STUDY OF STABILIZATION OF CH SOIL BY INCLUSION OF EGG SHELL POWDER

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

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(With specialization in Geotechnical Engineering)

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DECLARATION

I hereby declare that the work presented in this report entitled “Study of Stabilization of CH soil by inclusion of egg shell powder ” in partial fulfillment of the requirement for the award of the degree of Master of Technology in Civil Engineering with specialization in Geotechnical engineering submitted to the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-13 under Assam Science and Technology University, is an authentic record of my own work carried out in the said college for six months under the supervision and guidance of Bhaskar Jyoti Das, Associate Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati13, Assam. I do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

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This is to certify that the work presented in this report entitled — "STUDY OF STABILIZATION OF CH SOIL BY INCLUSION OF EGG SHELL POWDER " is carried out by HIMAKSHI DAS, Roll No:PG-CE-23/05, a student of M.Tech 3rd semester, Department of Civil Engineering, Assam Engineering College, under my guidance and supervision and submitted in the partial fulfilment of the requirement for the award of the Degree of Master of Technology in Civil Engineering with specialization in Geotechnical Engineering under Assam Science and Technology University.

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ABSTRACT

Expansive soils, such as CH (high plasticity clay) soils, pose significant challenges in construction and geotechnical engineering due to their high shrink-swell potential, poor strength, and low bearing capacity. Stabilizing these soils is critical to improving their engineering properties and ensuring structural stability. This study investigates the efficacy of using egg shell powder (ESP), an eco-friendly and cost-effective stabilizer, to enhance the performance of CH soils. Egg shells, primarily composed of calcium carbonate, provide a sustainable alternative to conventional chemical stabilizers like lime and cement.

The research involves a systematic evaluation of the geotechnical properties of CH soil treated with varying proportions of ESP (e.g.5%, 10%, 15% by weight of soil). Laboratory tests, including Atterberg limits, compaction characteristics, unconfined compressive strength (UCS), California Bearing Ratio tests are conducted to determine the effect of ESP inclusion. The results indicate significant improvements in soil strength.

The findings suggest that ESP is an effective and sustainable stabilizer for CH soils, offering a dual benefit of waste utilization and enhanced soil performance. This study contributes to the development of greener construction practices and provides a viable solution for managing problematic soils in various engineering applications.

KEYWORDS: EGGSHELL POWDER (ESP), Stabilization, Maximum Dry Density (MDD), OPTIMUM MOISTURE CONTENT (OMC), UCS , CBR

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CHAPTER -1

INTRODUCTION

1. GENERAL

Soil is a naturally occurring unconsolidated material which plays a fundamental role in geotechnical engineering as the primary medium for construction and infrastructure development. Its characteristics significantly influence the design and stability of foundations, slopes, retaining structures, and embankments, making its study essential for safe and sustainable engineering practices. Soil originates from the weathering of rocks through physical, chemical, and biological processes, resulting in a complex, heterogeneous mixture of mineral particles, organic matter, water, and air. Its properties vary widely based on its composition, structure, and environmental conditions. Soil contains almost all types of elements including the most important ones are oxygen, silicon, hydrogen, aluminium, calcium, sodium, potassium, magnesium and carbon. Atoms of these elements form different crystalline arrangement to yield common minerals with which the soil is made up of.

In geotechnical engineering, soil is categorized based on particle size, gradation, plasticity, and strength characteristics. These properties govern critical parameters such as bearing capacity, compressibility, permeability, and shear strength, which are vital for assessing the suitability of soil for construction purposes. But in many of the cases like road construction, foundation layers etc., soil of poor quality cannot be used directly because there are many engineering properties associated with the soils like low bearing capacity, high settlement, high erodibility, soil deformations etc. Therefore, it is required to improve the quality of the soil. The stabilization of geotechnical properties of soil aims to increase the shear strength, decrease properties like permeability, deformability etc, because some soils show major volume changes due to change in the moisture content.

Stabilization enhances soil shear strength and control of shrink-swell properties, improving load bearing capacity for pavements and foundations by increasing the sub-grade's load-bearing capacity. The most common improvement achieved through soil stabilization technique includes better soil gradation, reduction of swelling potential, increase in durability and strength. It is important either to remove the existing soil by adding admixture or cost-effective practices like most importantly use of waste materials. The stabilising materials can be natural or industrial wastes.

Agricultural and industrial wastes including rice husk, chicken eggshells, fly ash, ground granulated blast furnace slag (GGBFS), Marble powder (MP), Plastic waste, Portland cement, lime, waste glass, construction and demolition (C&D) waste etc. can be used for the purpose. Also, fibrous materials like jute fibre, polypropylene fibre, coir fibre etc. can be used.

1. Methods of soil stabilization

- Mechanical Stabilization: This refers to the alteration of soil compaction through the addition or removal of specific elements, also known as densification or compaction. The primary purpose is to have a soil resistant to deformation and displacement under loads, soil materials can be divided into two fractions: the granular fraction retained on a 75 micron IS sieve and the fine fraction passing a 75 micron IS sieve. The granular fraction provides strength and hardness, while the fine fraction offers cohesion and acts as a filler for the coarse fraction's voids. Mechanical stabilization has been largely used in the construction of cheap roads. This method deals with increasing the density of soil particles by compaction using rollers or compactors and applying deep vibrations to compact loose soils.
- Chemical Stabilization: Chemical stabilization is a process that utilizes reagents like quicklime, cement, flyash or other industrial products to enhance the strength of subgrade soil. It facilitates compaction and usually causes a slight increase in the compacted density. Few types of chemical stabilization are described below:

a.) Lime Stabilization: Hydrated(slaked) lime is highly effective in treating heavy, plastic clayey soils. Lime can be used alone or in combination with cement, bitumen, or fly ash. Lime is primarily utilized for stabilizing the foundations and subgrades of roads. Lime is a natural chemical that decreases the plasticity index of highly plastic soils, making them easier to handle. The amount of lime required may be used on the unconfined compressive strength or the CBR test criteria. Normally 2 or 8% of lime may be required for coarse grained soils and 5 to 10% for plastic soils. Adding lime to the soil to improve its plasticity, reduce swelling, and increase strength.

b.) Cement Stabilization: Engineered soil, water, and Portland cement mixture creates a semi-bound material with granular properties, improving soil shear and compressive strength. Cement, with advanced properties, is one of the cheapest binders available globally, with unit prices varying based on distribution network and manufacturing plant proximity.

c.) Bitumen Stabilization: Bituminous soil stabilisation is a widely used method using bitumen, asphalt, and tar materials. Bitumen are hydrocarbons, asphalts are petroleum-based, and tars are bituminous condensates from organic materials. Bituminous material stabilizes soil by binding particles or protecting it from water damage, or both effects may occur together. The mechanism of bitumen stabilization primarily involves asphalt in cohesionless and cohesive soils. It is basically the process of mixing bitumen or asphalt with the soil to enhance its engineering properties.

d.) Fly Ash Stabilization: Fly ash stabilization of soil is a process used in geotechnical engineering to improve the physical and chemical properties of soil. Fly ash, is a by-product from coal combustion in power plants that contains fine particles with pozzolanic properties. When mixed with soil, fly ash reacts with water and in the presence of lime or cement, forms cementitious compounds, enhancing the soil's strength and durability. The pozzolanic reaction between fly ash and soil increases compressive and shear strength. It is particularly used for clayey soils as it reduces the plasticity index of clayey soils, making them easier to handle and less susceptible to shrink-swell behaviour.

- Geotextile Reinforcement: This is a critical technique used in civil engineering and geotechnical applications to improve the stability, strength, and longevity of soil structures. Geotextiles are permeable fabrics made from synthetic or natural fibres designed to perform various functions such as separation, filtration, drainage, and reinforcement mainly used to reinforce and stabilize soil. This method is often used in slope stabilization.
- Soil Nailing: This method deals with the installation of grouted or threaded rods (nails) into the soil to provide additional stability, commonly used in excavations and slope stabilization.
- Biological Stabilization: In biological stabilization living organisms, primarily vegetation is used to stabilize soil and prevent erosion. This eco-friendly and cost-effective method is commonly employed in environmental engineering, agriculture, and land management to maintain soil structure, improve fertility and to stabilize soil and prevent erosion. The roots of plants help bind the soil particles together.

1.2 Materials used in soil stabilization

- Cement

- Lime
- Bitumen
- Geotextile
- Polymer
- Fibrous materials
- Different grades of soil
- Waste materials- industrial waste, solid municipal waste etc.
- Emulsions
- Aggregates of various grades
- Naturally available materials- sugarcane bagasse, coconut coir, areca nut fibre.

1.3 Purpose of soil stabilization:

Soil stabilization serves several purposes in civil engineering and construction projects. The primary goals of soil stabilization are to improve the engineering properties of soil and enhance its performance in terms of strength, durability, and load-bearing capacity. The specific purposes of soil stabilization include:

- Increase strength and load bearing capacity: One of the main objectives of soil stabilization is to increase the strength of the soil, making it capable of supporting heavier loads.
- Reduce permeability: Stabilization can be employed to reduce the permeability of soils, making them less susceptible to water infiltration and improving their resistance to erosion.
- Improve workability: Stabilized soils often exhibit improved workability, making them easier to compact and shape during construction.
- Improve Durability: Soil stabilization contributes to the long-term durability of structures by reducing the susceptibility of the soil to weathering and other environmental factors.
- Making construction more feasible: In some cases, construction may be challenging due to the presence of weak or problematic soils. Soil stabilization allows for the improvement of these soils, making construction more feasible and cost-effective.
- Environmental considerations: Soil stabilization can have environmental benefits like erosion control, improved water management, reduced land degradation, waste

utilization.

1.4 Advantages of soil stabilization

Soil stabilization offers several advantages in construction and civil engineering projects. These advantages contribute to improved performance, longevity, and cost-effectiveness of various structures and infrastructures. Here are some key advantages of soil stabilization:

- Soil stabilization alters the physical and mechanical properties of the soil, including its compressibility, shear strength, and permeability. This results in a more stable and predictable foundation for construction.
- Stabilized soils often allow for faster construction processes. Rapid curing times and improved workability enable quicker project completion, reducing overall construction timelines.
- Stabilizing soil can have positive environmental impacts by minimizing soil disturbance, reducing the need for excavation and disposal of soil, and mitigating erosion.
- Soil stabilization helps minimize settlement, ensuring a more uniform and stable foundation for structures.
- The improved properties of stabilized soils offer greater flexibility in design. Engineers can design structures with confidence, knowing that the stabilized soil will provide a stable and reliable foundation.
- Soil stabilization can lead to cost savings by allowing the use of in-situ soils rather than requiring the importation of expensive fill materials.

1.5 Application of soil stabilization:

- Road and Pavement Construction: Stabilized soil is often used to strengthen subgrades, bases, and sub-bases in roadways, highways, and airfields as it extends the life of pavements by improving resistance to cracking and rutting.
- Slope and Embankment Stabilization: Stabilized soil is used for natural or artificial slopes, embankments, and cuts to prevent landslides, erosion, or failure.

- Retaining Structures: Stabilized soil is used behind retaining walls to improve stability and load-bearing capacity also often combined with geosynthetics to manage drainage and enhance structural integrity.
- Foundation Improvement: Stabilized soils provide a firm and uniform base for buildings, bridges, and other structures, reducing settlement and improving load distribution. It is very essential for construction in areas with weak or expansive soils.
- Landfills and Waste Management: Stabilized soil has a great impact on landfill liners and caps, as it prevents leachate migration and ensures containment of hazardous materials.
- Erosion and Sediment Control: Soil when stabilized with vegetation cover and used on riverbanks, coastal areas, and construction sites prevents soil loss due to erosion hence it is frequently used for flood control and wetland restoration.
- Agricultural Applications: Stabilized soil improves the quality and stability of farmland, especially in areas prone to erosion or degradation also reduces runoff, improves water retention, and enhances productivity.

