.9	261.94	270.9	267.94	298.92	279.94
Moisture Content, %	W8 = W5/W7*100	38.7	47.1	38.9	45.5	38.8	44.7



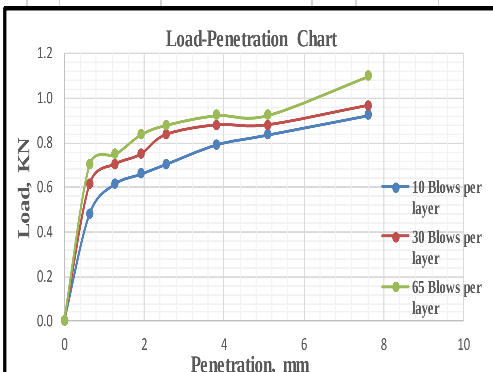
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	5.53	5.53	4.77	0	5.13	5.13	4.42	0	4.25	4.25	3.66

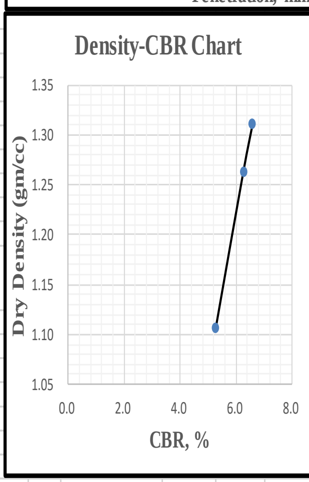
CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		11	0.5			13	0.6			15	0.7		
1.27		13	0.6			14	0.6			16	0.7		
1.91		13	0.6			15	0.7			17	0.7		
2.54	13.35	15	0.7	0.66	4.9	16	0.7	0.70	5.3	20	0.9	0.88	6.6
3.81		16	0.7			18	0.8			21	0.9		
5.08	20	18	0.8	0.79	4.0	20	0.9	0.88	4.4	23	1.0	1.01	5.1
7.62		20	0.9			23	1.0			25	1.1		
Soaked CBR, %		4.9				5.3				6.6			
24		1.09				1.22				1.25			
Swell, %		4.77				4.42				3.66			
Density Requirement:		95%		Target Density:			1.27			CBR		6.30	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 3m depth												
	BLOWS PER LAYER	56	No. OF LAYER		5		Material Description-Soil+1%WSF(1.5cm)+0%C	Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8501.3		8638.8		8752.1		8999.4		8777.8	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3300.3		3437.8		3551.1		3798.4		3576.8	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.610		1.677		1.732		1.853		1.745	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		21	314	326	336	22	30	35	38	41	214
G	Weight of container (gm)		17.34	17.01	15.22	16.21	15.43	15.49	16.56	17.09	17.03	15.39
H	Weight of container +wet soil(gm)		104.3	94.12	63.5	57.19	64.64	110.4	46.32	91.19	49.47	56.37
I	Weight of container +dry soil(gm)		88.23	79.96	53.45	48.34	53.63	88.92	38.53	71.61	40.38	44.98
J	Weight of water(gm)	H-I	16.07	14.16	10.05	8.85	11.01	21.48	7.79	19.58	9.09	11.39
K	Weight of dry soil	I-G	70.89	62.95	38.23	32.13	38.2	73.43	21.97	54.52	23.35	29.59
L	Moisture content%	J/K	22.67	22.49	26.29	27.54	28.82	29.25	35.46	35.91	38.93	38.49
M	Average moisture content(%)		22.58		26.92		29.04		35.69		38.71	
N	Dry density(Kg/m3)		1.313		1.321		1.343		1.366		1.258	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C





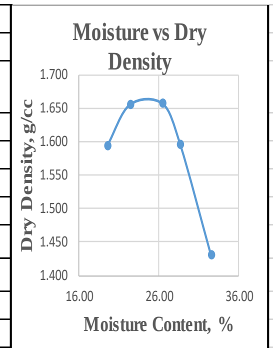
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9964	10323	10369	10559	10544	10770
Wt.of mold, g	W2	6726		6696		6729	
Wt.of wet sample, g	W3 = W1 - W2	3238	3597	3673	3863	3815	4041
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.54	1.71	1.74	1.84	1.81	1.92
Dry unit weight, g/cc	γw /(1+ W8/100)	1.11	1.15	1.26	1.27	1.31	1.37
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	460.4	484.5	465.8	483.9	473.3	421.3
Wt. of dry sample + cont., g	W4	354.5	353.9	360.3	361.2	365.9	324.1
Wt. of water, g	W5 = W3 - W4	105.9	130.56	105.52	122.74	107.44	97.26
Wt. of container, g	W6	82.26	81.95	82.73	84.92	84.57	82.93
Wt. of dry sample, g	W7 = W4 - W6	272.3	271.95	277.56	276.28	281.33	241.14
Moisture Content, %	W8 = W5/W7*100	38.9	48.0	38.0	44.4	38.2	40.3

SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	6.01	6.01	5.18	0	5.44	5.44	4.69	0	4.85	4.85	4.18

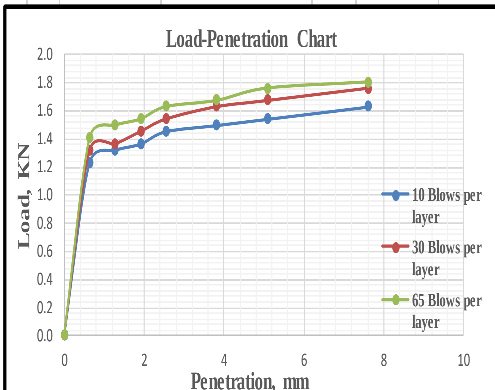
CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penetration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR	
			kN	kN	%		kN	kN	%		kN	kN	%
0		0	0.0			0	0.0			0	0.0		
0.64		11	0.5			14	0.6			16	0.7		
1.27		14	0.6			16	0.7			17	0.7		
1.91		15	0.7			17	0.7			19	0.8		
2.54	13.35	16	0.7	0.70	5.3	19	0.8	0.84	6.3	20	0.9	0.88	6.6
3.81		18	0.8			20	0.9			21	0.9		
5.08	20	19	0.8	0.84	4.2	20	0.9	0.88	4.4	21	0.9	0.92	4.6
7.62		21	0.9			22	1.0			25	1.1		
Soaked CBR, %		5.3				6.3				6.6			
Dry Density, g/cc		1.11				1.26				1.31			
Swell, %		5.18				4.69				4.18			
Density Requirement:		95%		Target Density:		1.36				CBR		6.88	

Madda Walabu Primary School at 3m depth							
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-=Soil+2%WSF(1.5cm)+8%C	Rammer Weight	4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9	

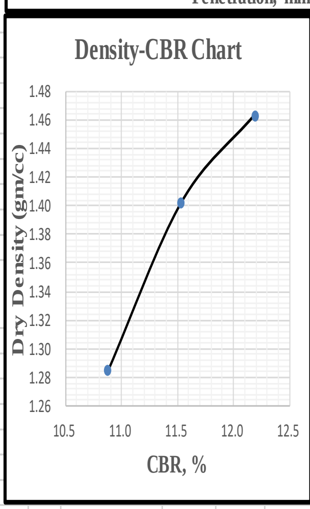
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		9110.4		9357.7		9500.3		9411.5		9089.1	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3909.4		4156.7		4299.3		4210.5		3888.1	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.907		2.028		2.097		2.054		1.897	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		38	21	58	214	30	33	25	28	322	45
G	Weight of container (gm)		15.67	16.13	16.22	17.67	15.78	17.9	16.78	16.32	17.05	17.31
H	Weight of container +wet soil(gm)		85.79	74.98	71.8	55.27	116.68	60.34	74.51	68.84	79.35	71.11
I	Weight of container +dry soil(gm)		74.67	65.05	61.54	48.44	95.76	51.34	61.75	56.99	64.52	57.48
J	Weight of water(gm)	H-I	11.12	9.93	10.26	6.83	20.92	9	12.76	11.85	14.83	13.63
K	Weight of dry soil	I-G	59.00	48.92	45.32	30.77	79.98	33.44	44.97	40.67	47.47	40.17
L	Moisture content%	J/K	18.85	20.30	22.64	22.20	26.16	26.91	28.37	29.14	31.24	33.93
M	Average moisture content(%)		19.57		22.42		26.54		28.76		32.59	
N	Dry density(Kg/m3)		1.595		1.656		1.658		1.595		1.431	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10187	10438	10421	10625	10677	10807
Wt.of mold, g	W2	6718		6629		6729	
Wt.of wet sample, g	W3 = W1 - W2	3469	3720	3792	3996	3948	4078
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.65	1.77	1.80	1.90	1.88	1.94
Dry unit weight, g/cc	γw /(1+ W8/100)	1.29	1.31	1.40	1.42	1.46	1.48
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	498.2	612.7	495.5	620.9	490.8	647.3
Wt. of dry sample + cont., g	W4	406.7	477.6	404.0	487.0	401.6	517.0
Wt. of water, g	W5 = W3 - W4	91.4	135.025	91.58	133.87	89.15	130.36
Wt. of container, g	W6	82.96	88.83	81.99	88.99	84.93	89.6
Wt. of dry sample, g	W7 = W4 - W6	323.8	388.815	321.97	398.02	316.67	427.37
Moisture Content, %	W8 = W5/W7*100	28.2	34.7	28.4	33.6	28.2	30.5



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	1.86	1.86	1.60	0	1.22	1.22	1.05	0	1.18	1.18	1.02

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

Penetration (mm)	Std load (kN)	10: Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	30: Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	65: Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		28	1.2			30	1.3			32	1.4		
1.27		30	1.3			31	1.4			34	1.5		
1.91		31	1.4			33	1.5			35	1.5		
2.54	13.35	33	1.5	1.45	10.9	35	1.5	1.54	11.5	37	1.6	1.63	12.2
3.81		34	1.5			37	1.6			38	1.7		
5.08	20	35	1.5	1.54	7.7	38	1.7	1.67	8.4	40	1.8	1.76	8.8
7.62		37	1.6			40	1.8			41	1.8		
Soaked CBR, %		10.9				11.5				12.2			
Dry Density, g/cc		1.29				1.40				1.46			
Swell, %		1.60				1.05				1.02			

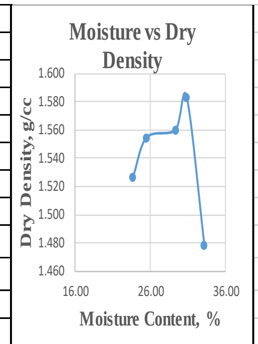
Density Requirement:	95%	Target Density:	1.58	CBR	12.92

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

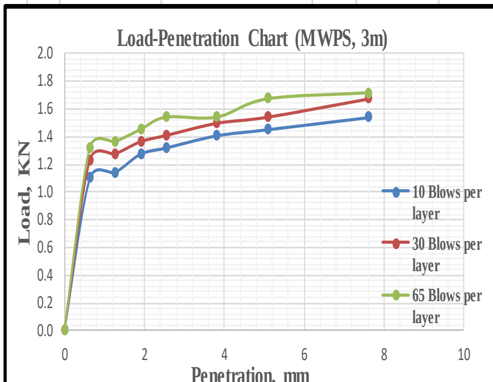
Madda Walabu Primary School at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+3%WSF(1.5cm)+7%C	Volume of Mold(mm3)	2049.9	

