Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Geotechnical Engineering Stream

Engineering Properties of Expansive Clay Soil stabilized with stone dust (A Case Study of Jimma City).

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfilment of the Requirement of Degree of Master of Science in Civil Engineering (Geotechnical Engineering).

By:

Asmamaw Balcha

March, 2020

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By:

Asmamaw Balcha

Main advisor: Prof. Emer T. Quezon, P. Eng

Co-advisor: Mr. Shelema Amena, MSc

March, 2020

Jimma Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled: "Engineering Properties of Expansive Clay Soil stabilized with stone dust (A Case Study of Jimma City)" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for this thesis have been duly acknowledged.

Candidate:

Asmamaw Balcha

Signature___________________________

As Master's Research Advisors, we hereby certify that we have read and evaluated this MSc Thesis prepared under our guidance by Asmamaw Balcha entitled: "Engineering Properties of Expansive Clay Soil stabilized with stone dust (A Case Study of Jimma City)".

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T. Quezon, P.Eng	[signature]	3 / 17 /2020
Main Advisor	Signature	Date
Mr. Shelema A., MSc.	____________	____/____/____
Co- Advisor	Signature	Date

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ABSTRACT

Expansive soil is one of soil type, which experiences significant volume change upon rainy and dry season. When it gets water, it swells and when it is dry, it became shrinking. It is not suitable for all type of infrastructure. The seasonal movement of such materials causes contract of the ground surface in the dry season and expand during the rainy season, which is the most challenging tasks for the geotechnical engineers. Therefore, to overcome such problems of expansive soil the stabilization method is very crucial. Therefore, blending expansive soil with granite stone dust stabilization method can improve the geotechnical properties of expansive soil and to increases the bearing capacity of soil used for sub grade and Shallow foundation of the structure. The purpose of this study is treating the expansive soil with stone dust to minimize damage that can happen due to the problem of expansive soil. This study focused on the Engineering properties of clay expansive soils blended with stone dust to improve the geotechnical properties of expansive soils by adding at 5%, 10%, 15%, 20%, and 25% Percentages of stone dust. The study area is in Jimma town. In this study, a Soil sample was excavated at 1.5m and 3m. Laboratory tests were conducted to determine moisture content, free swell test, grain size analysis, specific gravity, Hydrometer test, Atterberg limits, and compaction test; California Bearing Ratio and CBR swell tests, UCS and Complete silcate analysis test. Depending on the tests to be conducted in the laboratory the optimum percentage of stone dust are obtained at 15%. The Laboratory test result indicates the addition of stone dust to expansive soil improves the strength of the expansive soil. The OMC Varies from 31.4 to 17.653 and the MDD also varies from 1.327 g/cm3 to 1.644g/cm3.This value indicated that there is improvement in the engineering properties of expansive soil. The CBR of the value is increases from the 2.52% to 27.3%. The addition of stone dust highly increases the plastic limit and decreases the liquid limit, plasticity index, and shrinkage index of the expansive soil sample. Generally, it as the addtion of stone dust ratio increased the FS, LL, PL, OMC, CBR swell decreased and inversely the PL, MDD, CBR and UCS are increased and recommended that blending of expansive soil with stone dust can be used to increase the strength capacity of foundation and subgrade.in addition the stone dust can be gained with low cost, locally available and finally makes our environment to became safe.

Keywords: - bearing capacity blended CBR, expansive soil, index property, stabilization, stone dust, swelling and sub grade.

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ACRONYMS

AASHTO	American Association of State Highway and Transportation
AC	Activity of clay
ASTM	Society for testing and Materials
BCS	Black cotton soil
IS	Indian Standard
CBR	California Bearing Ratio
CSA	Central static agency
ESS1	Expansive soil one
ESS2	Expansive soil two
ESS3	Expansive soil three
FDRE	Federal Democratic Republic of Ethiopia
TP	Test Pit
SD	Stone Dust
ERA	Ethiopia Road Authority
FS	Free swelling
LL	Liquid Limit
JU	Jimma University
LS	Lateritic soil
NWC	Non- woven coil
OV	Oven dry
OMC	Optimum moisture content
PI	Plastic index
PL	Plastic limit
PSD	Particle size distribution

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Expansive soils are found all over the world which are inorganic clay to high compressibility and subjected to high shrinkage, high swelling potential and low bearing capacity. It is not suitable for the infrastructure. This leads to the construction of buildings on poor soils, which eventually lead to structural foundation failures.

Expansive soils are characterized by very low bearing capacity, high compressibility, low permeability and high volume change under changing moisture conditions. They tend to lose strength further upon wetting and other physical disturbances. These soils are especially troublesome as pavement sub grades and unsuitable for construction of embankments, buildings or other light structures in their natural state. [1].

The expansive soils are the one, which is more problematic for soils undergo swelling and shrinkage behavior as the moisture content changes in it Due to high shrinkage and swelling. For a safe construction project, it is necessary to improve the quality of the ground by adopting a suitable ground improvement technique in the project site. The values at 30% stone dust are also full fill the requirement of sub base material but when we are getting our suitability of admixes on lower percentage of stone dust. [2]

The present study was obtained the optimum percentage at addition of 15% of stone dust. Therefore, the addition of stone dust improves the engineering properties of soft soil from the researcher. From recent studies, it is observed that solid waste materials such as stone dust are used for a different type of structure. The damages may occur slowly over time and affect infrastructure at different times. Further, the cost associated with expansive soils damage total several cost and leads to delay of a construction project in Ethiopia

In this research to evaluate, the performance of expansive soils blended with the stone dust for possible improvement of the geotechnical engineering characteristics of soil and provides an opportunity to use the expansive soil for construction purpose. Stone dust is a waste material produced from aggregate crushing industries. The quantities of these waste materials imposing a hazardous effect on the environment and public health issues. To eliminate the adverse effect of these waste materials which can be disposed of in a proper and safe manner. Expansive soil is the engineering characteristics which mainly affected by fluctuation of moisture content. It is known as swelling soils, or shrink-swell soils. [3]

In our local from the previous study, there is a problem of expansive soil due to the fluctuation of wet and dry in the soil. According to past researcher, Jimma is one of the largest towns which are predominantly covered with red, black and gray soils. The red colored soils are located on higher elevations and good drained condition. In contrast, the black and gray soils are found in the part of the town having flat topography and unfavorable drainage condition. [4]

So replacing the expansive soil by select material is very expensive, so the present study indicate that the possibility of stone dust used with a minimum cost and overcome the problem happened due to expansive soil. Therefore, by stabilizing expansive soil with stone dust it is provide an opportunity to use the expansive soil for different infrastructure.

Generally, Expansive soils are high plasticity, compressible, and when contact with water; it becomes soft. Therefore, this softening leads to reduction of shear strength and leading to low bearing capacity.

1.2 Statements of the problem

Expansive soil is worldwide problem, which affects all infrastructures where this soil existing. The effect of stone dust on the geotechnical properties of weak soil, and concluded that the CBR and MDD of poor soils could be improved by mixing stone dust in the experiment. The liquid limit, plasticity index, and optimum moisture content decreases by adding stone dust that could turn into increase the usefulness of soil as highway sub-grade material. [5]

The expansive soils damage the structure built on it when it contacts with water, particularly light buildings and transportation infrastructures, in many countries. [6]

The estimation of damage caused by expansive soils contribute much to the burden that natural hazards cause on the economy each year-only flooding causes more damage than expansive soils. An appropriate, cost-effective technique must be used to improve the expansive soils can be the great benefit to both public and private to avoid the damage caused due to expansive soils on the structure.

In our country, there is a problem of expansive soil in different infrastructure due to change in moisture content. When there is much water the soil will swell and when it is dry it became shrinking. This leads a lot of problem in the structure constructed. like deformation, crack settlement and others. So this research is being conducted to overcome this problem by stabilizing agent called stone dust. The expansive soils are known by their property of stiff and fissured. These features suggest the presence of an extensive amount of expansive clay minerals. The deformations in the form of cracks represent a serious engineering problem for engineering structures; such as cracks in different infrastructure.

In the present study area, in Jimma town there is a problem of Expansive soil according to the past researcher. Jimma town soils are exposed by problem of expansive soil that needs treatment. In order to manage the problem, the research was done to evaluate the engineering properties of Jimma Expansive Clay which was stabilized with cement and lime as admixture. The use of lime and cement stabilizers increases the strength of expansive soil by filling void space of soil particles and reducing plasticity index. [7].

To overcome this problem treating the expansive soil with stone dust is very important in improving the engineering properties of soil. In addition, in order to get good bearing capacity of the soil this stabilization method is important.

1.3 Research Question

- How to evaluate and will improve the engineering property of expansive soil?
- What is the optimum percentage of stone dust used to stabilize in Jimma town for Expansive soil?
- What is the effect of stone dust at different percentage adding to Expansive soil?

1.4 Objectives of the study

1.4.1 General objective

- The general objective of the study is to treat Engineering properties of Expansive soil blended with stone dust stabilize and to improve the geotechnical properties of expansive soils for different construction.

1.4.2 Specific objectives

This study was undertaken on blending expansive and stone dust of typically found in the Jimma zone using various techniques, with the following objectives: -

1. To evaluate the engineering properties of the expansive soils and Granite stone dust.
2. To Determining the optimum percentage of granite stone dust required to stabilize expansive soil.
3. To Analysis the effect of the treating expansive soils with granite stone dust.

1.5 Scope of the study

The test was conduct for small number of sample and may be this indicates indicative rather than indicate the detailed stabilization method which used to treat the expansive soil. Furthermore, selected test that are very important to achieve the Specific of the research have been included. The sampling areas were limited to three because of time and money limitation.

1.6 Significance of the Study

This research is very significant for different infrastructure to the research incorporated the suitability of using stone dust for construction industries. In recent years, environmental issues big deal problem so to handle this problem stabilization of stone dust is very important since the dust particle can affect the environment.

This study was providing the improvement of expansive soil using stone dust. The purpose of adding stone dust to expansive soil is to improve the geotechnical properties and in order to get the safe, stable and durable structure. Owners, contractors, and consultants can get some benefit from the study as a source of information for building construction and in the road projects, in the case of Jimma city in the area of required soil improvement and existence of expansive soil. The study was being provided lessons that can help the concerned body can come up with appropriate measures to address problems caused by expansive soil. This work is brought to evaluate the expansive soils blended with the stone dust for possible improvement on their geotechnical characteristics and provide the opportunity to use the expansive soil for construction purpose.

1.7 Justification of the study

The reasoning for conducting this study was providing to improve the engineering property of expansive soil treated with stone dust. This study was performed because of expansive soil is exist as the world and the study were improving the geotechnical properties of expansive soil, Since the Jimma zone is highly covered with expansive soil. Improving the problem of expansive soil gives a lot of function for our infrastructure that is why study was needed to conduct this research. in laboratory by adding different percentage of stone dust to expansive soil it was improved the engineering properties this results to was to get a stable, long life, durable structure and made to minimizing structural damage caused by expansive soil.

CHAPTER TWO

2 REVIEW LITERATURE

This chapter provides some literature review on the improvement of the engineering property of expansive soil using stone dust mechanism. Under this chapter, the main purpose is looking to establish the academic and research areas that are relevant to the subject under study.

2.1 Expansive clay Soil

Now days, the problem of failure of structure is due to soil property varying so for this research were used a type of clay soil called Expansive soil which is change due to moisture content. It is necessary to provide the convenience of the type of soil for the purpose of describing the various materials encountered in the site exploration. Most of the soil classify in to coarse, fine, and organic. And the different types of clay soil have different physical and mechanical property.

Expansive soil is one type of clay soil. Expansive soils have own their characteristics to the presence of swelling clay minerals. As it gets wet, the clay minerals which absorb water molecules and it became expand and when it dries they shrink, leaving large voids in the soil. The Potentially expansive soils can get from the laboratory by their plastic properties. Inorganic clays of high plasticity, expansive clay soils can be easily recognized in the dry season by the deep cracks, in roughly polygonal patterns, in the ground surface.

Expansive soils are clay soil; which experiences significant volume change upon the wet and dry season. The seasonal movements of such materials cause the setting of the ground surface in the dry season and expand during the rainy season. This put in a difficult position and most challenging tasks for the geotechnical engineers to design structure on expansive soil and stone dust is a waste material that it gets from the artificial aggregate.

2.2 Identification of expansive soil

Geotechnical characteristics of expansive soils, with respect to bearing capacity, stress and deformation are highly sensitive to variation in moisture change of the clay soil. Such soils properties considerable volume changes on difference of their moisture content of the soil. The change in volume is often associated with loss of shear strength and deformation. These phenomena can cause a significant hazard to infrastructures, in particular lightweight structures, founded on such soils. Engineering problems due to expansive soils were reported from different parts of the world.

Identification and quantitative classification of expansive soils are very critical importance in geotechnical investigations. The purpose identification of expansive soil to ensure proper site selection, environmental compatibility, and economical designing, avoid construction delay as well as succeeding performance in infrastructure. Expansive soils can be characterized and classified based on their free swell, shrinkage limit and activity of the soil. [8]

2.3 Soil Improvements

2.3.1 Theoretical review

Soil improvement is of major concern in the construction activities due to rapid growth of urbanization and industrialization. The soil improvement is used for the techniques which improve the index properties and other engineering characteristic of weak soils. These expansive soils cover the entire world. In India expansive soil cover about 0.8x106 km2 area which is approximately one-fifth of its surface area. These soils contain montmorillonite mineral due to this they swell and shrink excessively with change of water content. Such tendency of soil is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place. Expansive soils can be stabilized by the addition of a small percentage of admixtures. These techniques have been used for many construction purposes, notably in highway, railroad and airport construction to improve sub grades. [9]

The gap of the present study is improving the geotechnical properties of expansive soil by blending with stone dust rather than used other admixture because of the stone dust is available and cost effective.

Also in our country Ethiopia Expansive soil is to be widely spread in. Although the extent and range of distribution of this problematic soil has not been studied thoroughly; the southern, south west part of the city of Addis Ababa areas, where most of the recent construction are being carried out and central part of Ethiopia following the major truck roads like Addis-Wolliso, DebreBirhan, Addis-Gohatsion, and Addis-Modjo are covered by expansive soils. Also areas like Mekele, Gambella and jimma are covered by expansive soil. [10]

Soil, from geotechnical engineering point of view, is defined as a natural aggregate of mineral grains, with or without organic constituents that can be separated by gentle mechanical means such as agitation in water, by contrast, rock is considered a natural aggregate of mineral grains connected by strong and permanent cohesive forces. According to the researcher, the processes of weathering of the rock decrease the cohesive forces binding the mineral grains and leads to the disintegration of bigger masses to smaller and particles. [11]

The soil samples in natural state and when mixed with varying percentages of lime and waste stone powder were used for the laboratory tests that included Atterberg limits tests, grain size analysis, standard Proctor compaction tests, unconfined compression tests and California bearing ratio tests. The results show significant reduction in plasticity and changed the optimum moisture content and maximum dry density of clayey soil with increasing percentage content of waste stone powder and lime. The results of the unconfined compressive strength (UCS) and California bearing ratio (CBR) tests show that at the different curing times, the addition of waste stone powder and lime caused an increase in the value of UCS up to 6% waste stone powder content and 7% lime content, and increase in the value of CBR to 6% waste stone powder content and 9% lime content. [12]

The gap of this study fills the ratios of stone dust used and the study only used stone dust as stabilizer rather than used two stabilizers at the same time because of time, availability and cost wastage. the excepted result of CBR, shrinkage limit, MDD and decreases the OMC, free swell and swelling potential of CBR

The research studied conducted compaction, plasticity, and strength laboratory tests on gravel soil using various percentages of stone dust contents, and found that by addition of stone dust, the plasticity characteristics had reduced and CBR of the mixes improved. Addition of 25, 35% of stone dust makes the gravel soil meet the specification of more as sub-base material. [13]

Presented the results of an experimental programmed undertaken to investigate the effect of stone dust and fly ash mixing in different percentage on expansive soil. They had observed that at optimum percentages, i.e., 20 to 30% of admixture, the swelling of expansive clay was almost controlled, and there is a marked improvement in other properties of the soil as well. It was concluded by them that the ratio of equal proportion of stone dust and fly ash content, is more effective than the addition of stone dust/ fly ash alone to the expansive soil in controlling the swelling nature. The main problem with regard to construction with tropically weathered soils is not in non-suitability but lack of adequate knowledge of behavior under different conditions and, therefore to use that soil as construction material it required to know the physical and mechanical properties of that soil and make it familiar for the engineers. [14]

The gap of this research is in the above literature it uses stone dust and fly ash together but the present study was used stone dust alone. Among the several alternatives for the improvement of expansive soil with stone dust is available and it is important in regarding to the economic and availability

Carried out The MDD of soil was found to increase with the increase in percentage of Stone Dust. On the other hand, OMC of soil decreases with the increase in percentage of Stone Dust. The CBR of soil first increases with the increase in percentage of stone dust from 0% to 30% and subsequently it decreases on further increasing the stone dust content to 50%. Thus optimum percentage of soil mixed with stone dust is at 30%. [15]

the suitability of stabilized black cotton soils with cement and quarry dust for road sub-base and foundations by mixing with 0- 6% cement and 0-20% quarry dust by weight of dry soil content. The laboratory tests such as California bearing ratio (CBR), unconfined compressive strength (UCS) and Compaction and from the test results, indicated there was an improvement in the Atterberg limit of the soil, including a decrease in the plasticity index (PI), liquid limit (LL), plastic limit (PL). In addition, there was an increase in maximum dry density (MDD) with an increase in quarry dust content in all cement proportions used and as compared with the values obtained from the natural soil. It was also observed that as QD increased the UCS and CBR values of the stabilized, black cotton soil increased with compaction effort. For their experiment, the peak UCS value of 1880KN/M 2 obtained from soil stabilized composed of 6% cement and 20% QD contents, and 186 % of the CBR value. The economic analysis of their research revealed that stabilized expansive soil with 6% cement and 20% QD results in savings of approximately 20% cots compared with the only cement stabilized the soil. [16]

The effect of quarry dust with different percentage of expansive soil, Atterberg's limits, compaction and CBR tests conducted on both unmodified and modified soil. From their experimental results, the addition of the Quarry dust to the soil had reduced the clay content, and it showed an increased in the amount of coarser particles, reduced the liquid limit of about 26.86% and plasticity index by 28.48% of unmodified soil. While, the OMC of soils there was a decreased by 36.71%, maximum dry density of soil increased by 5.88% by the addition of (40%) Quarry dust, and it is also identified that the addition of (40%) Quarry dust yields high CBR value [17]

The effects of adding quarry dust mixtures indicate that The dry density will increase with the addition of quarry dust and decreased in the optimum moisture content. [18]

The effect of quarry dust on geotechnical properties of soil, which was used in highway construction projects, and concluded that the CBR value steadily increased with an increase in the percentage of quarry dust content, and the improvement in CBR value, can be contributed to the significant improvement in the angle of shearing resistance. Higher CBR values of soil quarry dust mixes enhance their potential for use as a sub-base for flexible pavement. Quarry dust is considered as one of the well accepted as well as cost-effective ground improvement technique for weak soil deposits. These provide the primary function of reinforcement and drainage and thus improving the strength and deformation. [19]

the evaluation of marble dust for soil stabilization of expansive soil, usage of marble dust was investigated for soil stabilization in the scope of utilization of waste material. Soil stabilization is the process of altering the properties of a soil by applying some modifiers to meet specified Engineering requirements of road pavement layers. Soil stabilization can be taken as alternate to borrow selected materials and it has advantage that the effect to the environment is reduced and in areas where selected/granular materials are scarce, stabilization have comparative economic advantage. The presence of organic matters and sulphates affects the effectiveness of stabilizers. In road projects with weak sub grades, it is common practice to provide capping layers between the sub grade and the sub-base. The capping layer is of granular material of less quality of the specification requirement for sub-base material. [20]

The study brings carried out in the laboratory to evaluate the effectiveness of using foundry sand and fly ash with tile waste for soil stabilization by studying the compaction and strength characteristics for use as a sub-grade material. These wastes impose hazardous effect on environment and human health. These materials cannot be disposed of properly and their disposal is not economical. Utilization by exploiting their inherent properties is the one of the way to solve the above stated problem. The effect of mixing different proportions of foundry sand, fly ash and tile waste with clayey soil on compaction and California bearing ratio have been studied in this study. [21]

The geotechnical properties of stabilized expansive soil with quarry dust mixes indicate that suitability of waste material that is quarry dust for stabilization of expansive soil. Quarry dust is mixed with expansive soil sample in different proportions and their influence on geotechnical properties of expansive soil was studied. In this paper, the test results such as shear strength parameters, soaked CBR and differential free swell obtained on expansive clays mixed with different proportions of Quarry dust are presented. Also the performance of quarry dust treated expansive soil is discussed on the basis of cyclic plate load test criteria. From the results, it is observed that at optimum percentage, i.e.,10% quarry dust, there is a marked improvement in the strength of soil. [22]

The experimental study on the investigates the suitability of using waste glass(WG) as an admixture to cement stabilized black cotton soil(BCS) for roads, fills an embankment. The soil was stabilized with 0, 2, 4, 6 and 8% cement and 0, 5, 10, 15, and 20% WG by weight of the dry soil. Laboratory tests were carried out using the Standard Proctor (SP) compaction efforts, California Bearing Ratio (CBR) and compaction characteristics test to evaluate the effectiveness of WG on Ordinary Portland cement (OPC) stabilized BCS. The results obtained showed a decrease in the plasticity index (PI), liquid limit (LL), plastic limit (PL), and increase maximum dry density (MDD) with an increase in WG content in all cement proportions used and as compared to the values obtained for the natural soil. The peak 7 days UCS values of 1152kN/m 2 were obtained at 8% OPC and 20% WG. Similarly, the highest CBR value of 53.8% was obtained at an optimum blend of 8% OPC/20%WG. The results indicate that there is a potential in the use of WG as the admixture to strengthen Black cotton soils. [23]

The experimental study on load settlement behavior of sandy soil blended with coarse aggregate the plate load tests were conducted to study the sand blended with a coarse aggregate of various sizes and proportions. To strengthen the subsoil layers, coarse aggregates of 10mm and 20mm sizes were mixed with the sand in various proportions. The soil samples were prepared and tested first without mixing coarse aggregates, then by mixing coarse aggregates in varying percentages by weight starting from 5% to 30%. [24]

Performed the experimental study on sand, as a soil stabilizer an experimental program carried was out in this study aims to highlight the physical and mechanisms of stabilization of an expansive soil by adding an inert material (sand). The study aimed to analyze the effect of stabilization on the variation of soil consistency and the results have shown that soil consistency improved significantly. [25]

The experimental study on stabilization of black cotton soil with sand and non-woven coir explore the influence of Non-Woven Coir (NWC)/coir fiber mixed with black cotton soil used as sub grade material. The study performs by mixing black cotton soil with coir fiber in varying percentage of 0.15%-0.75% and the sand of 3%-15% and properties of soil evaluated. Addition of non-woven coir in BC soil improved the properties of soil. The Optimum content of non-woven coir was found to be 0.45%. In this case, CBR increases 67.8% as compared to CBR of virgin soil. CBR value gradually increases with an increase in sand and non-woven coir for different percentage, had got more stability when confined than other soil fills and show negligible long-term settlement and also used as the stabilizing agent. It was observed that CBR of black soil increased approximately linearly with an increase when the inclusion of NWC and sand. [26]

Generally, from the entire researcher the following conclusions can be drawn from the experimental work carried out in this investigation. When fly ash and stone dust is added to the expansive soils the Atterberg's limits, OMC, FSI is decreased and MDD, UCS, CBR values are increased. The optimum percentages of fly ash and stone dust observed are 25% and 30% respectively for improving the properties of expansive soils. It is observed from the study that the performance of stone dust is much more effective when compared to fly ash. Major construction (particularly dams, roads, foundation, and airfields) in countries lying within the tropical regions of the world like Ethiopia, necessitates using local materials. Many of these materials are suitable from an engineering point of view, some are not, but the responsibility of the differentiation lies with the engineer who, though, how many large, has been instructed in the use of that material for required construction by adjusting them as favorable for the required construction. Therefore, it is very important to have to look for the improvement of the expansive black cotton clay soil using different material based on their strength and economical evaluation of those materials. [21]

2.4 Material for Stabilizer

The additive material that used for this research is stone dust. In order to get a safe, stable, durable, and long life structure, this research used stabilization technique. So this study was used stone dust to improve Engineering properties of Expansive soil. So to get safe, good long life foundation and the sub grade of the different structure treating expansive soil is very important since the sub grade and the foundation is a platform for construction of the different infrastructure. The upper layer of this natural soil must stabilize to increase its strength, stiffness, and/or stability. For pavements constructed on embankment fills, the sub grade is a compacted borrows material. Other geotechnical aspects of the sub grade of interest in pavement design include the depth to rock and the depth to the groundwater table, especially if either of these is close to the surface

Stabilization is a broad sense for the various methods employed and modifying the properties of a soil to improve its engineering performance and used for a variety of engineering works. Soil stabilization is broadly used in connection with road, pavement and foundation construction. It improves the engineering properties of the soil in terms of volume stability, strength, and durability. [27]

soil stabilization is the adjustment of one or more soil properties to improve the geotechnical engineering characteristics and performance of the soil. Soil stabilization may result in any one or more of the following changes on the geotechnical property of the soil this can be achieved by mechanical or chemical methods. Soil type is one of the key features used to determine, which method and material should be used for achieving the best stabilization. Understanding the engineering properties of soil is crucial to obtain the required strength and economically suitable soil. Soil stabilization blended with stone dust is the process of maximizing the suitability of a soil for a given construction design purpose. It is possible to stabilize material using different material but regarding to cost and availability of material is important in getting to be structure stable and safe.

2.4.1 Granite Stone Dust

stone dust is the being a byproduct material when finishing and shaping of building stones in the stone crusher plant for the stabilization of clay soil. And also this Quarry stone dust produced from the process of Granite stone. the use of stone dust is not only as reduce the widely known environmental impacts if waste but also it attains a social responsibility, which control the use of the non-renewable resources and suggest a way for the construction industry to meet its increasing demands for material structures like building, airports, highways, tunnels are to be built, is soft and expansive and these type of soil do not have the properties which are desired for construction, so the best solution for stabilization or improve the soil. Therefore, the search for material to be used in soil stabilization is the field in which interest for researchers to resolve the problems related to the swelling of expansive clayey soil. [28]

Stone dust is a kind of solid waste material that is generated from stone crushing industry which is abundantly available. Disposal of such wastes poses lots of environmental problems such as landfill disposal problems, health and environmental hazards. The best way to eliminate these problems is to make use such waste. The experimental study was conducted on locally available soil by mixing it with Stone Dust. [29]

For this study, stone dust can get from aggregate, which means from Artificial Aggregate stone dust is byproduct material. If it is not used, it may lead environmental effects effect but if it used as stabilizing it decrease the environmental effect and also play a great role in social responsibility's if we study detail, we can possible to for every structure was expansive soil we occur. Stone dust results from creatures highly affect changes in the natural moisture content of the material and changes in the physical properties of the material

2.5 Engineering properties of Expansive soil

Soil is consisted of a multi-phase aggregation of a solid particles, water, and air. This composition of soils provides a rise to unique engineering properties investigation, and the description of its mechanical behavior needs some of the most classic principles of engineering mechanic. [30]

Engineering properties of the soil concerned with soil's mechanical properties: permeability, stiffness, and strength. These depend primarily on the physical properties of the soil nature of the grains, the current stress, the water content, and unit weight of the soil.

2.5.1 Mechanical Properties of Expansive soil

The soil has a surprisingly diverse set of mechanical properties. The empirical and theoretical study of soil mechanics has progressed to the point where soil engineers are able to consider a wide variety of mechanical properties when they design structures that involve large quantities of soil. [31]

Most of the soil is subjected by some external force. The force provides the result of changing the soil from one condition into another and the reaction showed a kind and a degree of change. Therefore, if one is to be able either to maintain a soil condition or to change it to a more suitable condition, he must first have an understanding of soil behavior;

because this behavior changes, so we have to consider the force and behavior of soil before any types of structural works are starting on the soil.

2.5.2 Physical properties of soil

The basic physical properties of soil are those that require defining the physical state of the soil. For the purpose of analysis and design, it is necessary to quantify the three constituent phases (solid, liquid and gas) and to be able to express their relationships in numerical terms. [32]

The physical properties of soil enable to determine the water content, density, porosity, specific gravity and other property of soil. The physical property of stabilizer called stone dusts which get from artificial aggregate is; specific gravity, index properties, compaction and California bearing ratio. [32]

2.6 Soil Stabilization

The new challenges of today in construction are poor foundation materials such as organic soils, old landfills, expansive and collapsing soils and non-availability of the material. So to overcome this problem study about soil from the original is very important

Based on their mode of origin, rocks can be divided into three basic types: igneous, sedimentary, and metamorphic.

Igneous rocks are formed by the solidification of molten magma ejected from deep within the earth's mantle. Different types of igneous rock are formed. Granite, gabbro, and basalt are some of the common types of igneous. [33]

Sedimentary rock also can be formed by chemical processes. The sedimentary rocks are categorized as chemical sedimentary rock. The chemical sedimentary rocks are the Composition Rock, Calcite, ($CaCO3$) Limestone, Halite ($NaCl$) Rock salt, Dolomite [$CaMg(CO3)$] Dolomite, Gypsum ($CaSO4$.) [34]

Metamorphic rock derived from several igneous, sedimentary, and low-grade metamorphic rocks with a well-foliated texture and visible flakes of platy and micaceous minerals. Metamorphic rock generally contains large quantities of quartz and feldspar as well. Marble is formed from calcite and dolomite by re crystallization. The mineral grains in marble are larger than those present in the original rock. Green marbles are colored by hornblendes, serpentine, or talc. Black marbles contain bituminous material, and brown marbles contain iron oxide and limonite. Quartzite is a metamorphic rock formed from quartz-rich sandstones. Silica enters into the void spaces between the quartz and sand grains and acts as a cementing agent. Quartzite is one of the hardest rocks. Under extreme heat and pressure, metamorphic rocks may melt to form magma, and the cycle is repeated [33]

Soils are formed by weathering of rocks. Weathering is the process of breaking down rocks by mechanical and chemical processes into smaller pieces. In chemical weathering, the original rock minerals are transformed into new minerals by chemical reaction. Water and carbon dioxide from the atmosphere form carbonic acid, which reacts with the existing rock minerals to form new minerals and soluble salts. Soluble salts present in the groundwater and organic acids formed from decayed organic matter also cause chemical weathering. An example of the chemical weathering of orthoclase to form clay minerals, silica, and soluble potassium carbonate Mechanical weathering is caused by the. Expansion and contraction of rocks from the continuous gain and loss of heat, which results in ultimate disintegration. The physical properties of soil are dictated primarily by the minerals that constitute the soil particles and, hence, the rock from which it is derived. The mineral grains that form the solid phase of a soil aggregate are the product of rock weathering. The size of the individual grains varies over a wide range. Many of the physical properties of soil are dictated by the size, shape, and chemical composition of the grains. [33]

Soil stabilization may be generally defined as the adjustment of one or more soil properties to improve the geotechnical engineering characteristics and performance of the soil. Soil stabilization may result in any one or more of the following changes on the geotechnical property of the soil: - increase the drain ability of the soil, stability, sharing resistance and bearing capacity of soil and reduce volume changes, settlement, control the undesirable effects associated with. [34]

this can be achieved by mechanical or chemical methods. Soil type is one of the key features used to determine, which method and material should be used for achieving the best stabilization. Understanding the engineering properties of soil is crucial to obtain the required strength and economically suitable soil. Stabilization is the process of maximizing the suitability of a soil for a given construction design purpose.

2.7 Mode of Stabilization

2.7.1 Mechanical Stabilization

By mixing or blending soils with stone dust, provide for good gradations to obtain a material meeting the required specification. The soil blending can be used at the where different infrastructure constructed. The blended material then spread and compacted at required densities by conventional means. Also with the increase in fine content, the efficacy of the method may decrease. Mechanical stabilization result increases the strength of the soil as well as a reduction in settlement of a soil.

2.7.2 Chemical Stabilization

Chemical stabilization is the mixing of expansive soil with one or a combination of admixtures of powder, slurry or liquid. Chemical stabilization results in the modification of the soil through chemical reactions taking place between the stabilizer and the minerals present in the soil. Among the various chemical stabilization techniques adopted for expansive soils, additive stabilization is most widely adopted for controlling the swell-shrink properties of expansive soils [35]

The addition of inorganic and organic chemical compounds can increase the strength, bearing capacity and durability of soils these chemical compounds perform mainly as cementations and binding agents or as waterproof or as water repellant agent. The changes in the consistency of clay soils induced by many of these compounds are also important. The addition of chemicals to the soils improves the geotechnical properties of soils. These chemical whether it is organic or inorganic chemical compounds which are acts as cementations and bonding action. [35]

Cement, lime slag, fly ash, sodium silicate etc. are used as inorganic stabilizer whereas Bituminous materials are used as an organic stabilizer The addition of chemical agents such as cement, cement kiln dust fly ash lime or a combination of these to soils, result in the formation of cementations bonds between soil particles and stabilizers and the physical and mechanical properties of the soil are altering significantly.