1.6 Egg shell powder

1.6.1 Introduction

Eggshell powder is a finely ground material obtained from the shells of eggs. It is an innovative and sustainable product with applications across multiple domains, including nutrition, agriculture, construction, and environmental management. The increasing focus on sustainability has elevated eggshell powder from a byproduct of food processing to a valuable resource in various industries**.** Eggshells are composed primarily of calcium carbonate ($CaCO_3$), which constitutes about 95% of their weight, along with small amounts of other minerals such as magnesium, potassium, and phosphorus. This makes eggshell powder a rich, natural source of calcium and other essential nutrients.

1.6.2 Composition of Eggshell Powder

Eggshells are primarily composed of calcium carbonate ($CaCO_3$), making up 95% of their total weight. The remaining components include:

- Organic Matrix: Proteins like collagen, which act as binding agents in the eggshell structure.
- Trace Minerals:
    a. Magnesium (0.5–1%)
    b. Phosphorus (0.1%)
    c. Potassium, Sodium, and Zinc (in trace amounts)

1.6.3 Properties of egg shell powder

Eggshell powder is a material with a unique set of physical, chemical, and mechanical properties. These properties make it suitable for applications across various industries, including health, agriculture, and construction. The physical, chemical and mechanical properties are mentioned below:

- Physical Properties
    a. Appearance: Egg shell is a fine, white or off-white powder after grinding.
    b. Texture: The texture is smooth when finely ground, with slight abrasiveness suitable for certain applications like exfoliants in cosmetics.
    c. Density: The density of egg shell is approximately 2.7 g/cm^3, which is similar to calcium carbonate from other sources.
    d. Particle Size: It varies depending on the grinding process, typically in the range of 10–100 micrometers.
- Chemical Properties
    a. Primary Components: Calcium Carbonate ($CaCO_3$): Makes up around 95% of the eggshell powder by weight.
    b. Secondary Components: Magnesium, phosphorus, Potassium, sodium, zinc etc.
    c. Egg shell is mildly alkaline, pH typically ranging from 9 to 12, making it suitable for neutralizing acidic soils and water.
    d. Thermal Stability: Egg shell decomposes at temperatures above **825°C**, releasing carbon dioxide ($CaCO_3 \rightarrow CaO + CO_2$), leaving behind calcium oxide (lime).
- Mechanical Properties

a. Hardness: Eggshell powder exhibits moderate hardness, making it suitable as a filler in construction materials like cement or as an abrasive in cosmetic products.
b. Strength: When used in composites, it enhances the mechanical properties of materials, such as compressive strength in concrete.

- Biological Properties:

a. Egg shell powder is non-toxic and safe for use in dietary supplements, pet feed, and medical applications like bone grafts or dental materials.
b. Egg shell powder biodegrades naturally, contributing to eco-friendly and sustainable applications.

Fig 1.1 Egg shells kept for air drying

Fig 1.2 Eggshell powder after grinding

Fig 1.3: Egg shell powder being weighed for laboratory test

CHAPTER -2

LITERATURE REVIEW

2. GENERAL

The studies of soil stabilization by using Egg shell powder were done by different researchers worldwide at different times. Some of the literatures are discussed briefly in this chapter.

2. Review of Literature

Amu O O, Fajobi A B and Oke B O (2005): This paper indicates the influence on clay soil when egg shell is combined along with lime and added to the soil as a stabilizer. The MDD, CBR and UCS value were found to be better when only lime is added at 7% by dry weight of soil as compared to the combination of egg shell powder (4%) and lime (+3%). The study also achieved an extreme CBR estimation of 7.8% at 20% addition of egg shell powder however the CBR value of the original soil without including the admixture accomplished an estimation of 1%.

A. J. Olarewaju et al. (2011): This study examined the possibility of using egg shell powder as a stabilization material for lateritic soils as a sub-grade of road construction. The study revealed that after addition of egg shell powder to the soil maximum dry density (MDD) , and CBR value of the soil increased as compared to the original soil.

U. N. Okonkwo et al. (2012): This study examined the addition of egg shell powder to lateritic soils stabilized with cement. The conclusion is that the parameter of shear strength of lateritic soils can increase up to 35% compared to the original soil after addition of egg shell powder.

Paul et al. (2014): In this study several laboratory experiments were conducted to look into the usage of egg shell powder and quarry dust as stabilizing additives to improve the geotechnical qualities of expansive soils. The results depicted the increase in CBR value as compared to normal soil without any additives.

Saji Geethu, Mathew Nimisha (2016): In this study, Egg Shell Powder (ESP) and Quarry Dust (QD) were used to study the effect on the properties of clayey soil and it was revealed that with addition of ESP, there is a considerable decrease in Atterberg's Limits, and after 20% the value seems to be almost constant. OMC increases and maximum Dry Density decreases with increase in percentage of ESP. With addition of varying percentage ESP Cohesion decreases and Angle of Internal Friction increases. Shear Strength increases with increase in percentage of ESP and after 20% strength is almost constant. Permeability increases with increase in ESP.

Anoop S.P et al. (2017): This study features the soil stabilization with the replacement of lime with egg shell powder. This study reflects about the increase in tensile strength of soil when 25 % of the lime was substituted by egg shell powder. In the study 0.5% to 2% of eggshell powder were introduced to overall soil weight in the formation of mixture.

Birundha P,et.al (2017): In this study , Egg Shell Powder and Quarry Dust were used to study the effect on the properties of clayey soil. An improvement in the engineering properties of soil by addition of ESP and QD will help to find an application for waste materials to improve the properties of clayey soil. Addition of various percentages of ESP and quarry dust into the soil decreases optimum moisture and increases maximum dry density as compared to the normal soil.

James et al. (2017): In this study eggshell powder was blended in three different quantities with (4% lime: 0.5% eggshell, 1% eggshell and 2% eggshell). The results of the study revealed an increase in CBR value as compared to the normal soil without any stabilizers.

Oluwatuji O. E et al. (2018): This study reflects about the soil stabilization of lateritic soil that was treated with crushed eggshell powder and cement both mixed in equal proportion which were added to the soil ranging from (0 % to 8%) over the soil weight. The results showed an increase in CBR value with increased stabilization, moreover the UCS value also increased. Moreover 8% mixing of crushed eggshell powder with the overall soil weight offered increased stabilization and was potentially applicable in highway construction.

Silmi Surjandani N. et.al (2018): This paper depicts the consequence of egg shell powder mixture in clay soil with higher plasticity. The study revealed that when the soil possessing (0 to 1.25) liquidity index were combined with egg shell powder, the liquidity index were observed to be increasing at a greater amount. Increased liquidity index resulted in reduced shear strength of the soil which was the foremost outcome of the study.

Alzaidy. M.N.J (2019): In this paper, the effect of the combination of egg shell powder and plastic waste strips in some engineering properties of clayey soil represented by compaction characteristics, unconfined compressive strength, swelling potential, California bearing ratio test and finally shear strength parameters have been studied. The aim of this paper is to investigate the influence of plastic wastes, eggshell powder contents and the curing duration in the strength behaviour of clayey soil. An increase in egg shell powder content causes to an increase in unconfined compressive strength. A significant net positive change has been noticed in the engineering characteristics of the clayey soil after adding both of ESP and plastic waste strip. These beneficial changes depend on ESP, PWS contents and the curing duration.

Munirwan. R. P et al. (2019): In this study it is found that when clay is stabilized with egg shell powder (ESP) there is an increase in specific gravity for a low percentage of ESP and decrease for a higher percentage. The liquid limit value also showed a decrease with increasing ESP mixture. The soil density of clay decreased with OMC value, and the maximum dry unit weight increases at a low percentage of ESP (3%) and decreases for 6% and 9%. In general, with the increase of the percentage of ESP, the maximum dry unit weight of the soil and soil shear strength parameter were increased compared to the soil without ESP addition.

Alqaisi. R. O. (2020): This research paper reflected on the effect of ESP as a supplementary additive to lime stabilization in expansive soil. The addition of Egg Shell Powder alone to soil had a marginal effect on the geotechnical properties of stabilized expansive soils. The unconfined compressive strength (UCS) of treated soils increased as compared to the origin soil.

Aneesh P.C. et.al (2020): It is an experimental study focused on stabilization of cochin clay with Egg Shell Powder (ESP) and plastic waste. In the study 3 various proportions of ESP (2%, 5%, 8%) and plastic wastes (0.25%, 0.5%, 0.75%, 1%) were added to obtain optimum percentage of each additive. It was found that the combination of 5% ESP and 0.5% plastic obtained the maximum compressive strength of 86.24kN/m2 and thereafter the value went on decreasing.

Kola Veerabrahmam (2021): This study reflected on a fact that the clay content was reduced with an increase in density and liquid limit, subsequently the plastic limit was reduced with the increase of UCS by adding the eggshell powder to the soil. The optimal dried density of the soil was increased and optimum moisture content was decreased respectively when 0% to 20%

of eggshell powder was mixed with soil. The CBR values were increased until 15% ESP at which the maximum value was attained, and further addition decreased the CBR value.

Dr. K. Harish et.al (2023): This research paper reflected on the study of decreasing swelling and shrinkage behaviour of clay soil and increasing soil strength, workability, shear strength and permeability after addition of egg shell powder at 5%, 10% and 15% to the dry weight of soil. The study revealed that after addition of egg shell powder, liquid limit of the soil was observed to be decreasing and the plastic limit of the soil was found to be increasing. The bearing capacity of the soil was found to be increasing after addition of egg shell powder at 5% and 10% however the bearing capacity of the soil decreased when 15% egg shell powder was added to the clay soil.

Mohamed A. Sakr et.al (2023): In this study, soft clay soil is improved with eggshell powder. An experimental testing program is carried out to investigate impact of using eggshell powder to enhance the characteristics of soft clay soil, which includes X-Ray diffraction analysis, Scanning electron microscope, as well as triaxial shear and compressibility parameters. The X ray diffraction analysis showed that the peak value of kaolinite is decreased by adding eggshell powder to the soft clay. This happens as a result of the formation of new compounds by the chemical interaction between eggshell powder and clay minerals. Scanning electron microscope analysis revealed that the soil particles have been changed from being a flaky shape to one with a flocculating structure. The shear strength and cohesion of soft clay is found to be gradually increased with the increase in egg shell percentage.

CHAPTER -3

METHODOLOGY

3. GENERAL

This chapter reflects on the different laboratory tests that were performed on collected soil sample by using apparatus and test procedures. The laboratory tests were conducted following the righteous rules as mentioned in respective IS CODES.

Fig 3.1: Collection of soil sample from North Guwahati area.

3.1 Soil Collection and Preparation:

In this study soil sample of about 100- 110kg is collected from a village named Molong in the North Guwahati area. The soil was collected from an open field which is at a distance of 8.17 km from the Brahmaputra North River Bank. The first 1.5 feet layer of soil was removed which may contain leaves, shrubs, branches etc. The soil used for the study was excavated from a depth of about 3 feet below the ground surface. After the collection of the soil sample, it is allowed to dry at room temperature for few weeks. Oven dried samples are not used in this experimental study as during oven drying of the soil specimen the intermolecular attraction of the soil particles get destroyed easily in comparison with the air-dried soil samples. The soil used here are air-dried soil samples as oven dried samples results in disturbance of the soil structure.

Fig 3.2: Collected soil sample being air dried in laboratory

3.2 Materials Collection and Preparation:

3.2.1 Egg shell Powder collection:

Eggshells are collected from household waste, restaurants, AEC hostels and washed thoroughly to remove any organic residues. Egg shells are then dried the in an oven at 105°C for 24 hours and some under sunlight for 48 hours.