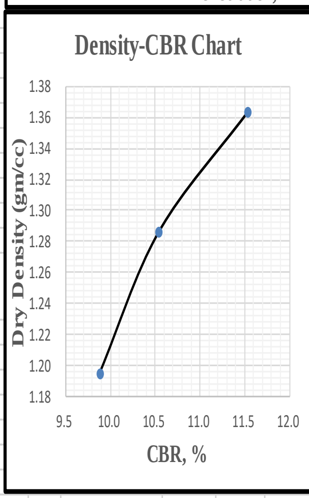
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		9071.4		9200.2		9336.7		9446.8		9237.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3870.4		3999.2		4135.7		4245.8		4036.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.888		1.951		2.018		2.071		1.969	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		33	214	35	202	31	222	336	21	38	58
G	Weight of container (gm)		17.53	16.59	16.4	16.42	16.21	17.91	17.01	16.36	16.12	16.46
H	Weight of container +wet soil(gm)		79.37	67.16	56.87	99.15	105.76	65.89	56.13	61.35	63.67	119.5
I	Weight of container +dry soil(gm)		67.63	57.41	48.33	83.02	85.46	55.01	47.07	50.58	51.85	93.78
J	Weight of water(gm)	H-I	11.74	9.75	8.54	16.13	20.3	10.88	9.06	10.77	11.82	25.72
K	Weight of dry soil	I-G	50.1	40.82	31.93	66.6	69.25	37.1	30.06	34.22	35.73	77.32
L	Moisture content%	J/K	23.43	23.89	26.75	24.22	29.31	29.33	30.14	31.47	33.08	33.26
M	Average moisture content(%)		23.66		25.48		29.32		30.81		33.17	
N	Dry density(Kg/m3)		1.527		1.555		1.560		1.583		1.479	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C



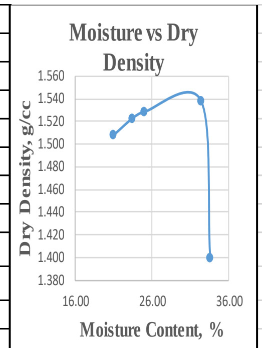
Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9987	10284	10345	10493	10568	10632
Wt.of mold, g	W2	6637		6723		6736	
Wt.of wet sample, g	W3 = W1 - W2	3350	3647	3622	3770	3832	3896
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.59	1.73	1.72	1.79	1.82	1.85
Dry unit weight, g/cc	γw /(1+ W8/100)	1.20	1.26	1.29	1.32	1.36	1.38
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	408.6	414.9	381.7	375.9	373.2	367.6
Wt. of dry sample + cont., g	W4	327.6	323.3	306.7	299.2	300.6	295.0
Wt. of water, g	W5 = W3 - W4	81.0	91.55	75	76.73	72.67	72.54
Wt. of container, g	W6	83.31	82.65	84.61	84.16	83.76	81.48
Wt. of dry sample, g	W7 = W4 - W6	244.3	240.68	222.06	215.01	216.79	213.55
Moisture Content, %	W8 = W5/W7*100	33.1	38.0	33.8	35.7	33.5	34.0



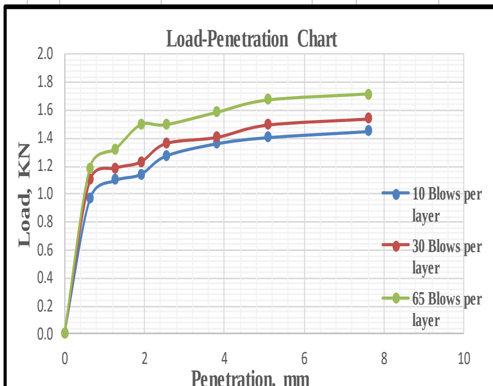
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.01	3.01	2.59	0	1.22	1.22	1.05	0	1.18	1.18	1.02

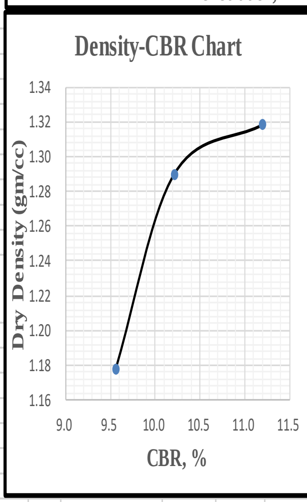
CBR DATA (4 days Soaked)												
Ring factor		0.044	kN/div									
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		25	1.1			28	1.2			30	1.3		
1.27		26	1.1			29	1.3			31	1.4		
1.91		29	1.3			31	1.4			33	1.5		
2.54	13.35	30	1.3	1.32	9.9	32	1.4	1.41	10.5	35	1.5	1.54	11.5
3.81		32	1.4			34	1.5			35	1.5		
5.08	20	33	1.5	1.45	7.3	35	1.5	1.54	7.7	38	1.7	1.67	8.4
7.62		35	1.5			38	1.7			39	1.7		
Soaked CBR, %		9.9				10.5				11.5			
24		1.20				1.29				1.36			
Swell, %		2.59				1.05				1.02			
Density Requirement:		95%		Target Density:			1.50			CBR		12.79	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 3m depth												
	BLOWS PER LAYER	56	No. OF LAYER		5		Material Description-		Rammer Weight		4.54Kg	
	MOLD DIAMETER	150mm	Height of Mold		116mm		Soil+4%WSF(1.5cm)+6%C		Volume of Mold(mm3)		2049.9	
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8939.3		9055.8		9118.4		9375.6		9034.4	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3738.3		3854.8		3917.4		4174.6		3833.4	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.824		1.880		1.911		2.036		1.870	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		321	339	28	343	277	53	36	55	358	324
G	Weight of container (gm)		17.19	15.43	16.84	16.12	15.12	17.7	16.82	15.65	16.39	17.23
H	Weight of container +wet soil(gm)		91.01	78.7	59.31	79.16	69.37	81.92	65.91	84.25	90.71	105.24
I	Weight of container +dry soil(gm)		78.17	67.8	51.19	67.26	58.73	68.83	53.9	67.46	72.21	82.92
J	Weight of water(gm)	H-I	12.84	10.90	8.12	11.90	10.64	13.09	12.01	16.79	18.50	22.32
K	Weight of dry soil	I-G	60.98	52.37	34.35	51.14	43.61	51.13	37.08	51.81	55.82	65.69
L	Moisture content%	J/K	21.06	20.81	23.64	23.27	24.40	25.60	32.39	32.41	33.14	33.98
M	Average moisture content(%)		20.93		23.45		25.00		32.40		33.56	
N	Dry density(Kg/m3)		1.508		1.523		1.529		1.538		1.400	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C



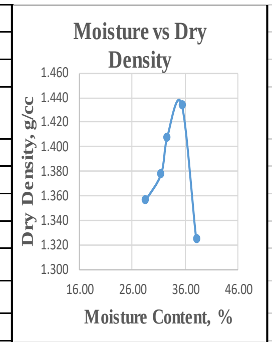


Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9994	10287	10395	10617	10444	10734
Wt.of mold, g	W2	6659		6737		6721	
Wt.of wet sample, g	W3 = W1 - W2	3335	3628	3658	3880	3723	4013
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.72	1.74	1.84	1.77	1.91
Dry unit weight, g/cc	γw /(1+ W8/100)	1.18	1.21	1.29	1.31	1.32	1.39
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	475.7	417.6	464.9	421.8	418.1	422.4
Wt. of dry sample + cont., g	W4	374.9	318.1	366.3	324.7	333.2	331.0
Wt. of water, g	W5 = W3 - W4	100.8	99.46	98.59	97.16	84.91	91.37
Wt. of container, g	W6	82.55	83.25	81.82	84.09	84.38	81.94
Wt. of dry sample, g	W7 = W4 - W6	292.3	234.87	284.48	240.57	248.85	249.07
Moisture Content, %	W8 = W5/W7*100	34.5	42.3	34.7	40.4	34.1	36.7

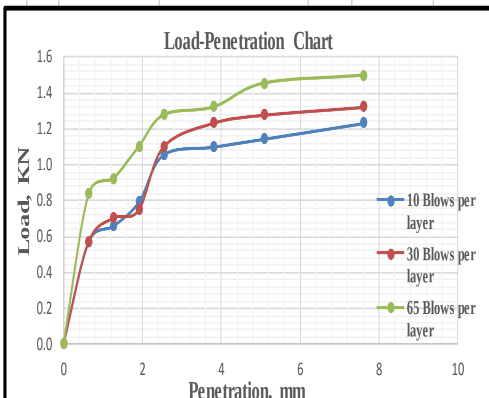
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.35	3.35	2.89	0	2.79	2.79	2.41	0	2.18	2.18	1.88

CBR DATA (4 days Soaked)												
Ring factor		0.044	kN/div									
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		22	1.0			25	1.1			27	1.2		
1.27		25	1.1			27	1.2			30	1.3		
1.91		26	1.1			28	1.2			34	1.5		
2.54	13.35	29	1.3	1.28	9.6	31	1.4	1.36	10.2	34	1.5	1.50	11.2
3.81		31	1.4			32	1.4			36	1.6		
5.08	20	32	1.4	1.41	7.0	34	1.5	1.50	7.5	38	1.7	1.67	8.4
7.62		33	1.5			35	1.5			39	1.7		
Soaked CBR, %		9.6				10.2				11.2			
24		1.18				1.29				1.32			
Swell, %		2.89				2.41				1.88			
Density Requirement:			95%		Target Density:			1.46		CBR		12.34	

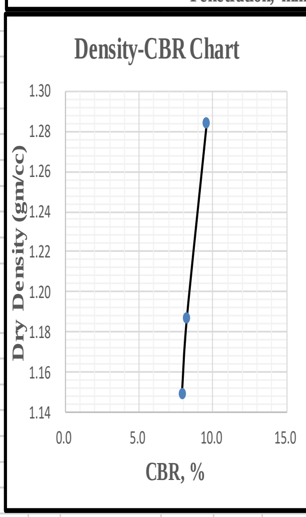
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Madda Walabu Primary School at 3m depth												
BLOWS PER LAYER		56	No. OF LAYER	5	Material Description-Soil+4.5%WSF(1.5cm)+4%C		Rammer Weight		4.54Kg			
MOLD DIAMETER		150mm	Height of Mold	116mm			Volume of Mold(mm3)		2049.9			
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8773.3		8913.5		9029.1		9181.4		8953.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3572.3		3712.5		3828.1		3980.4		3752.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.743		1.811		1.867		1.942		1.830	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		28	38	202	21	30	43	343	341	35	41
G	Weight of container (gm)		16.25	16.03	15.78	15.99	15.24	16.75	17.84	16.31	16.73	17.07
H	Weight of container +wet soil(gm)		69.31	121.23	54.89	68.11	91.23	90.04	65.18	54.51	71.41	73.12
I	Weight of container +dry soil(gm)		57.95	97.13	45.44	55.77	72.35	72.19	52.91	44.45	56.33	57.61
J	Weight of water(gm)	H-I	11.36	24.1	9.45	12.34	18.88	17.85	12.27	10.06	15.08	15.51
K	Weight of dry soil	I-G	41.70	81.1	29.66	39.78	57.11	55.44	35.07	28.14	39.6	40.54
L	Moisture content%	J/K	27.24	29.72	31.86	31.02	33.06	32.20	34.99	35.75	38.08	38.26
M	Average moisture content(%)		28.48		31.44		32.63		35.37		38.17	
N	Dry density(Kg/m3)		1.356		1.378		1.408		1.434		1.325	



Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9942	10250	10221	10543	10391	10652
Wt.of mold, g	W2	6640		6811		6695	
Wt.of wet sample, g	W3 = W1 - W2	3302	3610	3410	3732	3696	3957
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.57	1.71	1.62	1.77	1.76	1.88
Dry unit weight, g/cc	γw /(1+ W8/100)	1.15	1.15	1.19	1.20	1.28	1.31
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	460.2	411.1	470.8	414.2	451.1	422.0
Wt. of dry sample + cont., g	W4	359.2	302.9	367.2	308.3	352.7	319.1
Wt. of water, g	W5 = W3 - W4	100.9	108.17	103.61	105.82	98.39	102.91
Wt. of container, g	W6	82.26	81.95	82.73	84.92	84.57	82.93
Wt. of dry sample, g	W7 = W4 - W6	277.0	220.99	284.45	223.41	268.1	236.14
Moisture Content, %	W8 = W5/W7*100	36.4	48.9	36.4	47.4	36.7	43.6



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.51	4.51	3.89	0	3.55	3.55	3.06	0	3.02	3.02	2.60

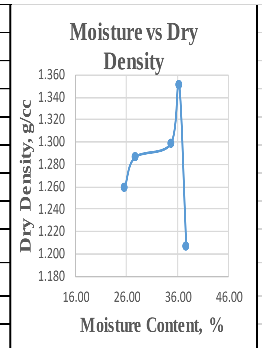
CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		13	0.6			13	0.6			19	0.8		
1.27		15	0.7			16	0.7			21	0.9		
1.91		18	0.8			17	0.7			25	1.1		
2.54	13.35	24	1.1	1.06	7.9	25	1.1	1.10	8.2	29	1.3	1.28	9.6
3.81		25	1.1			28	1.2			30	1.3		
5.08	20	26	1.1	1.14	5.7	29	1.3	1.28	6.4	33	1.5	1.45	7.3
7.62		28	1.2			30	1.3			34	1.5		
Soaked CBR, %		7.9				8.2				9.6			
Dry Density, g/cc		1.15				1.19				1.28			
Swell, %		3.89				3.06				2.60			
Density Requirement:		95%		Target Density:			1.30			CBR		9.75	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

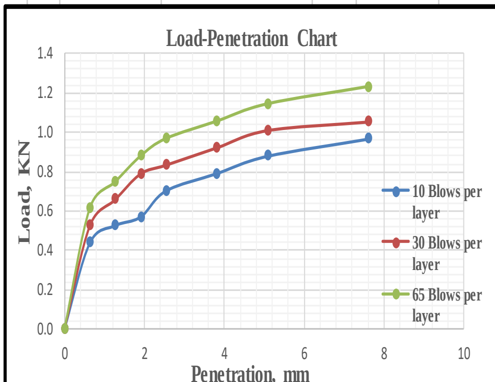
Madda Walabu Primary School at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+5%WSF(1.5cm)+3%C	Volume of Mold(mm3)	2049.9

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8442.5		8566.9		8786.3		8975.1		8605.7	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3241.5		3365.9		3585.3		3774.1		3404.7	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.581		1.642		1.749		1.841		1.661	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		202	340	214	288	326	38	21	67	55	98
G	Weight of container (gm)		16.12	16.66	15.17	15.63	16.24	15.13	16.77	16.09	15.89	16.23
H	Weight of container +wet soil(gm)		76.43	54.54	52.59	67.23	49.19	63.17	79.6	55.08	78.99	67.01
I	Weight of container +dry soil(gm)		63.89	46.98	44.47	56.08	40.45	51.19	62.9	44.69	61.89	52.99
J	Weight of water(gm)	H-I	12.54	7.56	8.12	11.15	8.74	11.98	16.70	10.39	17.10	14.02
K	Weight of dry soil	I-G	47.77	30.32	29.30	40.45	24.21	36.06	46.13	28.60	46.00	36.76
L	Moisture content%	J/K	26.25	24.93	27.71	27.56	36.10	33.22	36.20	36.33	37.17	38.14
M	Average moisture content(%)		25.59		27.64		34.66		36.27		37.66	
N	Dry density(Kg/m3)		1.259		1.286		1.299		1.351		1.207	

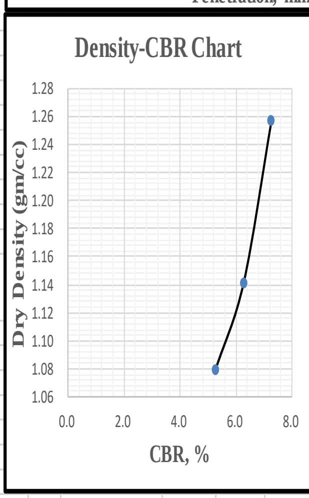


Location and Depth-Madda Walabu Primary School at 3m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9877	10161	10153	10365	10310	10532
Wt.of mold, g	W2	6741		6848		6680	
Wt.of wet sample, g	W3 = W1 - W2	3136	3420	3305	3517	3630	3852
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.49	1.62	1.57	1.67	1.72	1.83
Dry unit weight, g/cc	γw /(1+ W8/100)	1.08	1.14	1.14	1.20	1.26	1.33
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	494.9	458.4	496.5	485.1	494.5	453.5
Wt. of dry sample + cont., g	W4	381.5	346.8	383.7	371.6	383.5	351.3
Wt. of water, g	W5 = W3 - W4	113.4	111.57	112.84	113.44	111.02	102.25
Wt. of container, g	W6	82.28	82.78	82.95	84.68	84.59	82.29
Wt. of dry sample, g	W7 = W4 - W6	299.2	264	300.74	286.94	298.91	269
Moisture Content, %	W8 = W5/W7*100	37.9	42.3	37.5	39.5	37.1	38.0



SWELL DATA (Surcharge Weight 4.54kg)

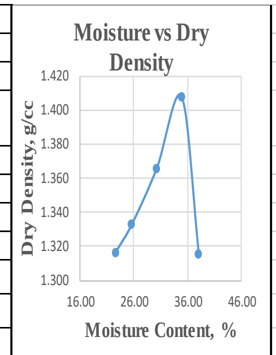
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	5.08	5.08	4.38	0	4.71	4.71	4.06	0	3.91	3.91	3.37

CBR DATA (4 days Soaked)

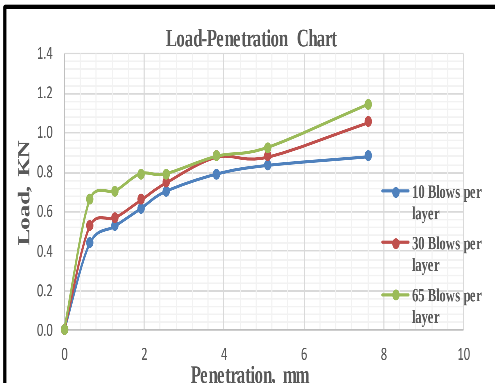
Ring factor 0.044 kN/div

Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		10	0.4			12	0.5			14	0.6		
1.27		12	0.5			15	0.7			17	0.7		
1.91		13	0.6			18	0.8			20	0.9		
2.54	13.35	16	0.7	0.70	5.3	19	0.8	0.84	6.3	22	1.0	0.97	7.3
3.81		18	0.8			21	0.9			24	1.1		
5.08	20	20	0.9	0.88	4.4	23	1.0	1.01	5.1	26	1.1	1.14	5.7
7.62		22	1.0			24	1.1			28	1.2		
Soaked CBR, %		5.3				6.3				7.3			
Dry Density, g/cc		1.08				1.14				1.26			
Swell, %		4.38				4.06				3.37			
Density Requirement:		95%		Target Density:			1.28			CBR		7.59	

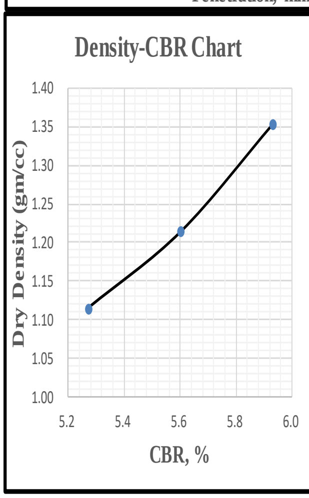
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Bale Robe Teachers Collage at 1.5m depth												
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-Soil+1%WSF(1.5cm)+0%C		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm			Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8511.3		8632.1		8847.5		9091.9		8924.1	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3310.3		3431.1		3646.5		3890.9		3723.1	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.615		1.674		1.779		1.898		1.816	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		337	358	28	21	53	324	277	58	36	339
G	Weight of container (gm)		16.71	15.9	16.23	17.62	16.34	17.71	16.08	17.57	16.92	16.13
H	Weight of container +wet soil(gm)		109.4	84.92	76.6	98.47	89.52	55.72	107.53	67.38	53.19	69.63
I	Weight of container +dry soil(gm)		92.78	71.82	64.01	82.39	72.12	47.11	84.29	54.3	43.1	55.03
J	Weight of water(gm)	H-I	16.62	13.1	12.59	16.08	17.4	8.61	23.24	13.08	10.09	14.6
K	Weigth of dry soil(gm)	I-G	76.07	55.92	47.78	64.77	55.78	29.4	68.21	36.73	26.18	38.9
L	Moisture content%	J/K	21.85	23.43	26.35	24.83	31.19	29.29	34.07	35.61	38.54	37.53
M	Average moisture content(%)		22.64		25.59		30.24		34.84		38.04	
N	Dry density(Kg/m3)		1.317		1.333		1.366		1.408		1.316	



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9931	10352	10325	10654	10587	10747
Wt.of mold, g	W2	6674		6783		6639	
Wt.of wet sample, g	W3 = W1 - W2	3257	3678	3542	3871	3948	4108
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.55	1.75	1.68	1.84	1.88	1.95
Dry unit weight, g/cc	γw /(1+ W8/100)	1.12	1.17	1.21	1.25	1.35	1.35
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	421.5	416.6	375.7	379.5	418.7	443.0
Wt. of dry sample + cont., g	W4	327.5	305.6	294.7	284.5	325.7	331.0
Wt. of water, g	W5 = W3 - W4	94.0	111	81	95	93	112
Wt. of container, g	W6	84.61	81.71	84.68	83.89	84.12	81.15
Wt. of dry sample, g	W7 = W4 - W6	242.9	223.85	209.97	200.64	241.61	249.8
Moisture Content, %	W8 = W5/W7*100	38.7	49.6	38.6	47.3	38.5	44.8



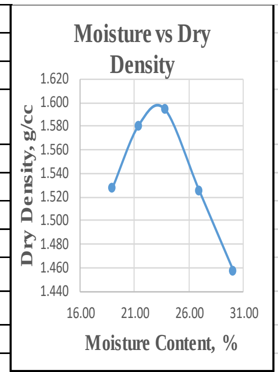
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	6.33	6.33	5.46	0	5.73	5.73	4.94	0	5.11	5.11	4.41

CBR DATA (4 days Soaked)													
Ring factor	0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		10	0.4			12	0.5			15	0.7		
1.27		12	0.5			13	0.6			16	0.7		
1.91		14	0.6			15	0.7			18	0.8		
2.54	13.35	16	0.7	0.70	5.3	17	0.7	0.75	5.6	18	0.8	0.79	5.9
3.81		18	0.8			20	0.9			20	0.9		
5.08	20	19	0.8	0.84	4.2	20	0.9	0.88	4.4	21	0.9	0.92	4.6
7.62		20	0.9			24	1.1			26	1.1		