2.7.3 Modification Method

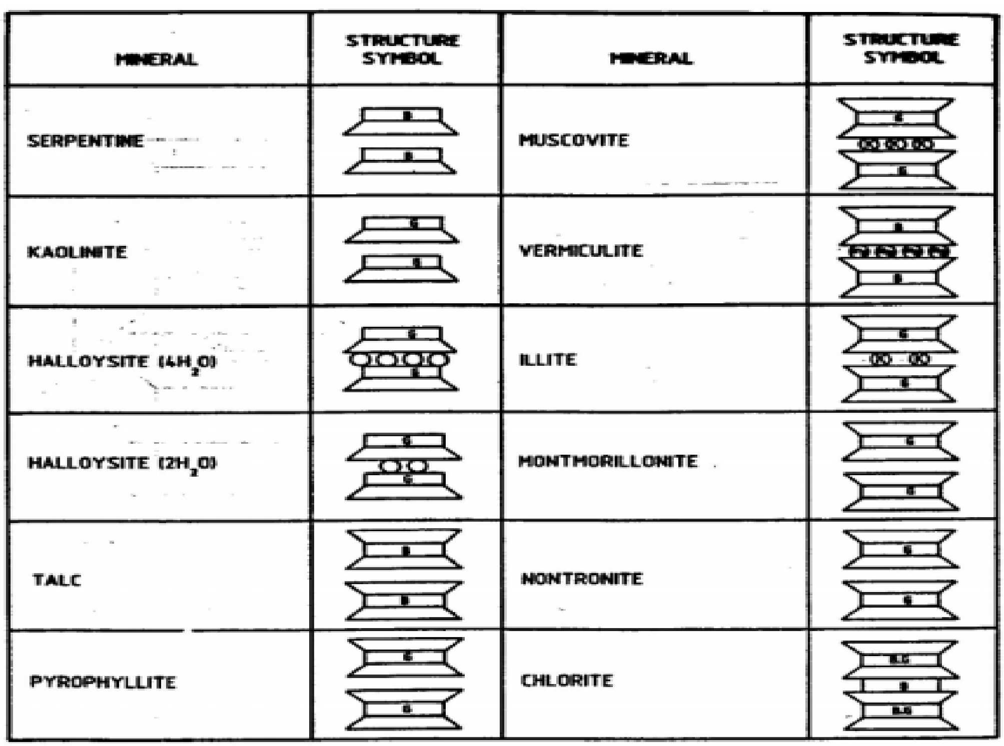
Soil stabilization by modification usually results in something less that a thoroughly cemented hardened or semi-hardened material. This can be accomplished by compacting by mechanical blending, by adding stone dust materials in small amounts or by adding chemical modifiers. It can reduce the plasticity of clay soils.

2.7.4 Additive Method

The additive refers to a manufactured commercial product that when added to the soil in proper quantities, was improve the quality of the soil layer the additive substance is improving the expansive soil. The selection and the amount of additive percentage were based on the soil type and degree of improvement in soil quality desired but always small amount of the additive is high changes the geotechnical engineering property of the soil such as gradation, workability and plasticity, it improves the strength and durability sufficiently to permit a thickness reduction design in all over.

The most common clay minerals found in tropical soils are grouped as Kaolinite and montmorillonite. They are essentially hydrous aluminum silicates. Since clays minerals are of chemical weathering of rocks, both climates, which determines weathering and the parent rock influence the type of minerals found.

Montmorillonite is also formed when chemical alterations take place within poorly drained soils in an alkaline environment and in the presence of magnesium ions. Kaolinite is a non-expansive clay mineral with low activity and is found in soils. Illite has properties intermediate between Kaolinite and Montmorillonite. It occurs widely in sedimentary rocks in temperate zone. The below figure shows the mineral names and structure diagrams of the various clay minerals are shown in figure below



MINERAL	STRUCTURE SYMBOL	MINERAL	STRUCTURE SYMBOL
SERPENTINE		MUSCOVITE	
KAOLINITE		VERMICULITE	
HALLOYSITE (4H$_2$O)		ILLITE	
HALLOYSITE (2H$_2$O)		MONTMORILLONITE	
TALC		NONTRONITE	
PYROPHYLLITE		CHLORITE	

Figure 2-1 Structure diagram and properties of the various clay minerals. [36]

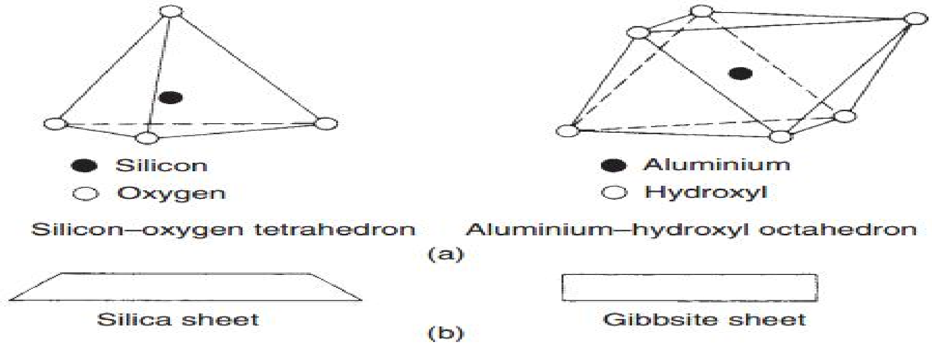


Figure 2-2: Clay minerals basic units [37]

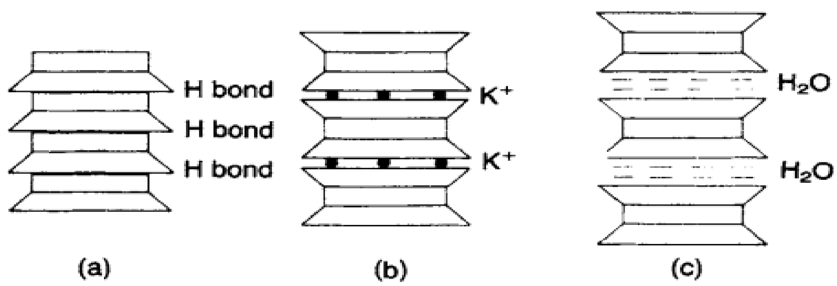


Figure 2-3:Clay minerals: (a) kaolinite, (b) illite and (c) montmorillonite. [37]

Of the three important clay minerals, kaolinite consists of repeating layers of elemental silica-gibbsite sheets in the layers are held together by hydrogen bonding. Kaolinite occurs as platelets. Illite consists of a gibbsite sheet bonded to two silica sheets one at the top and another at the bottom. It is sometimes called clay mica. The illite layers are bonded by potassium ions. The negative charge to balance the potassium ions comes from the substitution of aluminum for some silicon in the tetrahedral sheets. [37]

In montmorillonite there is isomorphous substitution of magnesium and iron for aluminum in the octahedral. Potassium ions are not present as in illite, and a large amount of water is attracted into the space between the layers. Particles of montmorillonite have lateral dimensions the greatest problem arises when montmorillonite mineral content in the soil is high. Thus, soil needs to be stabilized in order to make it suitable for construction. Soil stabilization is a common engineering technique used to improve the physical properties of weak soil and make it capable of achieving the desired engineering requirements. [38].

Besides kaolinite, illite and montmorillonite, other common clay minerals generally found are chlorite, halloysite, vermiculite, and attapulgite. The clay particles carry a net negative charge on their surfaces. This is the result both of isomorphous substitution and of a break in continuity of the structure at its edges. Larger negative charges are derived from larger specific surfaces. Some positively charged sites also occur at the edges of the particles. A list of the reciprocal of the average surface densities of the negative charges on the surfaces of some clay minerals follows. Oxygen Hydroxyl Aluminum, iron, magnesium Silicon, occasionally aluminum. Some partially hydrated cations in the pore water are also attracted to the surface of clay particles. These cations attract dipolar water molecules. The force of attraction between water and clay decreases with distance from the surface of the particles. This orientation of water around the clay particles gives clay soils their plastic properties.

It needs to be well recognized that the presence of clay minerals in a soil aggregate has a great influence on the engineering properties of the soil as a whole. Explanations suggest that the black color may be due to the presence of iron and titanium, which exist, in small quantities. Illite occasionally occur but in small quantities. In most cases only alluvial soils contain illite and only soils over volcanic rocks contain halloysite.

Table 2.1: Specific surface of clay minerals. [38]

Clay mineral	Specific surface (m^2/gm)
Kaolinite	10–20
Illite	80-100
Montimorillonite	800
Chlorite	5-50
Vermiculite	5-400
Halloysite	40

2.8 Chemical compositions

The chemical composition of the Expansive soil and stone dust refers the arrangement, the type and the molecules of chemical that they content. The basic ingredient of nearly all silicate injection processes is a solution of sodium silicate in water, known as ‘water glass’’ This solution contains both free sodium hydroxide and colloidal silica acid. The addition of salts or acids can cause the silicate solution to form a gel for example, [39]

According to hunter 1998 The pozzolanic reaction between soil and admixtures, results in the change in mineralogical phases of soil Hence, the mineralogical analysis of the treated soil becomes very essential Therefore, Silicate analysis of stone dust from the reaction of additive in the soil reacts with calcium (form lime) and alumina (form stone dust and clay) forms the mineral ettingite. This ettringite mineral improves the soil strength and reduce the swelling tendency of the soil. The description of the sequence given;

$6Ca+{}_{2}AI(OH)-{}_{4}+ (OH)-+{}_{3}(SO4)^{2}+ 26H_{2}O \longrightarrow Ca_{6}+ (AI(OH6)_{2}(SO_{4})\ {}_{3}26H_{2}O$. [39]

The admixture experienced cation exchange between Ca2+ in the admixture and soil cations (Na+, Ti+, Mg2+) and contributed to particle flocculation confirmed by SEM micrographs. These mechanisms resulted in a waterproofing effect on soil sample hence, the decrease in percent swell of treated expansive soil which was also confirmed by the X-ray CT-scan micrographs and lower moisture contents measured for the specimen treated with different [39]

2.8.1 Composition and structure of clay Minerals

Clay minerals are essentially crystalline in nature though some clay minerals do contain material which is non-crystalline (for example Allophone). Two fundamental building blocks are involved in the formation of clay mineral structures. They are Tetrahedral unit and octahedral The tetrahedral unit consists of four oxygen atom (or hydroxyls, needed to balance the structure) placed at the apices of a tetrahedron enclosing a silicon atom which combines together to form a shell-like structure with all the tips pointing in the same direction The oxygen at the bases of all the units lie in a common plane. [37]

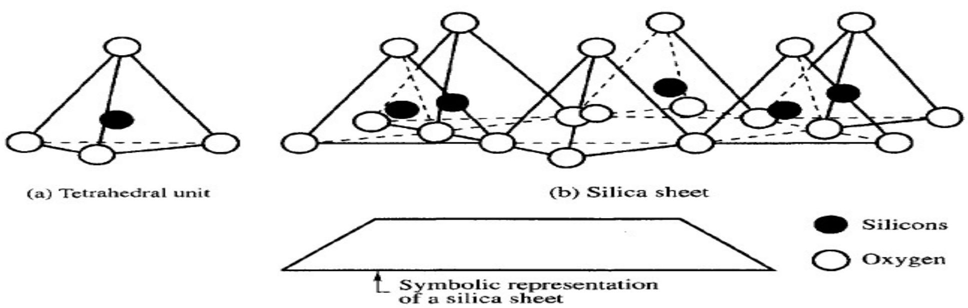


Figure 2-4:Basic Structural units in the silicon sheet [37]

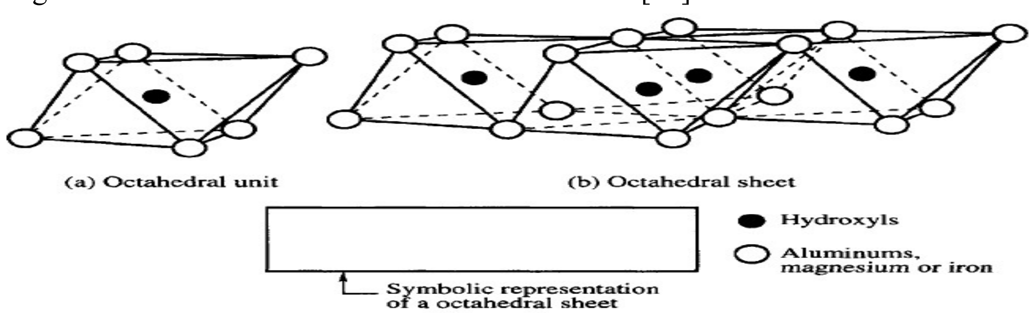


Figure 2-5: Basic structural units in octahedral sheet-Gibbsite sheet [37]

2.8.2 Formation of clay Minerals composition

The actual formation of the sheet silicate minerals, the phenomenon of isomorphism substitution frequently occurs. Isomorphism (meaning same form) substitution consists of the substitution of one kind of atom for another [36].

Table 2.2: Composition of Basic Common Clay minerals [36]

Name of mineral	Structural formula
I. Kaolinite group	
Kaolinite	Al4Si4O10(OH)8
Halloysite	Al4Si4O6(OH)16
II. Montmorillonite group	
Montmorillonite	$Al_4Si_4O_{20}(OH)_4nH_2O$
III. Illite group	
Illite	$K_y(Al4Fe2.Mg_4.Mg_6)Si_{8-y}Al_y(OH)_4O_{20}$

Table 2.3: Oxide composition in percent for different test pits of Jimma soil [4]

Ser. No	Location	Test Pit Designatio	SiO_2	Al2O3	Fe2O3	CaO	Mg O	Na_2O	K_2O	Mn O	P2O5	TiO_2	H_2O	LOI	(S/S) ratio
1	A	TP -3-	42.3	23.7	14.1	0.56	0.64	<0.01	0.66	0.36	0.08	1.81	4.9	10.5	1.12
2	Ke	TP- 5-2	52.5	17.1	10.4	0.42	0.58	<0.01	0.62	0.04	0.06	1.78	7.4	8.21	1.90
3	J	T P-	52.5	12.7	16.6	<0.01	0.28	<0.01	0.64	0.26	0.29	2.53	3.8	9.33	1.79

According to [4] study the clay mineral contain the above elements with a different percent in different places of jimma. The present study has studied the chemical composition of stone dust from The Federal Democratic Republic of Ethiopia Ministry of mines, Petroleum and Natural Gas from Geological Survey of Ethiopia.

The chemical composition of stone dust that was get for present study test result indicates that the composition of the elements of [SiO2 (63.32%)+Al2O3(16.82%) + Fe2O3(5.04%)] was 85.18 %. Marginal increase in plastic limits is observed with addition of chemical to the expansive clay [37].

CHAPTER THREE

3 MATERIALS AND RESEARCH METHODOLOGY

This chapter refers the approaches and techniques that the way to worked the research in order to solve and overcome the problem that is happened due to expansive soil. It includes the selection of study area, sampling techniques, the procedure, data collection methods, the procedure of analysis of the data and the way of the study worked.

3.1 Study Area and Description

The study was conducted in Jimma zone. Jimma is the largest town in Southwestern Ethiopia located at latitude and longitude of 7^{0}40’N and 36^{0}50’E respectively in Oromia National Regional State. It is 350km from Addis Ababa. The town has a rolling terrain with an elevation ranging from 1670m to 1770m above mean sea level.

Jimma is predominantly covered with red, black and gray soils. The red colored soils are found on rolling topography with higher elevation and well drainage condition. The black and gray soils, which cover the central and large part of the town, are found on flat topography of the town with lower elevation and unfavorable drainage condition [4]

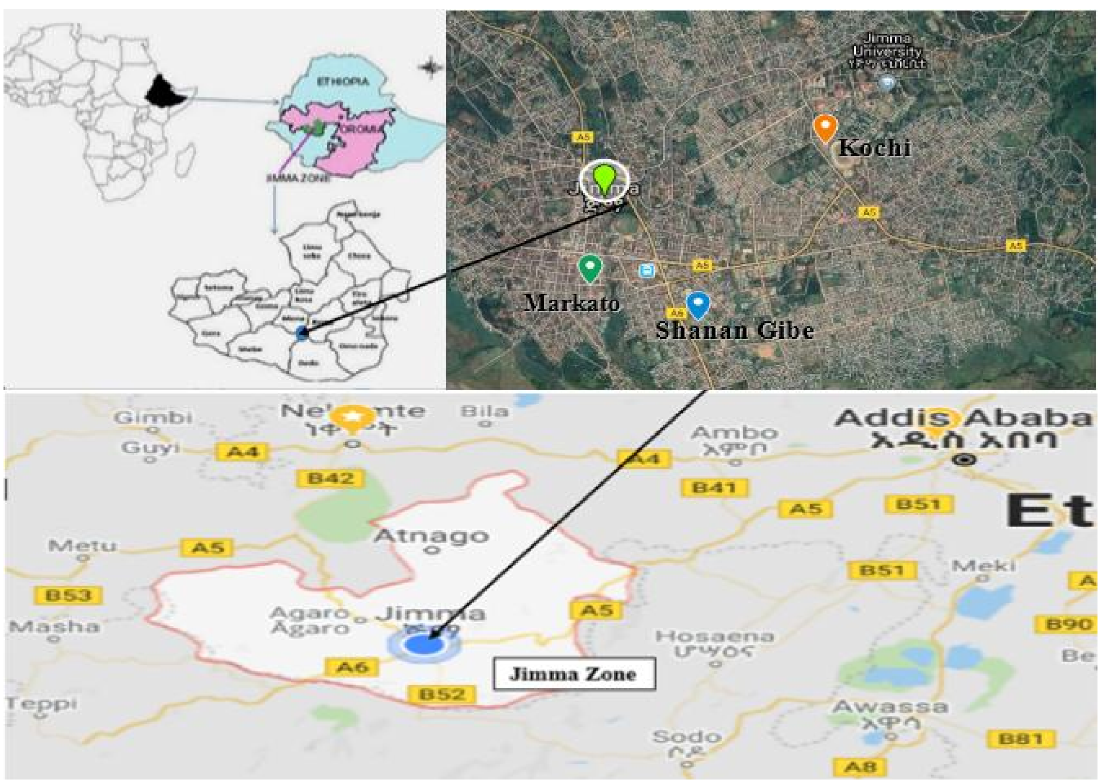


Figure 3-1: Map of study area (from Google map of 2020)

3.2 Study Design

The research design was based on a purposive sampling selection processing which the place was affected by expansive soil in order to improve the geotechnical properties of expansive soil, in terms of which a representative sample of both expansive and stone dust materials were surveyed. The study was conducted by using both quantitative and experimental methods.

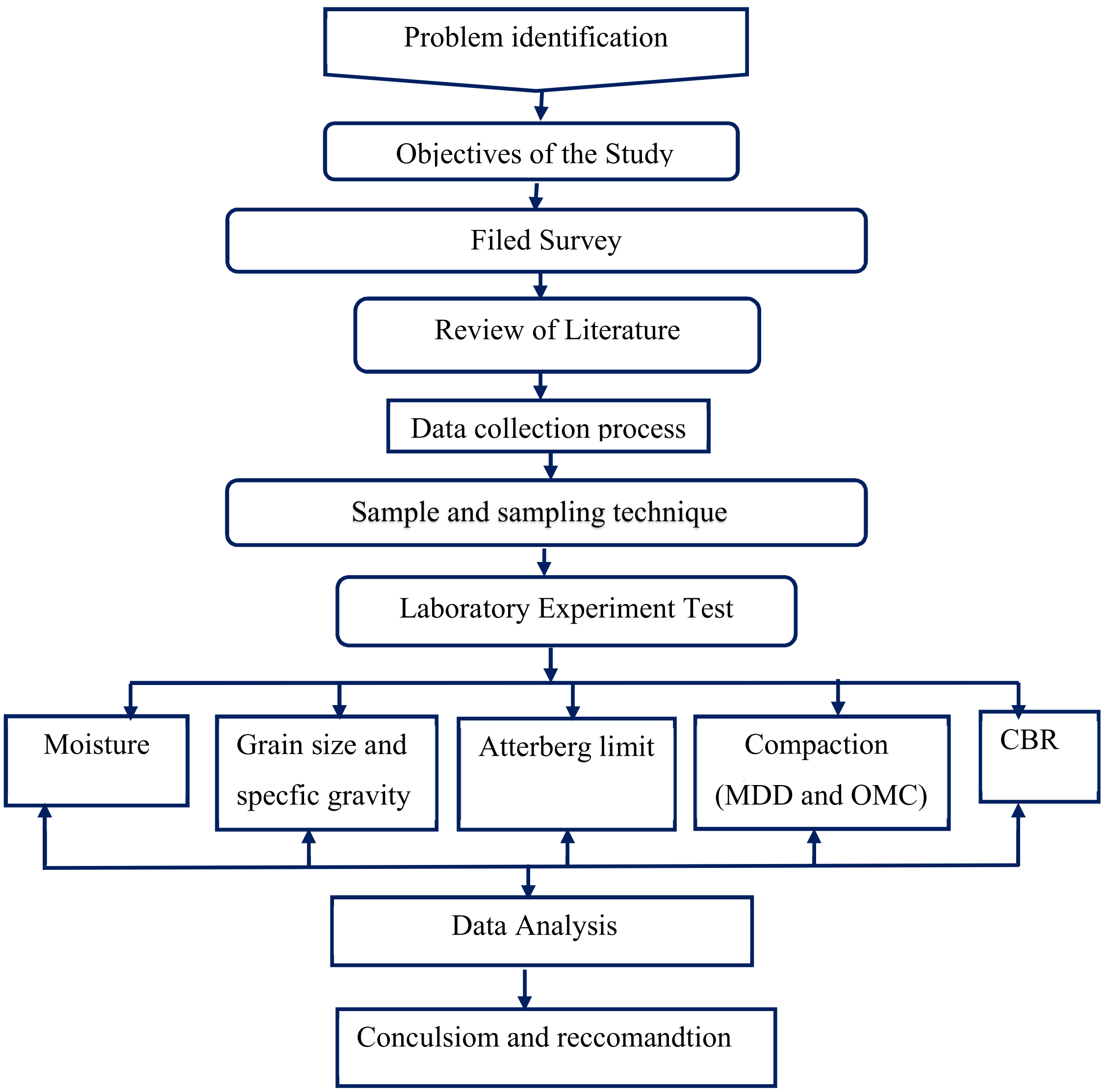


Figure 3-2 Flow chart of research design

3.3 Sampling Techniques and Procedure

The stone dust Sample was taken from the quarry site (crusher) in jimma above Gabrel church and from the ERA which worked in jimma district. The study was takes three Test pit of different location of jimma Town namely Shanan Gibe, Kochi, and merkato and taken two samples from each test pit, which means six samples from all test pit. It was selected by visual observation and by considering the research, which worked previously in jimma town. The soil samples were first has air-dried and laboratory tests were conducted according to ASTM and AASHTO soil testing standard procedures. The study was used conducted laboratory test, in order to obtain their engineering property, and to evaluate and improved geotechnical property of the soil used by different percentage of stone dust 5%,10%,15%,20%and 25%. The optimum percentage required to achieve the research is at 15% of stone dust. The study was evaluating the engineering property of expansive soil improved used by analysis and by recommended that stone dust blended with expansive soil is used for different infrastructure. So in terms of obtained safe, strong and durable structure the study plays a great role to achieve the required strength.

3.4 Data Variable

While the study was worked there is data variable. These data variable is classified in to dependent and independent variable.

3.4.1 Dependent variable

The dependent variable is a variable which response the output the parameter stone dust, which is the optimum percentage of stone dust, required to stabilize the soil.

3.4.2 Independent variable

In this study, the independent variable, which is measured, those are the Laboratory Test CBR, compaction (OMC, MDD) Atterberg limits (liquid limit, plastic limit, and plasticity index), Compaction characteristics, Free swelling and unconfined Compressive Strength.

3.5 Materials and Method

The material was used for this study is the representative expansive soils and Quarry stone dust collected from different locations in Jimma Town.

The laboratory Test is according to the standard specification.

Table 3.1: Test Method Procedures

No.	Name of Test	ASTM	AASHTO
1	Specific Gravity	D 854-83	
2	Grain Size Analysis		T11 and T27
3	Atterberg Limits	D4318-98	
4	Soil classification	D2487-98	
6	Modified compaction		T 180-95
7	CBR		T 1993
8	UCS	D2166	

In this study, different activities are carried out; from field soil identification up to the documentation of the paper. Generally, the study has three main stages in order to complete the research. The first was The-fieldwork stage. During this stage literature review and site selection for representative sample was selected. The second one is the field and laboratory work stage; in this stage the soil samples and stone dust sample bringing to the laboratory and test was conducted. The last one is post fieldwork stage. The results from laboratory test, analysis of the test results was including interpretation and finally report preparation prepare. The significance of the stabilizer for expansive soil strength improvement was studied by blending stone dust with the collected samples in different percentages at 0%,5%,10%,15%,20% and 25% Perform the laboratory test. The laboratory tests were conducted include determination of the Atterberg limits, compaction characteristics, and California Bearing Ratio (CBR) of treated expansive soil with stone dust.

3.6 Data collection process

Data was obtained from laboratory tests to investigate and stabilize the soil with stone dust. The soil sample and the stabilized stone dust sample were collect from jimma town. The laboratory Test were conducted the effect of stone dust on the CBR, Compaction (MDD and OMC), and index properties. Determine the engineering properties of the treated expansive and stone dust in the laboratory; the expansive soil was stabilized with stone dust in varying percentages in order to get the required strength. And also stone dust stabilizer used is very significant in reducing the damage that could cause by expansive soil and reduce the cost and time lost due to removal of the expansive soil and bearing in expansive soil during the construction period. The proportional of stone dust mix to treat with expansive soil was improve the engineering property of expansive soil that the result of the test meet with local, national, and international standard and specifications used for the required structure.

3.7 Preparation of Specimens

After the specimen was collected and transported to the laboratory, the sample was air dry for a week. The test specimens were prepared for each individual soil and performed the test for natural soil and the specimens were prepared using a different percentage of stone dust proportion by weight of mixed soil. There is natural soil and stone dust at 5%, 10%, 20% and 25% percentage for those three each Test pit.

3.8 Laboratory test results

This is the data to be obtained from the results of experimental procedures at the laboratory. The laboratory test was conducted for each natural soil in order to evaluate the mechanical and physical properties of stone dust and expansive soil in detail procedure for the identification of the engineering property of the soil. The mixing was designed to analysis effect of stone dust soil on the engineering property of expansive soil with the aspect of using the mixed expansive soil with stone dust in construction subgrade of a highway, backfill of retaining wall and foundation placement for civil structures. Before starting the laboratory test, the prepared samples were first air-dry under the sun to allow moisture to evaporate and obtain air-dry sample for the test, then reduced sample to required size by weighting the sample for the test.

Table 3.2: Blending ratio of stone dust and expansive soil.

S.No	stone dust (SD) used by % for blending	% of expansive soil (ESS1)	% of expansive soil (ESS2)	% of expansive soil (ESS3)
1	0	100%	100%	100%
2	5%	95%	95%	95%
3	10%	90%	90%	90%
4	15%	85%	85%	85%
5	20%	80%	80%	80%
6	25%	15%	15%	15%

3.8.1 Natural moisture content

Moisture content is the ratio of the mass of water to the mass of solids in the sample expressed as a percentage. The purpose of this study is to determine the water (natural moisture) content of the soils both at 1.5m and 3m depth.

Table 3.3: Determination of Natural soil for Different Test pit

Test pit	TP1@1.5m	TP2@1.5m	TP3@1.5m	TP1@3m	TP2@3m	TP3@3m
NMC	34.79	32.84	32.42	32.42	30.65	29.32

3.8.2 Free Swelling

The free swelling test is used to determine the increase in the volume of soil without any external constraint when the sample of the soil subjected to submergence in the water. The free swell test is conducted by using 10gm of dry soil passing through sieve No 40 sieve.

$S_f=[\frac{Vf-Vo}{Vo}]*100$

Table 3.4: Free swell test result of natural soil

Test pit	Location	Depth (m)	Free Swell (%)
1	Shenan Gibe	1.5	113.5
2	Kochi	1.5	107.67
3	Markato	1.5	100.30

3.8.3 Sieve Analysis

Sieve analysis test allows the determination of the distribution of particles sizes in materials. For present study (AASHTO T-88) method was used for analysis

For present study a type of sieve used was wet sieve analysis. This test was aimed that the particle size distribution or gradation of the disturbed soil sample used for the sample particle distribution.

Table 3.5: Results of sieve analysis for all test pits

particle size	percent pass for ESS1	percent pass for ESS2	percent pass for ESS3
9.5	100	100	100
4.75	99.76	99.76	99.69
2	99.24	99.20	98.98
0.85	98.30	98.09	97.36
0.425	96.62	96.24	95.42
0.3	94.70	94.24	92.57
0.15	92.97	92.34	90.08
0.075	90.41	89.64	86.43
0.04	81.87	77.66	74.88
0.0287	78.32	75.90	73.18
0.0184	76.55	70.63	68.10
0.011	69.46	67.12	64.71
0.0078	67.69	65.36	59.63
0.0056	64.15	60.09	57.94
0.0041	60.60	56.57	52.85
0.0029	55.29	49.55	47.77
0.0021	49.97	42.52	39.30
0.0013	42.88	39.00	35.91

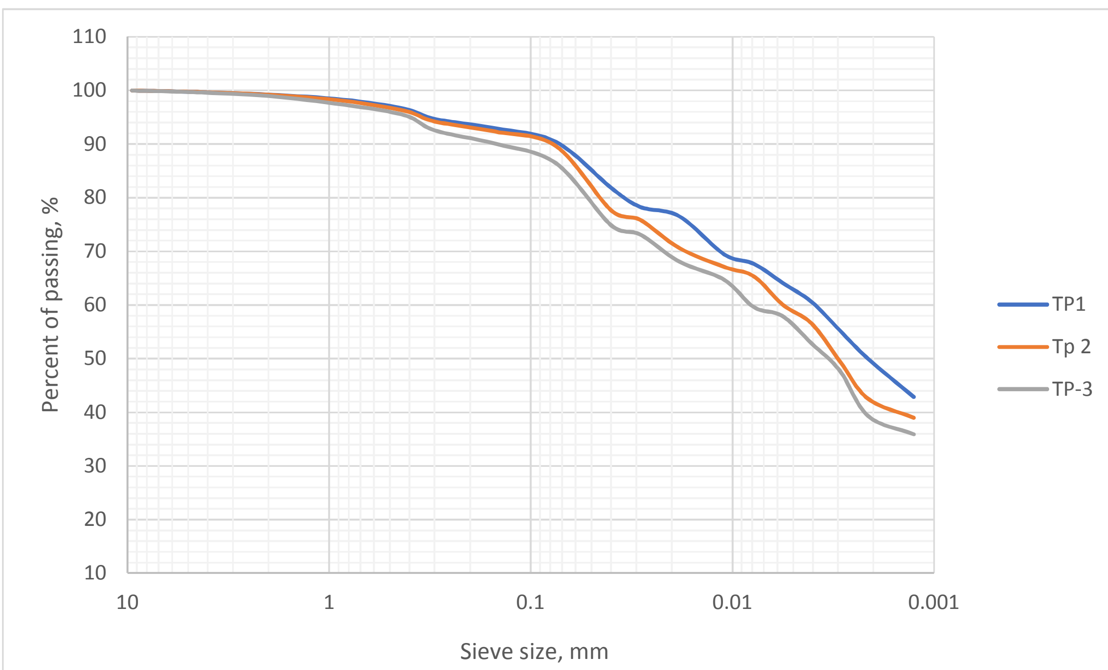


Figure 3-3: The grain size distribution of 15% ESS1.

3.8.4 Specific Gravity

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The Procedures for performing the specific gravity are provided as follows according to ASTM D854-98: Method A- procedure for oven drying specimens. The purpose of this laboratory test conducted was to determine the specific gravity of soil by using a Pynchon meter. The importance of determining the specific gravity in this study is to determine particle sizes in hydrometer analysis. Also specific gravity of soils is an important quantity which is frequently used in determination of different properties of soils in laboratory as well as in real practice. In the present tests, it will be used to calculate the percentage finer in hydrometer analysis and in the computation of zero air-void curves for compaction test.

Table 3.6: Specific gravity of natural soil sample.

Sample Designation	Specific Gravity of Soil @ 1.5m	Specific Gravity of Soil @3m
Expansive soil sample1 (ESS1)	2.53	2.48
Expansive soil sample2 (ESS2)	2.71	2.67
Expansive soil sample2 (ESS3)	2.70	2.66

3.8.5 Hydrometer Analysis

Hydrometer analysis is primarily used to know the grain size distribution of a fine-grained soil. The fine-grained soil, sieve analysis test does not give a reliable test result. This because a fine-grained soil consists of different sizes of particles starting from 0.075 mm to 0.0002 mm, and it is not practicable to design sieve having so smaller grain size. Also, there is a chance of loss of the sample during sieving. Therefore, hydrometer analysis is done for grain size analysis of fine-grained soils Hydrometer analysis is based on Stokes law. According to this Law, the velocity at which grains settle down out of suspension, all other factors being equal, is dependent upon the shape, weight, and size of the grain size of the particles. Hydrometer analysis is a widely used method of obtaining an estimate of the distribution of soil particle sizes from the No. 200 (0.075 mm). The below table shows the hydrometer test analysis of Test pit 1 and the rest hydrometer analysis test result of ESS2 and ESS3 is listed in Appendix.