3.2.2 Eggshell Powder Preparation:

Dried eggshells using mixture grinder and then kept in airtight bottle to use in later stages during the laboratory tests to be performed. Egg shell powders are sieved by the dry sieve method to ensure the particle size.

Fig 3.3: Finely grinded Egg Shell Powder

3.3 Description of tests performed:

Laboratory tests were performed for the determination of the physical properties as well as the strength of the soil according to the IS code and are discussed below briefly:

3.3.1 Sieve Analysis:

This test was performed according to the IS Code-Determination of gradation of the soil samples by wet sieve analysis according to IS 2720 (Part 4)-1985. Sieve Analysis is generally done by two methods- Dry method and Wet method. Dry sieve method is performed when the soil retains on 4.75mm IS sieve after sieving. Whereas wet sieve analysis is performed on soil passing through 4.75mm IS sieve and retained on 75-micron IS sieve. Here only wet sieve analysis of the untreated soil is done because of the removal of the clay particles intact to it as the soil taken for testing is clayey soil. Sieves used in this methods are-4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ, 75μ. 200g oven dried soil sample passing through 4.75mm IS sieve is taken for this experiment. Sieve analysis is carried out to determine the Particle-Size Distribution of a material. Graph is plotted between Sieve (mm) and % finer which is obtained from the fine sieve analysis.

3.3.2 Liquid limit test by Static Cone Penetration:

This test was performed according to the IS specification IS:2720(Part 5)-1985. Liquid limit (WL) is the water content corresponding to the arbitrary limit between liquid limit and plastic limit. Liquid limit is defined as the minimum water content at which the soil is still in the liquid state, but has a small shearing strength against flowing. Graph between Cone penetration (x) and water content(y) should be plotted to determine the liquid limit of the soil. The water content corresponding to a cone penetration of 20mm is then taken as the liquid limit. The set of values used for the graphs are such that the penetration should be in between 14-28mm. The sieve used for performing this experiment is 425μ passing.

Fig 3.4: Cone Penetration

3.3.3 Determination of Plastic limit:

This test was performed according to the IS specification IS:2720(Part 5)-1985. Plasticity is defined as the property of soil which allows it to be deformed rapidly, without rupture, without elastic rebound and without volume change. Plastic limit (WP) is the water content between the plastic and the semi-solid states of consistency of soil. It is defined as the minimum water content at which the soil will just begin to crumble when rolled into a thread approximately 3mm in diameter. IS sieve in performing this experiment is 425μ passing. The plasticity index,

IP = WP-WL.

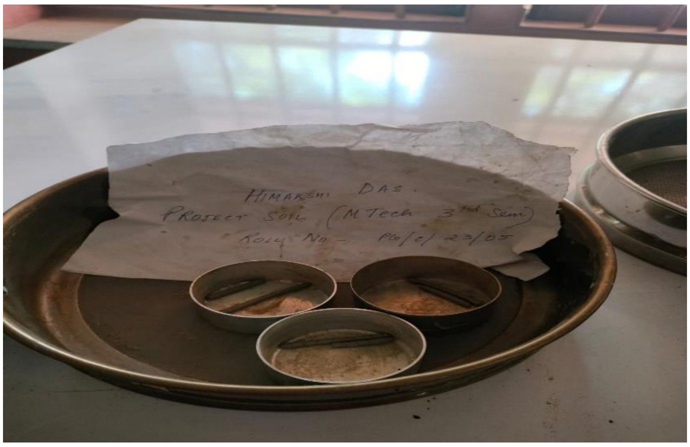

Fig 3.5: Plastic threads of Plastic limit method

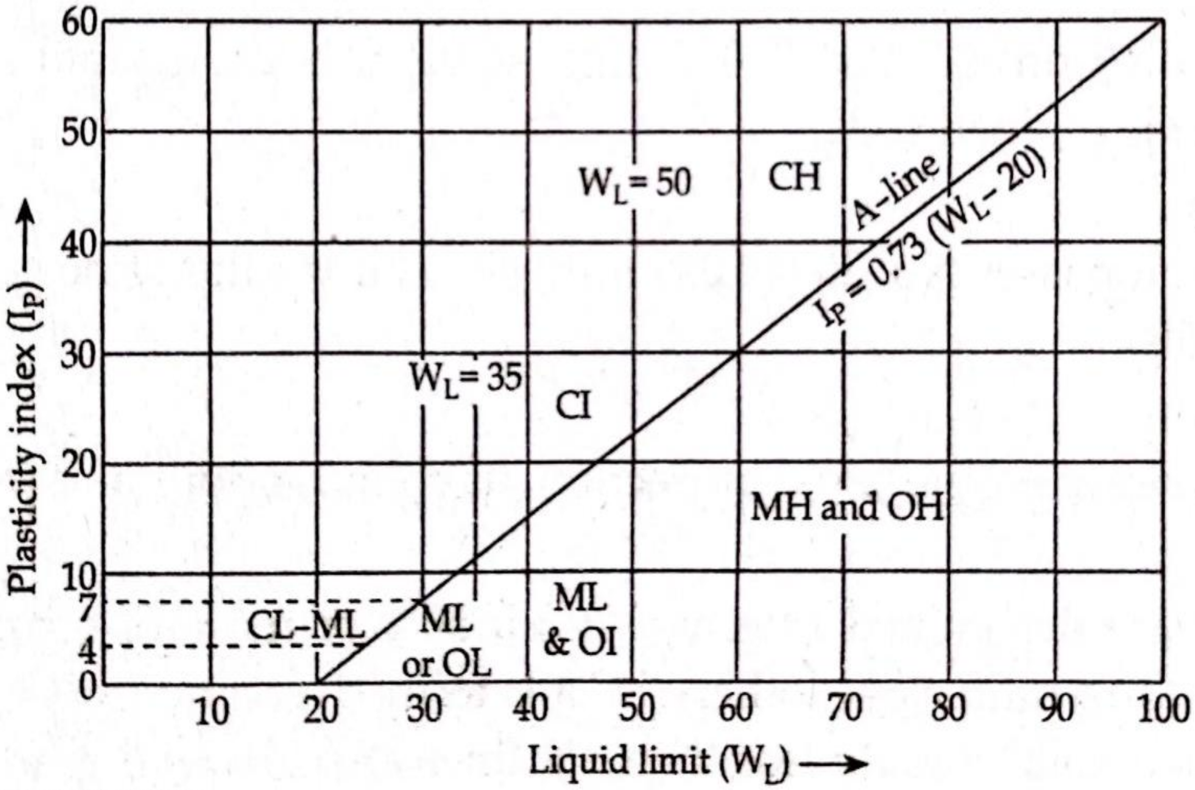

Fig 3.6: Plasticity Chart

3.3.4 Determination of Specific Gravity by Density Bottle

The specific gravity is performed as per IS-2720 (Part 3/ Section 1)-1980: Method of test of soil. Part-8 Determination of specific gravity, section-1 Fine grained soil. The specific gravity of soil particles is the mass density of soil to that of distilled water at the standard temperature of 27°C. It is the ratio between mass of the given volume of soil to that of equivalent volume of water. It is denoted by the symbol G. The apparatus required for performing this test includes density bottle of 50ml capacity, digital balance, vacuum desiccator, oven.

The procedure includes the following steps:

- Firstly, the density bottle was cleaned and dried properly before conducting the test
- . The density bottle along with the stopper been weighed and denoted as M1
- 5-10 g of soil sample was taken in the density bottle and weigh the bottle along with the stopper as M2.
- Now add distilled water to the soil in the density bottle up to the soil level and shake gently to mix soil and water.
- Now the stopper of density bottle was removed and placed in the vacuum desiccator and connect the vacuum pump.
- Take out the bottle after attaining constant temperature and dry the outer surface using cloth and weighed the bottle as a total of mass of bottle, soil and water as M3.
- In the last step, bottle was emptied and filled solely with distilled water along with stopper and weighed as M4. The specific gravity is determined by the following equation G = M2- M1/(M4-M1)-(M3-M2).

Fig 3.7: Density bottles kept in desiccator

3.3.5 Compaction test:

Dynamic compaction method: This test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compaction as per IS: 2720 (Part 7). Compaction is the process of expelling the air from the soil sample by applying any mechanical energy. The expulsion of air from the soil reduces the porosity of the soil and thereby increases the density of the soil. This can be achieved by repetitive application of loads either in dynamic manner or static loading. Several methods are used for compaction like tamping, vibration, etc. Generally, two types of compaction test are performed as developed by R.R. Proctor are the Standard Proctor Test and Modified Proctor Test. In the Standard Proctor Test, the soil is compacted by a 2.6kg rammer at a free fall of 310mm. The mould is filled with three layers and each layer is given 25 numbers of blows. Whereas in Modified Proctor Test, a 4.89kg rammer is used at a free fall of 450mm along with the mould filled with five layers of soil. Proctor compaction tests are most commonly used to determine the compaction characteristics for proper control over the field compaction. These dynamic compaction tests are laborious and time consuming and also limitations are there in determination of maximum dry density and optimum moisture content. Thus, to improve the properties of the soil, compaction technique is adopted for the strength improvement of the soil. In this experimental study, Standard Proctor Test has been carried out. The soil samples were prepared at different water content of about 2kg each and kept it for 24 hours before performing the test.

Fig 3.8: Standard Proctor test being performed.

3.3.6 Unconfined Compressive strength Test

This test is performed to determine the Unconfined Compressive strength (UCS) of the soil in the laboratory. The specimens used while doing the test are undisturbed, remoulded or compacted specimen. The UCS (qu) is the load per unit area at which a cylindrical specimen fails in compression without any confining pressure. **qu**= **P A** Where P = axial load at failure, A=corrected area= A0/(1-ε) *A*0= Initial cross-sectional area of the specimen, *ε*=axial strain

Fig 3.9: Sample after failure at UCS test

Fig 3.10: UCS Apparatus

The UCS test in this study is conducted at maximum dry density and OMC obtained from the Standard Proctor Test. The UCS test is conducted as per IS 2720-10.

3.3.7 California Bearing Ratio (CBR) Test

The test is conducted in accordance to IS 2720 (Part 16): 1987. The soil sample for this study is prepared at maximum dry density and optimum moisture content obtained from the Standard Proctor test.

Fig 3.11: CBR Test Apparatus

3.3.8 Progress of the study

All the above-mentioned laboratory tests are conducted as per IS Code regulations. Egg shell powder is mixed at 5%, 10% and 15% to the dry weight of the soil sample and the change in the properties of the soil sample is observed.

Fig 3.12: Egg shell powder being weighed for sieve analysis test.

CHAPTER -4

EXPERIMENTAL TEST RESULTS

4.1 Introduction

This chapter include the laboratory test results and findings from different tests carried out from the experiments of the untreated soil in the Laboratory.

4.2 Observation and Calculations

4.2.1 Sieve Analysis

Total mass of oven dried sample =200 gram.