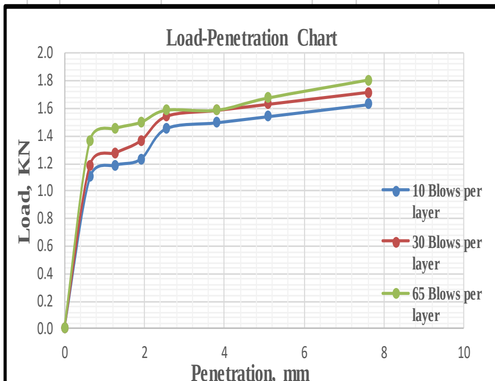
Soaked CBR, %	5.3	5.6	5.9
24	1.12	1.21	1.35
Swell, %	5.46	4.94	4.41

Density Requirement:	95%	Target Density:	1.34	CBR	5.91

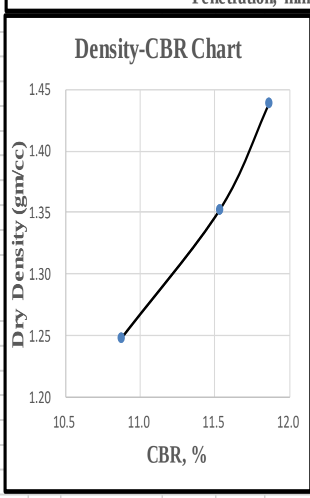
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Bale Robe Teachers Collage at 1.5m depth											
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description- Soil+2%WSF(1.5cm) +8%C	Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold		116mm		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5
A	Weight of mold +wet soil(gm)		8924.4		9134.2		9245.7		9170.4		9087.7
B	Weight of mold(gm)		5201		5201		5201		5201		5201
C	Weight of wet soil(gm)	A-B	3723.4		3933.2		4044.7		3969.4		3886.7
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9
E	Wet density(Kg/ m^3)	C/D	1.816		1.919		1.973		1.936		1.896
Moisture content determination(%)											
	Determiation No.		1		2		3		4		5
F	Container No.		34	41	214	22	17	336	30	38	26	22
G	Weight of container (gm)		17.73	16.53	17.25	16.69	17.19	15.92	16.74	17.03	16.25	15.63
H	Weight of container +wet soil(gm)		56.83	75.47	68.69	77.7	75.83	53.63	98.56	53.29	56.75	74.53
I	Weight of container +dry soil(gm)		50.74	65.89	60.02	66.51	64.83	46.23	81.12	45.64	47.53	60.72
J	Weight of water(gm)	H-I	6.09	9.58	8.67	11.19	11	7.4	17.44	7.65	9.22	13.81
K	Weigth of dry soil(gm)	I-G	33.01	49.36	42.77	49.82	47.64	30.31	64.38	28.61	31.28	45.09
L	Moisture content%	J/K	18.45	19.41	20.27	22.46	23.09	24.41	27.09	26.74	29.48	30.63
M	Average moisture content(%)		18.93		21.37		23.75		26.91		30.05
N	Dry density(Kg/m3)		1.527		1.581		1.594		1.526		1.458



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10078	10392	10400	10681	10637	10841
Wt.of mold, g	W2	6731		6756		6773	
Wt.of wet sample, g	W3 = W1 - W2	3347	3661	3644	3925	3864	4068
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.59	1.74	1.73	1.86	1.84	1.93
Dry unit weight, g/cc	γw /(1+ W8/100)	1.25	1.29	1.35	1.42	1.44	1.49
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	431.1	438.2	451.4	385.1	410.7	469.9
Wt. of dry sample + cont., g	W4	356.4	346.9	370.8	313.1	340.1	381.2
Wt. of water, g	W5 = W3 - W4	74.6	91.26	80.58	72.01	70.68	88.72
Wt. of container, g	W6	83.61	81.91	82.28	83.21	83.18	82.27
Wt. of dry sample, g	W7 = W4 - W6	272.8	264.99	288.53	229.89	256.88	298.94
Moisture Content, %	W8 = W5/W7*100	27.4	34.4	27.9	31.3	27.5	29.7



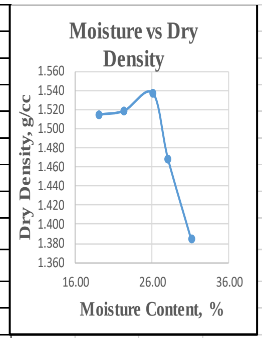
SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.96	2.96	2.55	0	1.98	1.98	1.71	0	1.24	1.24	1.07

CBR DATA (4 days Soaked)

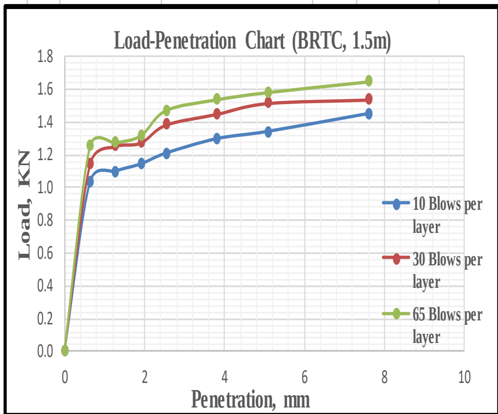
Ring factor 0.044 kN/div

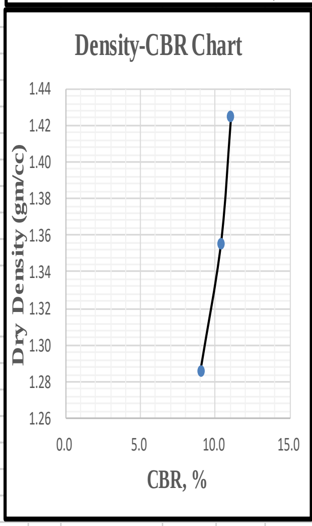
Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		25	1.1			27	1.2			31	1.4		
1.27		27	1.2			29	1.3			33	1.5		
1.91		28	1.2			31	1.4			34	1.5		
2.54	13.35	33	1.5	1.45	10.9	35	1.5	1.54	11.5	36	1.6	1.58	11.9
3.81		34	1.5			36	1.6			36	1.6		
5.08	20	35	1.5	1.54	7.7	37	1.6	1.63	8.1	38	1.7	1.67	8.4
7.62		37	1.6			39	1.7			41	1.8		
Soaked CBR, %		10.9				11.5				11.9			
24		1.25				1.35				1.44			
Swell, %		2.55				1.71				1.07			
Density Requirement:		95%		Target Density:		1.51				CBR		12.28	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)												
Bale Robe Teachers Collage at 1.5m depth												
	BLOWS PER LAYER	56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg		
	MOLD DIAMETER	150mm	Height of Mold		116mm	Soil+3%WSF(1.5cm)+7%C		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8900.2		9010.7		9174.3		9056.8		8921.6	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3699.2		3809.7		3973.3		3855.8		3720.6	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/m^3)	C/D	1.805		1.858		1.938		1.881		1.815	
Moisture content determination(%)												
	Determiation No.		1		2		3		4		5	
F	Container No.		40	12	67	41	322	341	23	30	21	214
G	Weight of container (gm)		16.57	17.19	17.38	16.92	15.37	16.18	15.08	16.16	17.17	15.77
H	Weight of container +wet soil(gm)		62.82	77.02	97.27	63.92	91.82	82.22	101.27	64.02	87.29	62.05
I	Weight of container +dry soil(gm)		55.77	66.93	83.2	55.02	76.33	68.27	82.19	53.63	70.7	51.03
J	Weight of water(gm)	H-I	7.05	10.09	14.07	8.9	15.49	13.95	19.08	10.39	16.59	11.02
K	Weigth of dry soil(gm)	I-G	39.2	49.74	65.82	38.1	60.96	52.09	67.11	37.47	53.53	35.26
L	Moisture content%	J/K	17.98	20.29	21.38	23.36	25.41	26.78	28.43	27.73	30.99	31.25
M	Average moisture content(%)		19.14		22.37		26.10		28.08		31.12	
N	Dry density(Kg/m3)		1.515		1.519		1.537		1.469		1.384	



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C





Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10212	10497	10423	10677	10548	10888
Wt.of mold, g	W2	6697		6717		6694	
Wt.of wet sample, g	W3 = W1 - W2	3515	3800	3706	3960	3854	4194
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.67	1.81	1.76	1.88	1.83	1.99
Dry unit weight, g/cc	γw /(1+ W8/100)	1.29	1.33	1.36	1.40	1.43	1.52
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	487.6	406.0	412.6	419.2	426.0	462.4
Wt. of dry sample + cont., g	W4	394.4	321.3	336.6	333.6	350.0	371.7
Wt. of water, g	W5 = W3 - W4	93.2	84.69	75.94	85.64	76.01	90.7
Wt. of container, g	W6	81.53	83.07	82.59	81.79	83.11	83.62
Wt. of dry sample, g	W7 = W4 - W6	312.9	238.25	254.03	251.79	266.87	288.12
Moisture Content, %	W8 = W5/W7*100	29.8	35.5	29.9	34.0	28.5	31.5

SWELL DATA (Surcharge Weight 4.54kg)

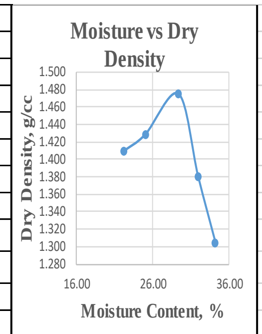
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.17	3.17	2.73	0	2.74	2.74	2.36	0	2.01	2.01	1.73

CBR DATA (4 days Soaked)

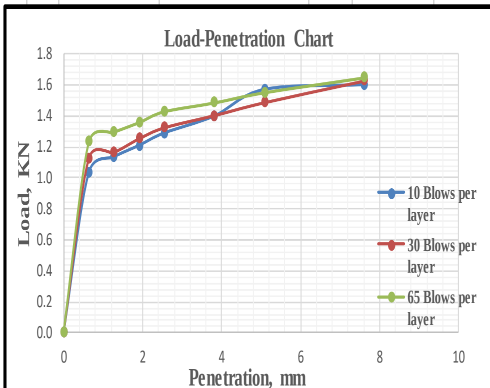
Ring factor 0.044 kN/div

Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		24	1.0			26	1.1			29	1.3		
1.27		25	1.1			29	1.3			29	1.3		
1.91		26	1.1			29	1.3			30	1.3		
2.54	13.35	28	1.2	1.21	9.1	32	1.4	1.39	10.4	34	1.5	1.47	11.0
3.81		30	1.3			33	1.5			35	1.5		
5.08	20	31	1.3	1.34	6.7	35	1.5	1.52	7.6	36	1.6	1.58	7.9
7.62		33	1.5			35	1.5			38	1.7		
Soaked CBR, %		9.1				10.4				11.0			
Dry Density, g/cc		1.29				1.36				1.43			
Swell, %		2.73				2.36				1.73			
Density Requirement:		95%		Target Density:			1.46			CBR		11.70	