Table 3.7: Hydrometer Analysis of test pit 1

Time (minutes)	Actual Hydrometer Reading	Temp.	correction for hydrometer reading	F				Correction factor (a)	Effe. Depth of Hydrometer (L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted Percent of finer
			T° correction	meniscus correction	zero correction	Composite Correction	Corrected H.Reading						
1	50	21	0.2	1	-5	-3.8	46.2	0.98	8.2	0.01400	0.0400	90.55	81.87
2	48	21	0.2	1	-5	-3.8	44.2	0.98	8.4	0.01400	0.0287	86.63	78.32
5	47	21	0.2	1	-5	-3.8	43.2	0.98	8.6	0.01400	0.0184	84.67	76.55
15	43	21	0.2	1	-5	-3.8	39.2	0.98	9.2	0.01400	0.0110	76.83	69.46
30	42	21	0.2	1	-5	-3.8	38.2	0.98	9.4	0.01400	0.0078	74.87	67.69
60	40	21	0.2	1	-5	-3.8	36.2	0.98	9.7	0.01400	0.0056	70.95	64.15
120	38	21	0.2	1	-5	-3.8	34.2	0.98	10.1	0.01400	0.0041	67.03	60.60
240	35	21	0.2	1	-5	-3.8	31.2	0.98	10.6	0.01400	0.0029	61.15	55.29
480	32	21	0.2	1	-5	-3.8	28.2	0.98	11.0	0.01400	0.0021	55.27	49.97
1440	28	21	0.2	1	-5	-3.8	24.2	0.98	11.7	0.01400	0.0013	47.43	42.88

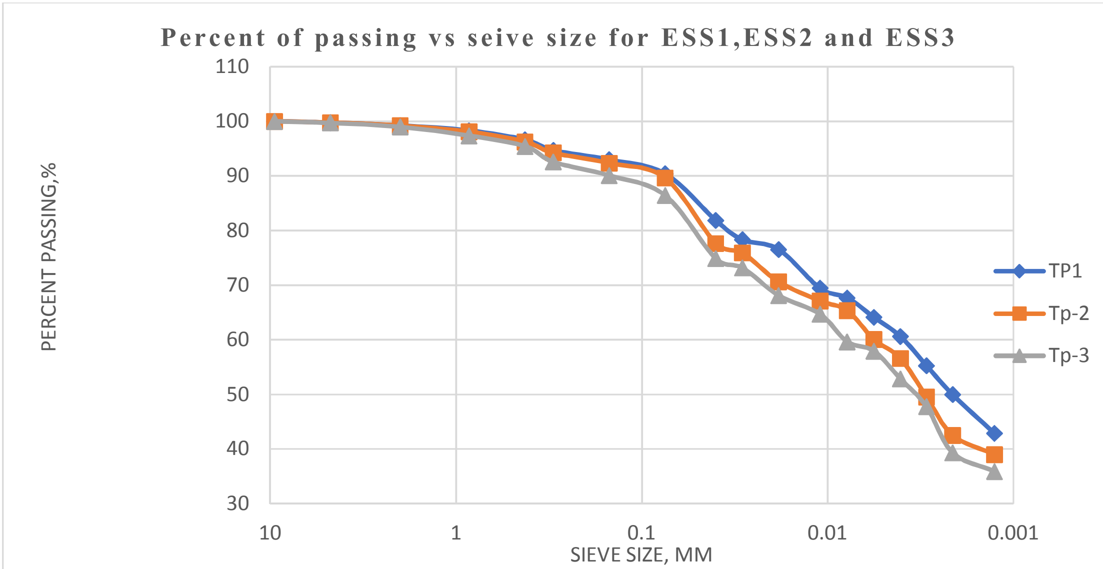


Figure 3-4: Particle seize distribution

3.8.6 Atterberg Limits Tests

The Atterberg limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. It is based on a change in the soil's behavior.

Determining the Atterberg's limits were help in examining the consistency of the soil and also used for classifying the soil type either using AASHTO or USCS soil classification systems since both systems use the atterbereg limit of the soil. It also used for the compared with the atterberg limit of engineering properties of soil with the other engineering behavior of soils, which helps to easily determine the other engineering properties soil; on the other hand, Atterberg limit can be used to differentiate between silt and clay, distinctions in a soil are used in assessing the soils that are to have structures built on them. Soils when wet retain water, and some expand in volume. The amount of expansion is related to the ability of the soil to take in water and its structural make-up. These tests are mainly used on expansive clay soils since these are the soils that expand and shrink due to moisture content. Clays and silts react with the water and thus change sizes and have varying shear strengths, these tests are used widely in the preliminary stages of designing any structure to ensure that the soil were used to get required amount of shear strength and not too much change in volume as it expands and shrinks with different moisture contents

Table 3.8: Laboratory result of Atterberg limit test of the stabilized @1.5m

Location	Natural		5%		10%		15%		20%		25%	
	LL	Pl	LL	PL	LL	PL	LL	PL	LL	PL	LL	PL
TP1	111.9	24.3	95.5	28.7	88.0	42.7	81.8	53.8	68.0	60.7	62.3	56.1
TP2	101.1	38.1	93.9	39.5	88.4	42.7	77.6	43.5	71.3	44.6	63.2	46.1
TP3	93.96	40.3	92.6	42.3	87.9	44.8	82.6	46.4	71.7	49.4	64.7	53.3

Table 3.9: Laboratory result of Atterberg limit test of the stabilized @3m

Location	Natural		5%		10%		15%		20%		25%	
	LL	Pl	LL	PL	LL	PL	LL	PL	LL	PL	LL	PL
TP1	101.9	37.9	92.9	39.3	84.7	43.4	64.6	54.5	63.2	56.0	61.0	57.9
TP2	95.5	41.4	91.1	40.5	84.4	43.2	73.5	44.2	67.9	45.4	57.3	47.9
TP3	91.7	41.8	87.3	43.8	83.4	45.5	65.5	51.1	65.5	51.1	54.6	53.5

3.8.7 Compaction Tests

The laboratory compaction test is being performed to determine the relationship between the moisture content and the dry density of soil.

The compaction test is a laboratory method of experimentally determining the optimum moisture content at which a given soil type will become compacted, dense and achieve its maximum dry density. [45]

In general, the engineering properties expansive soil improve the geotechnical properties of the soil, by increasing the soil density. The soil compacted lower than the optimum water content. This test was done to determine the maximum dry density (MDD) and optimum moisture content (OMC) of the sample material.

Table 3.10: Test result of OMC and MDD compaction characteristic @1.5m

Location	Natural		5%		10%		15%		20%		25%	
	OMC(%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%))	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)
Tp1	31.4	1.32	30.3	1.4	26.6	1.49	21.0	1.57	19.7	1.6	17.6	1.64
TP2	34.1	1.34	27.5	1.41	21.0	1.49	19.4	1.51	17.9	1.5	16.3	1.58
TP3	27.7	1.40	23.2	1.44	21.4	1.49	19.0	1.53	17.8	1.6	16.6	1.59

Table 3.11: The result of OMC and MDD compaction characteristic@3m

Location	Natural		5%		10%		15%		20%		25%	
	OMC(%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%))	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)	OMC (%)	MDD (g/cm³)
Tp1	29.9	1.37	26.2	1.43	23.9	1.49	20.8	1.56	18.9	1.6	16.9	1.67
TP2	27.9	1.40	23.1	1.45	19.9	1.57	18.6	1.60	17.7	1.6	16.2	1.65
TP3	28.1	1.41	24.1	1.44	21.8	1.44	19.4	1.49	17.9	1.5	15.7	1.62

From the above table the optimum moisture content of all test pit was decreasing as the addition of the stone dust and the maximum dry density was increased as the stone dust adding to the expansive soil. The MDD shows a slight increase and OMC shows a decrease in the treatment of weak subgrade soil with stone dust additive agents. this indicate that the addition of the stone dust to expansive soil improve the geotechnical properties of expansive soil.

The figure below shows the moisture density relation of compaction characteristic of test pit 1 at different percentage of stone dust stabilized with Expansive soil.

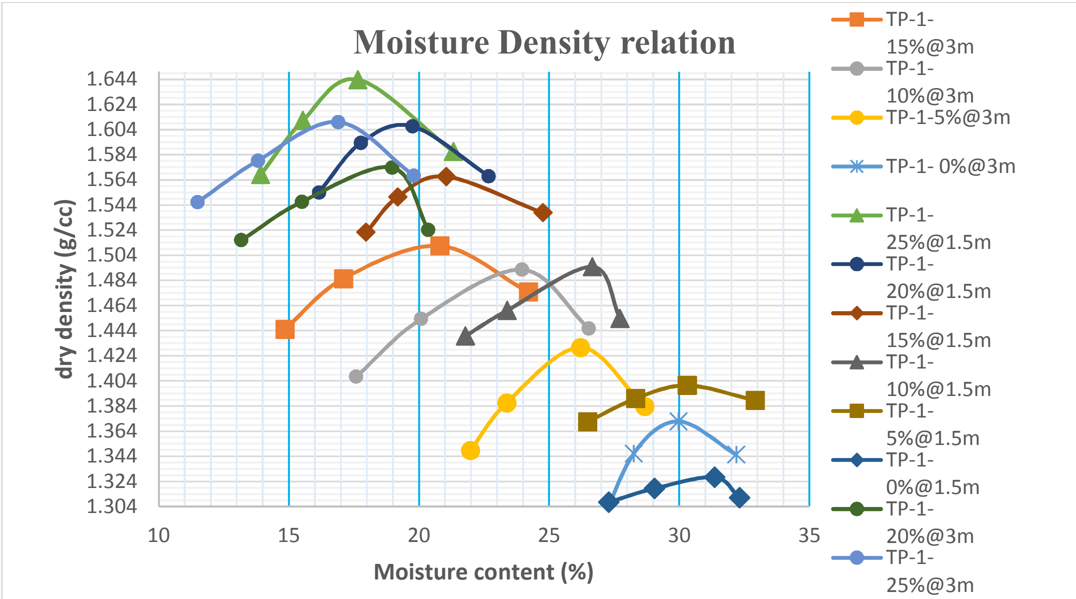


Figure 3-5: Moisture density relations

3.8.8 California Bearing Ratio (CBR)

The CBR test is one of the most commonly used methods to evaluate the strength of a sub grade soil, sub base, and base course material. The CBR value for a soil depends upon its density, moisture content, and moisture content after soaking.

The CBR values are determined by the force needed to penetrate the plunger 2.54 mm, and 5.08 mm into the compacted specimens. The method uses material passing 19 mm size and provides the CBR value of material at optimum water content. The specimen shall be soaked before penetration. A surcharge is placed on the surface to represent the mass of pavement material above the base course. Expansion of the sample is measured during soaking to check for potential swelling. To determine the strength and swelling potential of the samples, a test has been carried out by 4-days soaking three point CBR and loaded Swell testing procedure. The material strength has been used for design purpose by interpolating the CBR values at different compaction levels, with 10, 30 and 65 blows and compacting in 5 layers by heavy compaction. Water to be added was calculated from compaction test results which are the OMC obtained at MDD and by considering the natural moisture content of the material on the test.

Table 3.12: The CBR test result value For TP1,TP2 and TP3@ 1.5m

Sample Designations	Compaction test				CBR test result		
	OMC (%)	MDD (g/cm3)	95% of MDD	NO of blow	swell	CBR %	CBR
ESS1Shenan Gibe	29.973	1.372	1.429	10	0.13	2	2.52
				30	0.17	2.5	
				65	0.22	2.9	
ESS2 Kochi	27.946	1.40	1.432	10	0.19	2.21	2.61
				30	0.21	2.76	
				65	0.24	4.21	
ESS3 merkato	28.924	1.409	1.481	10	0.4	2.63	2.85
				30	0.6	3.43	
				65	0.8	4.32	

The maximum dry density is 1.3, the target density which is at the compactness requirement of 95% is 1.43 and finally the CBR of the natural soil is 2.52,2.61 and 2.85 this show that the value of CBR is below 3 which is below The ERA requirement thus the result indicate that the soil is highly expansive soil.

The swell of expansive soil is so high this leads damages, cracks or failures and creates other problem in different structure. So this soil must have needed some treatments in order to get safe, stable and durable structure.

The value of CBR in % at 95 of MDD is 27.3 and Swell in % is 1.17 this result indicates that the value of CBR is increased from the 2.52 to 27.3 as number of adding stone dust to the expansive soil The CBR is increased up to require to reach the optimum.so from the test result of CBR, the CBR result is increased starting from the 5% to the 15% then it became decreased the present study show that the optimum moisture used to achieve the strength is at 15%.

inversely the swelling became decrease from the 3.04 to 1.17 this indicate that the soil initially it is so expansive but after the adding of stone dust the swelling will became decreased so the stone dust improves expansive soil damage which can come due to the absorption of water. Generally, from the above result the optimum strength obtained at the addition of 15% of stone dust and 85 % Expansive soil to Achieves the required strength.

3.8.9 Classification of the Soil

The purpose of soil classification is to make the possible estimation of soil properties by a relation with soils of the same class whose properties are known and to provide the geotechnical engineers, classify soils according to their engineering properties as they relate to use for foundation support or building material. The classification system for soils is unified soil classification system (USCS) and AASHTO soil classification system.

AASHTO classify the soil into seven major groups: A-l up to A-7. Soils classified under groups A-1, A-2, and A-3 are granular materials of which more than 35% or less of the particles pass through the No. 200 sieve. Soils of which more than 35% pass through the No. 200 sieve are classified under groups A-4, A-5, 4-6, and A-7. And the USCS classifying the minerals and organo-mineral soils for engineering purposes based on laboratory determination of particle-size.

Table 3.13: AASHTO and USCS soil classification

S.No	Sample location	Sample designation	USCS	AASHTO
1	Shenan gibe	ESS1	CH	A-7-5
2	Kochi	ESS2	CH	A-7-5
3	Merkato	ESS3	CH	A-7-5

In the present study the soil is classified under CH and A-7-5 these indicate that the soil is highly expansive and classified as highly clay. This due to the high value of liquid limit and plasticity index. but after the addition of the stone dust the liquid limit decreases from 111.35 to 62.27 and plasticity is also decrease from 87.10 to 11.30 this shows that the addition of stone dust in the expansive soil can improve the geotechnical properties of expansive soil.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

This chapter presented the results of blended expansive with stone dust, and the data analysis that experimental laboratory study on the effect of using stone dust mixing with expansive soil for Foundation purpose. The expansive soil samples were mixed with the stone dust at 0%,5%,10%,15%,20% and at 25% proportion by weight. The laboratory test such as The Atterberg's limit, gradation test, compaction, CBR and UCS are carried out on expansive soil with stone dust carried out for the improvement of geotechnical engineering properties of expansive soil.

4.1 Laboratory Test Result and Discussion

The main purpose of this experimental study was to determine the suitability of blending expansive soil with stone dust, which may help to reduce the problem of time and money consuming, due to replacing expansive soil with other non-expansive soil. The following b laboratory tests has been carried out for the improvement of geotechnical engineering properties of expansive soil. The Complete Silicate Analysis of Stone dust, The Atterberg's limit, gradation test, free swell compaction, and CBR test and CBR swell Test for a mixed soil were performed.

4.1.1 Complete Silicate Analysis

The present study has got the following complete silicate analysis. This element indicates the more interaction between soil and stone dust. This stone dust contains only 1.03 in percent and when it burns it loose by 1.71 Percent.

Table 4.1:Compete Silicate Analysis

Constitue	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_2	TiO_2	H_2O	LOI
Percentage	63.32	16.82	5.04	2.3	0.7	5.18	2.30	0.2	0.20	0.25	1.03	1.71

Since stone dust contains KCl, CaCl2 and FeCl this shows the laboratory study carried out for investigation, observed that the liquid limit values are decreased and.the plastic limits increase. So using Stone dust is improving the Expansive at the required strength since it contains elements which are reacting with the expansive soil.

From the above Expansive soil chemical reaction with the stone dust complete silicate analysis that was study from The Federal Democratic Republic of Ethiopia Ministry of mines, Petroleum and Natural Gas from Geological Survey of Ethiopia. Shows that the reaction between the elements of expansive soil with the element of stone dust makes to increase the strength of the structure or improve the geotechnical properties of expansive soil. This is because of the pozolonic reaction between the expansive soil and the stone dust. The reaction between silicate and Aluminum makes to reduce the water content exist in the soil this type of reaction makes to increase or improve the geotechnical properties of expansive soil and able to reduce the swelling of the expansive soil.

$Na_{(2n-4)} (Sio_n) + HCI \longrightarrow Sio_n(OH)_{4-2n} + NaCI$

The reaction between, Sodium hydroxide silicon carbide

$4NaOH + SiC + 2H_2O \longrightarrow Na2SiO_3 + Na_2CO_3 + 4H_2$

The chemical composition of stone dust that was get for present study test result indicates that the composition of the elements of [SiO2 (63.32%) +Al2O3(16.82%) +Fe2O3(5.04%)] was 85.18 % which it fulfills the minimum requirement of 70 % which is written in the ASTM C-618, this indicate that there is significant reaction between the element of expansive soil and the stone dust elements.

4.1.2 Natural Soil

The most important parameter used to evaluate the geotechnical engineering properties and identification of natural soil for construction. in this study Determination of natural soil FS, Atterberg limit, compaction characteristics and CBR tests were conducted.

Table 4.2: Geotechnical properties of expansive soil

Location	**Moisture**	**Free swell Result**	**Specific Gravity**	**Atterberg limit**		**Compaction**		**CBR**	**CBR swell**
				LL	PI	OMC (%)	MDD		
Shanan	34.79	113.5	2.53	111.99	87.1	31.4	1.33	2.52	.9.51
Kochi	32.84	107.67	2.59	101.06	62.9	34.09	1.35	2.61	8.48
Merkato	32.42	100.30	2.62	93.962	53.7	27.74	1.40	2.85	8.21

Table 4.3: Geotechnical properties of stabilized expansive soil at Optimum percentage

Location	Free swell result	Specific Gravity	Atterberg limit		Compaction		CBR	CBR swell
			LL	PI	Omc(%)	MDD (kN/cu. m)		
Shanan	20.56	2.70	81.824	27.97	21.045	1.567	27.73	0.31
Kochi	18.87	2.73	77.560	26.82	19.417	1.517	24.4	0.29
Merkato	18.10	2.82	76.54	26.54	19.014	1.526	26.5	0.26

4.1.3 Free Swell Test Result

The free swell tests are used to know the expansiveness of the soil. The soil sample for this study was classified under highly expansive soil. The table below shows the free swell test result of natural and the stabilize soil.

Table 4.4: Free swell result

Location	Natural		5%		10%		15%		20%		25%	
	Depth		Depth		Depth		Depth		Depth		Depth	
	1.5m	3m	1.5	3	1.5	3	1.5	3	1.5	3	1.5	3
	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
TP1	113.5	106.3	50.9	48.0	40.9	37.1	20.6	18.6	16.7	12.6	7.7	5.5
TP2	107.7	101.4	48.1	46.5	42.3	37.9	18.9	14.0	16.2	15.7	12.9	7.7
TP3	100.3	97.2	48.0	34.0	37.9	26.9	18.1	12.6	15.7	10.9	8.49	5.9

From the above Table 4.4 the free swell of natural soil is above 100 this indicate that the soil is highly expansive soil. But after the addition of stone dust the free swell test result is radically changed thus adding stone dust to expansive soil can improve the geotechnical properties of the expansive soil

4.1.4 Atterberg Limits

The Atterberg limit tests were performed for natural soil of all the collected samples. The main objective of these tests is to identify the plasticity of the natural soil. Based on the laboratory result the collected sample where classified form high plastic to low plastic soil for each soil sample. The Atterberg limit of natural soil is high and when the stone dust is added to the expansive soil the liquid limit and index properties are radically changed.

Table 4.5: Atterberg limit test result of expansive clay soils@1.5m

Ser.No	Name sample	Liquid limit(LL%)	Plastic limit(PL%)	Plastic Index(PI%)	ERA (2000) Requirement for PI in (%) (< 30%)
1	ESS_1	111.995	24.89	87.10	Poor
2	ESS_2	101.065	38.14	62.93	Poor
3	ESS_3	93.962	40.30	53.66	Poor

Thus; the liquid limit of the natural soil for test pit 1(ESS1) is 111.995.the index properties of natural soil are 87.10, but when stone dust is added to the expansive soil the liquid limit is changed to the 81.84 and the plastic index became changed to the 27.97 so this variation indicate that the addition of the stone can improve the engineering properties of expansive soil. The atterberg limit of natural soil indicates that soil is highly expansive. And also the plastic index is very high which is not good. Those lead some effects in infrastructure so this soil needs treatment. And when it adds stone dust on this expansive soil the liquid limit decrease and the plastic index became decrease. So adding stone dust to expansive soil makes to create change on the Atterberg limit test.

Table 4.6: Atterberg limit test result at Optimum 15% of Stone dust at 1.5m

Ser.No	Name sample	Liquid limit (LL%)	Plastic limit (PL %)	Plastic Index (PI %)	ERA (2000) Requirement for PI in (%) (< 30%)
1	ESS_1	81.824	53.86	27.97	Satisfied
2	ESS_2	77.560	50.74	26.82	Satisfied
3	ESS_3	76.54	49.67	26.54	Satisfied

Table 4.7: Atterberg limit test result at Optimum 15% of Stone dust at 3m

Ser.No	Name sample	Liquid limit(LL%)	Plastic limit(PL%)	Plastic Index(PI%)	ERA (2000) Requirement for PI in (%) (< 30%)
1	ESS_1	64.643	54.47	10.17	Satisfied
2	ESS_2	73.566	44.20	29.36	Satisfied
3	ESS_3	65.537	51.08	14.45	Satisfied

4.1.5 Compaction Test

The compaction test showed that the addition of stone dust on the expansive soil change the compaction characteristics OMC and MDD of the expansive, from the laboratory test result it can be seen that there is a decrease in the OMC and increase in MDD value with increasing in the percentage of stone dust. Generally, the percentage the MDD and OMC of expansive increase and decrease as the adding of stone dust.

4.1.6 California Bearing Capacity (CBR)

The investigation of the possibility to use the blended expansive soil stone dust for construction purpose depends on the bearing capacity of the soil in order to carry the load applied on it, therefore it is very important to analyze the bearing capacity of the soil whether it satisfies the required design standard for all-cause, and it is also important to state which ratio of the blended soil percentage satisfy which type of grade requirement for construction of sub grade of a highway. The laboratory CBR test is generally carried out on remolded samples. The sample should be compacted to the expected field dry density of the appropriate water content.

They are two types of CBR - one point CBR and three point CBR

Three points is recommended to get good and accurate for analysis -Three point CBR

Their difference is in the number of molds and layers. If the process is within one point CBR The value is expected 100% and required one mold and 56 blows 5 layers, within three points CBR Value is expected greater than 95% and required three molds, 10 blows 30 blows and 65 blows The CBR values were determined at 2.54mm penetration of 95% of MDD for the sub-grade. The CBR values that present study was get in 2.54mm is greater than that of the CBR Value of 5.08mm. To consider the worst case, the sample was soaked for 4 days. So that study was soaked for 96 hours. The 95% of maximum dry density of the sample was founded by multiplying the Maximum dry density at each sample. It means a compaction attained in filled is 95% of the relative density.

% swell = (Reading after soaking – Reading before soaking)/Height of specimen * 100

The Height of the specimen is calculated from the Height of mold minus the height of base plate and height of disk plate. the height of mold that the present study was used are 172.5mm and the height of disk plate and base plate is 0.1cm(10mm) and 50mm respectively. This result becomes=172.5-(10+50) =112.5mm and the swelling calculated as; Swell%= (h final-h initial)/hsp

In this study, the CBR of the expansive soil mixed stone dust values were ranging from 2.52% to about 27.3%. The reason between higher differences can be the compaction test of density attained during a compaction test. From compaction laboratory test result, it can observe that there is a big difference between natural expansive soil and stone dust at the same compaction effort. More specifically, the maximum dry densities of compacted expansive have an average of 1.429 g/cm^3 with that of CBR value were range 2.52 %. It indicates that by adding of stone dust 15% increase the CBR value of the expansive soil one from 2.52 % to 27.3% and put the range of expansive soil for sub-grade construction from poor to good statues. For the other result of the blending cause mixing of expansive soil with stone dust makes to change expansive soil result.

From the graph the swelling at 95% maximum dry density that is 1.327 g/cc is 0.17%. That means the stabilized material swells at 0.17%. The volume of the stabilized material increases by 0.17%. The CBR test was developed to measure the bearing capacity of soil used for different infrastructure. The CBR values were determined at 2.54mm penetration of 95% of MDD for the sub-grade. The CBR values of natural sub-grade soils of the three samples (ESS1, ESS2 and ESS3).

Table 4.8: The CBR value of Natural soil and sub-grade class.

Sample Designations	Depth	compaction test			CBR @ 95% of MDD	Class of sub-grade
		OMC (%)	MDD (g/cm3)	95% of MDD		
Expansive soil sample1(ESS1)	1.5	31.4	1.327	1.429	2.52	Not suitable
Expansive soil sample(ESS2)	1.5	34.087	1.346	1.432	2.61	Not suitable
Expansive soil sample(ESS3)	1.5	27.736	1.404	1.481	2.79	Poor
Expansive soil sample1(ESS1)	3	29.973	1.372	1.468	2.58	Not suitable
Expansive soil sample(ESS2)	3	27.946	1.400	1523.	2.63	Not suitable
Expansive soil sample(ESS3)	3	28.924	1.409	1.572	2.89	Not suitable

4.1.7 Unconfined Compressive Strength

By using the OMC and MDD of Compaction Test result using ASTM D2166 the following result were drawn out. The Unconfined compressive strength of the expansive soil was from the moisture content of the three trials the average is 31.7% then

The unconfined compressive strength of the ESS1, ESS2, and ESS3 is 85.72, 97 and 150 kpa respectively and the addition of stone dust to expansive soil increase the value of UCS. At 15% for expansive soil the UCS became 335.02.

4.2 The Effect Adding stone dust on engineering properties of Expansive soil

4.2.1 The Effect Adding stone dust on Free swell

The effect of free swell from the laboratory test result indicates that the free swell index values of the expansive soil have decreased with the increase in the percentage of stone dust this resulted to the reduction of swelling and shrinkage of the expansive soil. From the test results, it is observed that at 15 % addition of stone dust with expansive soil has resulted in a decrease in the free swell index of the soil. From the result, it is noticed that at 15 % addition of stone dust highly decreases the free swell index of expansive soil.

4.2.2 The Effect Adding stone dust on Atterberg Limits

The effect of adding stone dust on the expansive soil sample show the changes on the Atterberg limit of the expansive soil. The liquid limit and plastic index decreased while the plastic limit increased. The Atterberg limit of the soil shows highly the great variation when there is an addition of stone dust on the expansive soil. Generally, the result indicates that a decrease in the liquid limit, and plasticity index at different percentage of stone dust.

Table 4.9:The effect of stone dust on the atterberg limit of natural soil

Ser.No	Location	Depth of sample (m)	Liquid limit LL (%)	Plastic limit(PL) (%)	Plastic index(PI) (%)
1	Shanan gibe	1.5	111.995	24.9	87.10
		3	101.925	37.92	63.80
2	Kochi	1.5	101.065	38.14	62.93
		3	95.518	41.36	54.16
3	Merkato	1.5	93.962	40.30	53.66
		3	91.670	41.77	49.90

From the above table the natural moisture content of liquid limit was above 90 this shows that the soil is highly expansive soil so this type of soil is not used for different type of infrastructure if it uses the structure leads to fail.

Table 4.10: The effect of the atterberg limit of stabilized@ the 15 %

Ser.No	Location	Name sample	Depth of sample (m)	Liquid limit,	Plastic limit,	Plastic index,
				LL (%)	PL (%)	PI (%)
1	Shanan gibe	15%	1.5	81.824	53.86	27.97
			3	64.643	54.47	10.17
2	Kochi	15%	1.5	77.560	50.74	26.82
			3	73.556	44.20	29.36
3	Merkato	15%	1.5	76.54	49.67	26.54
			3	65.537	51.08	14.45

From the above table at 15% of adding stone dust to Expansive soil the Liquid limit and plastic index is decreased and the Plastic limit were increased this indicate that the addition of stone dust can improve the expansiveness of the soil

4.2.3 Effect of Adding stone dust on Specific gravity

The specific gravity of the Stone Dust is 2.58. The addition of the stone dust can make to change variation in the Expansive soil.

Table 4.11: Effect of Specific gravity

Sample Designation	Specific Gravity of Soil @ 1.5m	Specific Gravity of Soil @3m
Expansive soil 1	2.53	2.48
Stone dust 5% with ESS1	2.62	2.56
Stone dust 10% with ESS1	2.71	2.67
Stone dust 15% with ESS1	2.70	2.66
Stone dust 20% with ESS1	2.67	2.62
Stone dust 25% with ESS1	2.63	2.58

Specific gravity of natural soil is 2.53 and when it adds stone dust the specific gravity it became increase to 2.70. After it reaches the maximum point then it became decrease.

4.2.4 Effect of Adding stone dust on Compaction Test

The result indicated the effect of stone dust on MDD and OMC of samples content of expansive soil sample there is the highly change in the MDD and OMC of the soil with different percentage addition of expansive soil in all cause of the mixing the OMC decrease and reversibly the MDD of the expansive soil increase, from the result the MDD of the expansive soil value obtained maximum at the percentage of 15 %is 1.567 g/cm^3 with the OMC of 21.86%.It was further assumed that the partial breaks down of the stone was held to obtain the maximum MDD since when they are broken it will absorb the water, which allows obtaining the maximum dry density.

The various percentage of stone dust mixed with expansive soil; the result shows that there is an increment in the MDD and decrement of the OMC of the blended expansive soil. This is due to the soil contain less Brocken small rocks and the rocks found in this soil are do not fractured during applied of compaction on the small rocks, due to this it is less probability to absorb the water which is the main factor with increasing the MDD and reduction of OMC of the blended soil, from the result the MDD value obtain a maximum at the percentage of 15% with 1.567 g/cm^3 with the OMC of 21.045 % .for expansive soil sample and the minimum MDD was found during the blending is 1.327 and the OMC of 31.4%. The below graph shows that the MDD and OMC of stone dust blended with expansive soil.