Table 4.1 Particle size distribution of soil sample

Sieve size (mm)	Retained (g)	% Retained	Cumulative % retained	% Finer
4.75	0	0	0	100
2.36	0.03	0.01	0.01	99.99
1.18	0.19	0.09	0.11	99.89
0.6	0.36	0.18	0.29	99.71
0.425	0.42	0.21	0.50	99.51
0.3	0.62	0.31	0.81	99.19
0.15	2.11	1.05	1.86	98.14
0.075	4.39	2.20	4.06	95.95

Sand = 100 – 95.95 = 4.05%

Fig 4.1: Particle size distribution of untreated soil sample

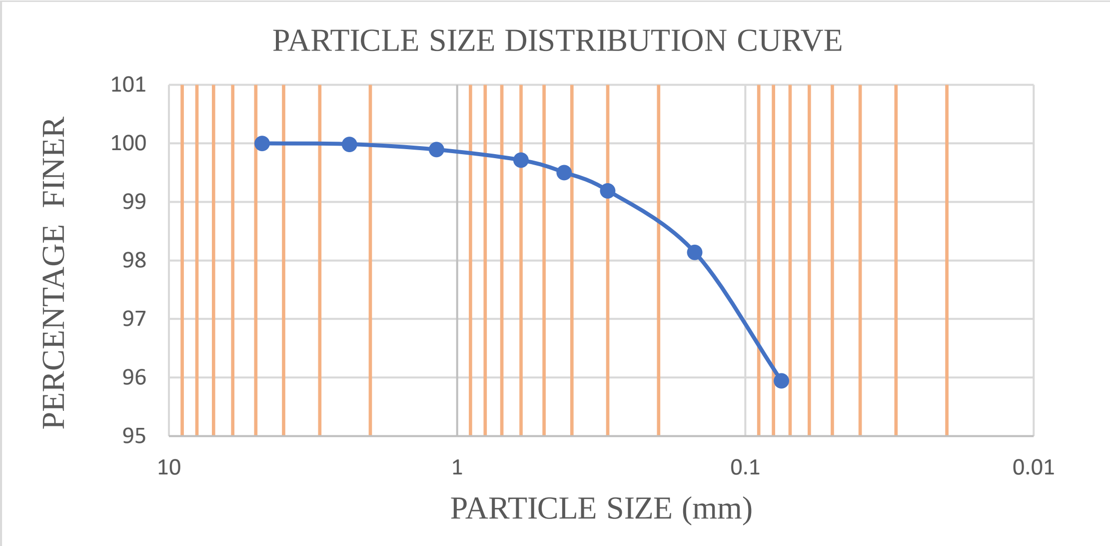

Table: 4.2 Particle size distribution of Egg Shell Powder (ESP)

Sieve Size(mm)	Retained (g)	% Retained	Cumulative % Retained	% Finer
4.75	0	0	0	100
2	0	0	0	100
1.18	0.04	0.01	0.01	99.99
0.6	0.45	0.09	0.10	99.90
0.425	3.97	0.79	0.89	99.11
0.3	9.55	1.91	2.80	97.20
0.15	117	23.40	26.20	73.80
0.075	220	44.00	70.20	29.80

Total mass of Egg Shell Powder taken = 500 gram

Fineness Modulus (Egg Shell Powder) =1.00%

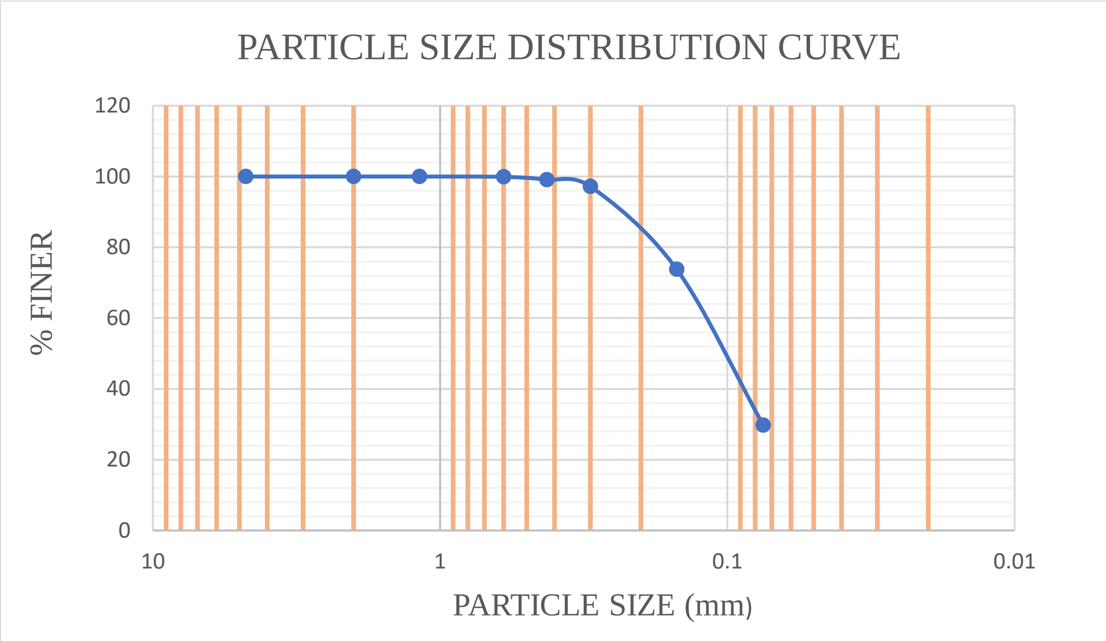

Fig 4.2: Particle Size Distribution curve for Egg Shell Powder

4.2.2 Liquid Limit Test

Total mass of the soil sample taken = 300 gm

Table : 4.3 Table for moisture content determination in liquid limit

Empty weight of container (W1) gm	Weight of container and wet soil (W2) gm	Weight of container and dry soil (W3) gm	Weight of moisture W4=(W2-W3) gm	Weight of dry material W5=(W3-W1) gm	Cone Penetration (mm)	Moisture content (W=100*W4/W5) %
15.00	28.03	23.65	4.38	8.65	17	50.68
14.57	23.44	20.34	3.10	5.77	19	53.78
15.36	24.62	21.25	3.37	6.00	21	56.22
15.95	26.34	22.47	3.86	6.53	22	59.18
16.09	22.55	20.07	2.47	3.99	25	62.00

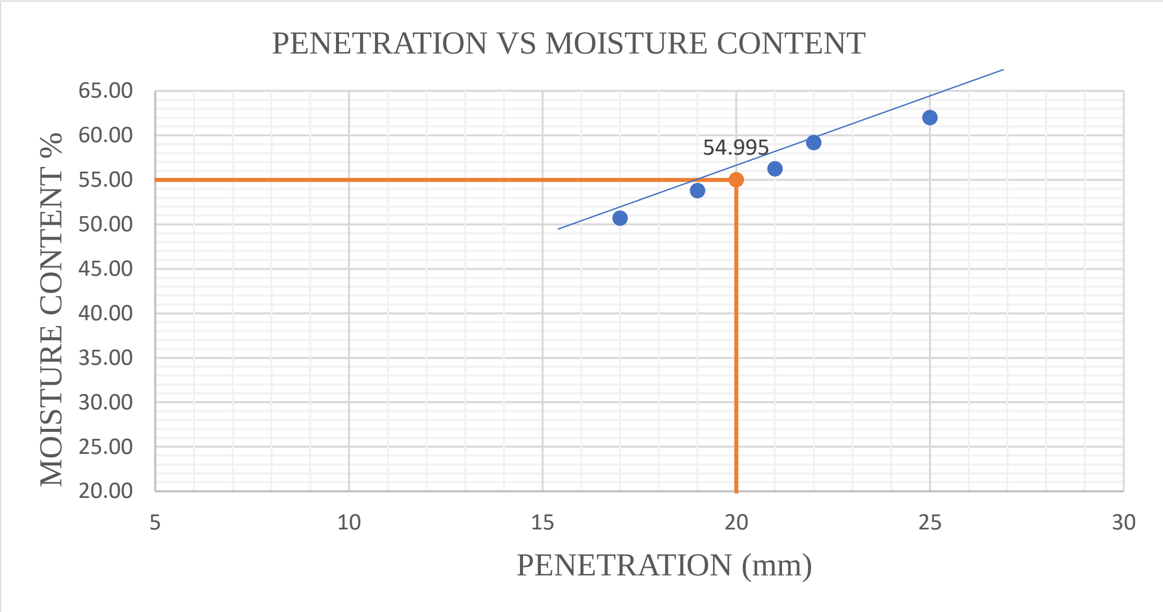

Fig 4.3 Liquid Limit of untreated soil (0 % ESP)

Liquid Limit = 54.99%

4.2.3 Plastic Limit Test

Total mass of sample Taken = 80 gram

Table= 4.4 Table for determining moisture content at Plastic Limit

Empty weight of container (w0) g	Weight of container and wet soil (w1) g	Weight of container and oven dried soil(w2) g	Weight of water (w1-w2) g	Weight of oven dried soil (w2-w0) g	Water content (w)= (w1-w2/w2-w0) *100
10.32	11.38	11.19	0.19	0.86	22.57
9.36	10.71	10.43	0.28	1.08	25.81
8.63	9.77	9.56	0.21	0.93	22.64

Plastic limit= 23.67, from Table 4.4

Plasticity index = 31.32

Soil type = CH soil (Clay with High Plasticity)

4.2.4 Determination of specific gravity

Total mass of the sample taken = 5-10g

Table 4.5 Specific gravity values

Density bottle no.	Weight of empty density bottle and stopper (w1) g	Weight of density bottle, stopper and soil(w2) g	Weight of density bottle, stopper, soil and distilled water(w3) g	Weight of density bottle, stopper and distilled water(w4) g	Specific Gravity(G)
1	25.26	34.58	80.94	75.25	2.56
2	26.77	36.45	83.15	77.01	2.73
3	21.17	30.44	76.02	70.42	2.53

Specific gravity = 2.61

4.2.5 Standard Proctor test

Diameter of mould = 100mm

Volume of mould = 1000cc

Height of mould = 127.5mm

Weight of sample taken = 2kg Empty mould + base plate = 3844 g

Table 4.6: Standard Proctor Test for untreated soil

Mass of compacted soil + Mould with base (g)	Empty container (g)	Wet soil +container (g)	Dry soil +container (g)	Bulk density (KN/m^3)	Water content (%)	Dry density (KN/m3)	Dry density (g/cc)
5430	19.17	24.10	23.48	15.60	14.31	13.65	1.39
5494	13.86	19.83	19.00	16.23	16.23	13.96	1.42
5526	15.63	20.91	20.14	16.54	17.26	14.11	1.44
5570	16.30	26.01	24.49	16.98	18.64	14.31	1.46
5612	16.06	24.48	23.08	17.39	20.01	14.49	1.48
5666	18.32	31.36	29.01	17.92	21.91	14.70	1.50
5760	15.14	36.55	32.13	18.84	26.00	14.95	1.53
5740	15.69	38.62	33.49	18.65	28.81	14.48	1.48
5714	10.78	34.13	28.71	18.39	30.20	14.13	1.44