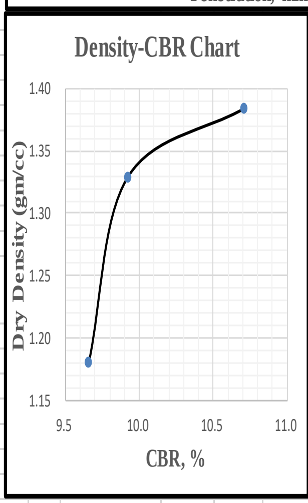
Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Bale Robe Teachers Collage at 1.5m depth											
BLOWS PER LAYER		56	No. OF LAYER	5	Material Description-		Rammer Weight		4.54Kg		
MOLD DIAMETER		150mm	Height of Mold	116mm	Soil+4%WSF(1.5cm)+6%C		Volume of Mold(mm3)		2049.9		
	Determination No		1		2		3		4		5
A	Weight of mold +wet soil(gm)		8729.9		8861.5		9113.1		8934.8		8790.4
B	Weight of mold(gm)		5201		5201		5201		5201		5201
C	Weight of wet soil(gm)	A-B	3528.9		3660.5		3912.1		3733.8		3589.4
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9
E	Wet density(Kg/m^3)	C/D	1.721		1.786		1.908		1.821		1.751
Moisture content determination(%)											
	Determiation No.		1		2		3		4		5
F	Container No.		341	38	337	21	202	214	22	232	43	89
G	Weight of container (gm)		15.19	16.06	15.67	15.14	17.67	15.84	16.9	16.34	17.87	16.09
H	Weight of container +wet soil(gm)		64.42	61.14	68.22	71.16	92.06	74.01	69.97	78.09	67.94	63.1
I	Weight of container +dry soil(gm)		55.23	53.2	57.78	59.87	75.25	60.74	56.9	63.41	54.89	51.4
J	Weight of water(gm)	H-I	9.19	7.94	10.44	11.29	16.81	13.27	13.07	14.68	13.05	11.7
K	Weigth of dry soil(gm)	I-G	40.04	37.14	42.11	44.73	57.58	44.9	40	47.07	37.02	35.31
L	Moisture content%	J/K	22.95	21.38	24.79	25.24	29.19	29.55	32.68	31.19	35.25	33.14
M	Average moisture content(%)		22.17		25.02		29.37		31.93		34.19
N	Dry density(Kg/m3)		1.409		1.428		1.475		1.381		1.305



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9957	10368	10424	10676	10511	10752
Wt.of mold, g	W2	6638		6693		6622	
Wt.of wet sample, g	W3 = W1 - W2	3319	3730	3731	3983	3889	4130
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.77	1.77	1.89	1.85	1.96
Dry unit weight, g/cc	γw /(1+ W8/100)	1.18	1.23	1.33	1.34	1.38	1.43
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	451.2	455.5	485.8	464.1	481.2	421.7
Wt. of dry sample + cont., g	W4	358.9	340.1	385.4	353.2	381.2	329.8
Wt. of water, g	W5 = W3 - W4	92.3	115.38	100.43	110.91	100.02	91.91
Wt. of container, g	W6	83.7	81.61	84.39	82	82.45	84.93
Wt. of dry sample, g	W7 = W4 - W6	275.2	258.51	300.96	271.17	298.71	244.86
Moisture Content, %	W8 = W5/W7*100	33.5	44.6	33.4	40.9	33.5	37.5



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.53	3.53	3.04	0	2.9	2.90	2.50	0	1.8	1.80	1.55

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		24	1.0			26	1.1			28	1.2		
1.27		26	1.1			27	1.2			30	1.3		
1.91		28	1.2			29	1.3			31	1.4		
2.54	13.35	29	1.3	1.29	9.7	30	1.3	1.32	9.9	33	1.4	1.43	10.7
3.81		32	1.4			32	1.4			34	1.5		
5.08	20	36	1.6	1.57	7.9	34	1.5	1.49	7.4	35	1.6	1.55	7.8
7.62		36	1.6			37	1.6			38	1.7		

	10	30	65
Soaked CBR, %	9.7	9.9	10.7
Dry Density, g/cc	1.18	1.33	1.38
Swell, %	3.04	2.50	1.55

Density Requirement: 95% Target Density: 1.41 CBR 10.58

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

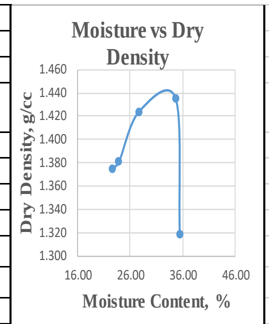
Bale Robe Teachers Collage at 1.5m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+4.5%WSF(1.5cm) +4%C	Rammer Weight	4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9	

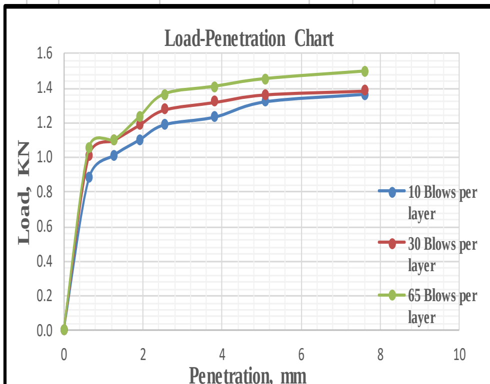
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8656.8	8708.1	8924.5	9164.5	8865.7
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3455.8	3507.1	3723.5	3963.5	3664.7
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.686	1.711	1.816	1.934	1.788

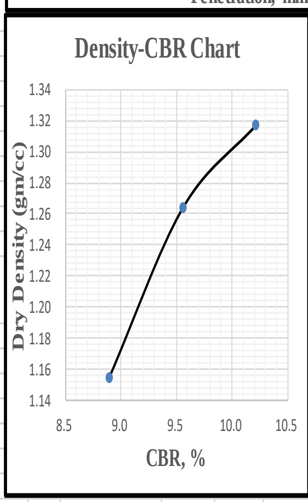
Moisture content determination(%)

	Determination No.		1		2		3		4		5	
F	Container No.		21	202	78	232	43	26	333	330	56	341
G	Weight of container (gm)		17.15	15.93	16.32	17.19	16.21	16.42	17.73	16.61	17.28	16.85
H	Weight of container +wet soil(gm)		70.2	86.36	56.64	94.53	67.53	61.63	52.19	77.3	64.37	65.27
I	Weight of container +dry soil(gm)		60.3	73.5	49.11	79.17	56.91	51.43	43.34	61.61	52.13	52.47
J	Weight of water(gm)	H-I	9.9	12.86	7.53	15.36	10.62	10.2	8.85	15.69	12.24	12.8
K	Weigth of dry soil(gm)	I-G	43.15	57.57	32.79	61.98	40.7	35.01	25.61	45	34.85	35.62
L	Moisture content%	J/K	22.94	22.34	22.96	24.78	26.09	29.13	34.56	34.87	35.12	35.93
M	Average moisture content(%)		22.64		23.87		27.61		34.71		35.53	
N	Dry density(Kg/m3)		1.375		1.381		1.423		1.435		1.319	



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C





Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9981	10261	10383	10600	10423	10703
Wt.of mold, g	W2	6646		6748		6614	
Wt.of wet sample, g	W3 = W1 - W2	3335	3615	3635	3852	3809	4089
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.72	1.73	1.83	1.81	1.94
Dry unit weight, g/cc	γw /(1+ W8/100)	1.16	1.16	1.26	1.25	1.32	1.34
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	458.8	468.8	474.9	459.5	460.2	413.9
Wt. of dry sample + cont., g	W4	357.0	343.3	370.3	340.9	357.3	310.6
Wt. of water, g	W5 = W3 - W4	101.8	125.43	104.62	118.61	102.88	103.39
Wt. of container, g	W6	82.71	82.51	84.35	83.97	81.72	82.42
Wt. of dry sample, g	W7 = W4 - W6	274.3	260.82	285.94	256.93	275.62	228.13
Moisture Content, %	W8 = W5/W7*100	37.1	48.1	36.6	46.2	37.3	45.3

SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.75	4.75	4.09	0	3.74	3.74	3.22	0	3.18	3.18	2.74

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

Penetration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		20	0.9			23	1.0			24	1.1		
1.27		23	1.0			25	1.1			25	1.1		
1.91		25	1.1			27	1.2			28	1.2		
2.54	13.35	27	1.2	1.19	8.9	29	1.3	1.28	9.6	31	1.4	1.36	10.2
3.81		28	1.2			30	1.3			32	1.4		
5.08	20	30	1.3	1.32	6.6	31	1.4	1.36	6.8	33	1.5	1.45	7.3
7.62		31	1.4			31.5	1.4			34	1.5		
Soaked CBR, %		8.9				9.6				10.2			
24		1.16				1.26				1.32			
Swell, %		4.09				3.22				2.74			
Density Requirement:		95%		Target Density:			1.37			CBR		10.51	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

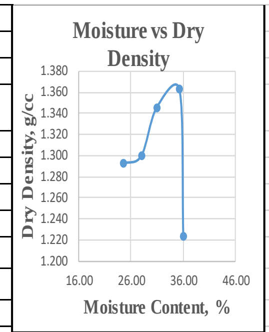
Bale Robe Teachers Collage at 1.5m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+5%WSF(1.5cm)+3%C	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

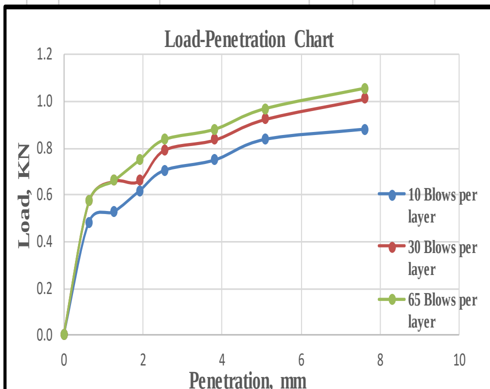
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8500.4	8612.2	8810.7	8982.3	8614.4
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3299.4	3411.2	3609.7	3781.3	3413.4
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.610	1.664	1.761	1.845	1.665

Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		321	25	78	336	329	38	58	333	54	26
G	Weight of container (gm)		16.14	15.98	15.38	16.29	15.86	16.12	17.37	16.73	17.01	15.8
H	Weight of container +wet soil(gm)		90.2	97.29	59.03	87.11	100.93	76.9	84.04	93.7	54.38	64.66
I	Weight of container +dry soil(gm)		75.68	81.2	49.69	71.25	80.85	62.54	67.1	73.06	44.59	51.55
J	Weight of water(gm)	H-I	14.52	16.09	9.34	15.86	20.08	14.36	16.94	20.64	9.79	13.11
K	Weigth of dry soil(gm)	I-G	59.54	65.22	34.31	54.96	64.99	46.42	49.73	56.33	27.58	35.75
L	Moisture content%	J/K	24.39	24.67	27.22	28.86	30.90	30.93	34.06	36.64	35.50	36.67
M	Average moisture content(%)		24.53		28.04		30.92		35.35		36.08	
N	Dry density(Kg/m3)		1.293		1.300		1.345		1.363		1.224	



Location and Depth- Bale Robe Teachers Collage at 1.5m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C

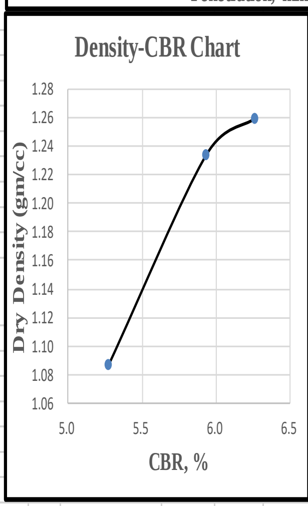


Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9968	10254	10374	10591	10414	10698
Wt.of mold, g	W2	6794		6761		6743	
Wt.of wet sample, g	W3 = W1 - W2	3174	3460	3613	3830	3671	3955
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.51	1.64	1.72	1.82	1.74	1.88
Dry unit weight, g/cc	γw /(1+ W8/100)	1.09	1.06	1.23	1.21	1.26	1.30