Table 4.12: The result of compaction test of stabilized for ESS1

Samples designation	OMC (%)	MDD (g/cm^3)
SD & ESS1 5%	30.312	1.400
SD & ESS1 10%	26.662	1.495
SD & ESS1 15%	21.045	1.567
SD & ESS1 20%	19.754	1.607
SD & ESS1 25%	17.653	1.644

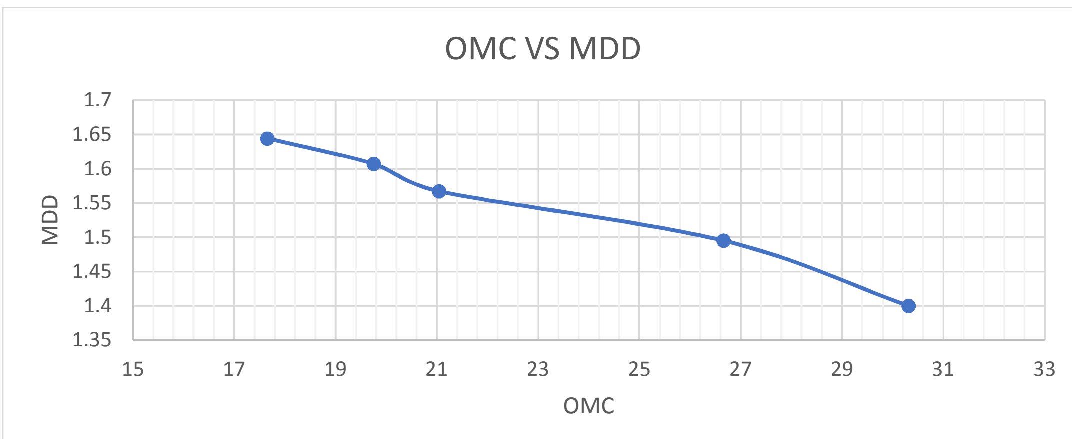


Figure 4-1:Effect of adding stone dust to expansive soil on OMC and MDD

Table 4.13: Test result of compaction test Stabilized for ESS2

Samples designation	**OMC (%)**	**MDD (g/cm^3)**
SD & ESS2 5%	27.533	1.402
SD & ESS2 10%	19.6	1.568
SD & ESS2 15%	18.06	1.603
SD & ESS2 20%	17.7	1.623
SD & ESS2 25%	16.2	1.648

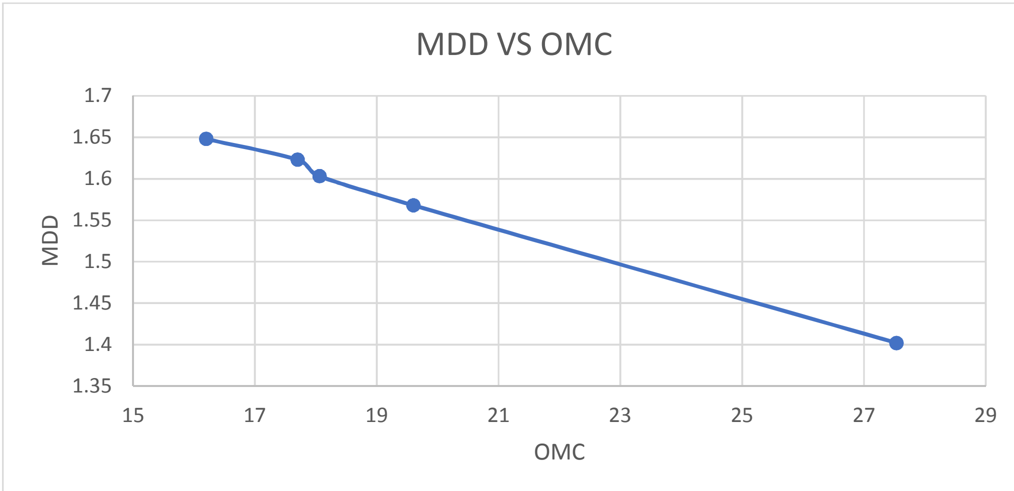


Figure 4-2: Effect of adding stone dust to expansive soil on OMC and MDD

Table 4.14:The result of compaction test Stabilized for ESS3

Samples designation	**OMC (%)**	**MDD (g/cm^3)**
SD & ESS3 5%	23.230	1.441
SD & ESS3 10%	21.450	1.489
SD & ESS3 15%	19.014	1.526
SD & ESS3 20%	17.809	1.557
SD & ESS3 25%	16.571	1.590

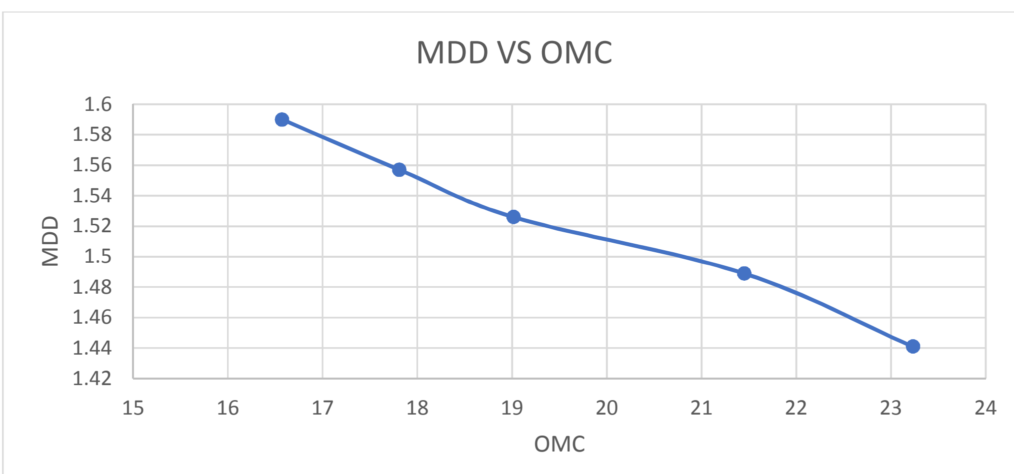


Figure 4-3: Effect of adding stone dust to expansive soil on OMC and MDD for test pit 3

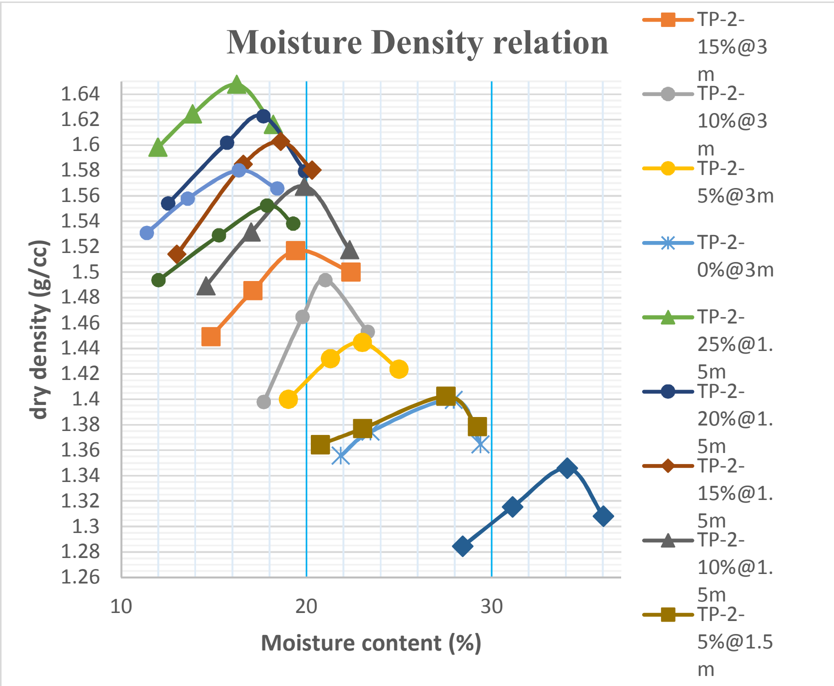


Figure 4-4: Compaction characteristic of Test pit 2

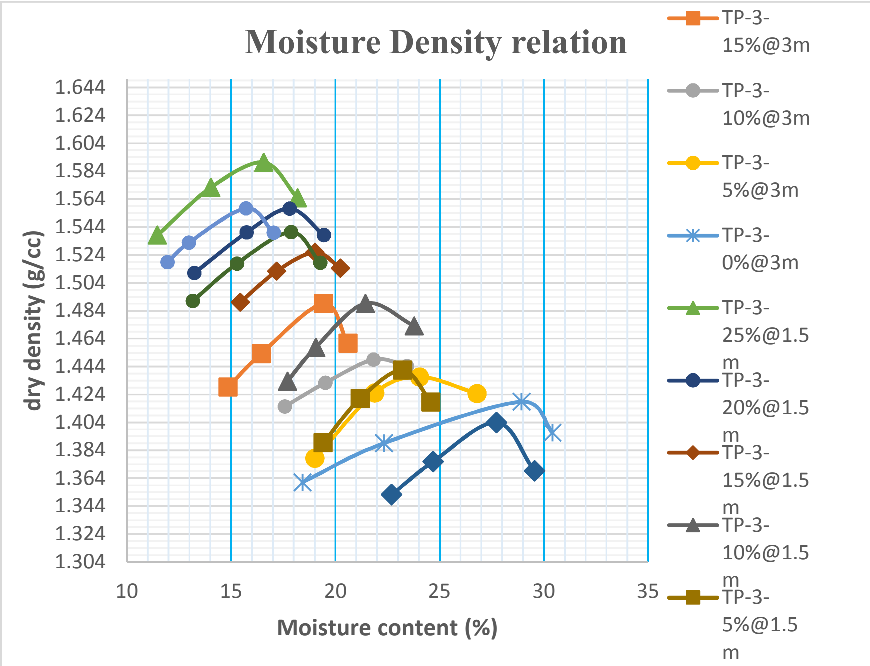


Figure 4-5: Compaction characteristic of Test pit 3

4.2.5 Effect of Adding Stone dust on CBR Test

The addition of stone dust on expansive soil makes to create increasing the strength of the expansive soil and improve the geotechnical properties of expansive soil adding of stone dust on expansive shows increasing on expansive soil as the percentage of stone dust increase. The MDD value in CBR is increased up to reaches the optimum. It increased up to 15% of adding stone dust. And Initially the result of expansive soil shows there this too low CBR value thus, the CBR value of expansive soil is 2.52,2.61and 2.79 for the 3 test pit respectively and when stone dust is added to this expansive soil the value of CBR changed Radically. For test pit 1 it changes from 2.52 to the 27.3.

Table 15.15:The CBR value when Stone dust blended with ESS 1 @1.5m

Test pit	0%		5%		10%		15%		20%		25%	
	CBR 95% OF MDD	**CBR**	**CBR 95% OF MDD**	**CBR**	**CBR 95% OF MDD**	**CBR**	**CBR 95% OF MDD**	**CBR**	**CBR 95% OF MDD**	**CBR**	**CBR 95% OF MD**	**CBR**
Shanan Gibe	1.42	2.5	1.43	9.27	1.45	16.7	1.46	27.3	1.45	16	1.44	11
Kochi	1.43	2.6	1.44	8.5	1.44	14.8	1.41	24.2	1.45	13.6	1.45	9.43
Merkato	1.48	2.8	1.49	10.	1.54	16.4	1.45	26.5	1.49	19.5	1.48	14.7

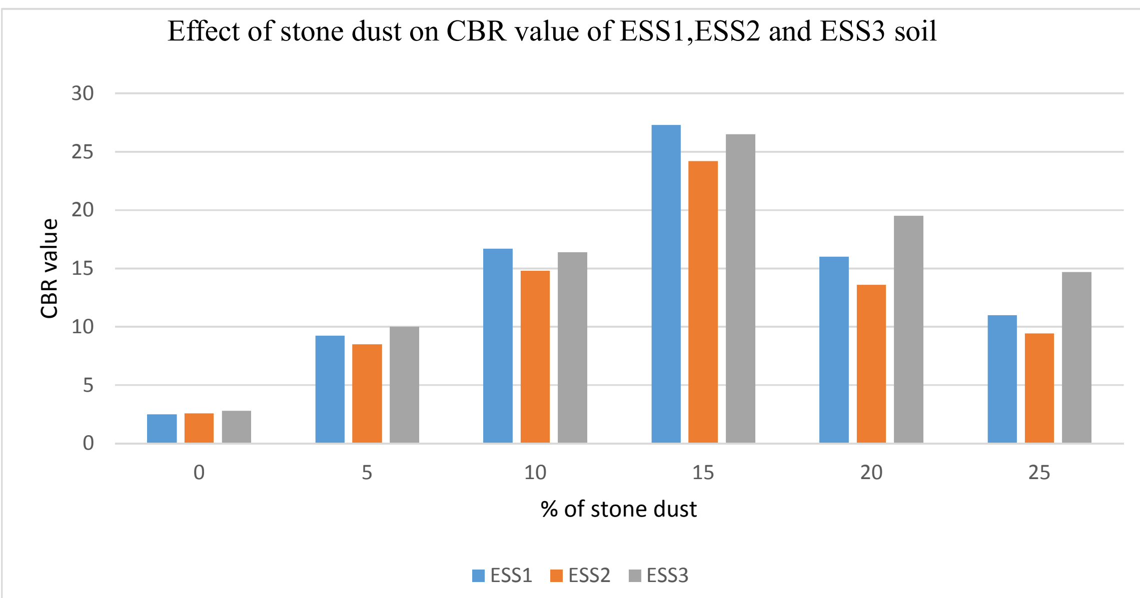


Figure 4-6: Effect of stone dust on CBR value of ESS1, ESS2 and ESS3

From the above table 4.15 the study shows that as the percentage of stone dust increase the result of CBR became increase until it reaches the maximum or the required strength. So the optimum percentage of the present study indicate at 15% of stone dust Therefore, adding stone dust to the expansive soil can improve the expansive soil.

Table 16.16: Test Result of CBR Swell

Test pit	0%	5%	10%	15%
	CBR Swell	CBR Swell	CBR Swell	CBR Swell
Shanan Gibe	9.51	6.34	2.7	0.13
Kochi	8.48	5.72	2.4	0.21
Merkato	8.21	5.14	2.5	0.15

The CBR Swell of Natural Soil is very High Which is 9.51,8.48, and 8.21 For TP1, TP2 and TP3 respectively. But after the addition of stone dust on the expansive soil the CBR swell test result was decreased to 0.13,0.21 and 0.15 For TP1, TP2 and TP3 respectively at the addition of 15% of stone dust. The Test result indicate that the addition of stone dust on the expansive soil reduce the swelling of the CBR. Stabilization with stone dust is important in decreasing swelling of the soil and increasing the strength of bearing Capacity.

4.2.6 Effect of adding stone dust on the classification of the soil.

From the below figures the expansive soil classification of AASHTO is classified under A-7-6 and USCS of CH but after the addition of the stone dust he soil is changed to A-2-5

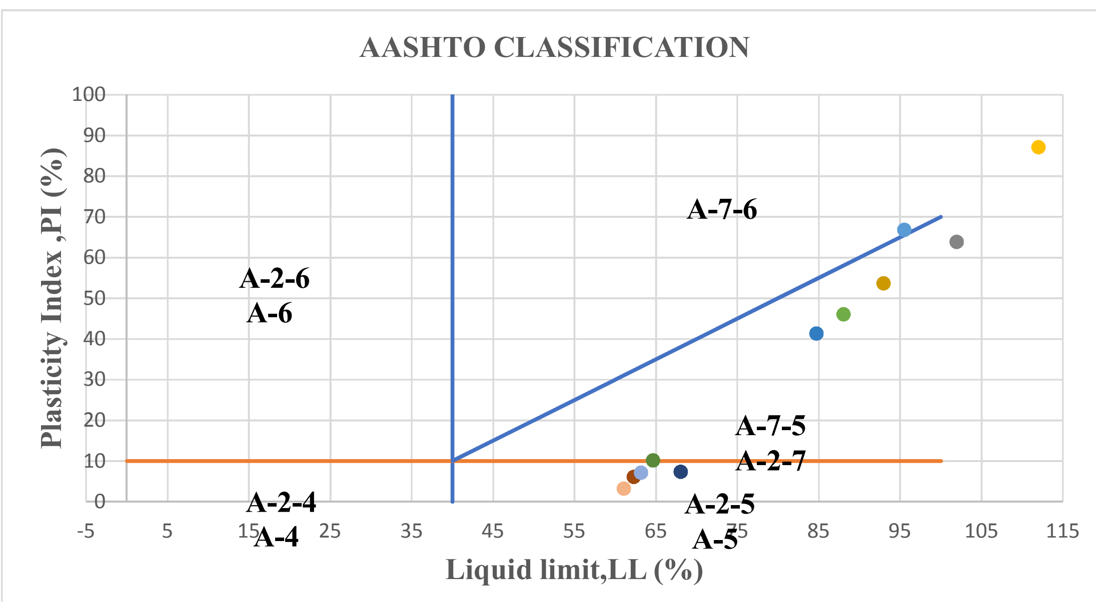


Figure 4-7: The AASHTO soil classification for Test 1

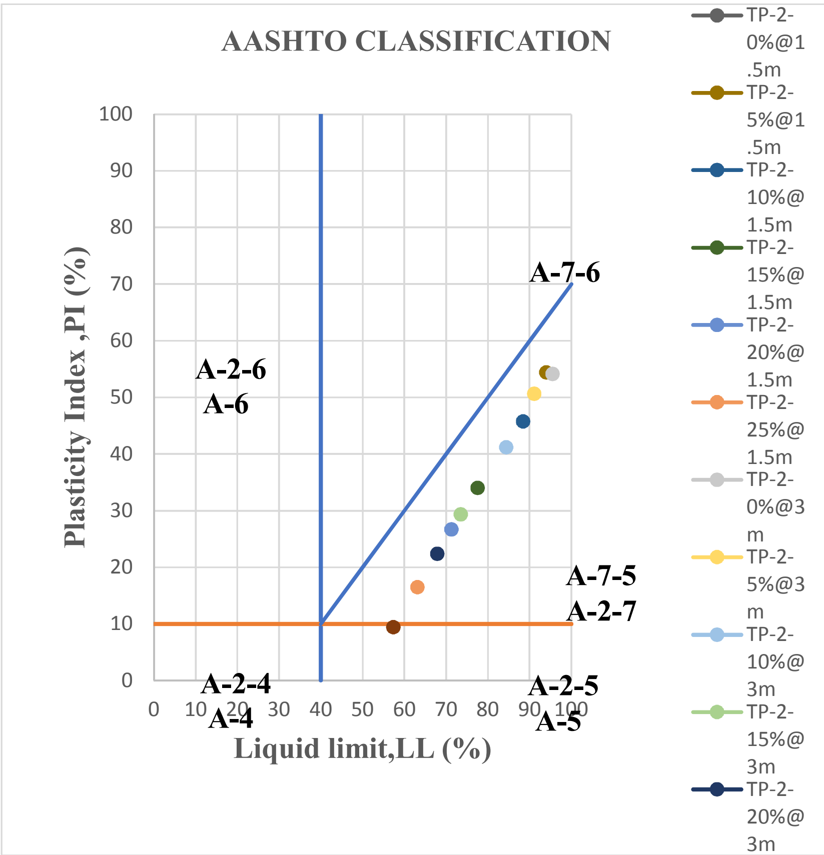


Figure 4-8: The AASHTO soil classification for Test pit 2

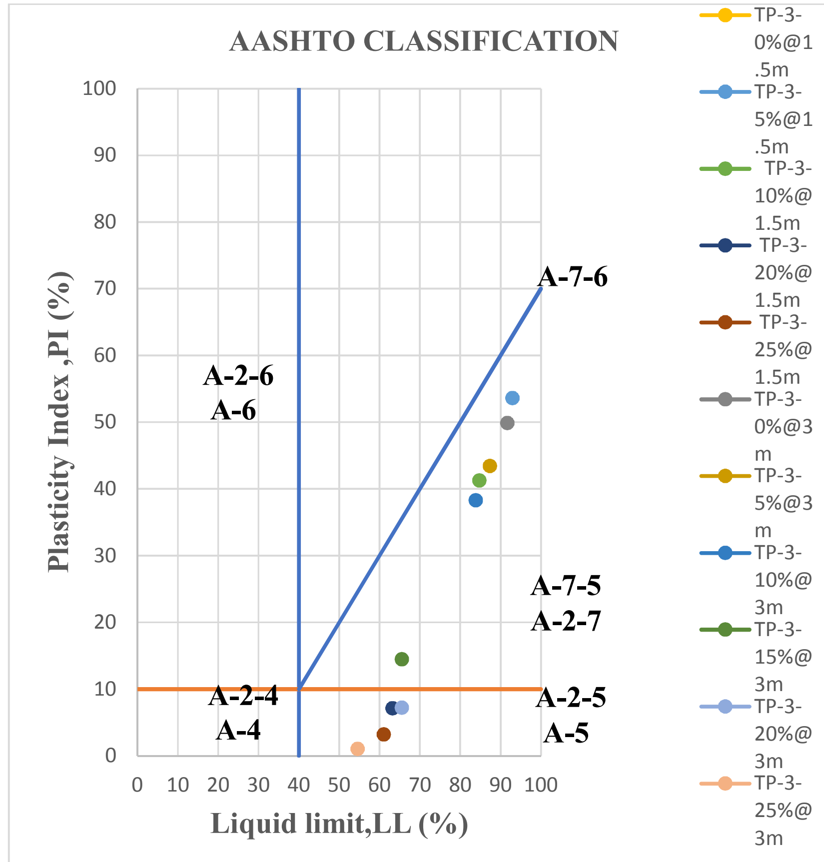


Figure 4-9: The AASHTO soil classification for Test pit 3

4.3 Discussion on effect of stone dust and optimum percentage determination

The effect of adding stone dust to the expansive soil makes to change the properties of expansive soil. Adding stone dust to expansive soil leads to make radical change in laboratory test of Specific gravity, atterberg limit, compaction characteristic and CBR. In compaction characteristic, when the stone dust added to expansive soil makes to decrease the moisture content and inversely the maximum density became increased these shows that adding stone dust can improve the compaction characteristic of MDD and OMC. And also the addition of stone dust on the CBR Can increase the result of CBR value and inversely it decreases the swelling potential of Expansive soil. the value of CBR are increased from 2.52 in natural to 27.3 at 15% stone dust. this indicate that adding stone dust to expansive soil can make to change the properties of expansive soil which results used for subgrade. So the addition of stone dust on expansive soil resulted to decrease on free swell, OMC, LL, PI and in the CBR swell. inversely the addition of stone dust on expansive soil makes to increase in the value of PL, MDD and CBR this indicate that the effect of adding stone dust on the expansive soil changes the properties of expansive soil and increase the strength of the expansive soil. therefore, the addition of stone dust on expansive soil improve the geotechnical properties of expansive soil.

The value of CBR after 15% became decreased this indicate that the optimum percentage required to achieve the study is at 15% and also the specific gravity of soil increase up to 15% and then became to decrease. This indicate that the required strength to achieve the study was at addition of 15% of stone dust. Generally adding stone dust to expansive soil can make to create effects on Laboratory test of soil so that as the result indicate adding stone dust to expansive soil is important in terms of obtaining strength and cost the optimum percentage of this study is at addition of 15% of stone dust this indicate that the required strength to achieve the study was at 15%.

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The present studies indicate that the soil Sample is highly expansive soil. This expansive soil is not good for every type of structure. So the use of stabilized expansive soil with stone dust is very crucial in improving in engineering properties of expansive soil. The use of stone dust as stabilizing of expansive is locally available material and it also reduces the environmental pollution caused by stone dust powder.

Based on the laboratory results, the effect of stone dust added to expansive soil changed the value of the FSI, LL, PI, OMC, CBR swell is decreased and the PL, SG, MDD, CBR values are increased. The optimum percentages stone dust observed at 15%.

From the addition of stone dust adding to expansive soil the following conclusions were drawn from the laboratory based on the studies carried out on:

- Specific gravity of Expansive soil increased with the addition of stone dust.

  Decreasing to The Free Swell Index (FSI) different in percentage of stone Dust. And improving the properties of expansive soils. It has been observed that the liquid limit decreased from 21%to 17% with the addition of stone dust. To decreasing to the Liquid Limit, Plastic Limit and Plasticity Index at different percentages.
- Increasing to the Maximum Dry Density (MDD) and decreasing on Optimum Moisture Content (OMC) in percentage stone Dust. It is observed that MDD of stone dust stabilized 1.327 to 1.644, 1.346 to 1.648, and 1.404 to 1.590 for ESS1, ESS2 and ESS3 respectively. Soil increases up to the addition of 15% Stone Dust. The compaction result show that; as the percentage of the stone dust content of the sample increase the optimum moisture content of the soil decrease and the dry density of the soil increase, the minimum optimum moisture content, and maximum dry density are obtained at 15 % mixing percentage.
- The CBR strength increases as addition of Stone Dust increase the reason of this effect is the pozzolanic reactions of stone dust with the amorphous silica and alumina present in soil and Stone Dust.
- Generally, the effect of adding of stone dust to expansive soil highly increases the PL, MDD, CBR, UCS and decreases the FS, LL, PI, OMC, CBR swell of the expansive soil sample.

5.2 Recommendation

Depend on the stabilizing of expansive soil with stone dust study results, the following points were recommended:

- The effect of mixing time and drying method have to evaluate on optimum stabilizers ratio shall be considered.
- Stabilizing of stone dust study, was not enough literature review on the studied area. It is recommended to do the detail geological investigation so that nature and mineralogical content of the soil can further be proved.
- This study was conducted by taking limited samples. It is recommended to conduct the research by a large number of samples. Therefore, the findings should be considered as indicative rather than definitive for the whole study area.
- The present study was conducted by taking limited samples, parameters in order to have the full understanding the effect of the stone dust on the expansive soil more samples and parameters, the mineralogical tests should also be performed to have more understood the effect of mineralogical content effect on the expansive when they blended.
- For the practical applicability of the stabilized expansive soil is crucial in terms of cost and availability. So in order to get safe environmental, durable and stable structure stabilization expansive soil with stone dust plays a great role.
- Further detailed laboratory analysis carried out on a number of additional samples from different locations of the town to get the optimum Percentage of stone dust analysis.

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APPENDIX–A; LABORATORY TEST RESULT FOR TEST PIT 1

A-1 Determination of Natural Moisture Content for Test pit 1

Determination of Natural Moisture Content Test pit 1					
	Unit				
Depth from NGS	M	TP1@1.5m		TP1@3m	
Specimen Trial		1	2	F2	D1
Can Code		DD	C1	F2	D1
Weight of Can	Gram	29.54	21.76	25.76	24.743
Weight of Can + Wet Soil	Gram	148.87	142.63	136.96	122.63
Weight of Can + Dry Soil	Gram	117.84	111.67	108.62	99.67
Moisture Content	%	35.14	34.43	34.20	30.64
Average moisture content	%	34.79		32.42	

A-2 Wet sieve analysis

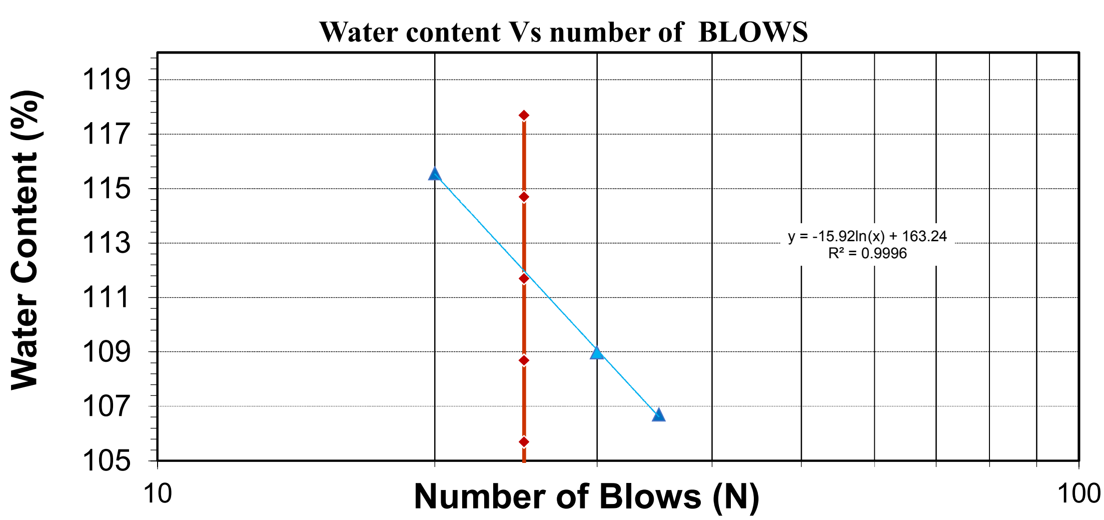
TEST METHOD: AASHTO T 11, T27							
Sample preparation : Oven-dried sample							
Mass dry soil (before wash)			1000gm				
Total mass, gm		1000					
Sieve Size mm	Mass of Retain, gm	% of Retain	% Cum. Retain	% of Pass			
9.5	0	0	0	100			
4.75	2.4	0.24	0.24	99.76			
2	5.2	0.52	0.76	99.24			
0.85	9.4	0.94	1.7	98.3			
0.425	16.8	1.68	3.38	96.62		AASHTO	USCS
0.3	19.2	1.92	5.3	94.7	% of gravel	0.76	0.24
0.15	17.3	1.73	7.03	92.97	% of Sand	8.83	9.35
0.075	25.6	2.56	9.59	90.41	% of Silt	26.2623	40.4386
Pan	904.1	90.41	100	0	% of Clay	64.1477	49.9714

B-2 Determination of specific gravity for ESS 1

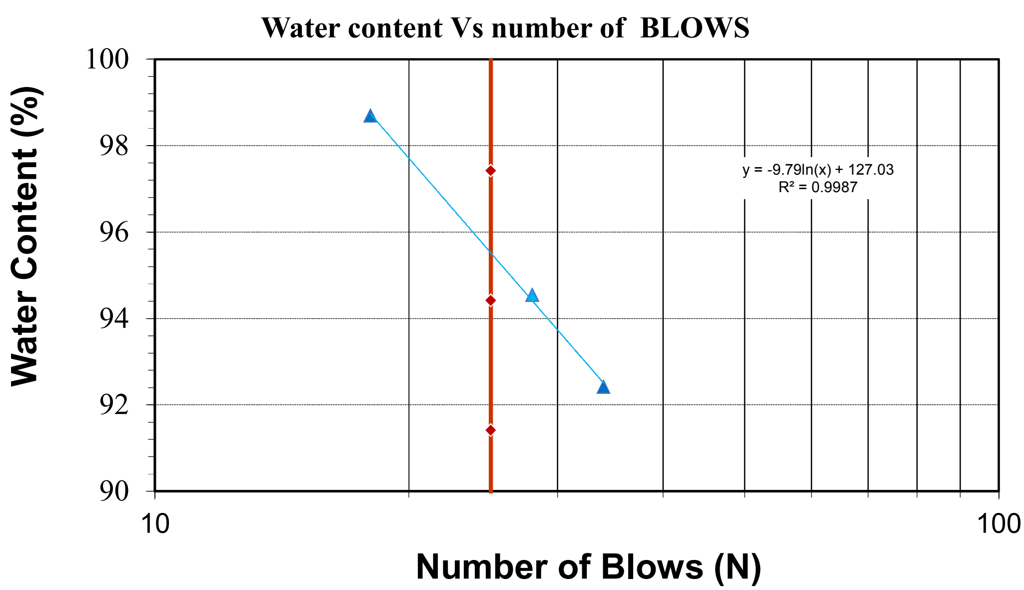
SG For Natural TP1			
Trial code	D1	K2	R1
Mass of dry, clean Calibrated pycnometer, M_p	29.36	28.43	27.41
Mass of specimen + pycnometer, $M_{ps,}$ in g	39.92	38.53	37.83
Mass of pycnometer + soil + water, M_{psw}, in g	132.43	130.43	129.5
Temperature of contents of pycnometer when M_{psw} was taken, Ti, in ^{o}c	22	22	22
Density of water @ Ti in g/cm3	0.9978	0.9978	0.9978
Mass of pycnometer + water at temperature Ti,g	125.95	124.73	122.99
Tx in $^o{}_c$	22	22	22
Density of water @ Tx in g/cm3	0.99757	0.99757	0.99757
K @ Tx	0.9998	0.9998	0.9998
Mass of pycnometer + water at temperature Tx,g	125.93	124.71	122.97
Specific gravity @ 20^{o}c	2.60	2.31	2.68
Average Specific gravity at 20^{o}c, G_s	2.53		

Atterberg Limit of Stabilized TP 1 result

TEST pit 1 @1.5 for natural soil			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	35	30	20
Can Number	---	---	G	I	s-2	B10	A10
Mass of Empty Can	M_C	(g)	17.16	15.14	17.80	19.64	17.54
Mass Can & Soil (Wet)	M_{CMS}	(g)	34.13	31.97	30.35	32.82	32.96
Mass Can & Soil (Dry)	M_{CDS}	(g)	31.23	28.17	23.87	25.94	24.69
Mass of Soil	M_S	(g)	14.07	13.03	6.07	6.31	7.16
Mass of Water	M_W	(g)	2.90	3.80	6.48	6.87	8.27
Water Content	W	(%)	20.61	29.19	106.70	108.97	115.57



TEST pit 1@1.5 for 5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	34	28	18
Can Number	---	---	H	a7	i-14	4-s	s-7
Mass of Empty Can	M_C	(g)	7.65	17.59	19.83	23.14	18.24
Mass Can & Soil (Wet)	M_{CMS}	(g)	24.02	38.00	31.04	32.05	31.20
Mass Can & Soil (Dry)	M_{CDS}	(g)	22.72	31.30	25.66	27.72	24.76
Mass of Soil	M_S	(g)	15.08	13.71	5.83	4.58	6.52
Mass of Water	M_W	(g)	1.30	6.70	5.39	4.33	6.44
Water Content	W	(%)	8.59	48.87	92.42	94.54	98.70



TEST pit @ 1.5 for 10%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	33	27	21
Can Number	---	---	10	a20	Si	l12	t2
Mass of Empty Can	M_C	(g)	5.85	19.64	6.21	5.87	6.75
Mass Can & Soil (Wet)	M_{CMS}	(g)	22.18	37.94	18.91	21.72	19.60
Mass Can & Soil (Dry)	M_{CDS}	(g)	16.88	32.96	13.11	14.34	13.44
Mass of Soil	M_S	(g)	11.03	13.32	6.90	8.47	6.69
Mass of Water	M_W	(g)	5.30	4.98	5.80	7.38	6.16
Water Content	w	(%)	48.06	37.41	83.99	87.18	92.01