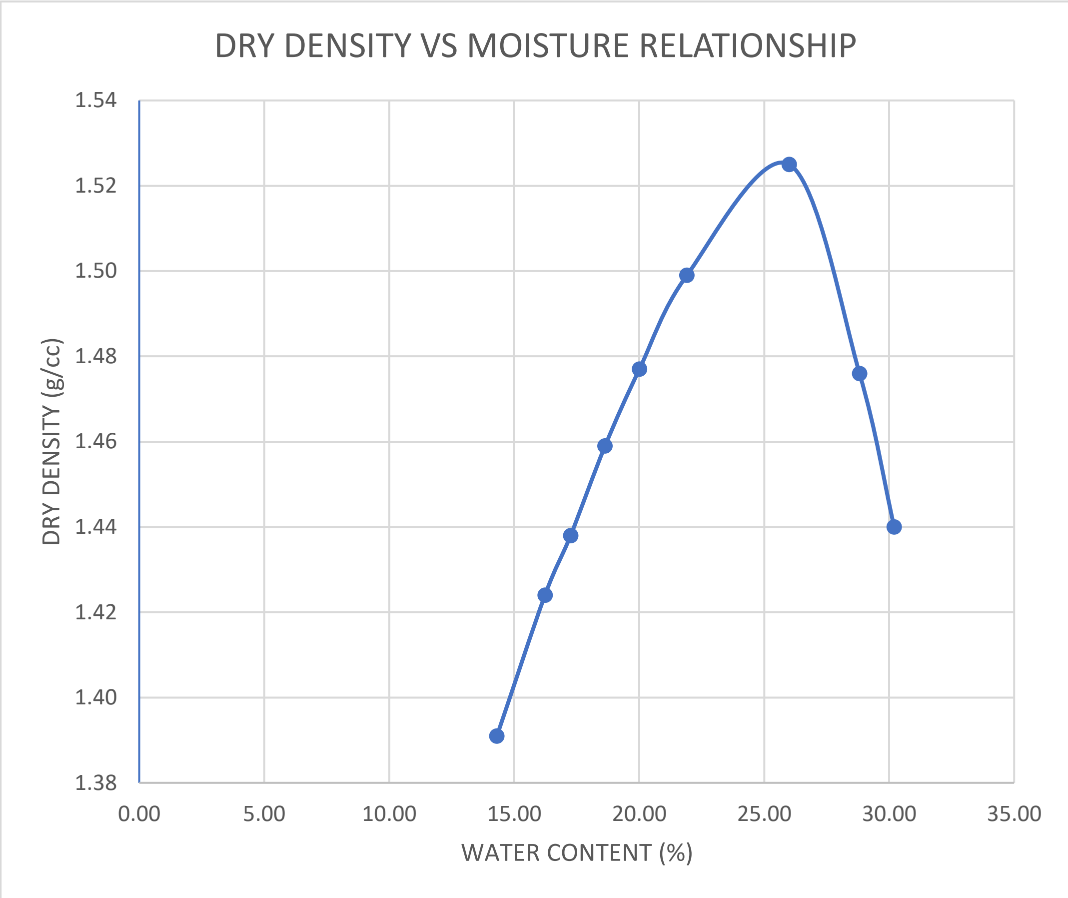

Fig 4.4 Dry Density Vs moisture content for untreated soil (0% ESP)

4.2.6 Unconfined compressive strength

Initial diameter of soil specimen= 38mm

Initial length = 76mm

Initial area = 11.34cm2

Soil specimen is mixed at OMC obtained from the Standard proctor test.

Table 4.7 Unconfined compression test values for 0% Egg shell Powder

Compression Dial Reading (ΔL) (0.01mm)	Proving Ring Dial Reading (1div=0.33 kg)	Axial strain(€= ΔL/L)	Area =A₀/(1-€) cm^2	Axial load (kg)	Compressive stress (kg/cm^2)	Axial strain %	Compressive stress (KPa)
0	0	0.00	0.00	0	0	0.00	0.00
0.5	28	0.01	11.42	9.24	0.81	0.66	79.38
1	53	0.01	11.49	17.49	1.52	1.32	149.26
1.5	72	0.02	11.57	23.76	2.05	1.97	201.42
2	89	0.03	11.65	29.37	2.52	2.63	247.30
2.5	103	0.03	11.73	33.99	2.90	3.29	284.27
3	113	0.04	11.81	37.29	3.16	3.95	309.75
3.5	121	0.05	11.89	39.93	3.36	4.61	329.41
4	127	0.05	11.97	41.91	3.50	5.26	343.36
4.5	131	0.06	12.05	43.23	3.59	5.92	351.71
5	134	0.07	12.14	44.22	3.64	6.58	357.25
5.5	136	0.07	12.22	44.88	3.67	7.24	360.03
6	135	0.08	12.31	44.55	3.62	7.89	354.85
6.5	133	0.09	12.40	43.89	3.54	8.55	347.09
7	129	0.09	12.49	42.57	3.41	9.21	334.23
7.5	111	0.10	12.58	36.63	2.91	9.87	285.51
8	106	0.11	12.67	34.98	2.76	10.53	270.66
8.5	80	0.11	12.77	26.40	2.07	11.18	202.77

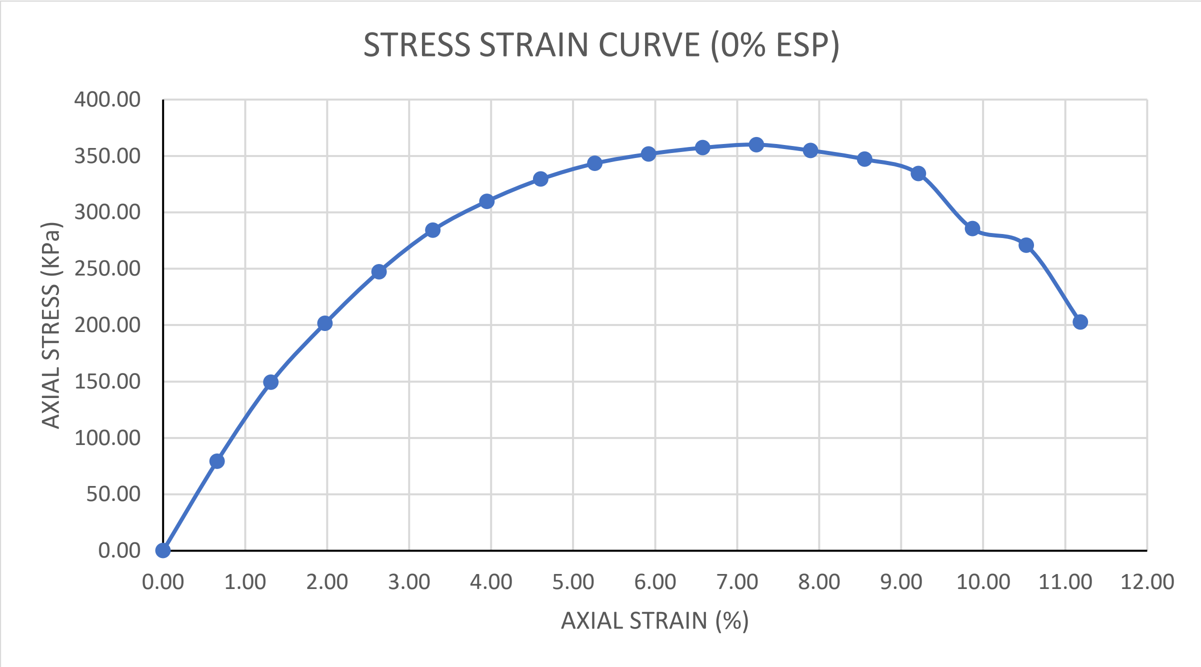

Fig 4.5 : UCS graph for 0% ESP

4.2.7 CBR Test

For Untreated soil 0% waste

Table 4.8 Load penetration data for CBR test of untreated soil

PENETRATION OF PLUNGER (mm)	LOAD (Kg)
0	0
0.5	4.26
1	8.52
1.5	12.78
2	17.04
2.5	21.3
3	24.14
4	28.4
5	31.24
7.5	35.5
10	39.76
12.5	44.02

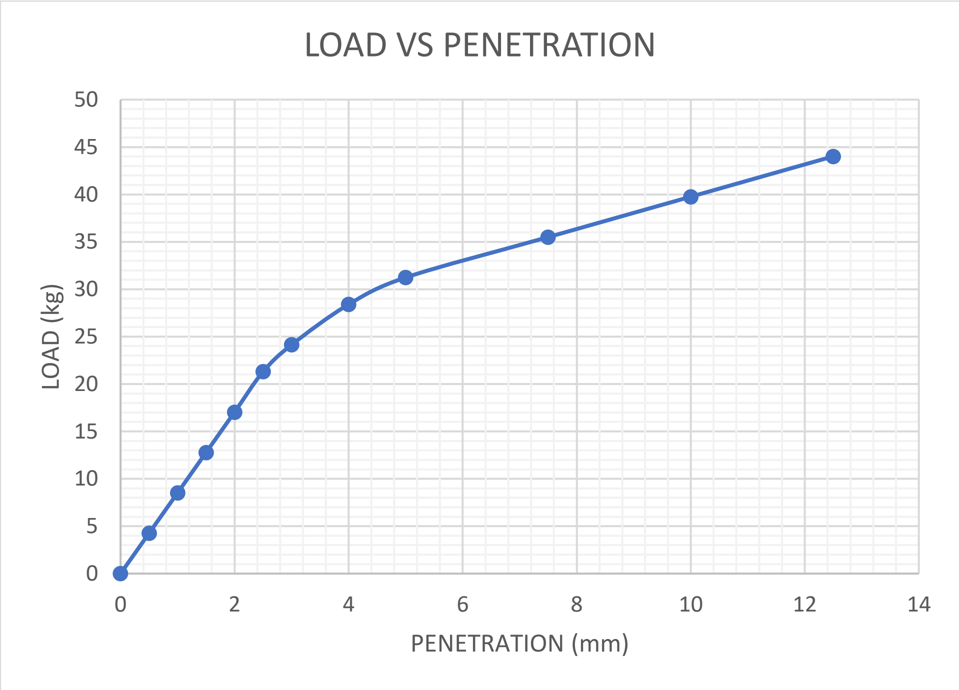

Fig 4.6: Load vs Penetration for 0% ESP

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CHAPTER-5

TEST RESULTS WITH ADDITION OF WASTE

5.1 Introduction

This chapter represents the results obtained when different percentages of Egg Shell Powder was added to the soil. The ESP were added at 5%, 10% and 15% to the dry weight of soil

5.2 Specific Gravity of ESP

Table : 5.1 Specific Gravity Of ESP

Density bottle no.	Weight of empty density bottle (w1)g	Weight of density bottle+ ESP and soil(w2)g	Weight of density bottle+ ESP, soil and distilled water(w3)g	Weight of density bottle, and distilled water(w4)g	Specific Gravity(G)
1	35.32	45.36	93.29	88.89	1.77
2	24.28	34.53	78.49	74.14	1.73
3	27.14	37.31	80.98	77.45	1.53
	SPECIFIC GRAVITY	1.67			

Specific Gravity of ESP = 1.67

5.3 Standard Proctor Test for 5% ESP

Weight of Empty mould +base plate=3302 gram

Mass of compacted soil + mould with base plate (g)	Mass of empty container (g)	Mass of container+ wet soil (g)	Mass of container + dry soil (g)	Bulk Density (g/cc)	Water Content (%)	Dry Density(g/cc)
4948	6.4	13.54	12.56	1.65	12.26	1.47
5058	9.99	24.92	22.67	1.76	17.74	1.49
5146	7.72	29.57	25.72	1.84	21.39	1.52
5240	9.01	25.5	22.2	1.94	25.02	1.55
5224	8.65	27.72	23.59	1.92	27.64	1.50
5180	8.52	24.15	20.48	1.88	30.69	1.43