Moisture Content Determination

Wt. of wet sample + cont., g	W3	446.3	458.1	468.0	462.0	474.2	484.5
Wt. of dry sample + cont., g	W4	345.4	324.8	359.7	335.3	365.7	359.9
Wt. of water, g	W5 = W3 - W4	100.9	133.31	108.35	126.67	108.44	124.53
Wt. of container, g	W6	84.58	81.39	82.23	84.84	83.59	81.3
Wt. of dry sample, g	W7 = W4 - W6	260.8	243.38	277.45	250.48	282.14	278.64
Moisture Content, %	W8 = W5/W7*100	38.7	54.8	39.1	50.6	38.4	44.7



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	5.35	5.35	4.61	0	4.97	4.97	4.28	0	4.11	4.11	3.54

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

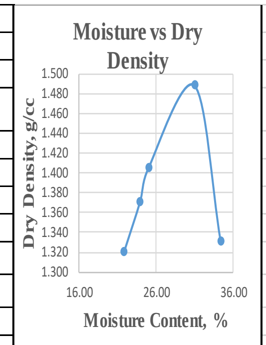
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		11	0.5			13	0.6			13	0.6		
1.27		12	0.5			15	0.7			15	0.7		
1.91		14	0.6			15	0.7			17	0.7		
2.54	13.35	16	0.7	0.70	5.3	18	0.8	0.79	5.9	19	0.8	0.84	6.3
3.81		17	0.7			19	0.8			20	0.9		
5.08	20	19	0.8	0.84	4.2	21	0.9	0.92	4.6	22	1.0	0.97	4.8
7.62		20	0.9			23	1.0			24	1.1		
Soaked CBR, %		5.3				5.9				6.3			
24		1.09				1.23				1.26			
Swell, %		4.61				4.28				3.54			
Density Requirement:		95%		Target Density:		1.29				CBR		6.34	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)							
Bale Robe Teachers Collage at 3m depth							
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+1%WSF(1.5cm)+0%C	Rammer Weight	4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9	

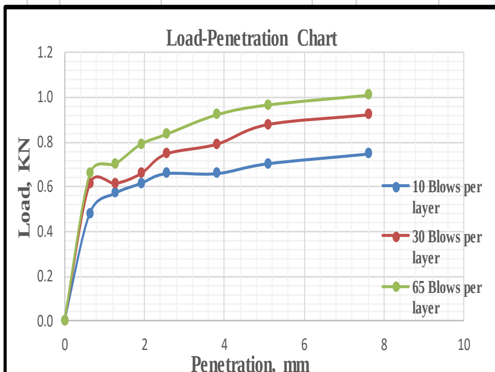
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8501.3	8683.1	8803.4	9197.8	8869.5
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3300.3	3482.1	3602.4	3996.8	3668.5
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.610	1.699	1.757	1.950	1.790

Moisture content determination(%)

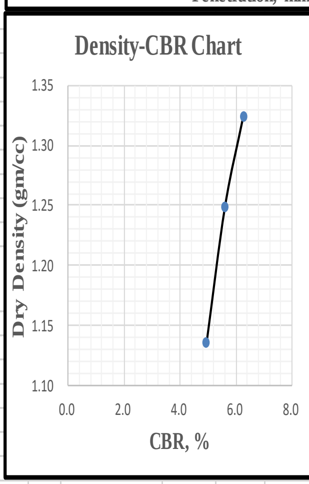
	Determiation No.		1		2		3		4		5	
F	Container No.		12	40	67	341	23	67	322	43	30	336
G	Weight of container (gm)		16.86	17.33	15.03	16.47	17.14	16.38	16.57	15.73	17.49	16.35
H	Weight of container +wet soil(gm)		81.22	87.47	69.39	63.63	98.09	78.48	119.9	47.68	95.59	54.73
I	Weight of container +dry soil(gm)		69.64	74.92	58.73	54.68	81.92	66.02	95.27	40.18	75.78	44.83
J	Weight of water(gm)	H-I	11.58	12.55	10.66	8.95	16.17	12.46	24.63	7.5	19.81	9.9
K	Weigth of dry soil(gm)	I-G	52.78	57.59	43.7	38.21	64.78	49.64	78.7	24.45	58.29	28.48
L	Moisture content%	J/K	21.94	21.79	24.39	23.42	24.96	25.10	31.30	30.67	33.99	34.76
M	Average moisture content(%)		21.87		23.91		25.03		30.99		34.37	
N	Dry density(Kg/m3)		1.321		1.371		1.406		1.489		1.332	



Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+1%WSF(1.5cm Length)+0%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9973	10372	10381	10666	10611	10801
Wt.of mold, g	W2	6663		6739		6745	
Wt.of wet sample, g	W3 = W1 - W2	3310	3709	3642	3927	3866	4056
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.57	1.76	1.73	1.87	1.84	1.93
Dry unit weight, g/cc	γw /(1+ W8/100)	1.14	1.21	1.25	1.29	1.32	1.36
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	415.2	459.0	489.6	419.5	507.3	463.7
Wt. of dry sample + cont., g	W4	322.7	340.4	377.0	315.3	388.7	351.0
Wt. of water, g	W5 = W3 - W4	92.5	118.6	112.61	104.27	118.66	112.74
Wt. of container, g	W6	81.52	82.32	84.6	83.72	81.98	82.7
Wt. of dry sample, g	W7 = W4 - W6	241.2	258.06	292.41	231.53	306.7	268.28
Moisture Content, %	W8 = W5/W7*100	38.4	46.0	38.5	45.0	38.7	42.0



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	5.76	5.76	4.97	0	5.67	5.67	4.89	0	4.16	4.16	3.59

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		11	0.5			14	0.6			15	0.7		
1.27		13	0.6			14	0.6			16	0.7		
1.91		14	0.6			15	0.7			18	0.8		
2.54	13.35	15	0.7	0.66	4.9	17	0.7	0.75	5.6	19	0.8	0.84	6.3
3.81		15	0.7			18	0.8			21	0.9		
5.08	20	16	0.7	0.70	3.5	20	0.9	0.88	4.4	22	1.0	0.97	4.8
7.62		17	0.7			21	0.9			23	1.0		
Soaked CBR, %		4.9				5.6				6.3			
24		1.14				1.25				1.32			
Swell, %		4.97				4.89				3.59			
Density Requirement:		95%		Target Density:				1.42		CBR		6.84	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

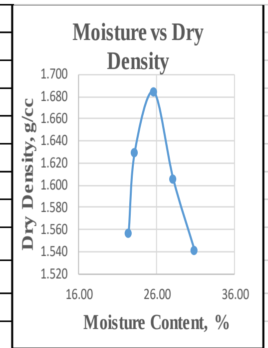
Bale Robe Teachers Collage at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm	Soil+2%WSF(1.5cm)+8%C	Volume of Mold(mm3)	2049.9

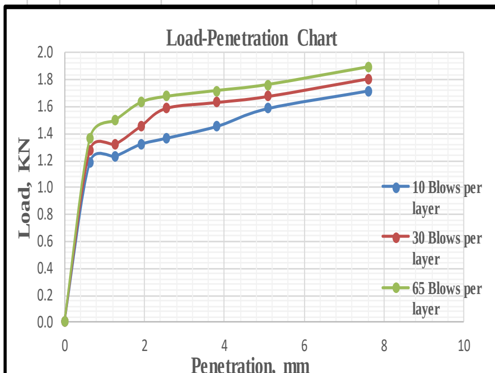
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		9104.1	9313.7	9535.5	9414.9	9332.8
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3903.1	4112.7	4334.5	4213.9	4131.8
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.904	2.006	2.114	2.056	2.016

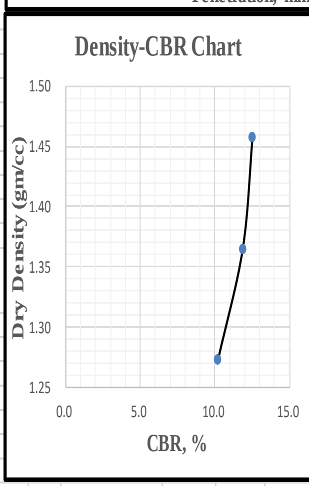
Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		22	202	341	337	214	89	38	38	30	43
G	Weight of container (gm)		17.27	16.81	15.94	16.02	17.26	16.47	17.39	15.18	16.61	15.19
H	Weight of container +wet soil(gm)		68.27	78.1	75.29	89.62	81.47	91.29	68.91	73.88	59.11	73.19
I	Weight of container +dry soil(gm)		59.18	66.63	63.92	76.07	67.84	76.73	57.52	61.12	49.22	59.38
J	Weight of water(gm)	H-I	9.09	11.47	11.37	13.55	13.63	14.56	11.39	12.76	9.89	13.81
K	Weigth of dry soil(gm)	I-G	41.91	49.82	47.98	60.05	50.58	60.26	40.13	45.94	32.61	44.19
L	Moisture content%	J/K	21.69	23.02	23.70	22.56	26.95	24.16	28.38	27.78	30.33	31.25
M	Average moisture content(%)		22.36		23.13		25.55		28.08		30.79	
N	Dry density(Kg/m3)		1.556		1.629		1.684		1.605		1.541	



Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+2%WSF(1.5cm Length)+8%C





Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	10120	10410	10423	10692	10678	10854
Wt.of mold, g	W2	6627		6687		6673	
Wt.of wet sample, g	W3 = W1 - W2	3493	3783	3736	4005	4005	4181
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.66	1.80	1.77	1.90	1.90	1.99
Dry unit weight, g/cc	γw /(1+ W8/100)	1.27	1.27	1.37	1.38	1.46	1.45

Moisture Content Determination

Wt. of wet sample + cont., g	W3	451.4	403.3	430.2	450.5	422.8	442.7
Wt. of dry sample + cont., g	W4	365.9	309.0	350.1	350.4	343.8	345.8
Wt. of water, g	W5 = W3 - W4	85.5	94.35	80.06	100.11	79.01	96.95
Wt. of container, g	W6	83.56	81.78	83.16	84.14	84.11	81.15
Wt. of dry sample, g	W7 = W4 - W6	282.4	227.18	266.93	266.23	259.64	264.64
Moisture Content, %	W8 = W5/W7*100	30.3	41.5	30.0	37.6	30.4	36.6

SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.04	2.04	1.76	0	1.61	1.61	1.39	0	0.99	0.99	0.85

CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		27	1.2			29	1.3			31	1.4		
1.27		28	1.2			30	1.3			34	1.5		
1.91		30	1.3			33	1.5			37	1.6		
2.54	13.35	31	1.4	1.36	10.2	36	1.6	1.58	11.9	38	1.7	1.67	12.5
3.81		33	1.5			37	1.6			39	1.7		
5.08	20	36	1.6	1.58	7.9	38	1.7	1.67	8.4	40	1.8	1.76	8.8
7.62		39	1.7			41	1.8			43	1.9		

Soaked CBR, %	10.2	11.9	12.5
24	1.27	1.37	1.46
Swell, %	1.76	1.39	0.85

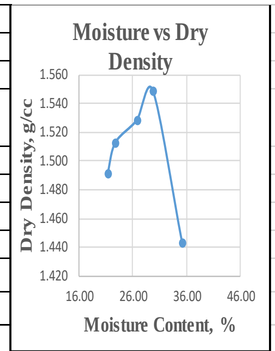
Density Requirement:	95%	Target Density:	1.60	CBR	14.40