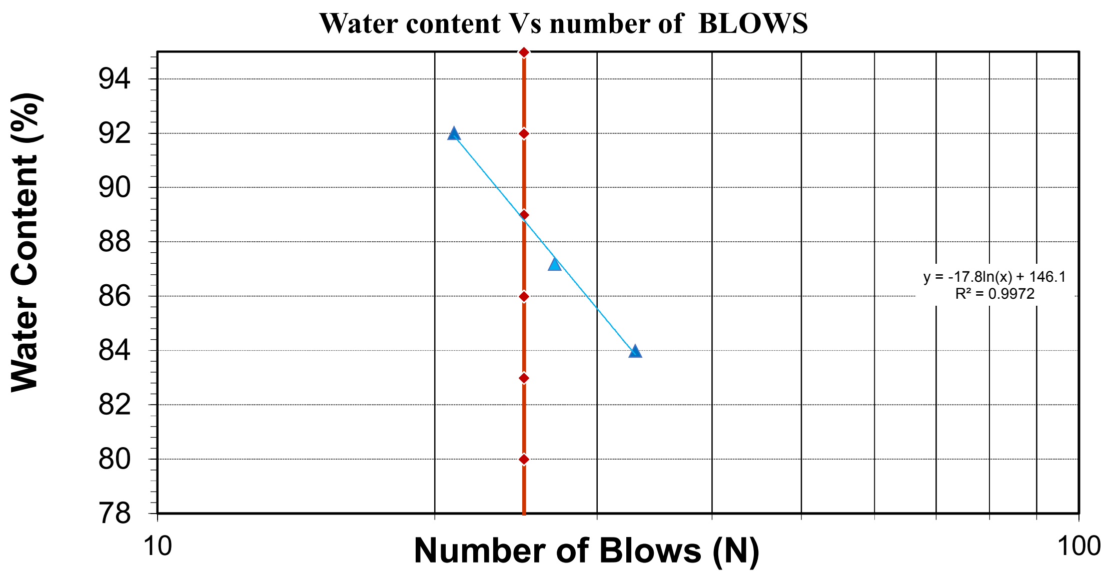
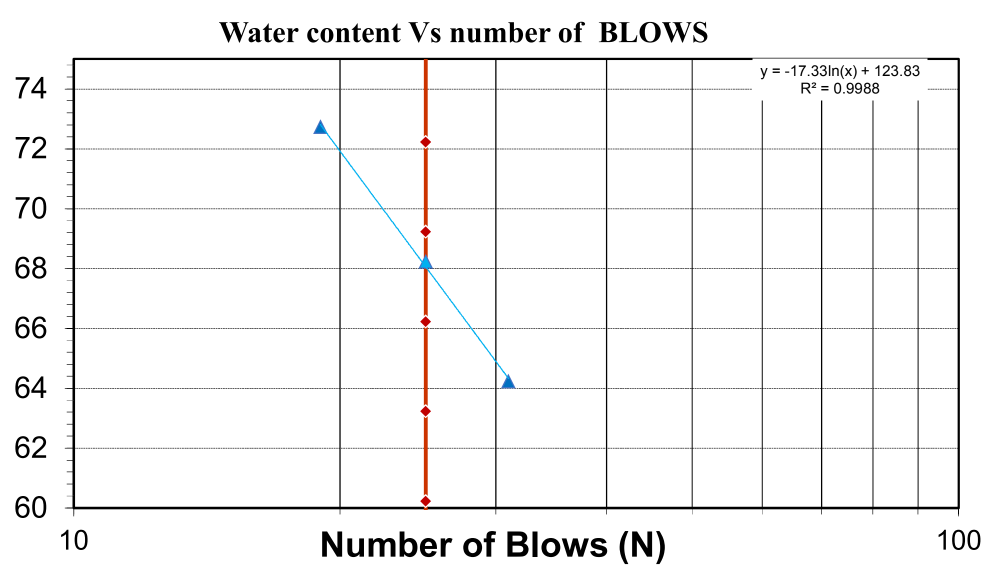
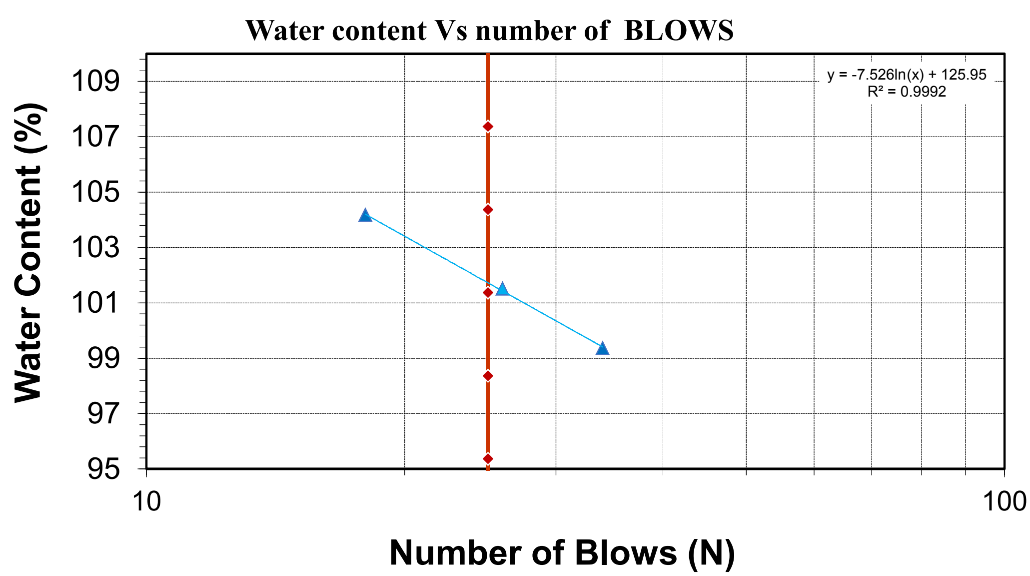


Table A- 5 Atterberg Limit of Stabilized TP 1@1.5 For 15%

TEST pit 1@1.5 for 15%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	20	26	32
Can Number	---	---	I	B	D3	A2	s-2
Mass of Empty Can	M_C	(g)	17.54	17.69	5.80	6.08	5.56
Mass Can & Soil (Wet)	M_{CMS}	(g)	30.17	31.15	20.24	19.61	21.52
Mass Can & Soil (Dry)	M_{CDS}	(g)	26.27	25.94	13.36	13.60	14.85
Mass of Soil	M_S	(g)	8.73	8.25	7.55	7.52	9.29
Mass of Water	M_W	(g)	3.90	5.20	6.88	6.02	6.67
Water Content	w	(%)	44.69	63.02	91.14	79.99	71.74



TEST@3m for Natural soil			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	34	26	18
Can Number	---	---	DD	s	c2	B4	EE
Mass of Empty Can	M_C	(g)	18.23	18.23	18.55	17.87	18.44
Mass Can & Soil (Wet)	M_{CMS}	(g)	38.99	35.98	27.36	32.96	32.95
Mass Can & Soil (Dry)	M_{CDS}	(g)	33.34	31.05	22.97	25.35	25.54
Mass of Soil	M_S	(g)	15.11	12.81	4.42	7.49	7.11
Mass of Water	M_W	(g)	5.64	4.93	4.39	7.60	7.40
Water Content	w	(%)	37.36	38.48	99.37	101.51	104.16



TEST pit @3m for@5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	33	24	17
Can Number	---	---	Y	3	t4	3a	Be
Mass of Empty Can	M_C	(g)	9.44	16.58	17.57	19.26	14.84
Mass Can & Soil (Wet)	M_{CMS}	(g)	24.52	37.59	31.78	34.12	34.80
Mass Can & Soil (Dry)	M_{CDS}	(g)	22.72	31.30	25.06	26.94	24.96
Mass of Soil	M_S	(g)	5.00	14.72	7.48	7.69	10.12
Mass of Water	M_W	(g)	1.80	6.29	6.73	7.18	9.84
Water Content	w	(%)	35.90	42.74	89.93	93.40	97.15

Table A- 7 Atterberg Limit of Stabilized TP 1@3m for 5%

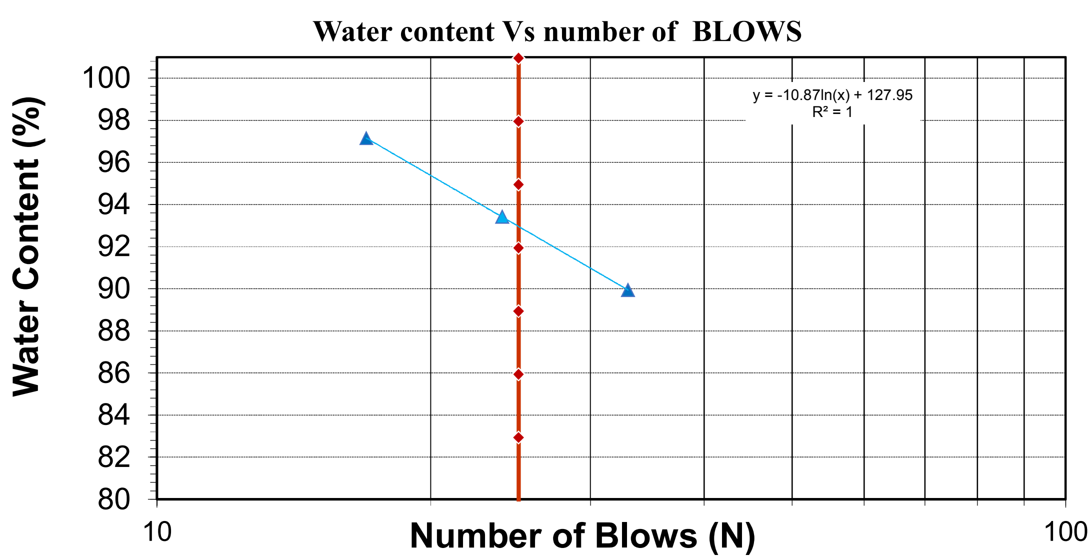
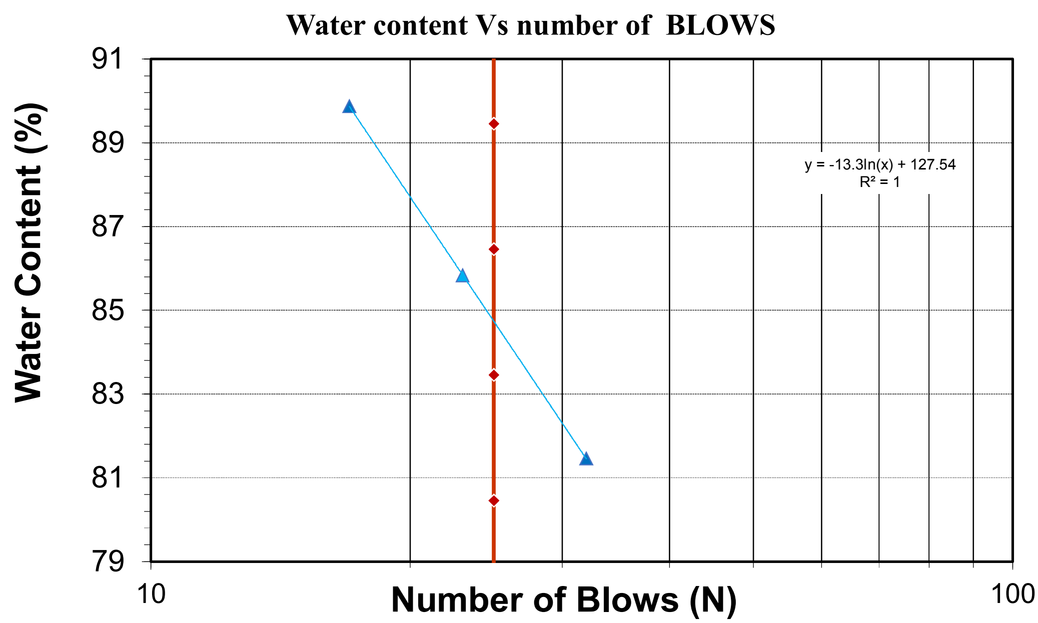


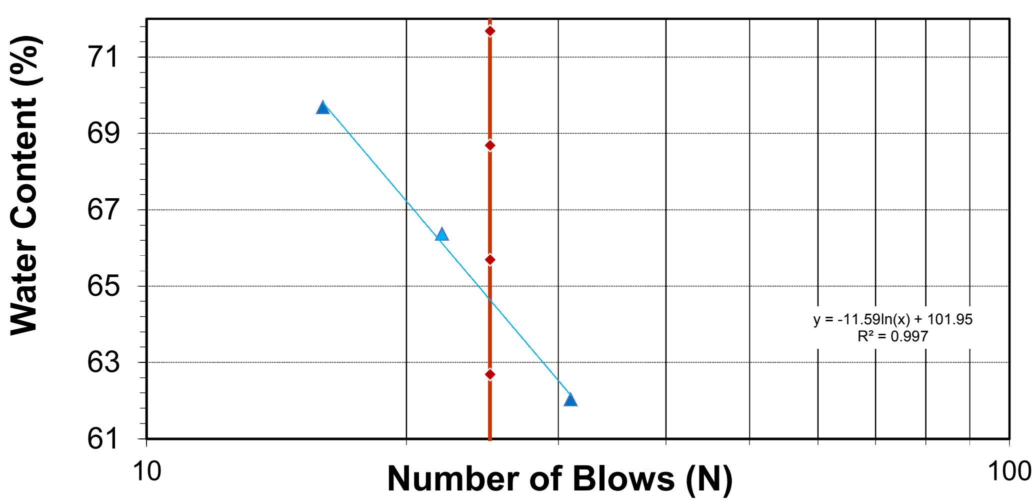
Table A- 8 Atterberg Limit of Stabilized TP 1@3m for 10%

TEST pit @ 3m for 10%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	32	23	17
Can Number	---	---	G9	W32	Pr	Q1	Et
Mass of Empty Can	M_C	(g)	6.96	20.86	7.97	8.78	7.29
Mass Can & Soil (Wet)	M_{CMS}	(g)	19.56	36.36	24.96	18.36	24.66
Mass Can & Soil (Dry)	M_{CDS}	(g)	15.67	31.75	17.34	13.94	16.44
Mass of Soil	M_S	(g)	8.72	10.89	9.36	5.15	9.15
Mass of Water	M_W	(g)	3.88	4.61	7.63	4.42	8.23
Water Content	*w*	(%)	44.55	42.33	81.46	85.83	89.87



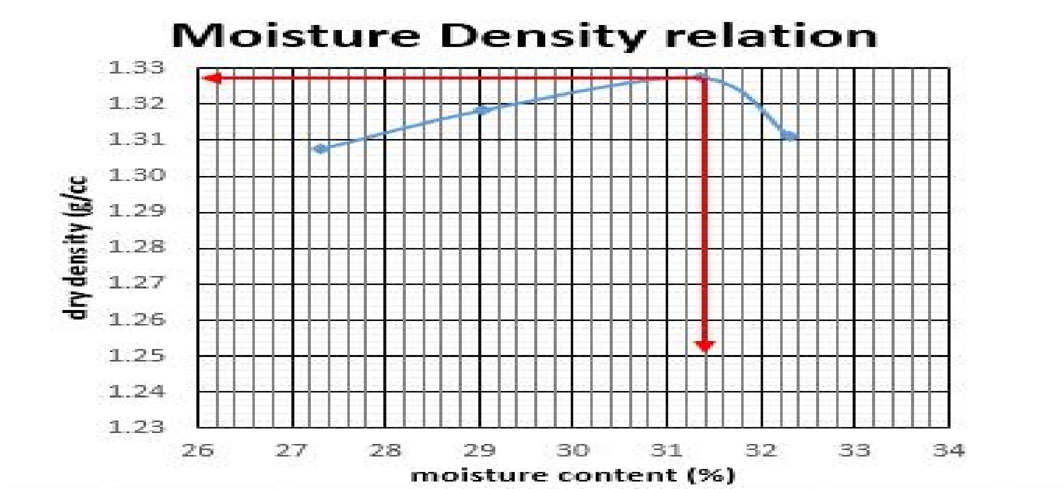
TEST@3m for 15%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	16	22	31
Can Number	---	---	T3	F22	D3	A2	G
Mass of Empty Can	M_C	(g)	16.76	16.68	13.02	11.64	10.89
Mass Can & Soil (Wet)	M_{CMS}	(g)	31.48	27.94	24.84	25.54	27.19
Mass Can & Soil (Dry)	M_{CDS}	(g)	25.75	24.44	19.99	20.00	20.95
Mass of Soil	M_S	(g)	8.99	7.76	6.96	8.36	10.06
Mass of Water	M_W	(g)	5.74	3.50	4.85	5.55	6.24
Water Content	*W*	(%)	63.83	45.11	69.69	66.37	62.03

Water content Vs number of BLOWS

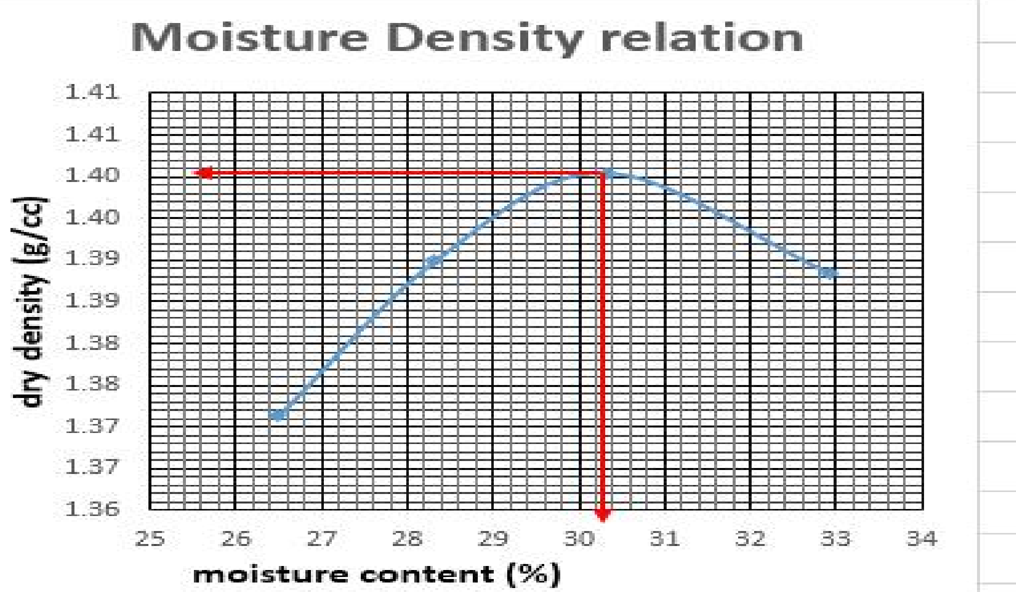


Compaction test Result for Test pit 1

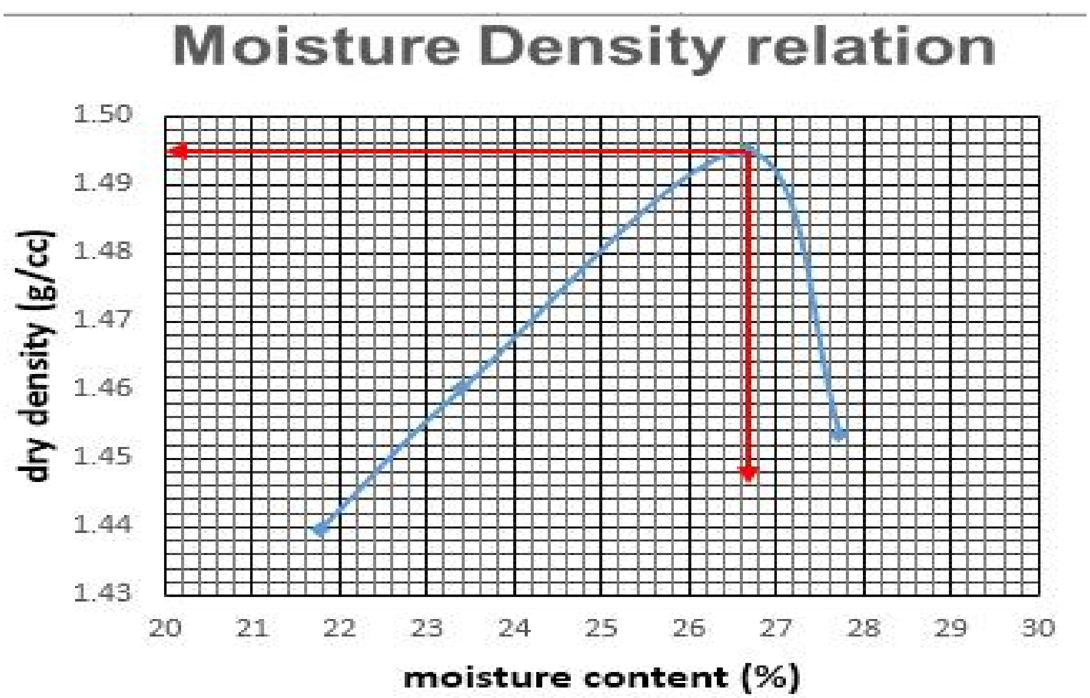
Wet density and dry density determination for natural					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10241.90	10320.40	10410.10	10390.80
Wt. of Mold	gram	6706.70	6706.70	6706.70	6706.70
Wt. Wet Soil	gram	3535.20	3613.70	3703.40	3684.10
Volume of Mold	cu.cm.	2124.00	2124.00	2124.00	2124.00
Wet Density	gr/cu.cm.	1.66	1.70	1.74	1.73
Container No.		Sg=1	F	A-16	BB
Wt. Cont + Wet soil	grams	170.83	140.05	141.99	156.15
Wt. Cont + Dry soil	grams	139.93	116.73	115.94	124.93
Weight of Water	grams	30.90	23.33	26.05	31.22
Weight of Container	grams	26.74	36.43	32.87	28.33
Weight of Dry Soil	grams	113.19	80.30	83.07	96.60
Moisture content	%	27.30	29.05	31.36	32.32
Dry Density	gr/cu.cm.	1.31	1.32	1.33	1.31



Wet density and dry density determination for test pit 1 for 5%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10390.8	10495.1	10582.9	10626.6
Wt. of Mold	gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	gram	3684.1	3788.4	3876.2	3919.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.735	1.784	1.825	1.846
Container No.		Ts2	CSA	10	1
Wt. Cont + Wet soil	grams	166.2	129.8	161.5	161.55
Wt. Cont + Dry soil	grams	137.2	108.7	130.4	128.33
Weight of Water	grams	29.00	21.10	31.10	33.22
Weight of Container	grams	27.7	34.2	27.8	27.4
Weight of Dry Soil	grams	109.5	74.5	102.6	100.93
Moisture content	%	26.484	28.322	30.312	32.914
Dry Density	gr/cu.cm.	1.371	1.390	1.400	1.389



Wet density and dry density determination 10%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10430.6	10534.4	10728.4	10650.1
Wt. of Mold	gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	gram	3723.9	3826.7	4021.7	3943.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.753	1.802	1.893	1.857
Container No.		T3-96	P15	2	GS-3
Wt. Cont + Wet soil	grams	219.005	137.61	148.728	105.96
Wt. Cont + Dry soil	grams	186.484	117.898	124.717	86.943
Weight of Water	grams	32.52	19.71	24.01	19.02
Weight of Container	grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	grams	149.314	84.275	90.057	68.599
Moisture content	%	21.780	23.390	26.662	27.722
Avg. Moisture Content	%	21.780	23.390	26.662	27.722
Dry Density	gr/cu.cm.	1.440	1.460	1.495	1.454



Wet density and dry density determination 15%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10520.9	10632.3	10736.2	10784.8
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3814.2	3924.6	4027.5	4075.1
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.796	1.848	1.896	1.919
Container No.		T12	WA	GS6	Uc
Wt. Cont + Wet soil	grams	162.863	101.953	90.364	91.536
Wt. Cont + Dry soil	grams	143.537	89.527	79.806	78.078
Weight of Water	grams	19.33	12.43	10.56	13.46
Weight of Container	grams	35.953	24.745	29.637	23.731
Weight of Dry Soil	grams	107.584	64.782	50.169	54.347
Moisture content	%	17.964	19.181	21.045	24.763
Dry Density	gr/cu.cm.	1.522	1.550	1.567	1.538

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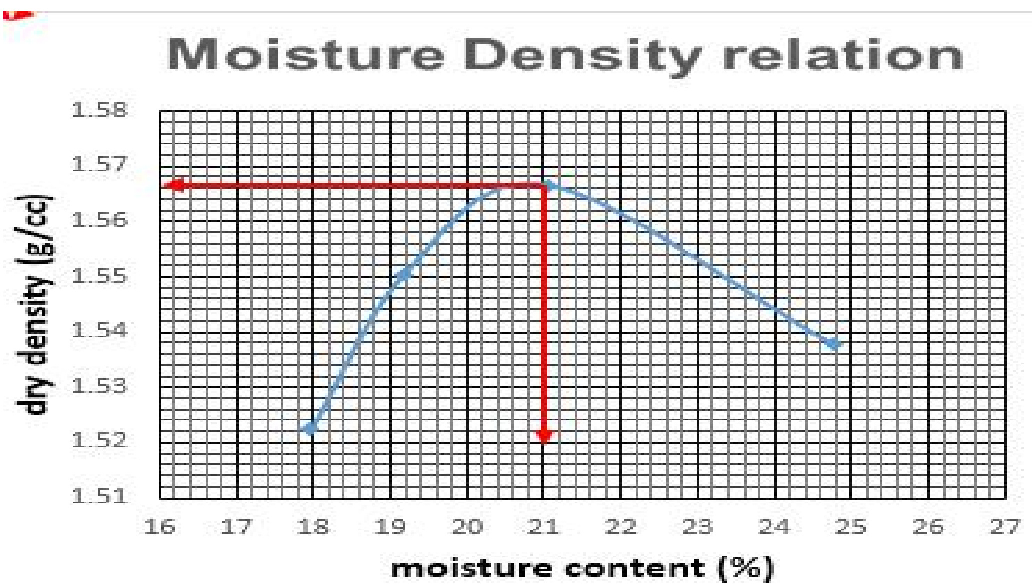
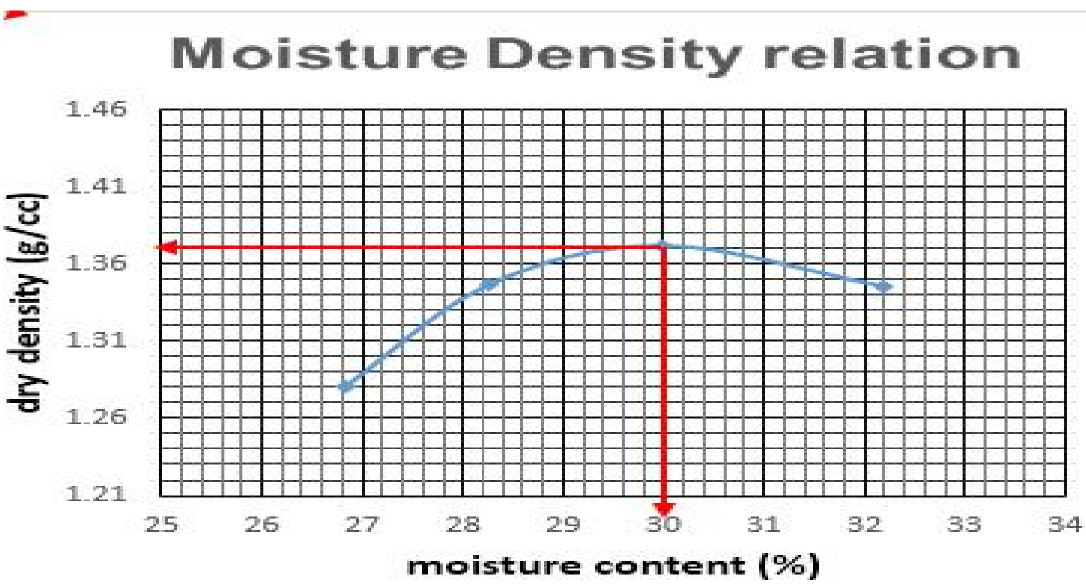
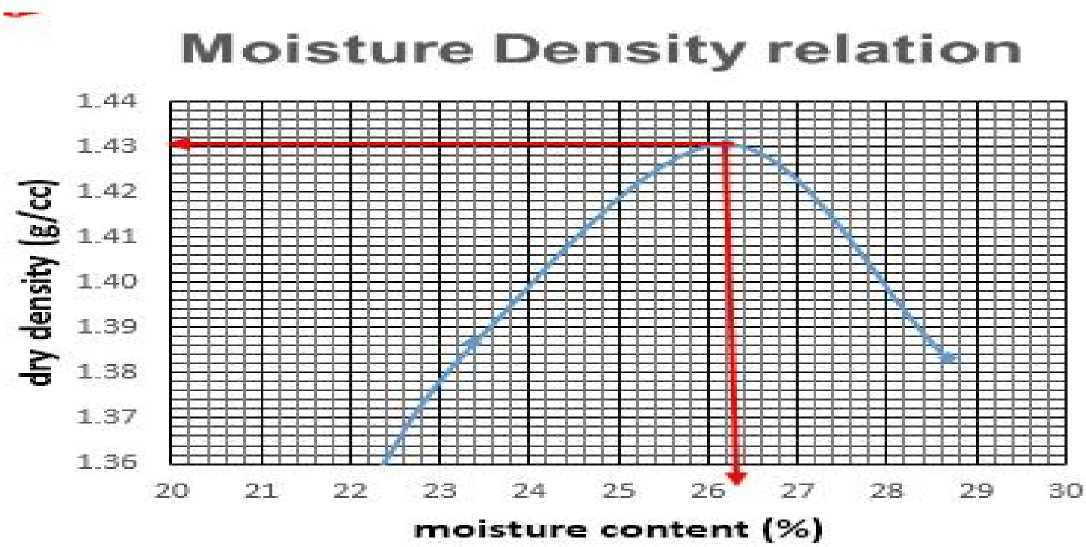


Wet density and dry density determination for natural					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10155.4	10200.5	10320.5	10310.8
Wt. of Mold	Gram	6706.7	6533.2	6533.2	6533.2
Wt. Wet Soil	Gram	3448.7	3667.3	3787.3	3777.6
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.624	1.727	1.783	1.779
Container No.		A2	F	SS	F
Wt. Cont + Wet soil	Grams	176.925	138.642	145.985	146.15
Wt. Cont + Dry soil	Grams	144.947	116.126	120.135	119.432
Weight of Water	Grams	31.98	22.52	25.85	26.72
Weight of Container	Grams	25.75	36.426	33.89	36.426
Weight of Dry Soil	Grams	119.197	79.7	86.245	83.006
Moisture content	%	26.828	28.251	29.973	32.188
Dry Density	gr/cu.cm.	1.280	1.346	1.372	1.345

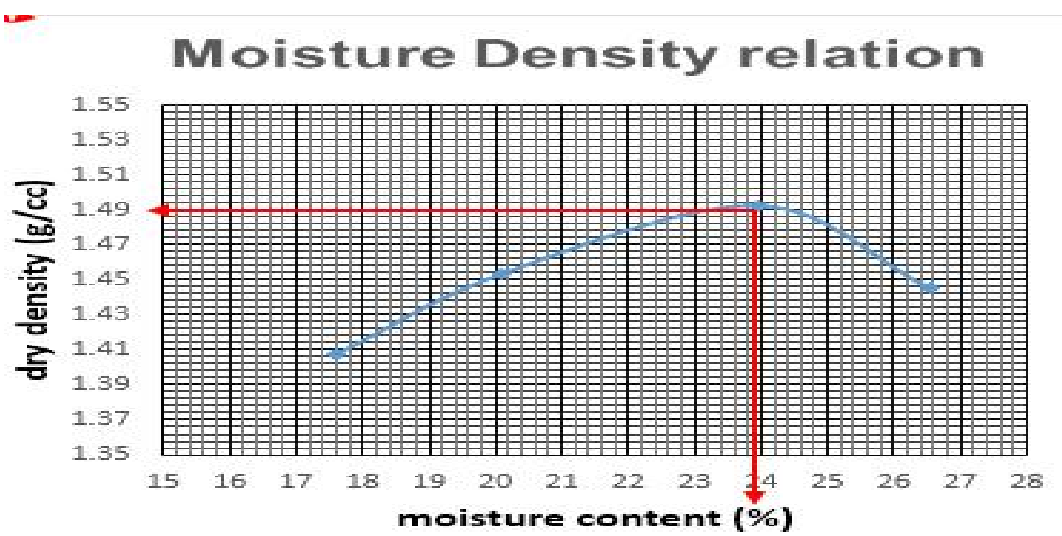


Compaction Characterstic Determination at 5%

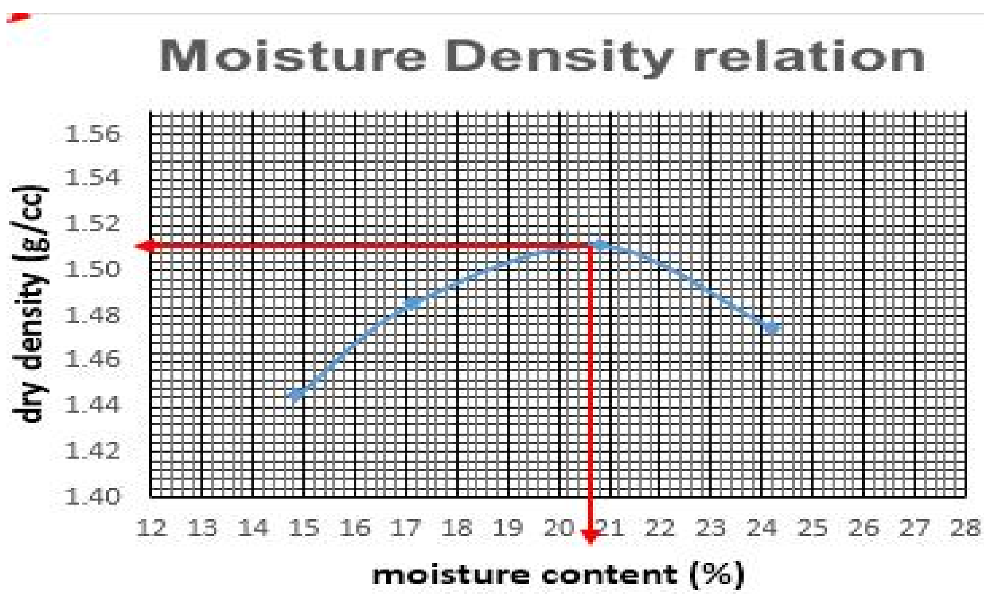
Wet density and dry density determination 5%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10200.8	10340.9	10543.5	10490.6
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3494.1	3633.2	3834.8	3780.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.645	1.711	1.805	1.780
Container No.		D	G	A1-c	11
Wt. Cont + Wet soil	grams	153.26	120.9	172.052	156.934
Wt. Cont + Dry soil	grams	130.98	105.18	146.64	127.964
Weight of Water	grams	22.28	15.72	25.41	28.97
Weight of Container	grams	29.614	37.925	49.693	26.929
Weight of Dry Soil	grams	101.366	67.255	96.947	101.035
Moisture content	%	21.980	23.374	26.212	28.673
Dry Density	gr/cu.cm.	1.349	1.386	1.430	1.383