Table 5.2 Standard Proctor Table for 5% ESP

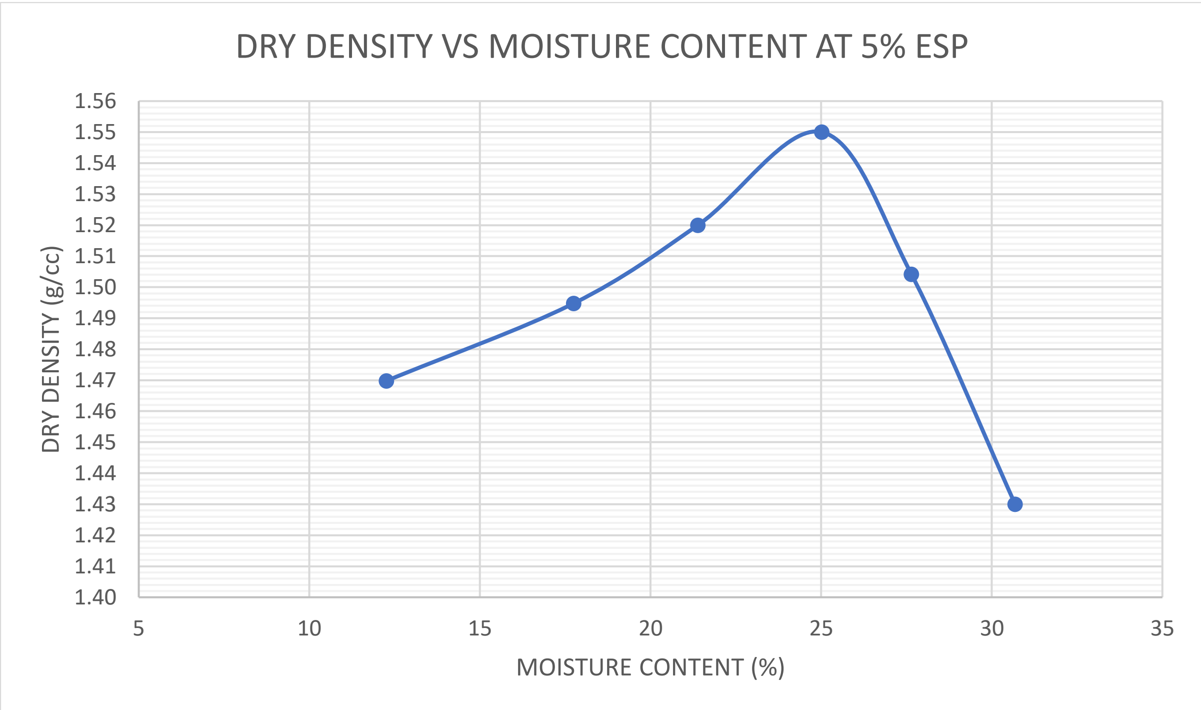

Fig: 5.1 Dry density vs moisture curve for 5% ESP

5.4 UCS Test

For soil with 5% ESP

Table 5.3 values for UCS test for soil with 5% ESP

Area A_o / (1-€) cm^2	Axial load (Kg)	Compressive stress (kg/cm^2)	Axial strain %	Compressive stress (Kpa)
0	0	0	0	0
11.42	2.64	0.23	0.66	22.68
11.49	4.29	0.37	1.32	36.61
11.57	5.28	0.46	1.97	44.76
11.65	6.27	0.54	2.63	52.79
11.73	7.26	0.62	3.29	60.72
11.81	7.92	0.67	3.95	65.79
11.89	8.58	0.72	4.61	70.78
11.97	9.57	0.80	5.26	78.40
12.05	10.23	0.85	5.92	83.23
12.14	10.89	0.90	6.58	87.98
12.22	11.88	0.97	7.24	95.30
12.31	12.54	1.02	7.89	99.88
12.40	12.87	1.04	8.55	101.78
12.49	13.53	1.08	9.21	106.23
12.58	14.19	1.13	9.87	110.60
12.67	14.85	1.17	10.53	114.90
12.77	15.51	1.21	11.18	119.13
12.86	16.17	1.26	11.84	123.28
12.96	16.50	1.27	12.50	124.85
13.06	16.83	1.29	13.16	126.39
13.16	17.49	1.33	13.82	130.35
13.26	17.82	1.34	14.47	131.80
13.36	18.15	1.36	15.13	133.21
13.47	18.48	1.37	15.79	134.58
13.57	18.81	1.39	16.45	135.91
13.68	19.14	1.40	17.11	137.21
13.79	19.80	1.44	17.76	140.81
13.90	20.13	1.45	18.42	142.01
14.01	20.46	1.46	19.08	143.18
14.13	20.79	1.47	19.74	144.30
14.25	20.79	1.46	20.39	143.12
14.36	20.79	1.45	21.05	141.94
14.48	21.12	1.46	21.71	142.99
14.61	21.12	1.45	22.37	141.79

14.73	21.45	1.46	23.03	142.78
14.86	21.45	1.44	23.68	141.56
14.99	20.79	1.39	24.34	136.02
15.12	20.46	1.35	25.00	132.70

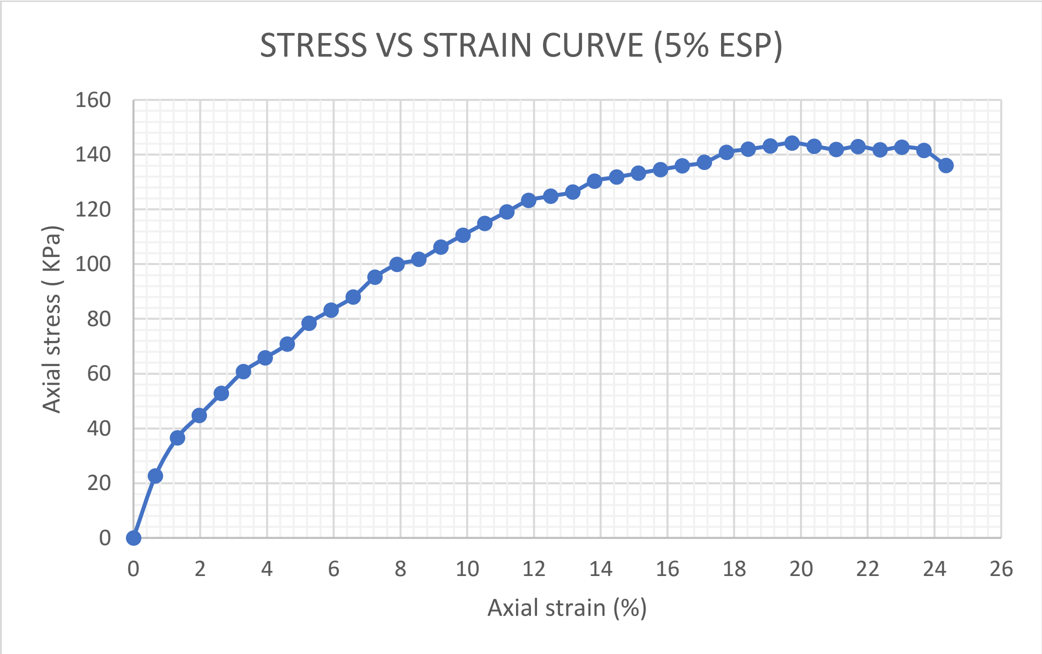

Fig 5.2: UCS test graph for soil with 5% ESP

5.5 CBR test

For soil with 5% ESP

Table: 5.4 CBR test values for soil with 5% ESP

PENETRATION OF PLUNGER (mm)	LOAD (Kg)
0	0
0.5	7.1
1	14.2
1.5	21.3
2	26.98
2.5	32.66
3	36.92
4	42.6
5	46.86
7.5	52.54
10	58.22
12.5	63.90

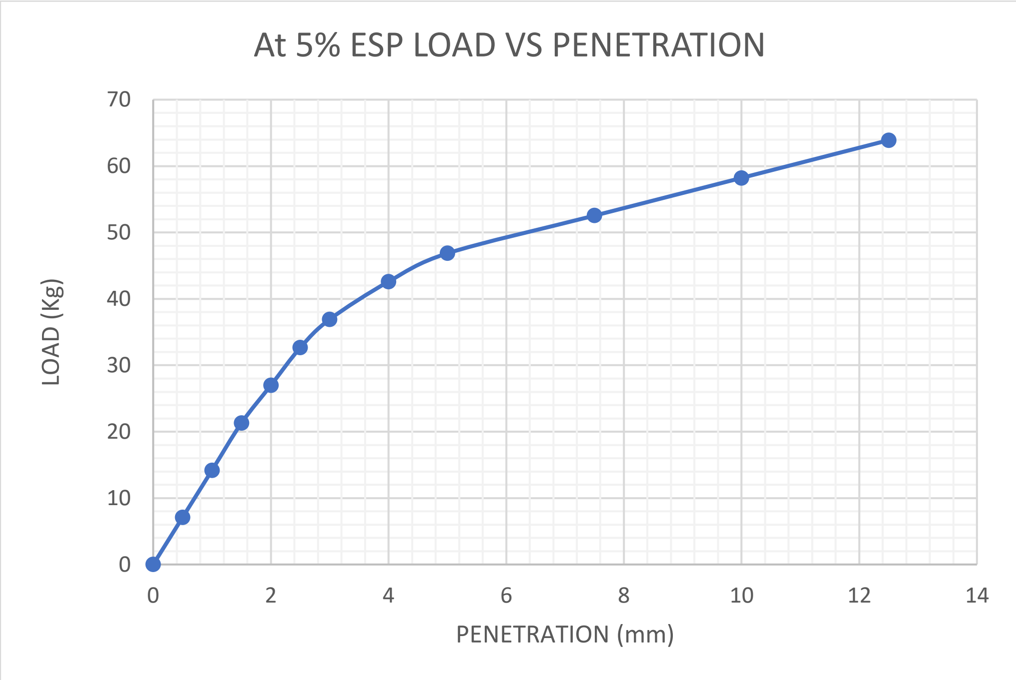

Fig: 5.3 CBR curve for soil with 5% ESP

5.6 Standard Proctor Test for soil with 10% ESP

Table 5.5 : Values for Standard Proctor Test of soil with 10% ESP

Mass of compacted soil+ mould with base plate (g)	Mass of empty container (g)	Mass of container + wet soil(g)	Mass of container +dry soil (g)	Bulk Density (g/cc)	Water Content(%)	Dry Density (g/cc)
5922	8.65	24.23	21.95	1.72	17.14	1.47
6056	9.01	21.73	19.56	1.86	20.57	1.54
6144	6.39	22.28	19.29	1.95	23.18	1.58
6132	8.52	28.18	24.12	1.93	26.03	1.53
6110	9.99	27.33	23.41	1.91	29.21	1.48