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

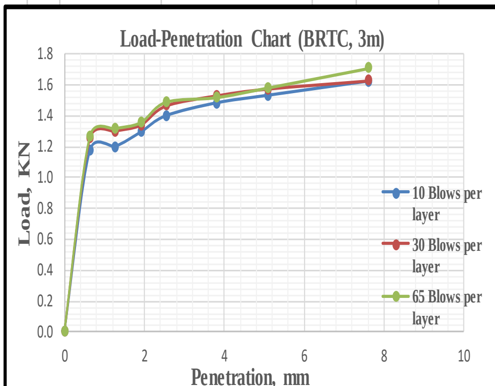
Bale Robe Teachers Collage at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+3%WSF(1.5cm)+7%C	Rammer Weight	4.54Kg		
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9		

	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8911.3		9008.8		9174.5		9321.7		9201.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3710.3		3807.8		3973.5		4120.7		4000.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.810		1.858		1.938		2.010		1.951	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		21	321	30	333	58	54	326	26	214	329
G	Weight of container (gm)		17.43	16.89	16.01	15.93	16.09	17.67	15.74	15.38	16.69	17.53
H	Weight of container +wet soil(gm)		99.74	74.4	91.6	112.65	49.64	68.84	107.14	56.61	98.64	123.36
I	Weight of container +dry soil(gm)		85.9	63.84	77.22	95.15	42.91	57.48	86.23	47.12	77.6	95.38
J	Weight of water(gm)	H-I	13.84	10.56	14.38	17.5	6.73	11.36	20.91	9.49	21.04	27.98
K	Weigth of dry soil(gm)	I-G	68.47	46.95	61.21	79.22	26.82	39.81	70.49	31.74	60.91	77.85
L	Moisture content%	J/K	20.21	22.49	23.49	22.09	25.09	28.54	29.66	29.90	34.54	35.94
M	Average moisture content(%)		21.35		22.79		26.81		29.78		35.24	
N	Dry density(Kg/m3)		1.492		1.513		1.529		1.549		1.443	

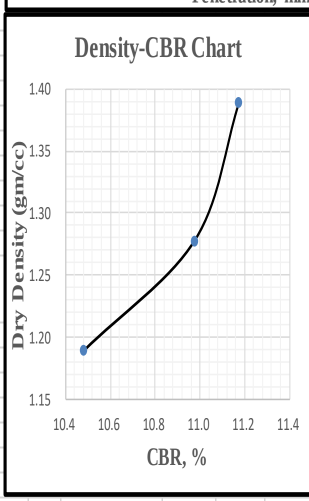


Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+3%WSF(1.5cm Length)+7%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9989	10366	10375	10717	10544	10812
Wt.of mold, g	W2	6654		6794		6639	
Wt.of wet sample, g	W3 = W1 - W2	3335	3712	3581	3923	3905	4173
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.58	1.76	1.70	1.86	1.86	1.98
Dry unit weight, g/cc	γw /(1+ W8/100)	1.19	1.25	1.28	1.34	1.39	1.45
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	443.0	465.4	417.6	438.7	460.8	484.2
Wt. of dry sample + cont., g	W4	353.6	353.8	334.0	338.5	365.8	375.9
Wt. of water, g	W5 = W3 - W4	89.5	111.61	83.52	100.14	95.01	108.33
Wt. of container, g	W6	83.93	81.73	81.65	84.14	82.62	83.22
Wt. of dry sample, g	W7 = W4 - W6	269.6	272.08	252.38	254.38	283.21	292.69
Moisture Content, %	W8 = W5/W7*100	33.2	41.0	33.1	39.4	33.5	37.0



SWELL DATA (Surcharge Weight 4.54kg)

No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.58	2.58	2.22	0	2.23	2.23	1.92	0	1.6	1.60	1.38

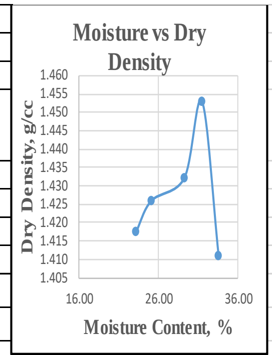
CBR DATA (4 days Soaked)

Ring factor 0.044 kN/div

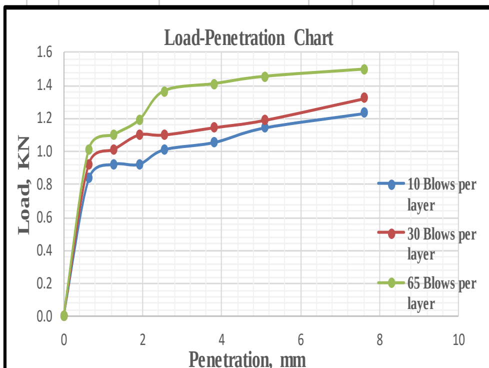
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		27	1.2			29	1.3			29	1.3		
1.27		27	1.2			30	1.3			30	1.3		
1.91		29	1.3			31	1.3			31	1.4		
2.54	13.35	32	1.4	1.40	10.5	33	1.5	1.47	11.0	34	1.5	1.49	11.2
3.81		34	1.5			35	1.5			35	1.5		
5.08	20	35	1.5	1.53	7.7	36	1.6	1.58	7.9	36	1.6	1.58	7.9
7.62		37	1.6			37	1.6			39	1.7		
Soaked CBR, %		10.5				11.0				11.2			
Dry Density, g/cc		1.19				1.28				1.39			
Swell, %		2.22				1.92				1.38			
Density Requirement:		95%		Target Density:		1.47				CBR		11.51	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)							
Bale Robe Teachers Collage at 3m depth							
BLOWS PER LAYER	56	No. OF LAYER	5	Material Description-Soil+4%WSF(1.5cm)+ 6%C	Rammer Weight	4.54Kg	
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9	

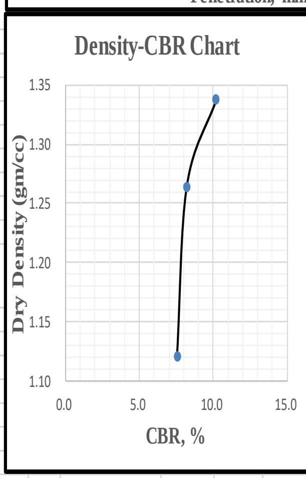
	Determination No		1		2		3		4		5	
A	Weight of mold +wet soil(gm)		8780.5		8857.7		8995.1		9116.4		9063.3	
B	Weight of mold(gm)		5201		5201		5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3579.5		3656.7		3794.1		3915.4		3862.3	
D	Volume of mold(cm^3)		2049.9		2049.9		2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.746		1.784		1.851		1.910		1.884	
	Moisture content determination(%)											
	Determiation No.		1		2		3		4		5	
F	Container No.		336	58	30	202	214	43	89	341	21	38
G	Weight of container (gm)		17.03	16.33	15.74	15.4	15.52	16.82	17.8	16.73	15.97	15.41
H	Weight of container +wet soil(gm)		115.6	78.46	89.53	59.79	57.63	93.63	103.6	53.83	92.51	71.62
I	Weight of container +dry soil(gm)		96.8	66.94	74.47	51.04	48.34	75.83	83.64	44.71	73.15	57.6
J	Weight of water(gm)	H-I	18.83	11.52	15.06	8.75	9.29	17.8	19.96	9.12	19.36	14.02
K	Weigth of dry soil(gm)	I-G	79.77	50.61	58.73	35.64	32.82	59.01	65.84	27.98	57.18	42.19
L	Moisture content%	J/K	23.61	22.76	25.64	24.55	28.31	30.16	30.32	32.59	33.86	33.23
M	Average moisture content(%)		23.18		25.10		29.24		31.46		33.54	
N	Dry density(Kg/m3)		1.418		1.426		1.432		1.453		1.411	



Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+4%WSF(1.5cm Length)+6%C



Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9970	10324	10317	10541	10580	10721
Wt.of mold, g	W2	6713		6659		6716	
Wt.of wet sample, g	W3 = W1 - W2	3257	3611	3658	3882	3864	4005
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.55	1.72	1.74	1.84	1.84	1.90
Dry unit weight, g/cc	γw /(1+ W8/100)	1.12	1.20	1.26	1.32	1.34	1.37
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	460.2	411.1	470.8	414.2	451.1	422.0
Wt. of dry sample + cont., g	W4	356.2	312.9	365.2	321.3	351.7	327.1
Wt. of water, g	W5 = W3 - W4	103.9	98.17	105.61	92.82	99.39	94.91
Wt. of container, g	W6	82.26	81.95	82.73	84.92	84.57	82.93
Wt. of dry sample, g	W7 = W4 - W6	274.0	230.99	282.45	236.41	267.1	244.14
Moisture Content, %	W8 = W5/W7*100	37.9	42.5	37.4	39.3	37.2	38.9



SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	2.89	2.89	2.49	0	2.4	2.40	2.07	0	2.01	2.01	1.73

CBR DATA (4 days Soaked)													
Ring factor		0.044	kN/div										
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		19	0.8			21	0.9			23	1.0		
1.27		21	0.9			23	1.0			25	1.1		
1.91		21	0.9			25	1.1			27	1.2		
2.54	13.35	23	1.0	1.01	7.6	25	1.1	1.10	8.2	31	1.4	1.36	10.2
3.81		24	1.1			26	1.1			32	1.4		
5.08	20	26	1.1	1.14	5.7	27	1.2	1.19	5.9	33	1.5	1.45	7.3
7.62		28	1.2			30	1.3			34	1.5		
Soaked CBR, %		7.6				8.2				10.2			
Dry Density, g/cc		1.12				1.26				1.34			
Swell, %		2.49				2.07				1.73			
Density Requirement:			95%		Target Density:			1.38		CBR		10.20	

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)

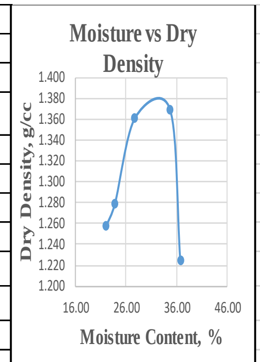
Bale Robe Teachers Collage at 3m depth

BLOWS PER LAYER	56	No. OF LAYER	5	Material Description- Soil+4.5%WSF(1.5cm)+4%C	Rammer Weight	4.54Kg
MOLD DIAMETER	150mm	Height of Mold	116mm		Volume of Mold(mm3)	2049.9

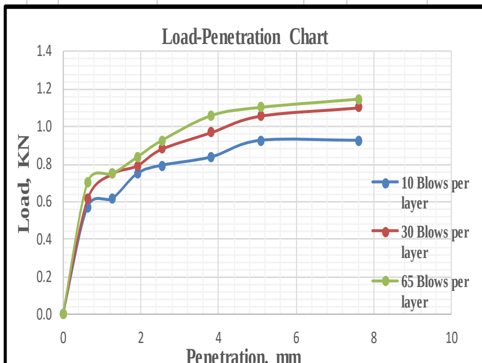
	Determination No		1	2	3	4	5
A	Weight of mold +wet soil(gm)		8348.1	8445.5	8767.3	8982.1	8631.8
B	Weight of mold(gm)		5201	5201	5201	5201	5201
C	Weight of wet soil(gm)	A-B	3147.1	3244.5	3566.3	3781.1	3430.8
D	Volume of mold(cm^3)		2049.9	2049.9	2049.9	2049.9	2049.9
E	Wet density(Kg/ m^3)	C/D	1.535	1.583	1.740	1.845	1.674

Moisture content determination(%)