Wet density and dry density determination 10%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10221.6	10414.4	10636.4	10592.1
Wt. of Mold	Gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	Gram	3514.9	3706.7	3929.7	3885.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.655	1.745	1.850	1.829
Container No.		G1	n2	t2	J
Wt. Cont + Wet soil	Grams	216.263	153.908	153.728	115.26
Wt. Cont + Dry soil	Grams	189.484	133.798	130.717	94.943
Weight of Water	Grams	26.78	20.11	23.01	20.32
Weight of Container	grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	grams	152.314	100.175	96.057	76.599
Moisture content	%	17.581	20.075	23.956	26.524
Dry Density	gr/cu.cm.	1.407	1.453	1.493	1.446



Wet density and dry density determination 15%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10231.9	10402.3	10586.2	10600
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3525.2	3694.6	3877.5	3890.3
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.660	1.739	1.826	1.832
Container No.		C23	f3	M3	R2
Wt. Cont + Wet soil	grams	99.84	88.639	90.954	88.369
Wt. Cont + Dry soil	grams	89.732	78.272	80.412	74.928
Weight of Water	grams	10.11	10.37	10.54	13.44
Weight of Container	Grams	21.683	17.673	29.725	19.395
Weight of Dry Soil	Grams	68.049	60.599	50.687	55.533
Moisture content	%	14.854	17.108	20.798	24.204
Dry Density	gr/cu.cm.	1.445	1.485	1.511	1.475



CBR of natural Soil

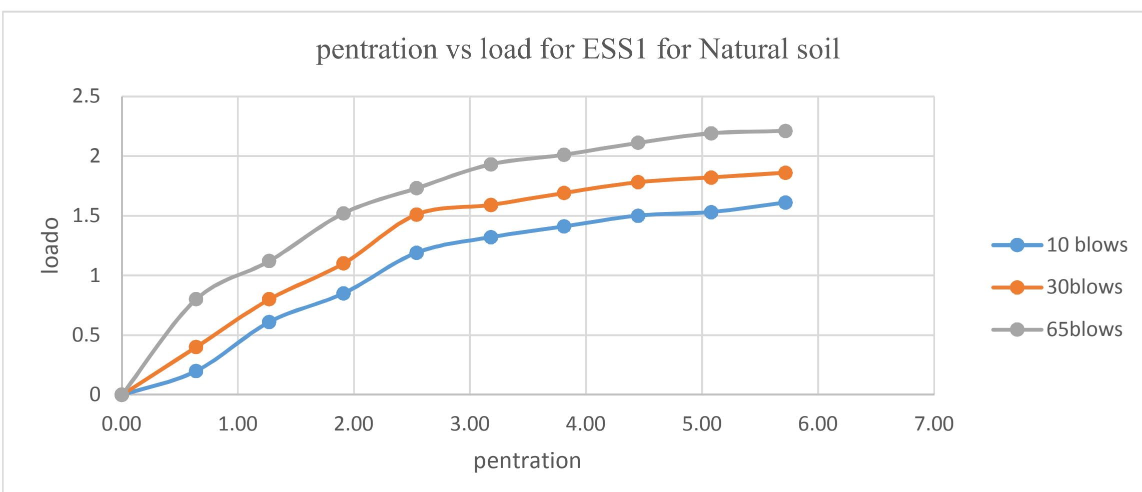
Compaction Determination for CBR of ESS1						
Compaction test	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.	A6	A6	B3	B3	C1	C1
Mass of soil + Mould g	10320.7	10270.4	9991.8	9989.4	9813.3	9734.8
Mass Mould g	6123.6	6123.6	6258.3	6258.3	6145.3	6145.3
Mass of Soil g	4197.1	4146.8	3733.5	3731.1	3668	3589.5
Volume of Mould g	2124	2124	2124	2124	2124	2124
Wet density of soil g/cc	1.976	1.952	1.758	1.757	1.727	1.690
Dry density of soil g/cc	1.518	1.469	1.429	1.393	1.388	1.328

Moisture Determination												
moisture content data	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak			After soak
Container no.	P6	E3	R1	H2	W2	C1	J3	K3	B1	P1	L1	J1
Mass of wet soil + Container g	109.6	84.3	158.5	128.6	139.4	130.5	138.8	139.7	115.6	128.2	150.5	172.3
Mass of dry soil + Container g	92.5	72.4	126.5	106.4	121.2	111.2	115.7	119.6	98.4	110.5	121.4	149.4
Mass of container g	31.6	35.5	31.4	37.4	33.6	34.7	32.5	37.4	28.2	37.9	35.4	38.3
Mass of water g	17.1	11.9	32.1	22.2	18.2	19.3	23.1	20.1	17.2	17.7	29.1	22.9
Mass of drysoil g	60.9	36.9	95.1	69.0	87.6	76.5	83.2	82.2	70.2	72.6	86.0	111.1
Moisture content %	28.1	32.2	33.7	32.2	20.8	25.2	27.8	24.5	24.5	24.4	33.8	20.6
Average moisture content %	30.2		32.9		23.0		26.1		24.4		27.2	

Table penetration vs load

Penetration(mm) / No. of layers	0.00	0.64	1.27	1.91	2.54	3.18	3.81	4.45	5.08	5.72
10	0	0.2	0.61	0.85	1.19	1.32	1.41	1.65	1.53	1.61
30	0	0.4	0.8	1.1	1.51	159	1.69	1.78	1.82	1.86
65	0	0.8	1.12	1.52	1.73	1.93	2.01	2.11	2.19	2.21

Reading	65 Blows		30 Blows		10 Blows	
	Gauge rdg Mm	Swell in %	Gauge rdg Mm	Swell in %	Gauge rdg Mm	Swell in %
Initial	28.05	9.73	20.3	9.51	25.5	9.33
Final	39.00		31.00		36	



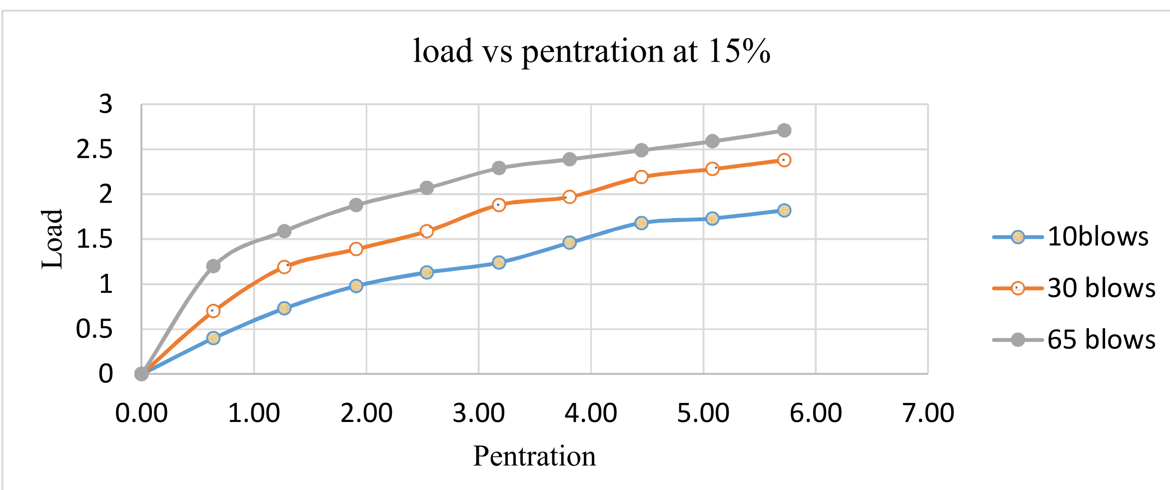
Compaction Determination						
COMPACTION DATA	65 Blows		30 Blows		10 Blows	
	Before soak	After soak	Before soak	After soak	Before soak	After soak
Mould No.	E6	E6	F3	F3	G1	G1
Mass of soil + Mould G	10430.4	10325.6	10297.4	10199.7	9894.6	9868.4
Mass Mould G	6310.3	6310.3	6510.6	6510.6	6139.6	6139.6
Mass of Soil G	4120.1	4015.3	3786.8	3689.1	3755	3728.8
Volume of Mould G	2124	2124	2124	2124	2124	2124
Wet density of soil g/cc	1.940	1.890	1.783	1.737	1.768	1.756
Dry density of soil g/cc	1.565	1.423	1.463	1.322	1.432	1.299

Moisture Determination												
MOISTURE CONTENT DATA	65 Blows				30 Blows				10 Blows			
	Before soak		After soak		Before soak		After soak		Before soak		After soak	
Container no.	DD	S6	T1	J11	P3	C3	Z3	L3	M1	N1	Y1	U1
Mass of wet soil + Container G	102.3	73.9	151.8	134.9	132.7	121.5	132.7	140.7	98.6	118.6	147.6	167.6
Mass of dry soil + Container G	86.8	67.8	124.9	107.7	116.6	103.4	108.6	114.8	83.9	104.6	117.7	135.5
Mass of container G	35.8	32.8	34.9	31.8	31.4	30.5	30.7	33.6	30.2	32.7	38.9	36.5
Mass of water G	15.5	6.1	26.9	27.2	16.1	18.1	24.1	25.9	14.7	14.0	29.9	32.1
Mass of drysoil G	51.0	35.0	90.0	75.9	85.2	72.9	77.9	81.2	53.7	71.9	78.8	99.0
Moisture content %	30.4	17.4	29.9	35.8	18.9	24.8	30.9	31.9	27.4	19.5	37.9	32.4
Average moisture content %	23.9		32.9		21.8		31.4		23.5		35.2	

Penetration vs load For 15%

Pentration (mm) / No.of Layers	0.00	0.64	1.27	1.91	2.54	3.18	3.81	4.45	5.08	5.72
10	0	0.4	0.73	0.98	1.13	1.24	1.46	1.68	1.73	1.82
30	0	0.7	1.19	1.39	1.59	1.88	1.97	2.19	2.28	2.38
65	0	1.2	1.59	1.88	2.07	2.29	2.39	2.49	2.59	2.71

Swell Determination at 15%						
	65 Blows		30 Blows		10 Blows	
	Gauge rdg Mm	Swell in %	Gauge rdg Mm	Swell in %	Gauge rdg mm	Swell in %
Initial	23.48	0.57	19.82	0.31	20.94	0.22
Final	24.12		20.17		21.19	



APPENDIX–B; THE LABORATORY TEST RESULT FOR TEST PIT 2

Time minutes	Actual Hydrometer Reading	Temp.	correction for hydrometer reading					Correction factor (a)	Effe. Depth of Hydrometer (L)	Values of K	Diameter of soil Particle (mm)	% finer, P	Adjusted Percent of finer
			T°	meniscus	Zero	Composite	Corrected						
			Correction	Correction	Correction	Correction	H.Reading						
1	48	21	0.2	1	-5	-3.8	44.2	0.98	8.5	0.01325	0.0386	86.63	77.66
2	47	21	0.2	1	-5	-3.8	43.2	0.98	8.6	0.01325	0.0274	84.67	75.90
5	44	21	0.2	1	-5	-3.8	40.2	0.98	9.1	0.01325	0.0178	78.79	70.63
15	42	21	0.2	1	-5	-3.8	38.2	0.98	9.4	0.01325	0.0105	74.87	67.12
30	41	21	0.2	1	-5	-3.8	37.2	0.98	9.6	0.01325	0.0075	72.91	65.36
60	38	21	0.2	1	-5	-3.8	34.2	0.98	10.1	0.01325	0.0054	67.03	60.09
120	36	21	0.2	1	-5	-3.8	32.2	0.98	10.4	0.01325	0.0039	63.11	56.57
240	32	21	0.2	1	-5	-3.8	28.2	0.98	11.0	0.01325	0.0028	55.27	49.55
480	28	21	0.2	1	-5	-3.8	24.2	0.98	11.7	0.01325	0.0021	47.43	42.52
1440	26	21	0.2	1	-5	-3.8	22.2	0.98	12.0	0.01325	0.0012	43.51	39.00

Table B- 1 Atterberg Limit of Stabilized TP 2@1.5 For Natural

TEST pit 2 @1.5 Natural			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	34	28	19
Can Number	---	---	M1	N21	GS	F32	A12
Mass of Empty Can	M_C	(g)	17.66	13.14	16.59	19.50	12.79
Mass Can & Soil (Wet)	M_{CMS}	(g)	33.64	30.36	26.60	30.17	34.56
Mass Can & Soil (Dry)	M_{CDS}	(g)	29.34	25.49	21.72	24.85	23.34
Mass of Soil	M_S	(g)	11.68	12.35	5.13	5.36	10.56
Mass of Water	M_W	(g)	4.29	4.88	4.87	5.32	11.22
Water Content	W	(%)	36.76	39.52	95.05	99.23	106.32

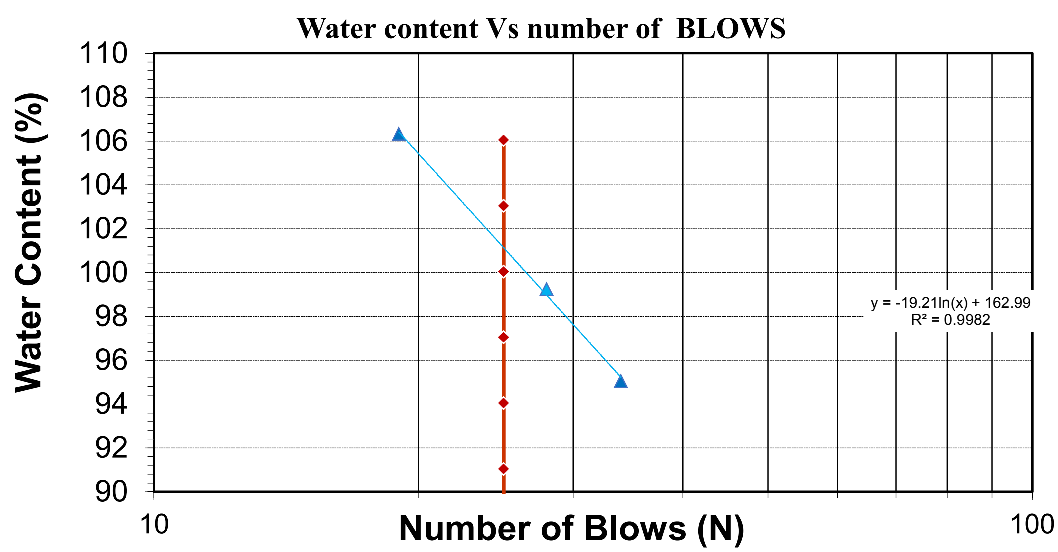


Table B-2 Atterberg Limit of Stabilized TP 2@1.5 For 5%

TEST PIT 2 @1.5 FOR 5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	33	26	18
Can Number	---	---	BA	BB1	H1	G43	S32
Mass of Empty Can	M_C	(g)	13.83	18.57	19.74	21.26	17.38
Mass Can & Soil (Wet)	M_{CMS}	(g)	24.26	34.35	30.48	32.80	31.59
Mass Can & Soil (Dry)	M_{CDS}	(g)	21.53	29.56	25.38	27.22	24.56
Mass of Soil	M_S	(g)	7.70	10.99	5.64	5.96	7.18
Mass of Water	M_W	(g)	2.74	4.79	5.11	5.58	7.03
Water Content	W	(%)	35.53	43.56	90.63	93.57	97.90

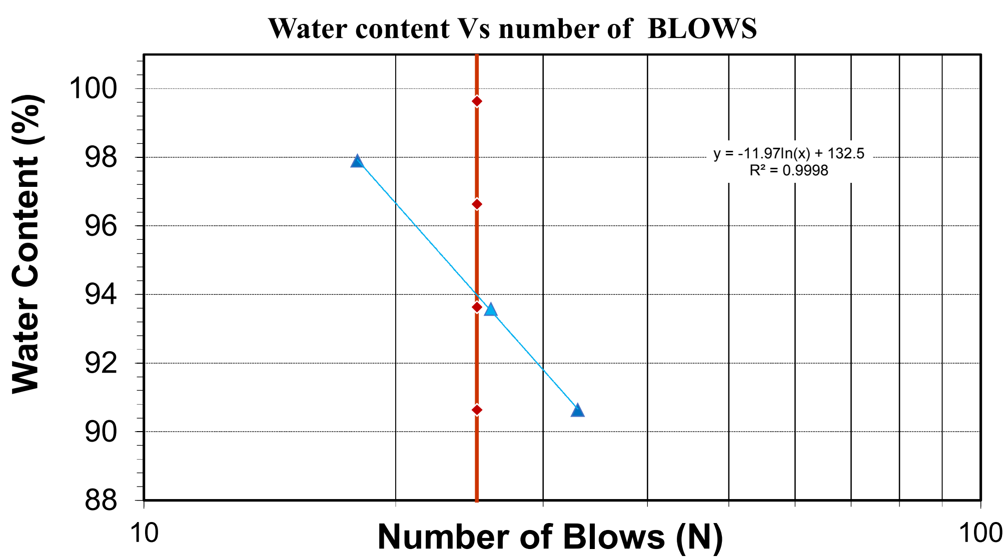


Table B- 3 Atterberg Limit of Stabilized T2@1.5 For 10%

TEST pit 2 @ 1.5 For 10%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	32	24	17
Can Number	---	---	a21	f2	J12	g32	H2
Mass of Empty Can	M_C	(g)	5.85	19.64	6.21	5.87	6.75
Mass Can & Soil (Wet)	M_{CMS}	(g)	21.32	37.53	20.41	21.86	19.60
Mass Can & Soil (Dry)	M_{CDS}	(g)	16.88	31.96	13.84	14.34	13.44
Mass of Soil	M_S	(g)	11.03	12.32	7.63	8.47	6.69
Mass of Water	M_W	(g)	4.44	5.57	6.57	7.52	6.16
Water Content	w	(%)	40.26	45.20	86.16	88.83	92.01

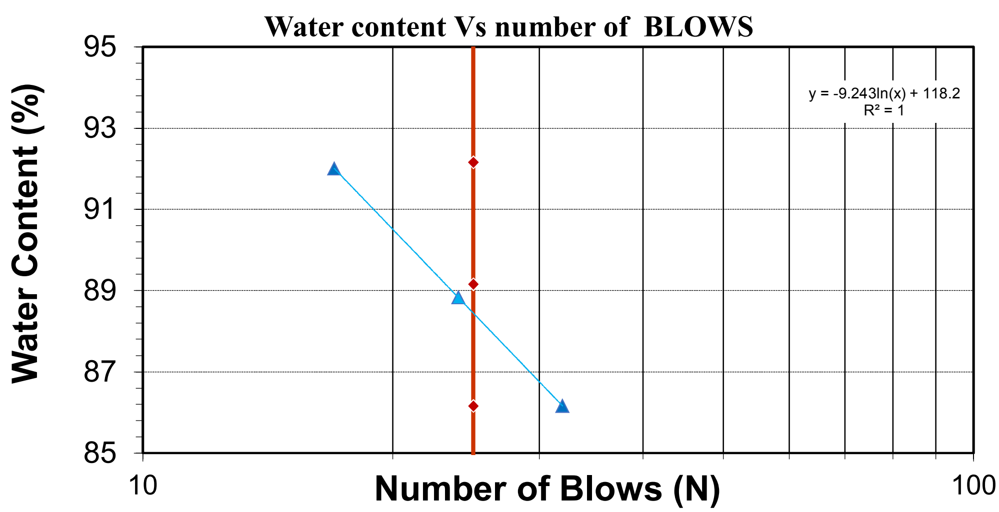


Table B-4 Atterberg Limit of Stabilized TP2@1.5 For 15%

TEST Pit 2@1.5 15%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	16	23	31
Can Number	---	---	I	B	D3	A2	s-2
Mass of Empty Can	M_C	(g)	17.54	17.69	5.80	6.08	5.56
Mass Can & Soil (Wet)	M_{CMS}	(g)	30.27	29.35	20.14	19.61	21.52
Mass Can & Soil (Dry)	M_{CDS}	(g)	26.27	25.94	13.36	13.60	14.85
Mass of Soil	M_S	(g)	8.73	8.25	7.55	7.52	9.29
Mass of Water	M_W	(g)	4.00	3.40	6.78	6.02	6.67
Water Content	w	(%)	45.83	41.22	89.82	79.99	71.74

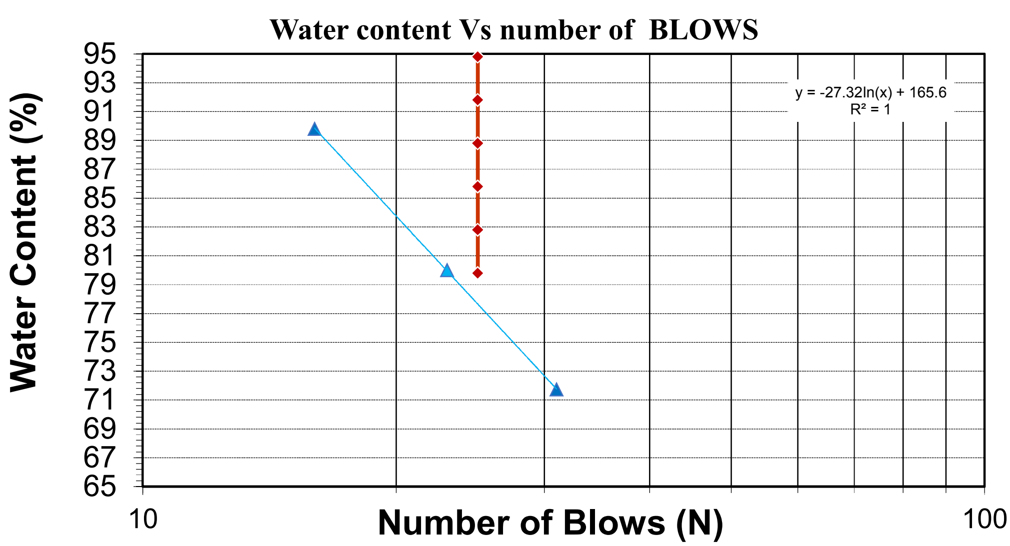


Table B-5 Atterberg Limit of Stabilized TP 2@3 for Natural

TEST2@3m Natural			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	33	27	19
Can Number	---	---	DD	S	c2	B4	EE
Mass of Empty Can	M_C	(g)	18.85	18.73	16.60	17.82	19.50
Mass Can & Soil (Wet)	M_{CMS}	(g)	39.15	36.36	27.16	32.48	31.55
Mass Can & Soil (Dry)	M_{CDS}	(g)	33.39	35	22.11	25.35	25.54
Mass of Soil	M_S	(g)	14.54	12.31	5.51	7.54	6.05
Mass of Water	M_W	(g)	5.76	5.31	5.05	7.12	6.00
Water Content	w	(%)	39.58	43.13	91.67	94.46	99.27

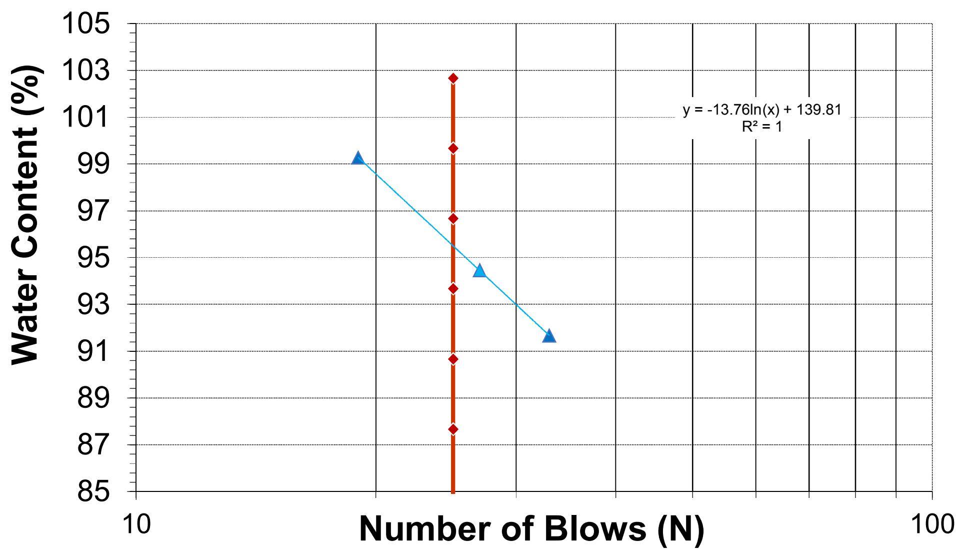


Table B-6 Atterberg Limit of Stabilized TP 2@3 For 5%

TEST pit 2 @3m for5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	Blows	-	-	32	26	18
Can Number	---	---	y	3	t4	3a	Be
Mass of Empty Can	M_C	(g)	19.39	18.85	17.57	19.26	14.84
Mass Can & Soil (Wet)	M_{CMS}	(g)	38.82	35.69	31.58	33.86	34.70
Mass Can & Soil (Dry)	M_{CDS}	(g)	32.72	31.30	25.06	26.92	24.96
Mass of Soil	M_S	(g)	13.34	12.45	7.48	7.66	10.12
Mass of Water	M_W	(g)	6.10	4.39	6.53	6.94	9.74
Water Content	w	(%)	45.70	35.28	87.26	90.59	96.16

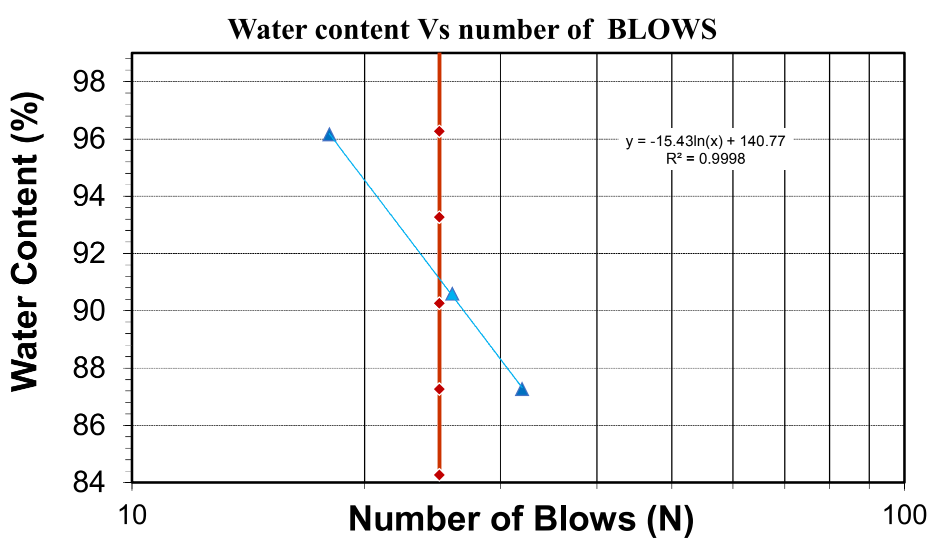


Table B-7 Atterberg Limit of Stabilized TP2@3 For 10%

TEST pit @ 3 for 10%			**PLASTIC LIMIT**		**LIQUID LIMIT**		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	31	25	17
Can Number	---	---	G9	W32	Pr	Q1	Et
Mass of Empty Can	M_C	(g)	6.96	20.86	7.97	8.78	7.29
Mass Can & Soil (Wet)	M_{CMS}	(g)	19.50	36.39	24.96	17.54	24.66
Mass Can & Soil (Dry)	M_{CDS}	(g)	15.67	31.75	17.34	13.54	16.44
Mass of Soil	M_S	(g)	8.72	10.89	9.36	4.75	9.15
Mass of Water	M_W	(g)	3.83	4.64	7.63	4.01	8.23
Water Content	w	(%)	43.88	42.61	81.46	84.34	89.87

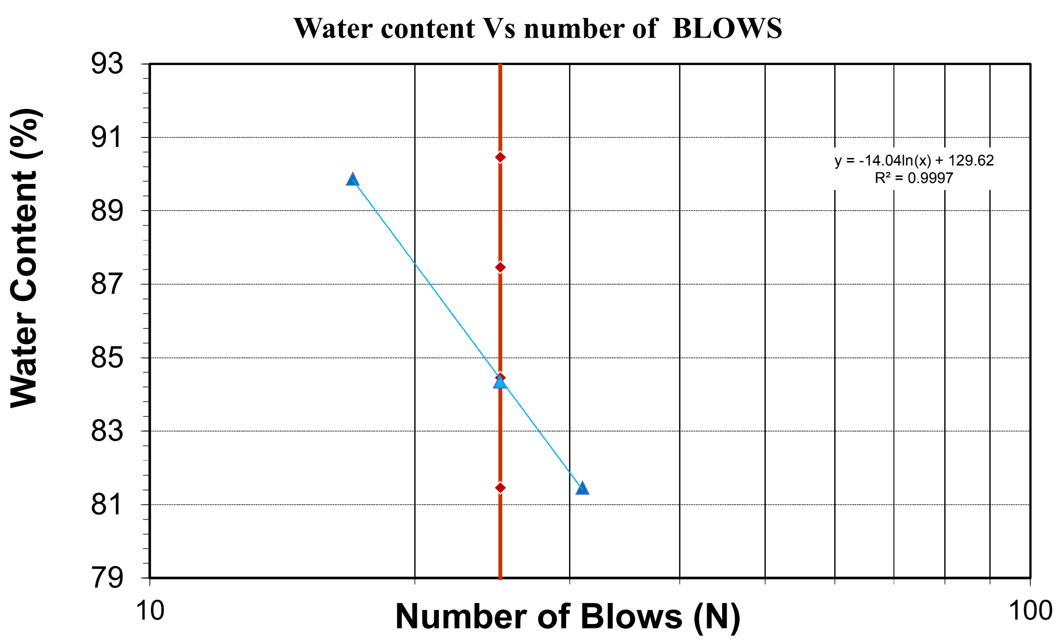
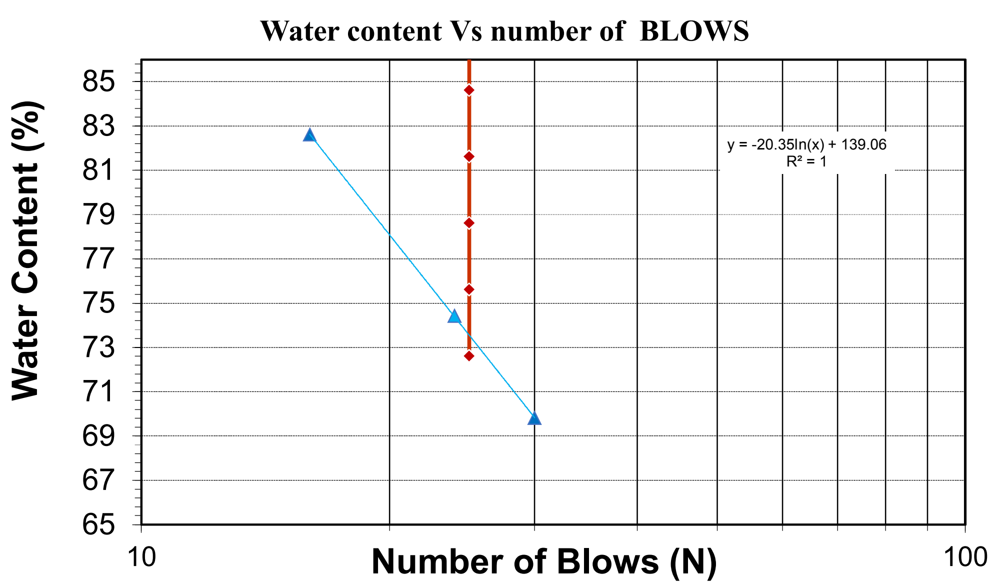
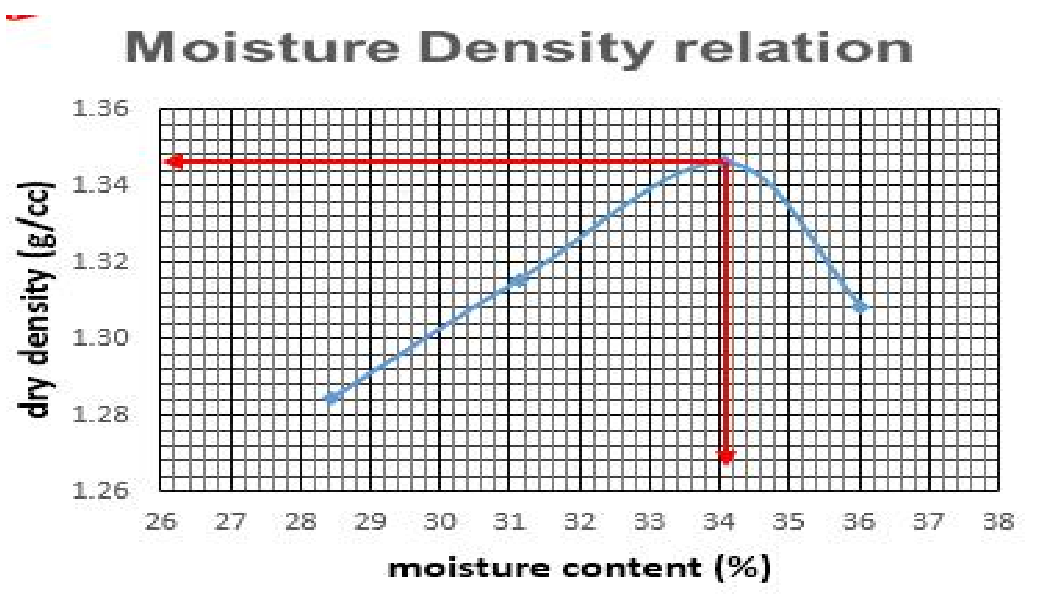