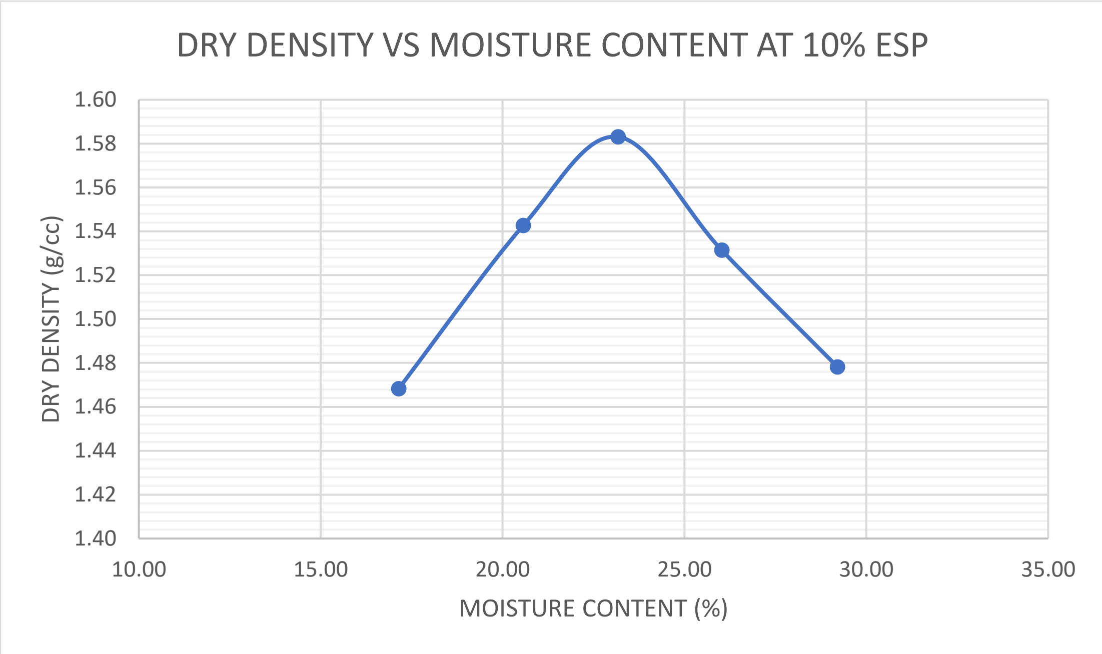

Fig: 5.4 Dry density vs moisture content curve for soil with 10% ESP

5.7 UCS test for soil with 10% ESP

Table 5.6 : values for UCS test of soil with 10% ESP

Compression dial reading (Δl) (0.01mm)	Proving Ring Dial Reading (1 div= 0.33kg)	Axial strain €= (Δl/l)	Area A_o / (1-€) cm^2	Axial load (Kg)	Compressive stress (kg/cm^2)	Axial strain %	Compressive stress (Kpa)
0	0	0	0	0	0	0	0
0.5	8	0.01	11.42	2.64	0.23	0.66	22.68
1	14	0.01	11.49	4.62	0.40	1.32	39.43
1.5	20	0.02	11.57	6.60	0.57	1.97	55.95
2	27	0.03	11.65	8.91	0.77	2.63	75.02
2.5	33	0.03	11.73	10.89	0.93	3.29	91.08
3	38	0.04	11.81	12.54	1.06	3.95	104.16
3.5	44	0.05	11.89	14.52	1.22	4.61	119.78
4	49	0.05	11.97	16.17	1.35	5.26	132.48
4.5	54	0.06	12.05	17.82	1.48	5.92	144.98
5	59	0.07	12.14	19.47	1.60	6.58	157.30

5.5	65	0.07	12.22	21.45	1.75	7.24	172.07
6	69	0.08	12.31	22.77	1.85	7.89	181.36
6.5	73	0.09	12.40	24.09	1.94	8.55	190.51
7	76	0.09	12.49	25.08	2.01	9.21	196.91
7.5	79	0.10	12.58	26.07	2.07	9.87	203.20
8	82	0.11	12.67	27.06	2.14	10.53	209.38
8.5	84	0.11	12.77	27.72	2.17	11.18	212.91
9	85	0.12	12.86	28.05	2.18	11.84	213.85
9.5	85	0.13	12.96	28.05	2.16	12.50	212.25
10	83	0.13	13.06	27.39	2.10	13.16	205.70
10.5	81	0.14	13.16	26.73	2.03	13.82	199.22

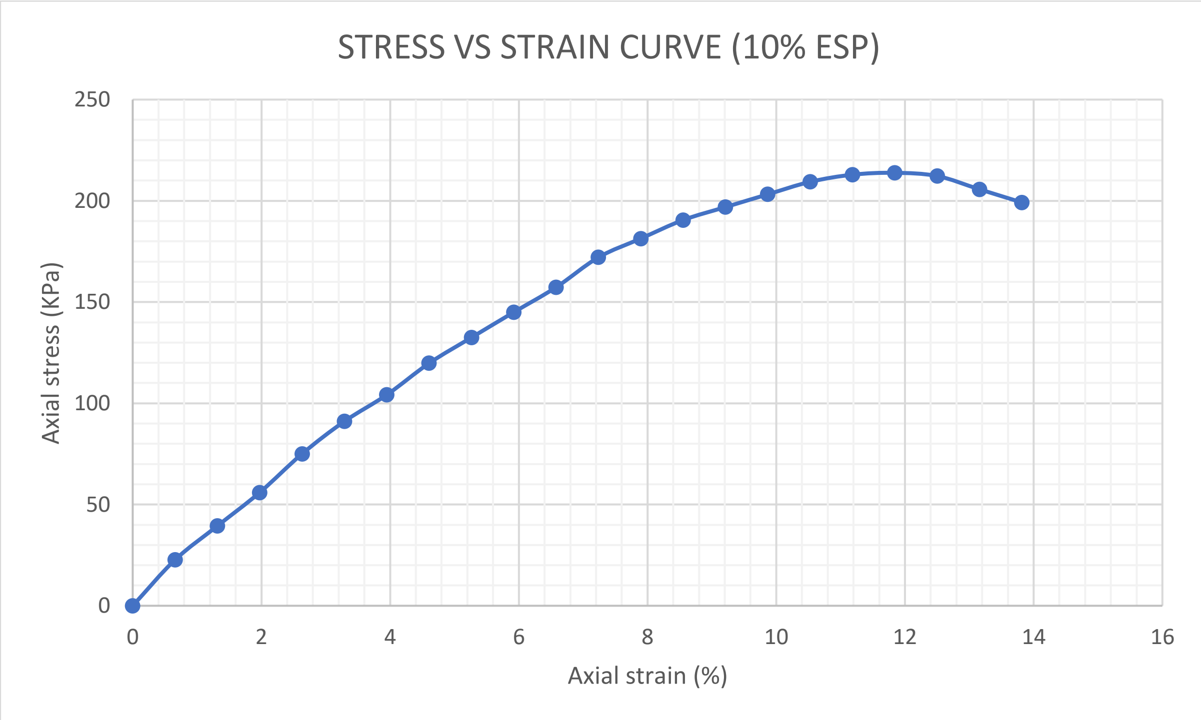

Fig: 5.5 Stress strain curve for soil with 10% ESP

5.8 CBR test for soil with 10% ESP

Table 5.7: values for CBR test

PENETRATION OF PLUNGER (mm)	LOAD (Kg)
0	0
0.5	14.2
1	25.56
1.5	36.92
2	49.7
2.5	59.64
3	69.58
4	80.94
5	88.04
7.5	97.98
10	103.66
12.5	110.76

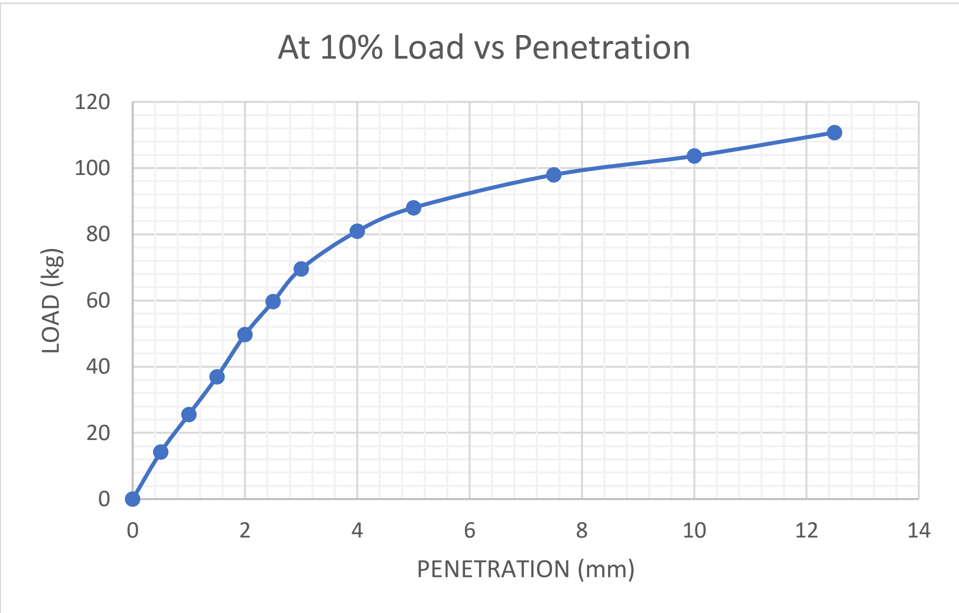

Fig 5.6: CBR graph for soil with 10% ESP

5.9 **Standard Proctor Test** for soil with 15% ESP

Table: 5.8 values for Proctor test with 15% ESP

Mass of compacted soil +mould with base plate (g)	Mass of empty container(g)	Mass of container +wet soil (g)	Mass of containe r + dry soil (g)	Bulk Density (g/cc)	Water content (%)	Dry Densit y (g/cc)
5946	9.01	23.43	21.44	1.75	16.01	1.51
6098	8.52	24.56	21.97	1.90	19.26	1.59
6158	10.02	28.03	24.70	1.96	22.68	1.60
6132	8.65	27.88	23.96	1.93	25.60	1.54
6122	6.39	26.44	22.01	1.92	28.36	1.50

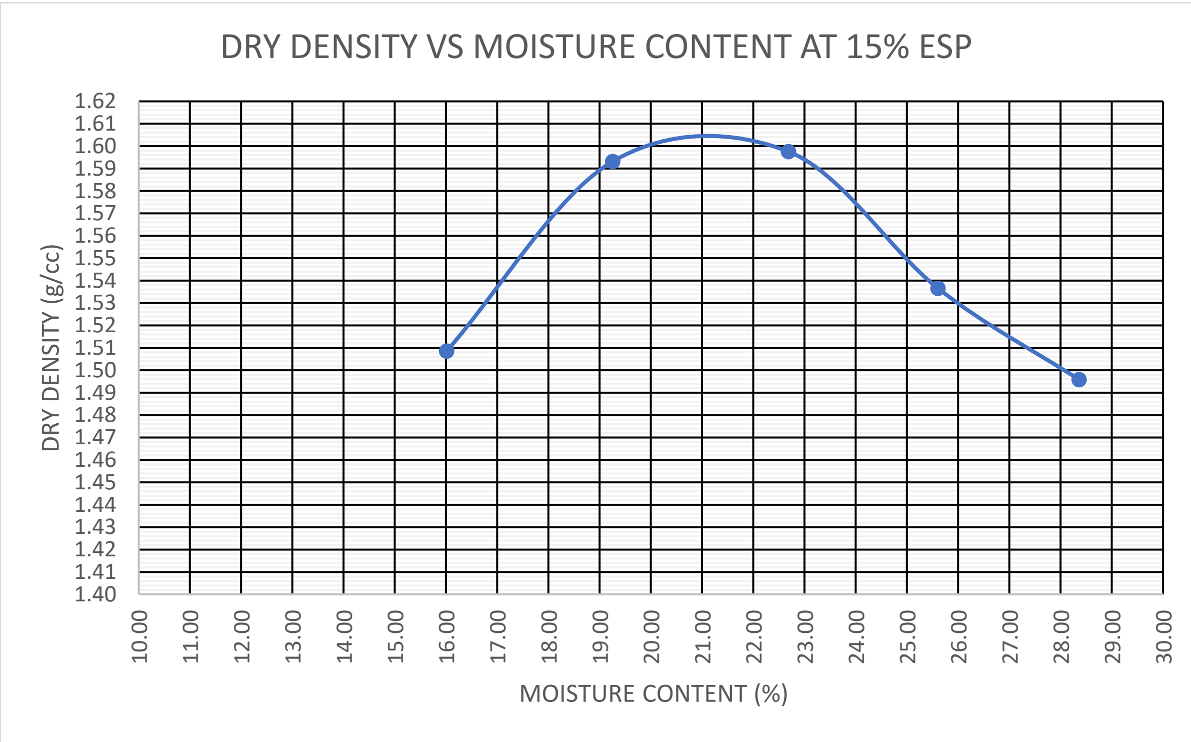

Fig 5.7: dry density vs moisture curve for 15% ESP

5.10 **UCS test** for soil with 15% ESP

Table: 5.9 values for UCS test with 15% ESP

Compression dial reading (Δl) (0.01mm)	Proving Ring Dial Reading (1 div= 0.33kg)	Axial strain €= (Δl/l)	Area A_o / (1-€) cm^2	Axial load (Kg)	Compressive stress (kg/cm^2)	Axial strain %	Compressive stress (Kpa)
0	0	0	0	0	0	0	0
0.5	9	0.01	11.42	2.97	0.26	0.66	25.51
1	17	0.01	11.49	5.61	0.49	1.32	47.88
1.5	23	0.02	11.57	7.59	0.66	1.97	64.34
2	29	0.03	11.65	9.57	0.82	2.63	80.58
2.5	35	0.03	11.73	11.55	0.99	3.29	96.60
3	42	0.04	11.81	13.86	1.17	3.95	115.13
3.5	48	0.05	11.89	15.84	1.33	4.61	130.67
4	53	0.05	11.97	17.49	1.46	5.26	143.29
4.5	58	0.06	12.05	19.14	1.59	5.92	155.72
5	62	0.07	12.14	20.46	1.69	6.58	165.29
5.5	67	0.07	12.22	22.11	1.81	7.24	177.37
6	69	0.08	12.31	22.77	1.85	7.89	181.36
6.5	71	0.09	12.40	23.43	1.89	8.55	185.29
7	72	0.09	12.49	23.76	1.90	9.21	186.55
7.5	73	0.10	12.58	24.09	1.91	9.87	187.77
8	72	0.11	12.67	23.76	1.87	10.53	183.84
8.5	72	0.11	12.77	23.76	1.86	11.18	182.49
9	71	0.12	12.86	23.43	1.82	11.84	178.62
9.5	71	0.13	12.96	23.43	1.81	12.50	177.29
10	70	0.13	13.06	23.10	1.77	13.16	173.48