	Determiation No.		1		2		3		4		5	
F	Container No.		30	214	277	58	38	336	21	36	337	202
G	Weight of container (gm)		16.01	15.92	15.67	17.32	16.48	15.99	16.53	17.77	16.43	16.21
H	Weight of container +wet soil(gm)		49.27	102.31	78.94	86.14	111.63	64.52	90.85	61.99	72.29	83.93
I	Weight of container +dry soil(gm)		42.96	87.52	67.2	72.51	91.26	53.82	71.53	50.7	57.33	65.68
J	Weight of water(gm)	H-I	6.31	14.79	11.74	13.63	20.37	10.7	19.32	11.29	14.96	18.25
K	Weigth of dry soil(gm)	I-G	26.95	71.6	51.53	55.19	74.78	37.83	55	32.93	40.9	49.47
L	Moisture content%	J/K	23.41	20.66	22.78	24.70	27.24	28.28	35.13	34.28	36.58	36.89
M	Average moisture content(%)		22.04		23.74		27.76		34.71		36.73	
N	Dry density(Kg/m3)		1.258		1.279		1.362		1.369		1.224	

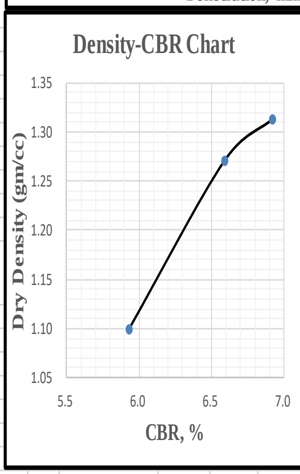


Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+4.5%WSF(1.5cm Length)+4%C



Unit Weight Determination

No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9921	10252	10399	10587	10488	10662
Wt.of mold, g	W2	6692		6684		6647	
Wt.of wet sample, g	W3 = W1 - W2	3229	3560	3715	3903	3841	4015
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.53	1.69	1.76	1.85	1.82	1.91
Dry unit weight, g/cc	γw /(1+ W8/100)	1.10	1.11	1.27	1.27	1.31	1.32
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	408.1	452.1	423.8	410.2	407.7	472.0
Wt. of dry sample + cont., g	W4	315.9	325.8	328.4	307.0	316.9	351.7
Wt. of water, g	W5 = W3 - W4	92.2	126.3	95.38	103.24	90.86	120.3
Wt. of container, g	W6	82.27	84.82	82.72	81.54	83.42	81.3
Wt. of dry sample, g	W7 = W4 - W6	233.6	240.97	245.67	225.43	233.45	270.42
Moisture Content, %	W8 = W5/W7*100	39.5	52.4	38.8	45.8	38.9	44.5



SWELL DATA (Surcharge Weight 4.54kg)

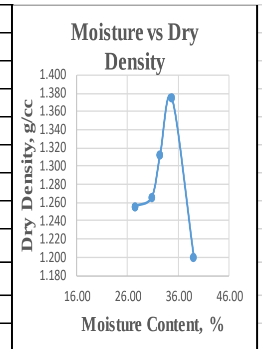
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	4.36	4.36	3.76	0	4.05	4.05	3.49	0	3.34	3.34	2.88

CBR DATA (4 days Soaked)

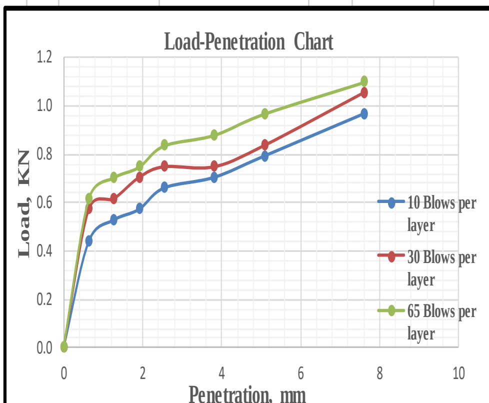
Ring factor 0.044 kN/div

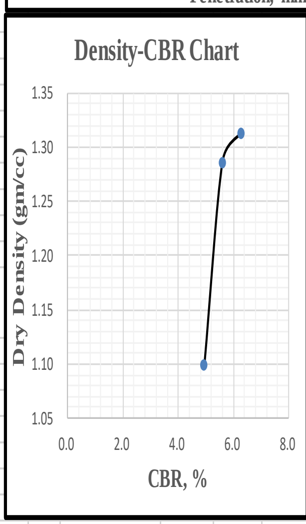
Penet-ration (mm)	Std load (kN)	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %	Gauge reading	Load kN	Corrected CBR kN	Corrected CBR %
0		0	0.0			0	0.0			0	0.0		
0.64		13	0.6			14	0.6			16	0.7		
1.27		14	0.6			17	0.7			17	0.7		
1.91		17	0.7			18	0.8			19	0.8		
2.54	13.35	18	0.8	0.79	5.9	20	0.9	0.88	6.6	21	0.9	0.92	6.9
3.81		19	0.8			22	1.0			24	1.1		
5.08	20	21	0.9	0.92	4.6	24	1.1	1.06	5.3	25	1.1	1.10	5.5
7.62		21	0.9			25	1.1			26	1.1		
Soaked CBR, %	5.9					6.6				6.9			
Dry Density, g/cc	1.10					1.27				1.31			
Swell, %	3.76					3.49				2.88			
Density Requirement:	95%		Target Density:			1.30				CBR	6.80		

Determination of Maximum Dry Density(Kg/m3) and Optimum Moisture Content(%)											
Bale Robe Teachers Collage at 3m depth											
BLOWS PER LAYER		56	No. OF LAYER		5	Material Description-		Rammer Weight		4.54Kg	
MOLD DIAMETER		150mm	Height of Mold		116mm	Soil+5%WSF(1.5cm)+3%C		Volume of Mold(mm3)		2049.9	
	Determination No		1		2	3		4		5	
A	Weight of mold +wet soil(gm)		8483.6		8593.1	8762.3		8996.1		8619.7	
B	Weight of mold(gm)		5201		5201	5201		5201		5201	
C	Weight of wet soil(gm)	A-B	3282.6		3392.1	3561.3		3795.1		3418.7	
D	Volume of mold(cm^3)		2049.9		2049.9	2049.9		2049.9		2049.9	
E	Wet density(Kg/ m^3)	C/D	1.601		1.655	1.737		1.851		1.668	
Moisture content determination(%)											
	Determiation No.		1		2	3		4		5	
F	Container No.		330	329	333	21	26	321	56	78	25	54
G	Weight of container (gm)		16.18	16.24	16.01	16.11	16.39	16.44	16.34	16.5	15.52	17.11
H	Weight of container +wet soil(gm)		65.35	63.1	58.63	68.14	74.22	82.17	79.45	87.89	67.06	52.67
I	Weight of container +dry soil(gm)		54.28	53.43	48.44	56.12	60.05	66.13	62.7	70.08	53.15	42.33
J	Weight of water(gm)	H-I	11.07	9.67	10.19	12.02	14.17	16.04	16.75	17.81	13.91	10.34
K	Weigth of dry soil(gm)	I-G	38.1	37.19	32.43	40.01	43.66	49.69	46.36	53.58	37.63	25.22
L	Moisture content%	J/K	29.06	26.00	31.42	30.04	32.46	32.28	36.13	33.24	36.97	41.00
M	Average moisture content(%)		27.53		30.73		32.37		34.69		38.98	
N	Dry density(Kg/m3)		1.256		1.266		1.312		1.375		1.200	



Location and Depth- Bale Robe Teachers Collage at 3m depth/Material Description:-Soil+5%WSF(1.5cm Length)+3%C





Unit Weight Determination							
No. of Blows per Layer		10		30		65	
CONDITION OF SAMPLE		Before soaking	After soaking	Before soaking	After soaking	Before soaking	After soaking
Wt.of wet sample + mold, g	W1	9988	10374	10483	10643	10531	10804
Wt.of mold, g	W2	6785		6740		6731	
Wt.of wet sample, g	W3 = W1 - W2	3203	3589	3743	3903	3800	4073
Volume of mold, cc	V	2105		2105		2105	
Wet unit weight, g/cc	γw = W3 / V	1.52	1.70	1.78	1.85	1.81	1.93
Dry unit weight, g/cc	γw /(1+ W8/100)	1.10	1.14	1.29	1.26	1.31	1.34
Moisture Content Determination							
Wt. of wet sample + cont., g	W3	423.1	401.3	370.4	435.2	427.1	464.8
Wt. of dry sample + cont., g	W4	328.2	296.6	291.2	321.9	333.3	347.8
Wt. of water, g	W5 = W3 - W4	94.9	104.67	79.16	113.24	93.84	117.02
Wt. of container, g	W6	81.3	84.97	83.82	81.19	82.81	84.03
Wt. of dry sample, g	W7 = W4 - W6	246.9	211.63	207.37	240.72	250.46	263.75
Moisture Content, %	W8 = W5/W7*100	38.4	49.5	38.2	47.0	37.5	44.4

SWELL DATA (Surcharge Weight 4.54kg)												
No. of Blows	10				30				65			
Initial Height of Sample:	Gauge reading		Swell		Gauge reading		Swell		Gauge reading		Swell	
	Initial	Final	mm	%	Initial	Final	mm	%	Initial	Final	mm	%
116 mm	0	3.88	3.88	3.34	0	2.96	2.96	2.55	0	2.59	2.59	2.23

CBR DATA (4 days Soaked)														
Ring factor		0.044	kN/div											
Penet-ration (mm)	Std load (kN)	Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		Gauge reading	Load	Corrected CBR		
			kN	kN	%		kN	kN	%		kN	kN	%	
0		0	0.0			0	0.0			0	0.0			
0.64		10	0.4			13	0.6			14	0.6			
1.27		12	0.5			14	0.6			16	0.7			
1.91		13	0.6			16	0.7			17	0.7			
2.54	13.35	15	0.7	0.66	4.9	17	0.7	0.75	5.6	19	0.8	0.84	6.3	
3.81		16	0.7			17	0.7			20	0.9			
5.08	20	18	0.8	0.79	4.0	19	0.8	0.84	4.2	22	1.0	0.97	4.8	
7.62		22	1.0			24	1.1			25	1.1			
Soaked CBR, %		4.9				5.6				6.3				
Dry Density, g/cc		1.10				1.29				1.31				
Swell, %		3.34				2.55				2.23				
Density Requirement:		95%		Target Density:			1.30			CBR		5.96		

Appendix 8 Cristallinity Size Calculation

Crystallinite size calculation for treated wheat straw and untreated wheat straw

Crystallinite size calculation for treated wheat straw					
No.	B obs. [°2Th]	B std. [°2Th]	Peak pos. [°2Th]	B struct. [°2Th]	Crystallite size [Å]
1	1.086	0.008	10.792	1.078	74
2	1.086	0.008	15.509	1.078	74
3	1.086	0.008	19.816	1.078	75
4	1.448	0.008	23.318	1.44	56
5	1.086	0.008	33.94	1.078	77
6	1.086	0.008	35.892	1.078	77
7	1.448	0.008	41.636	1.44	59
8	1.448	0.008	44.85	1.44	60
9	1.086	0.008	53.93	1.078	83
					Avg=70.56A
					7.056nm

Crystallinite size calculation for untreated wheat straw					
No.	B obs. [°2Th]	B std. [°2Th]	Peak pos. [°2Th]	B struct. [°2Th]	Crystallite size [Å]
1	1.448	0.008	10.2	1.44	55
2	3.621	0.008	15.544	3.613	22
3	1.086	0.008	23.759	1.078	75
4	1.086	0.008	26.6	1.078	76
5	1.448	0.008	35.992	1.44	58
6	1.448	0.008	50.44	1.44	61
7	1.086	0.008	55.015	1.078	83
					Avg=61.43A
					6.143nm