Table B-8 Atterberg Limit of Stabilized TP2@3 For 15%

TEST Pit2@3m for 15%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	16	24	30
Can Number	---	---	T3	F22	D3	A2	G
Mass of Empty Can	M_C	(g)	16.76	16.68	13.02	11.64	10.89
Mass Can & Soil (Wet)	M_{CMS}	(g)	31.43	26.14	25.74	25.34	27.98
Mass Can & Soil (Dry)	M_{CDS}	(g)	25.75	24.24	19.99	19.50	20.95
Mass of Soil	M_S	(g)	8.99	7.56	6.96	7.86	10.06
Mass of Water	M_W	(g)	5.69	1.90	5.75	5.85	7.02
Water Content	w	(%)	63.27	25.13	82.62	74.41	69.81

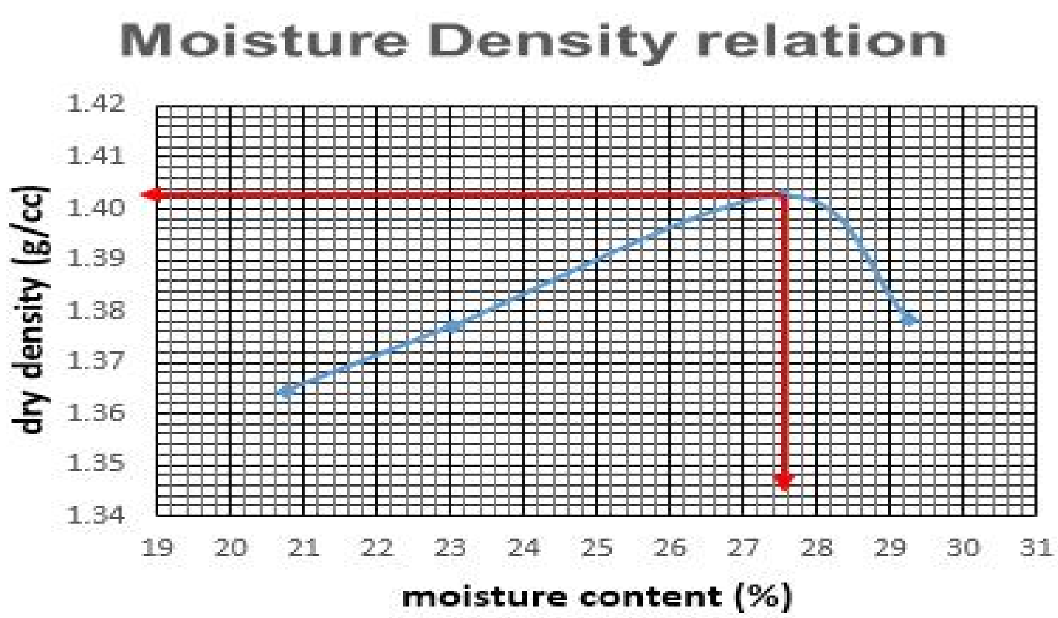


Wet density and dry density determination for natural					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10210.9	10370.4	10540.1	10486.18
Wt. of Mold	gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	gram	3504.2	3663.7	3833.4	3779.48
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.650	1.725	1.805	1.779
Container No.		C	U21	F1	N
Wt. Cont + Wet soil	grams	145.974	132.422	184.825	186.711
Wt. Cont + Dry soil	grams	120.673	107.961	145.821	145.71
Weight of Water	grams	25.30	24.46	39.00	41.00
Weight of Container	grams	31.729	29.393	31.396	31.935
Weight of Dry Soil	grams	88.944	78.568	114.425	113.775
Moisture content	%	28.446	31.134	34.087	36.037
Dry Density	gr/cu.cm.	1.284	1.315	1.346	1.308

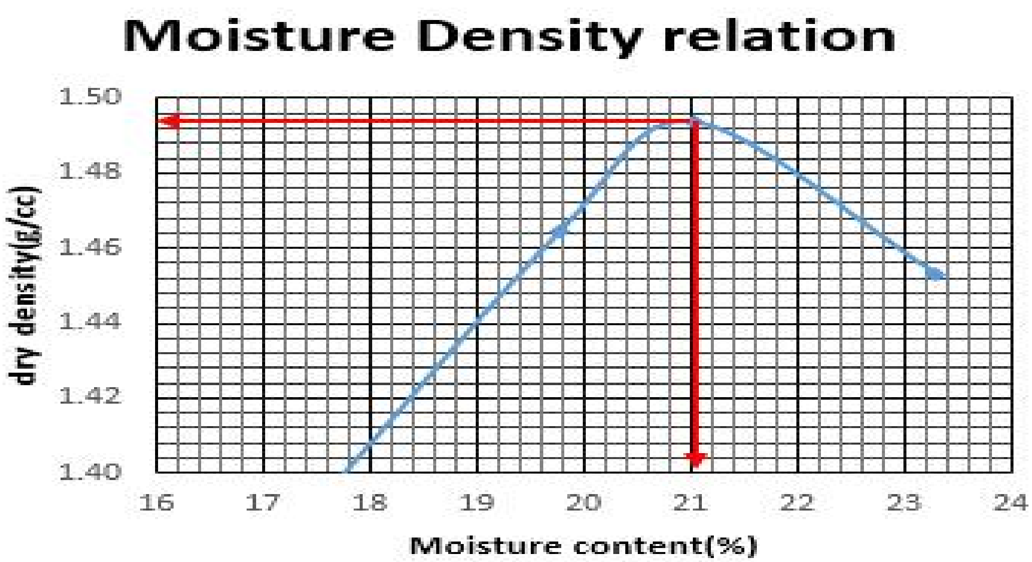


Compaction test result of test pit 2

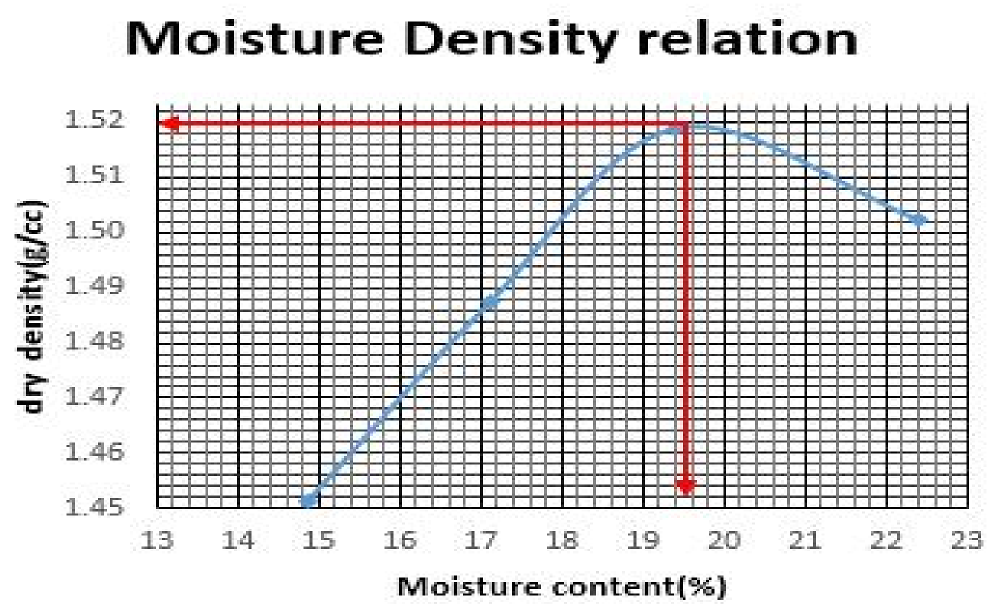
Wet density and dry density determination 5%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10205.8	10305.1	10505.5	10490.6
Wt. of Mold	Gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	Gram	3499.1	3598.4	3798.8	3783.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.647	1.694	1.789	1.781
Container No.		R	W1	N1	C23
Wt. Cont + Wet soil	Grams	172.93	144.684	153.895	161.853
Wt. Cont + Dry soil	Grams	148.264	123.583	127.739	132.437
Weight of Water	Grams	24.67	21.10	26.16	29.42
Weight of Container	Grams	29.374	31.955	32.739	31.837
Weight of Dry Soil	Grams	118.89	91.628	95	100.6
Moisture content	%	20.747	23.029	27.533	29.241
Dry Density	gr/cu.cm.	1.364	1.377	1.402	1.378



Wet density and dry density determination 10%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10201.6	10434.4	10546.4	10512.1
Wt. of Mold	Gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	Gram	3494.9	3726.7	3839.7	3805.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.645	1.755	1.808	1.792
Container No.		G1	n2	t2	J
Wt. Cont + Wet soil	Grams	199.963	141.638	140.018	107.86
Wt. Cont + Dry soil	Grams	175.484	123.798	121.717	90.943
Weight of Water	Grams	24.48	17.84	18.30	16.92
Weight of Container	Grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	Grams	138.314	90.175	87.057	72.599
Moisture content	%	17.698	19.784	21.022	23.302
Avg. Moisture Content	%	17.698	19.784	21.022	23.302
Dry Density	gr/cu.cm.	1.398	1.465	1.494	1.453

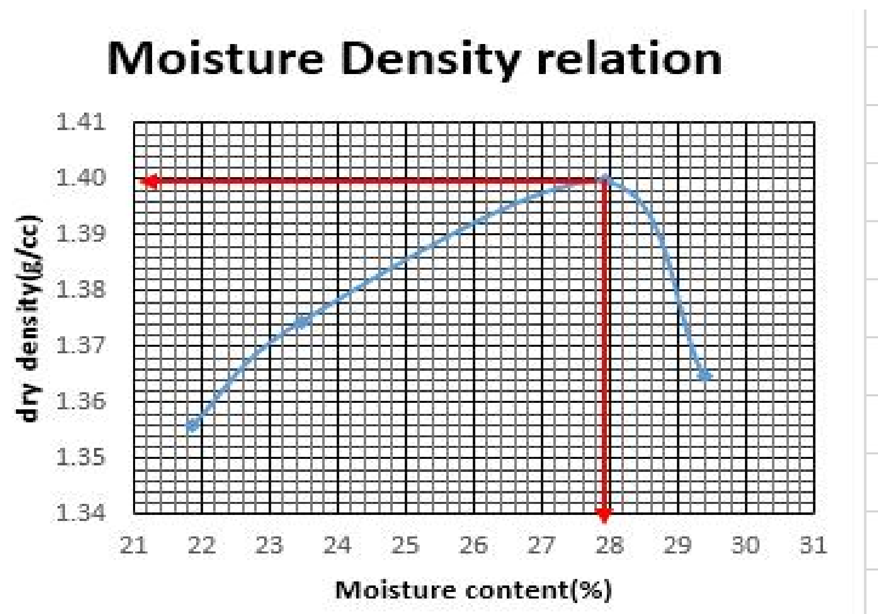


Wet density and dry density determination 15%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10241.9	10402.3	10556.2	10610
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3535.2	3694.6	3847.5	3900.3
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.664	1.739	1.811	1.836
Container No.		C23	f3	M3	R2
Wt. Cont + Wet soil	grams	99.84	88.639	90.254	87.369
Wt. Cont + Dry soil	grams	89.732	78.272	80.412	74.928
Weight of Water	grams	10.11	10.37	9.84	12.44
Weight of Container	grams	21.683	17.673	29.725	19.395
Weight of Dry Soil	grams	68.049	60.599	50.687	55.533
Moisture content	%	14.854	17.108	19.417	22.403
Avg. Moisture Content	%	14.854	17.108	19.417	22.403
Dry Density	gr/cu.cm.	1.449	1.485	1.517	1.500

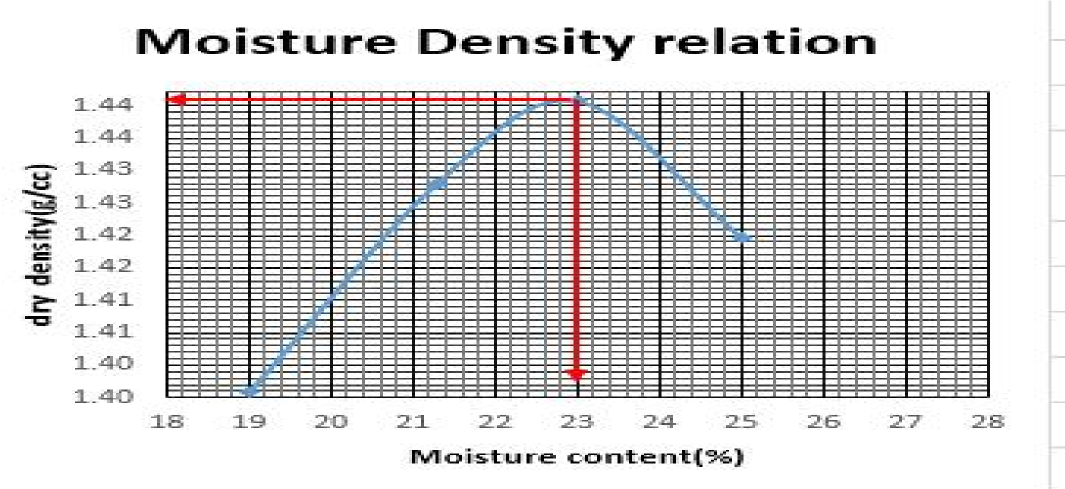


Compaction test result of test pit 2 @ 3m

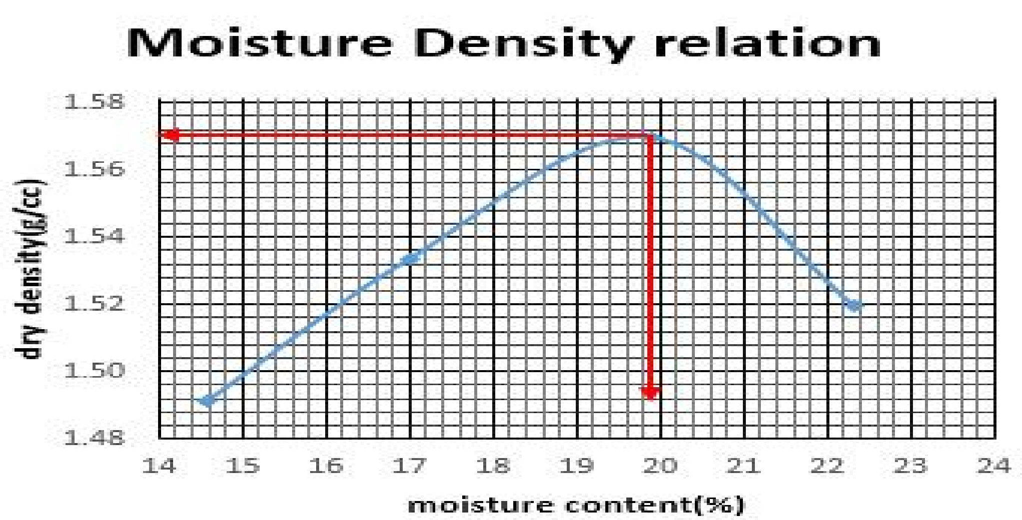
Wet density and dry density determination for natural					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10215.6	10310.7	10510.3	10457.4
Wt. of Mold	Gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	Gram	3508.9	3604	3803.6	3750.7
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.652	1.697	1.791	1.766
Container No.		SS	D	L2	W
Wt. Cont + Wet soil	Grams	129.934	150.138	117.852	146.471
Wt. Cont + Dry soil	Grams	111.426	128.532	99.513	121.47
Weight of Water	Grams	18.51	21.61	18.34	25.00
Weight of Container	Grams	26.742	36.426	33.89	36.426
Weight of Dry Soil	Grams	84.684	92.106	65.623	85.044
Moisture content	%	21.855	23.458	27.946	29.398
Avg. Moisture Content	%	21.855	23.458	27.946	29.398
Dry Density	gr/cu.cm.	1.356	1.374	1.400	1.365



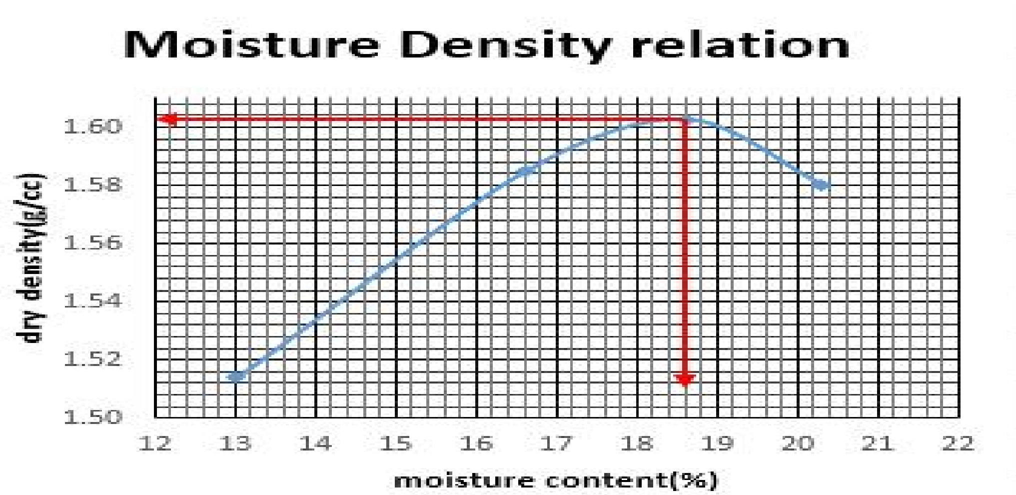
Wet density and dry density determination 5%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10245.8	10396.9	10483.5	10489.6
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3539.1	3689.2	3774.8	3779.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.666	1.737	1.777	1.780
Container No.		D	G	A1-c	11
Wt. Cont + Wet soil	grams	150.26	119.5	168.952	136.969
Wt. Cont + Dry soil	grams	130.98	105.18	146.64	114.964
Weight of Water	grams	19.28	14.32	22.31	22.01
Weight of Container	grams	29.614	37.925	49.693	26.929
Weight of Dry Soil	grams	101.366	67.255	96.947	88.035
Moisture content	%	19.020	21.292	23.015	24.996
Avg. Moisture Content	%	19.020	21.292	23.015	24.996
Dry Density	gr/cu.cm.	1.400	1.432	1.445	1.424



Wet density and dry density determination 10%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10330.6	10514.4	10698.4	10650.1
Wt. of Mold	gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	gram	3623.9	3806.7	3991.7	3943.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.706	1.792	1.879	1.857
Container No.		T3-96	P15	2	GS-3
Wt. Cont + Wet soil	grams	184.605	132.708	142.628	102.26
Wt. Cont + Dry soil	grams	165.848	118.298	124.717	86.943
Weight of Water	grams	18.76	14.41	17.91	15.32
Weight of Container	grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	grams	128.678	84.675	90.057	68.599
Moisture content	%	14.577	17.018	19.889	22.328
Dry Density	gr/cu.cm.	1.489	1.532	1.568	1.518



Wet density and dry density determination 15%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10340.9	10632.3	10746.2	10747.8
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3634.2	3924.6	4037.5	4038.1
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.711	1.848	1.901	1.901
Container No.		J41	3^5	GS6	Uc
Wt. Cont + Wet soil	grams	145.828	89.873	89.964	90.536
Wt. Cont + Dry soil	grams	132.738	79.439	79.806	78.078
Weight of Water	grams	13.09	10.43	10.16	12.46
Weight of Container	grams	32.14	16.576	25.218	16.732
Weight of Dry Soil	grams	100.598	62.863	54.588	61.346
Moisture content	%	13.012	16.598	18.608	20.308
Moisture Content	%	13.012	16.598	18.608	20.308
Dry Density	gr/cu.cm.	1.514	1.585	1.603	1.580

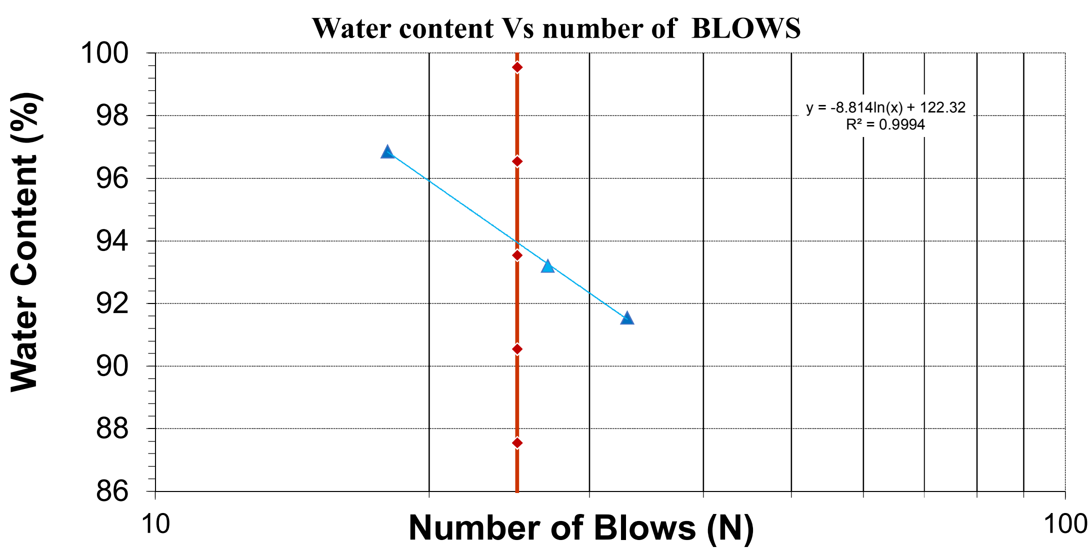


APPENDIX–C; LABORATORY TEST RESULT FOR TEST PIT 3

Time (minutes)	Actual Hydrometer Reading	Temp.	correction for hydrometer reading					Correction factor (a)	Effe. Depth of Hydrometer (L)	Values of K	Diameter of soil Particle (mm)	% finer,P	Adjusted Percent of finer
			T°	meniscus	zero	Composite	Corrected						
			correction	Correction	correction	Correction	H.Reading						
1	48	21	0.2	1	-5	-3.8	44.2	0.98	8.5	0.01309	0.0381	86.63	74.88
2	47	21	0.2	1	-5	-3.8	43.2	0.98	8.6	0.01309	0.0271	84.67	73.18
5	44	21	0.2	1	-5	-3.8	40.2	0.98	9.1	0.01309	0.0176	78.79	68.10
15	42	21	0.2	1	-5	-3.8	38.2	0.98	9.4	0.01309	0.0104	74.87	64.71
30	39	21	0.2	1	-5	-3.8	35.2	0.98	9.9	0.01309	0.0075	68.99	59.63
60	38	21	0.2	1	-5	-3.8	34.2	0.98	10.1	0.01309	0.0054	67.03	57.94
120	35	21	0.2	1	-5	-3.8	31.2	0.98	10.6	0.01309	0.0039	61.15	52.85
240	32	21	0.2	1	-5	-3.8	28.2	0.98	11.0	0.01309	0.0028	55.27	47.77
480	27	21	0.2	1	-5	-3.8	23.2	0.98	11.9	0.01309	0.0021	45.47	39.30
1440	25	21	0.2	1	-5	-3.8	21.2	0.98	12.2	0.01309	0.0012	41.55	35.91

Table A- 1 3Atterberg Limit of Stabilized TP 3@1.5 For Natural

TEST pit 2 @1.5 Natural			PLASTIC LIMIT		LIQUID LIMIT		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	33	27	18
Can Number	---	---	R2	C7	G1	D#	E1
Mass of Empty Can	M_C	(g)	16.88	14.95	17.97	21.58	22.57
Mass Can & Soil (Wet)	M_{CMS}	(g)	36.23	36.68	31.34	35.25	39.46
Mass Can & Soil (Dry)	M_{CDS}	(g)	30.56	30.56	24.95	28.65	31.15
Mass of Soil	M_S	(g)	13.69	15.62	6.98	7.08	8.58
Mass of Water	M_W	(g)	5.67	6.12	6.39	6.60	8.31
Water Content	W	(%)	41.40	39.20	91.55	93.19	96.86



Tab le A- 24 Atterberg Limit of Stablized TP 3@1.5 For 5%

TEST pit @1.5 5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	34	26	19
Can Number	---	---	j21	E3	A2	Re	T4
Mass of Empty Can	M_C	(g)	18.84	15.97	21.45	22.83	19.84
Mass Can & Soil (Wet)	M_{CMS}	(g)	27.18	27.23	31.25	30.55	31.41
Mass Can & Soil (Dry)	M_{CDS}	(g)	24.74	23.84	26.65	26.84	25.74
Mass of Soil	M_S	(g)	5.90	7.86	5.19	4.02	5.91
Mass of Water	M_W	(g)	2.44	3.40	4.61	3.71	5.67
Water Content	w	(%)	41.35	43.21	88.70	92.31	96.00

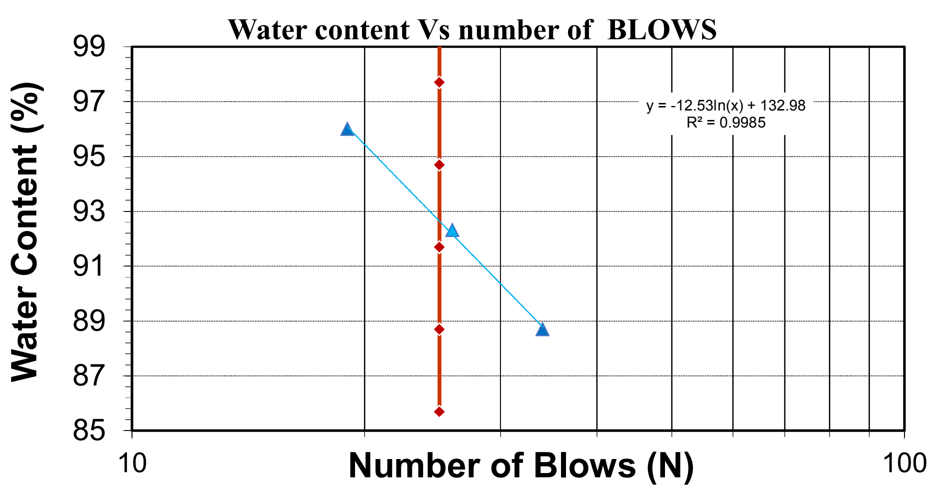


Table A- 35 Atterberg Limit of Stablized TP3@1.5 For 10%

TEST pit @ 1.5 for 10%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	33	25	19
Can Number	---	---	U2	T5	SS	G1	Y4
Mass of Empty Can	M_C	(g)	13.98	15.94	14.49	20.15	21.47
Mass Can & Soil (Wet)	M_{CMS}	(g)	24.71	27.94	24.21	40.82	35.69
Mass Can & Soil (Dry)	M_{CDS}	(g)	20.98	24.74	19.75	31.13	28.93
Mass of Soil	M_S	(g)	7.00	8.80	5.26	10.98	7.45
Mass of Water	M_W	(g)	3.73	3.21	4.47	9.68	6.76
Water Content	w	(%)	53.27	36.41	84.93	88.20	90.74

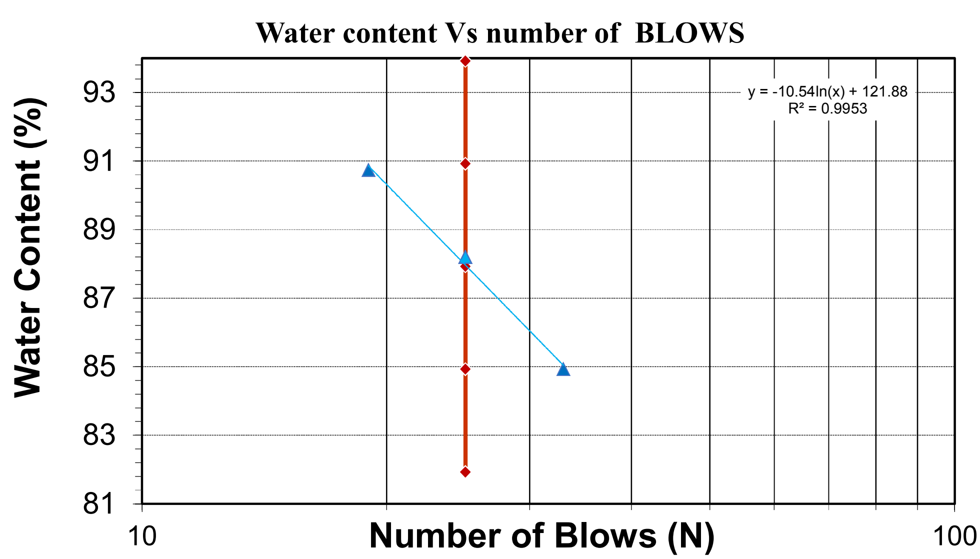


Table A- 46 Atterberg Limit of Stablized TP3@1.5For 15%

TEST Pit@1.5 for 15%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	32	23	18
Can Number	---	---	I	B	D3	A2	s-2
Mass of Empty Can	M_C	(g)	17.54	17.69	5.80	6.08	5.56
Mass Can & Soil (Wet)	M_{CMS}	(g)	30.57	29.55	19.24	17.37	21.18
Mass Can & Soil (Dry)	M_{CDS}	(g)	26.27	25.94	13.36	12.20	13.85
Mass of Soil	M_S	(g)	8.73	8.25	7.55	6.12	8.29
Mass of Water	M_W	(g)	4.30	3.60	5.88	5.18	7.33
Water Content	W	(%)	49.27	43.64	77.90	84.56	88.41

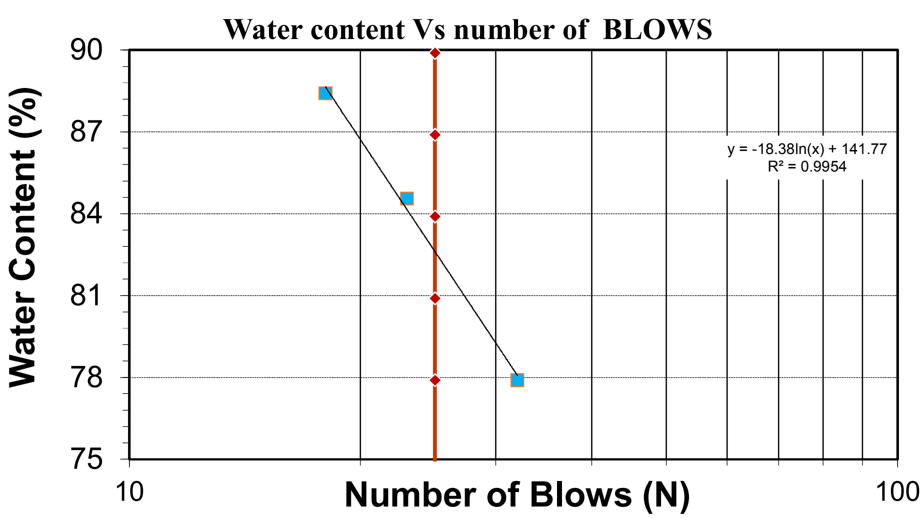


Table A- 5 3Atterberg Limit of Stablized TP 3@3 For Natural

TEST pit 2@1.5 Natural			PLASTIC LIMIT		LIQUID LIMIT		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	34	25	18
Can Number	---	---	q2	W12	G23	H5	K1
Mass of Empty Can	M_C	(g)	16.46	16.37	19.65	16.46	18.84
Mass Can & Soil (Wet)	M_{CMS}	(g)	36.77	31.28	33.95	31.56	31.56
Mass Can & Soil (Dry)	M_{CDS}	(g)	31.13	26.64	27.26	24.35	25.34
Mass of Soil	M_S	(g)	14.67	10.28	7.61	7.88	6.50
Mass of Water	M_W	(g)	5.64	4.64	6.69	7.22	6.22
Water Content	w	(%)	38.44	45.11	87.92	91.60	95.74

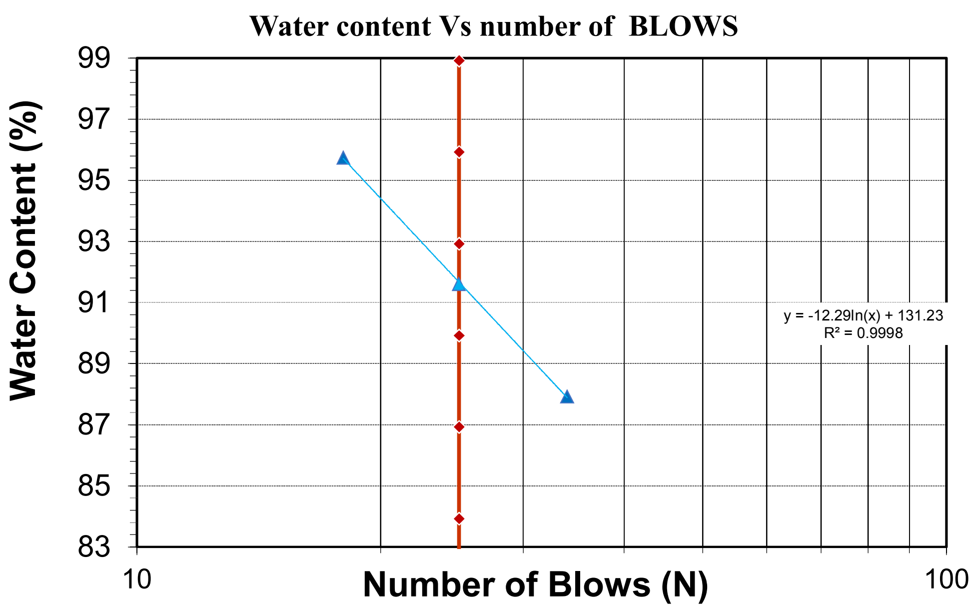


Table A- 64 Atterberg Limit of Stablized TP 3@3 For 5%

TEST pit @1.5 for 5%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	32	24	17
Can Number	---	---	R3	S1	DD	G5	c1
Mass of Empty Can	M_C	(g)	14.85	15.63	16.39	17.69	18.37
Mass Can & Soil (Wet)	M_{CMS}	(g)	30.26	28.57	29.55	30.26	32.71
Mass Can & Soil (Dry)	M_{CDS}	(g)	25.56	24.63	23.56	24.43	25.93
Mass of Soil	M_S	(g)	10.71	9.00	7.17	6.73	7.56
Mass of Water	M_W	(g)	4.70	3.94	5.99	5.83	6.78
Water Content	w	(%)	43.90	43.81	83.51	86.66	89.72

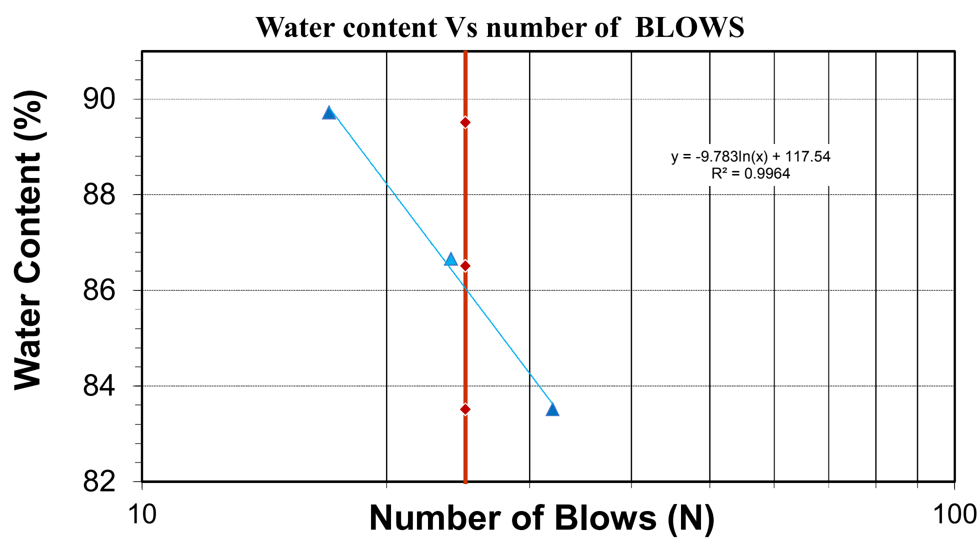


Table A- 75 Atterberg Limit of Stablized TP3@3 For 10%

TEST pit @ 3m for 10%			PLASTIC LIMIT		LIQUID LIMIT		
Variable	NO		1	2	1	2	3
	Var.	Units					
Number of Blows	N	blows	-	-	33	26	19
Can Number	---	---	S22	F11	J11	J41	H21
Mass of Empty Can	M_C	(g)	12.47	13.25	17.56	14.75	15.38
Mass Can & Soil (Wet)	M_{CMS}	(g)	23.23	25.26	31.74	24.14	26.86
Mass Can & Soil (Dry)	M_{CDS}	(g)	19.99	21.37	25.36	19.86	21.56
Mass of Soil	M_S	(g)	7.52	8.12	7.79	5.11	6.19
Mass of Water	M_W	(g)	3.24	3.89	6.38	4.28	5.30
Water Content	w	(%)	43.16	47.92	81.87	83.67	85.67

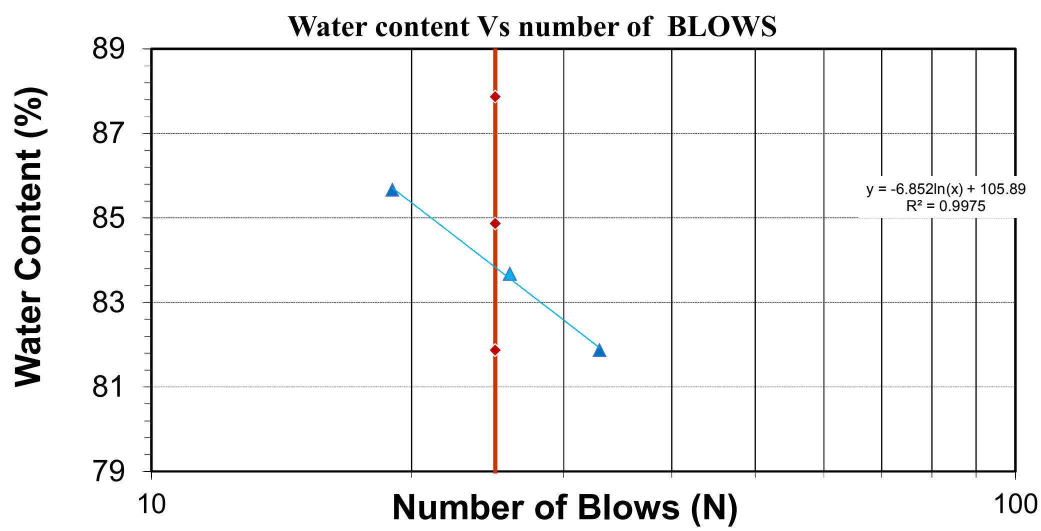
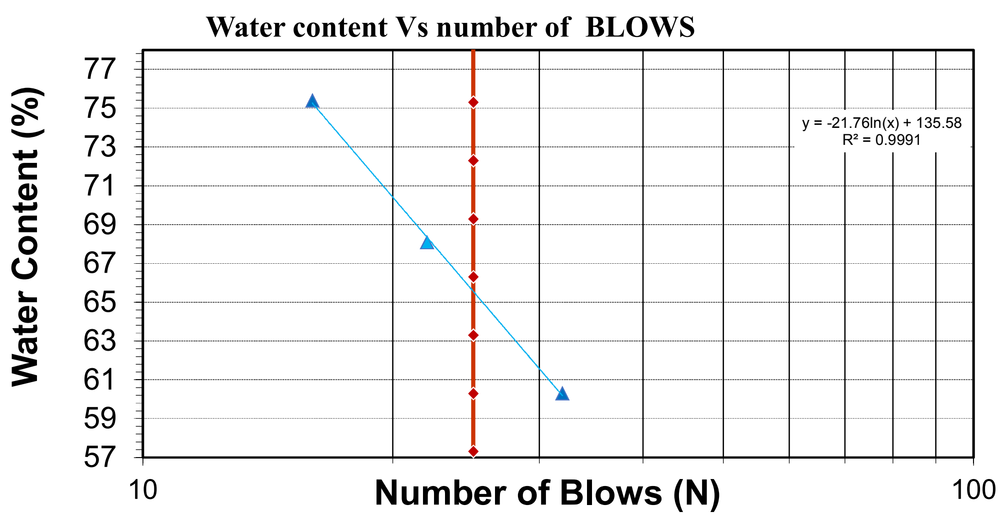


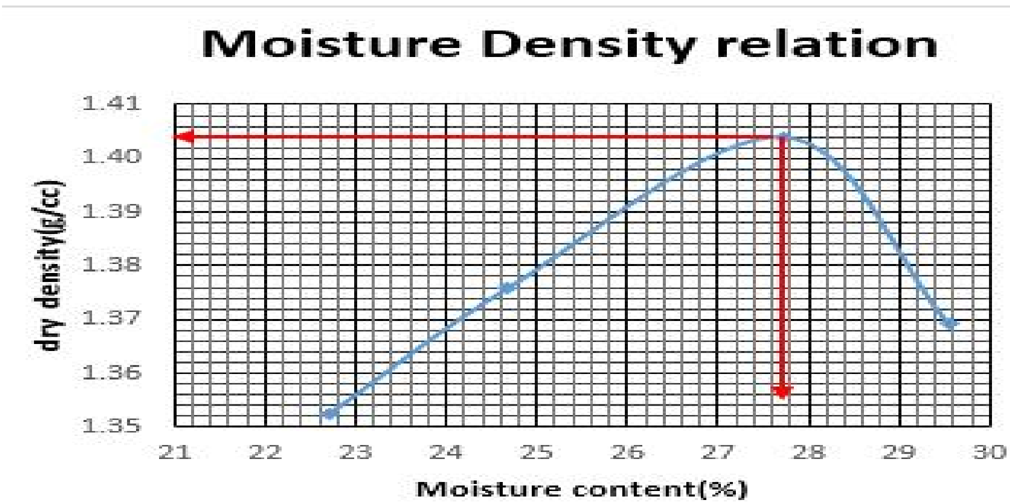
Table A- 86 Atterberg Limit of Stabilized TP3@3 For 15%

TEST Pit@3m 15%			**PLASTIC LIMIT**		**LIQUID LIMIT**		
Variable	**NO**		**1**	**2**	**1**	**2**	**3**
	Var.	**Units**					
Number of Blows	N	blows	-	-	32	22	16
Can Number	---	---	D21	E1	F32	B1	K21
Mass of Empty Can	M_C	(g)	18.35	17.26	14.56	17.43	17.32
Mass Can & Soil (Wet)	M_{CMS}	(g)	30.83	25.67	23.54	22.51	29.43
Mass Can & Soil (Dry)	M_{CDS}	(g)	26.24	23.10	20.16	20.45	24.23
Mass of Soil	M_S	(g)	7.89	5.85	5.60	3.03	6.91
Mass of Water	M_W	(g)	4.59	2.57	3.38	2.06	5.21
Water Content	w	(%)	58.20	43.97	60.30	68.08	75.40

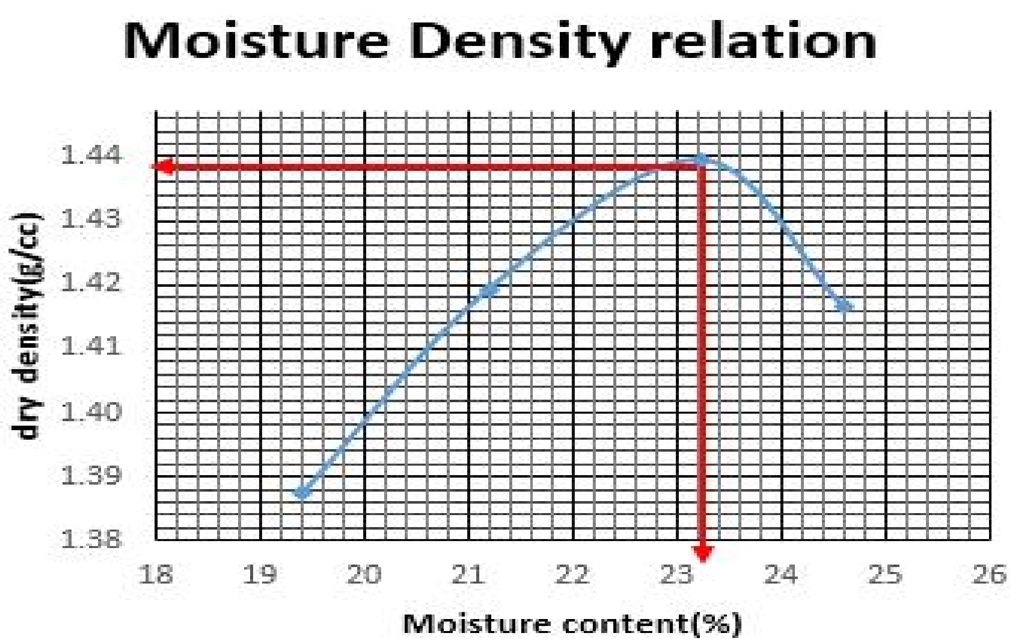


Compaction Test result for test pit 3

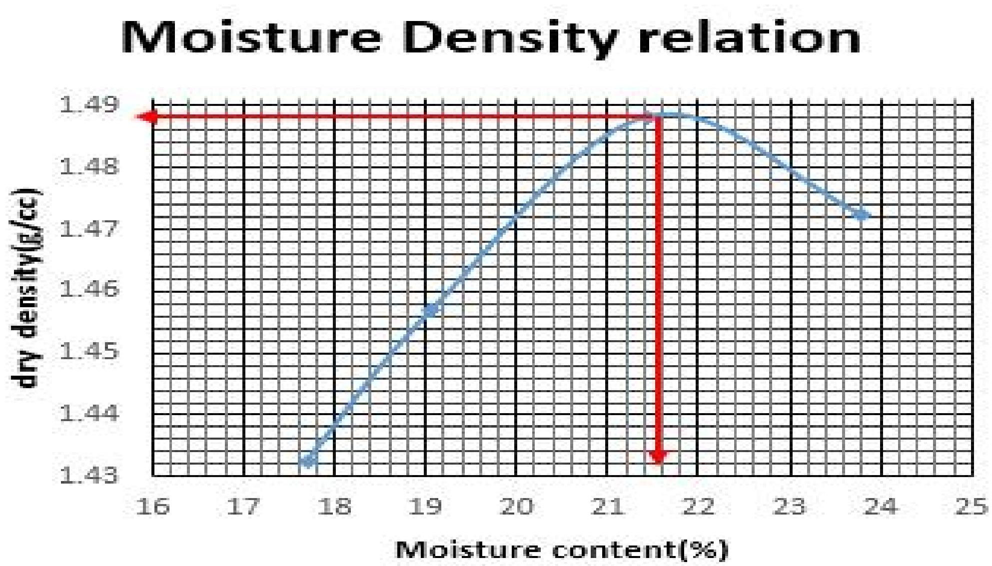
Wet density and dry density determination for natural					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10230.9	10350.4	10515.8	10474.3
Wt. of Mold	Gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	Gram	3524.2	3643.7	3809.1	3767.6
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.659	1.715	1.793	1.774
Container No.		d1	M1	C1	F21
Wt. Cont + Wet soil	Grams	135.674	146.543	164.529	146.529
Wt. Cont + Dry soil	Grams	115.741	124.742	135.941	119.572
Weight of Water	Grams	19.93	21.80	28.59	26.96
Weight of Container	Grams	27.924	36.426	32.869	28.328
Weight of Dry Soil	Grams	87.817	88.316	103.072	91.244
Moisture content	%	22.698	24.685	27.736	29.544
Avg. Moisture Content	%	22.698	24.685	27.736	29.544
Dry Density	gr/cu.cm.	1.352	1.376	1.404	1.369



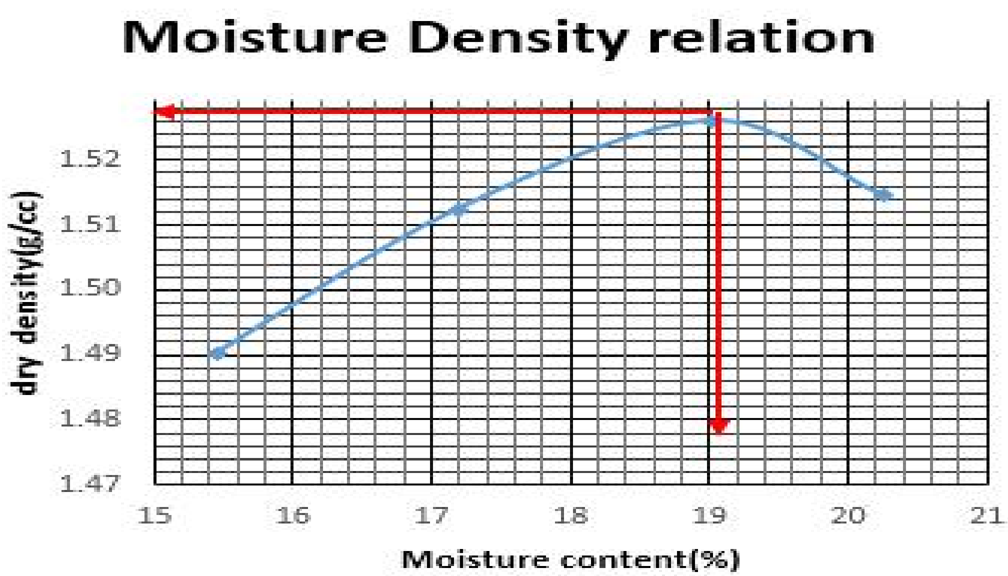
Wet density and dry density determination for 5%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10230.8	10365.1	10479.5	10460.6
Wt. of Mold	gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	gram	3524.1	3658.4	3772.8	3753.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.659	1.722	1.776	1.767
Container No.		Gh	E1	J	DD
Wt. Cont + Wet soil	grams	116.759	154.745	143.858	151.549
Wt. Cont + Dry soil	grams	101.64	132.858	121.574	126.746
Weight of Water	grams	15.12	21.89	22.28	24.80
Weight of Container	grams	23.748	29.576	25.647	25.896
Weight of Dry Soil	grams	77.892	103.282	95.927	100.85
Moisture content	%	19.410	21.191	23.230	24.594
Avg. Moisture Content	%	19.410	21.191	23.230	24.594
Dry Density	gr/cu.cm.	1.389	1.421	1.441	1.419



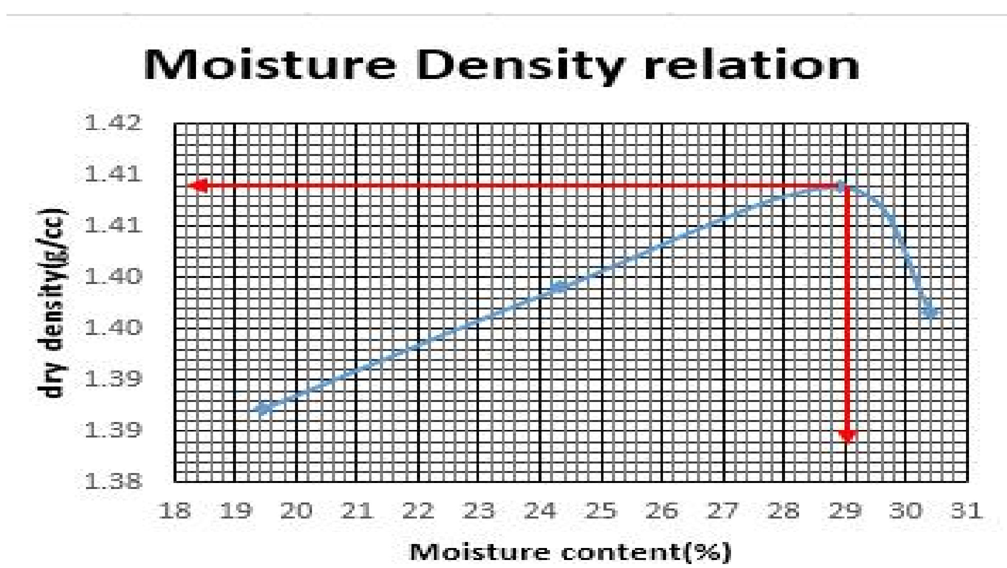
Wet density and dry density determination for 10%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10290.6	10394.4	10548.4	10580.1
Wt. of Mold	gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	gram	3583.9	3686.7	3841.7	3873.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.687	1.736	1.809	1.824
Container No.		Gd	P4	Wa	JF
Wt. Cont + Wet soil	grams	136.894	167.343	164.836	148.965
Wt. Cont + Dry soil	grams	121.894	145.932	141.845	123.865
Weight of Water	grams	15.00	21.41	22.99	25.10
Weight of Container	grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	grams	84.724	112.309	107.185	105.521
Moisture content	%	17.705	19.064	21.450	23.787
Avg. Moisture Content	%	17.705	19.064	21.450	23.787
Dry Density	gr/cu.cm.	1.434	1.458	1.489	1.473



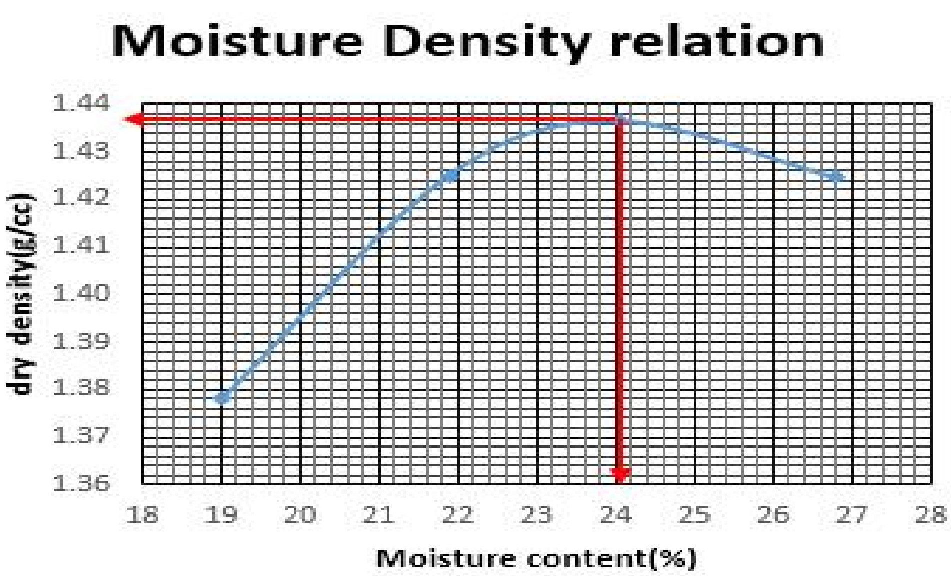
Wet density and dry density determination for 15%					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10360.9	10472.3	10566.2	10577.8
Wt. of Mold	gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	gram	3654.2	3764.6	3857.5	3868.1
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.720	1.772	1.816	1.821
Container No.		YD	C2	MK	P2
Wt. Cont + Wet soil	grams	142.643	88.993	89.364	89.536
Wt. Cont + Dry soil	grams	127.516	79.439	79.806	78.078
Weight of Water	grams	15.13	9.55	9.56	11.46
Weight of Container	grams	29.593	23.859	29.538	21.492
Weight of Dry Soil	grams	97.923	55.58	50.268	56.586
Moisture content	%	15.448	17.190	19.014	20.249
Avg. Moisture Content	%	15.448	17.190	19.014	20.249
Dry Density	gr/cu.cm.	1.490	1.512	1.526	1.514



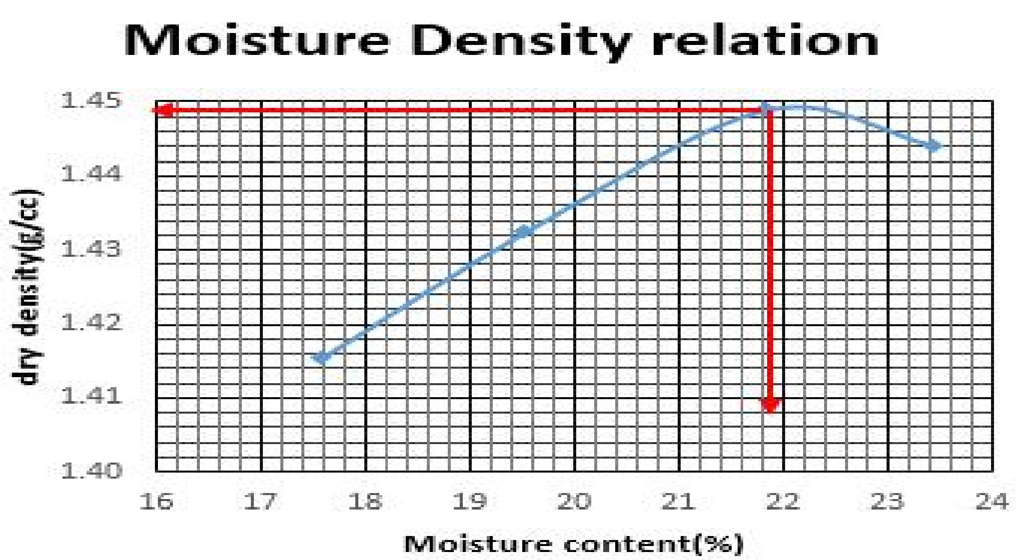
Wet density and dry density determination for natural (ESS1)					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10225.4	10401.4	10564.6	10575.3
Wt. of Mold	gram	6706.7	6706.7	6706.7	6706.7
Wt. Wet Soil	gram	3518.7	3694.7	3857.9	3868.6
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.657	1.740	1.816	1.821
Container No.		DS	W1	PP	g21
Wt. Cont + Wet soil	grams	140.521	156.341	131.551	147.841
Wt. Cont + Dry soil	grams	121.851	132.871	109.641	121.861
Weight of Water	grams	18.67	23.47	21.91	25.98
Weight of Container	grams	25.75	36.426	33.89	36.426
Weight of Dry Soil	grams	96.101	96.445	75.751	85.435
Moisture content	%	19.427	24.335	28.924	30.409
Avg. Moisture Content	%	19.427	24.335	28.924	30.409
Dry Density	gr/cu.cm.	1.387	1.399	1.409	1.397



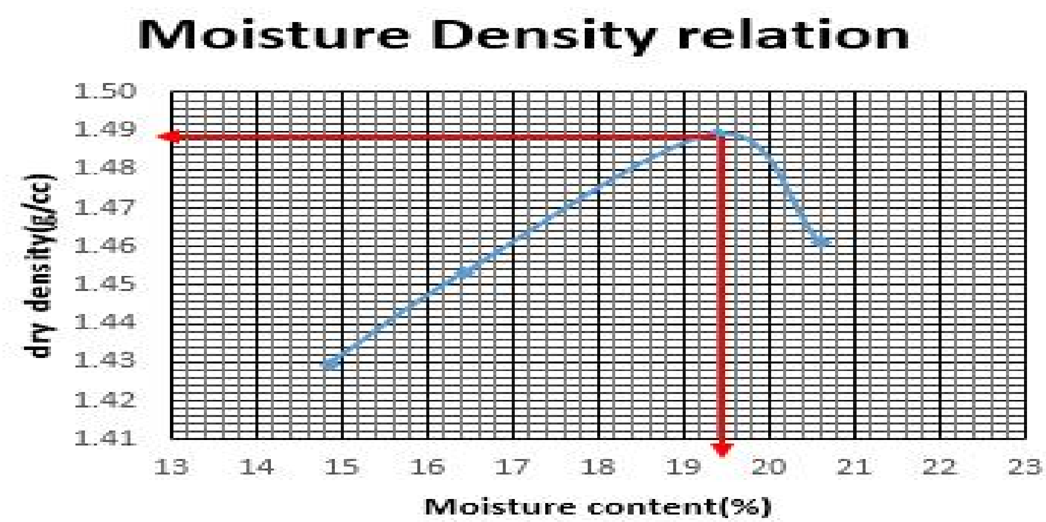
Wet density and dry density determination 5%SD					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10190.8	10396.9	10493.5	10546.6
Wt. of Mold	Gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	Gram	3484.1	3689.2	3784.8	3836.9
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.640	1.737	1.782	1.806
Container No.		D	G	A1-c	11
Wt. Cont + Wet soil	Grams	150.26	119.9	169.952	155.034
Wt. Cont + Dry soil	Grams	130.98	105.18	146.64	127.964
Weight of Water	Grams	19.28	14.72	23.31	27.07
Weight of Container	Grams	29.614	37.925	49.693	26.929
Weight of Dry Soil	Grams	101.366	67.255	96.947	101.035
Moisture content	%	19.020	21.887	24.046	26.793
Avg. Moisture Content	%	19.020	21.887	24.046	26.793
Dry Density	gr/cu.cm.	1.378	1.425	1.436	1.425



Wet density and dry density determination for 10%SD					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	gram	10241.6	10344.4	10456.4	10493.1
Wt. of Mold	gram	6706.7	6707.7	6706.7	6706.7
Wt. Wet Soil	gram	3534.9	3636.7	3749.7	3786.4
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.664	1.712	1.765	1.783
Container No.		G1	n2	t2	J
Wt. Cont + Wet soil	grams	216.263	141.408	140.728	107.96
Wt. Cont + Dry soil	grams	189.484	123.798	121.717	90.943
Weight of Water	grams	26.78	17.61	19.01	17.02
Weight of Container	grams	37.17	33.623	34.66	18.344
Weight of Dry Soil	grams	152.314	90.175	87.057	72.599
Moisture content	%	17.581	19.529	21.837	23.440
Avg. Moisture Content	%	17.581	19.529	21.837	23.440
Dry Density	gr/cu.cm.	1.415	1.432	1.449	1.444



Wet density and dry density determination for 15%SD					
Trial		1	2	3	4
Wt. of Mold + Wet Soil	Gram	10193.9	10302.3	10486.2	10452
Wt. of Mold	Gram	6706.7	6707.7	6708.7	6709.7
Wt. Wet Soil	Gram	3487.2	3594.6	3777.5	3742.3
Volume of Mold	cu.cm.	2124	2124	2124	2124
Wet Density	gr/cu.cm.	1.642	1.692	1.778	1.762
Container No.		C23	f3	M3	R2
Wt. Cont + Wet soil	Grams	99.84	88.239	90.254	86.369
Wt. Cont + Dry soil	Grams	89.732	78.272	80.412	74.928
Weight of Water	Grams	10.11	9.97	9.84	11.44
Weight of Container	Grams	21.683	17.673	29.725	19.395
Weight of Dry Soil	Grams	68.049	60.599	50.687	55.533
Moisture content	%	14.854	16.447	19.417	20.602
Avg. Moisture Content	%	14.854	16.447	19.417	20.602
Dry Density	gr/cu.cm.	1.429	1.453	1.489	1.461



APPENDIX–D; PHOTO TAKEN DURING STUDY

Figure D1; Photo preparing sample

Figure D2; Photo taken During Compaction Test

Figure D3; Photo taken During Freeswell test

Figure D4; Photo taken During Atterberg limit test

Figure D5; Photo taken While adjusting molds for compaction Test

Figure D6; Photo taken While adjusting for CBR Test

The Federal Democratic Republic of Ethiopia
Ministry of Mines, Petroleum and Natural Gas
Geological Survey of Ethiopia
Account No 1000009144278 Cash

08/01/2012

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Asmamaw Balcha
Addis Ababa

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1	Complete Silicate Analysis	1	849.00	849.00
2	Sample Preparation	1	30.00	30.00
3	Registration	-	-	10.00
	[illegible]			889.00

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Figure D7; photos showed worked of complete silicate analysis for this study from FDRE ministry of mines, petroleum and natural gas geological survey of Ethiopia