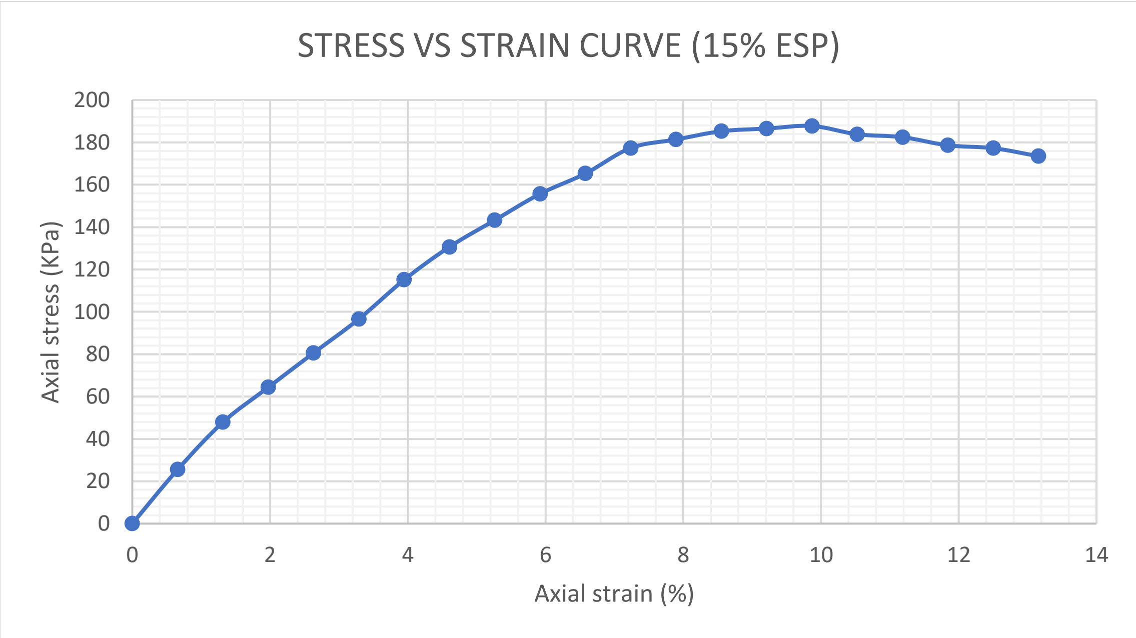

Fig: 5.8 Stress strain curve for soil with 15% ESP

5.11 CBR test for soil with 15% Egg shell powder

Table 5.10 values for CBR test of soil with 15% Egg shell powder

PENETRATION OF PLUNGER (mm)	LOAD (Kg)
0	0
0.5	17.04
1	29.82
1.5	41.18
2	52.54
2.5	62.48
3	69.58
4	82.36
5	90.88
7.5	102.24
10	112.18
12.5	122.12

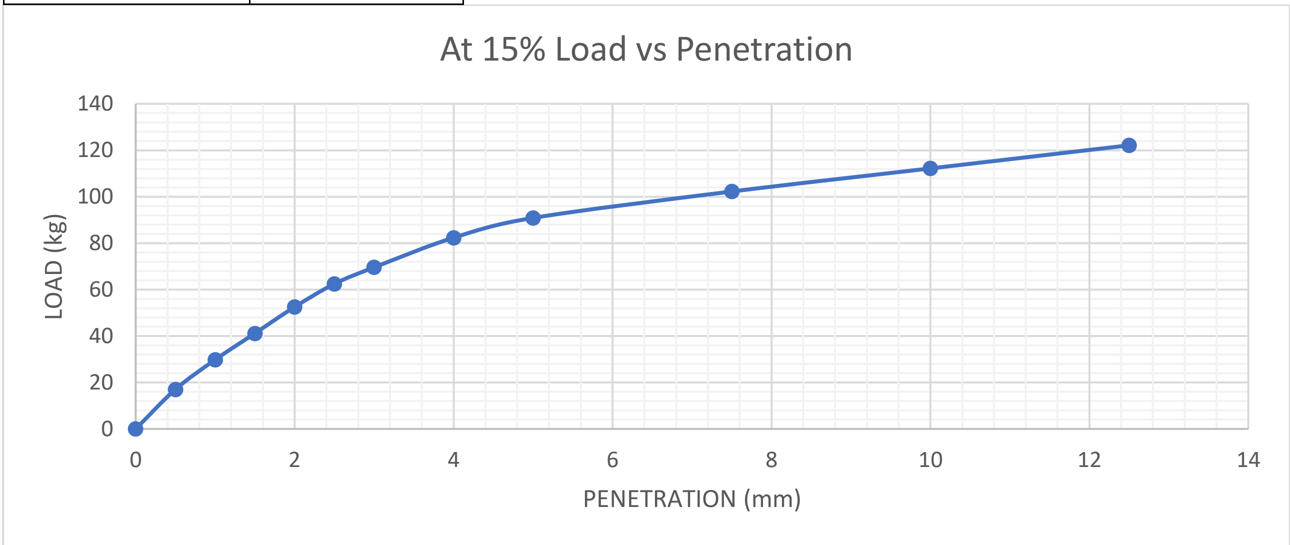

Fig 5.9: CBR graph for soil with 15% Egg shell powder

5.12 **Liquid limit test** for soil with 5% ESP

Table 5.11 values for liquid limit test with 5% ESP

Weight of container and wet soil (W2)gm	Weight of container and dry soil (W3)gm	Weight of moisture W4=(W2-W3)gm	Weight of dry material W5=(W3-W1)gm	Cone Penetration(mm)	Moisture content (W=100*W4/W5)%
20.31	17.41	2.90	7.34	14	39.51
28.17	22.42	5.75	12.40	19	46.37
16.02	13.59	2.43	4.83	21	50.31
25.24	18.68	6.56	11.68	24	56.16

Liquid Limit = 48.08%

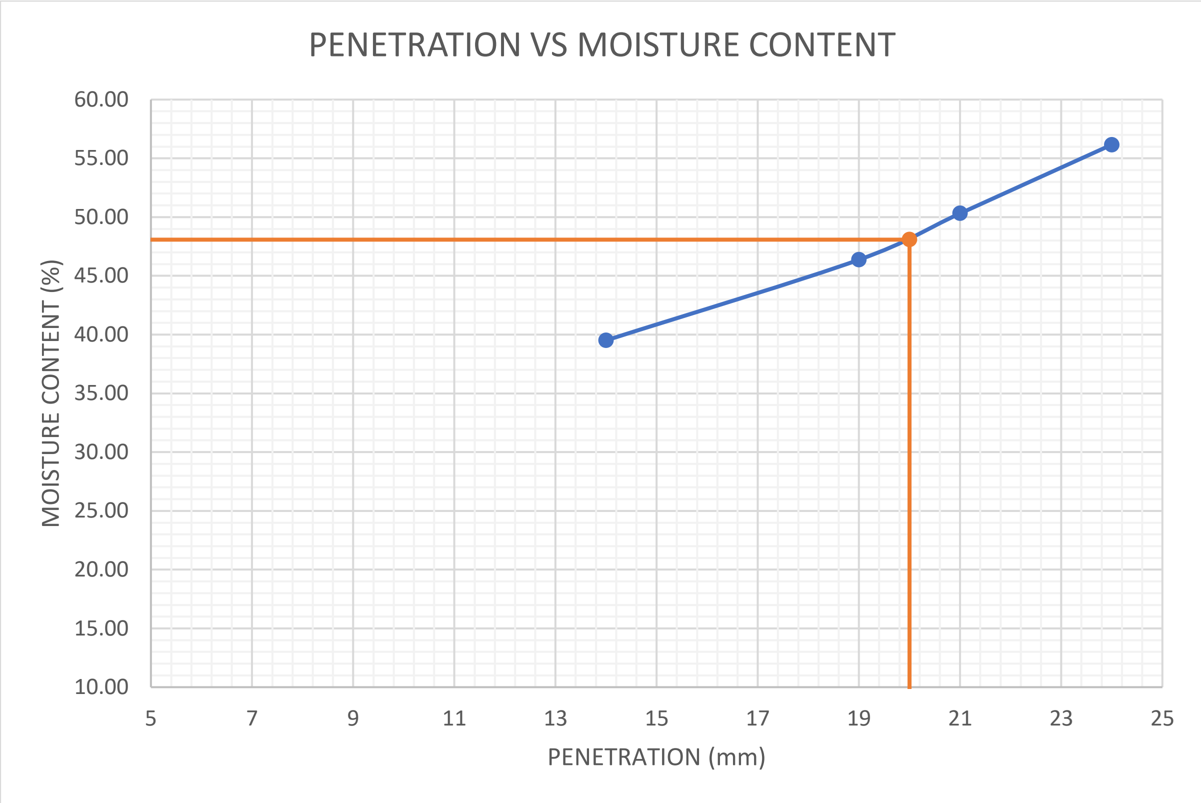

Fig 5.10 Moisture content vs penetration curve for 5% ESP

5.13 Plastic Limit Test for soil with 5% ESP

Table: 5.12 values for plastic limit method with 5% Egg shell powder in soil sample

Empty weight of container (w0) g	Weight of container and wet soil (w1)g	Weight of container and oven dried soil(w2)g	Weight of water (w1-w2)g	Weight of oven dried soil (w2-w0)g	Water content (w)= (w1-w2/w2-w0)*100
9.28	10.44	10.19	0.25	0.91	27.47
6.61	8.00	7.71	0.29	1.10	26.36
9.70	12.79	12.16	0.63	2.46	25.61
		PLASTIC LIMIT 26.48			

Plastic Limit of Soil = 26.48

5.14 Liquid limit test for soil with 10% ESP

Table: 5.13 values for liquid limit method with 10% Egg shell powder in soil sample

Weight of container and dry soil (W3)gm	Weight of moisture W4=(W2-W3)gm	Weight of dry material W5=(W3-W1)gm	Cone Penetration(mm)	Moisture content (W=100*W4/W5)%
19.49	4.07	9.61	14	42.35
22.23	6.13	13.37	18	45.85
18.06	4.41	9.06	21	48.68
22.16	7.04	13.13	25	53.62

Liquid Limit = 47.62

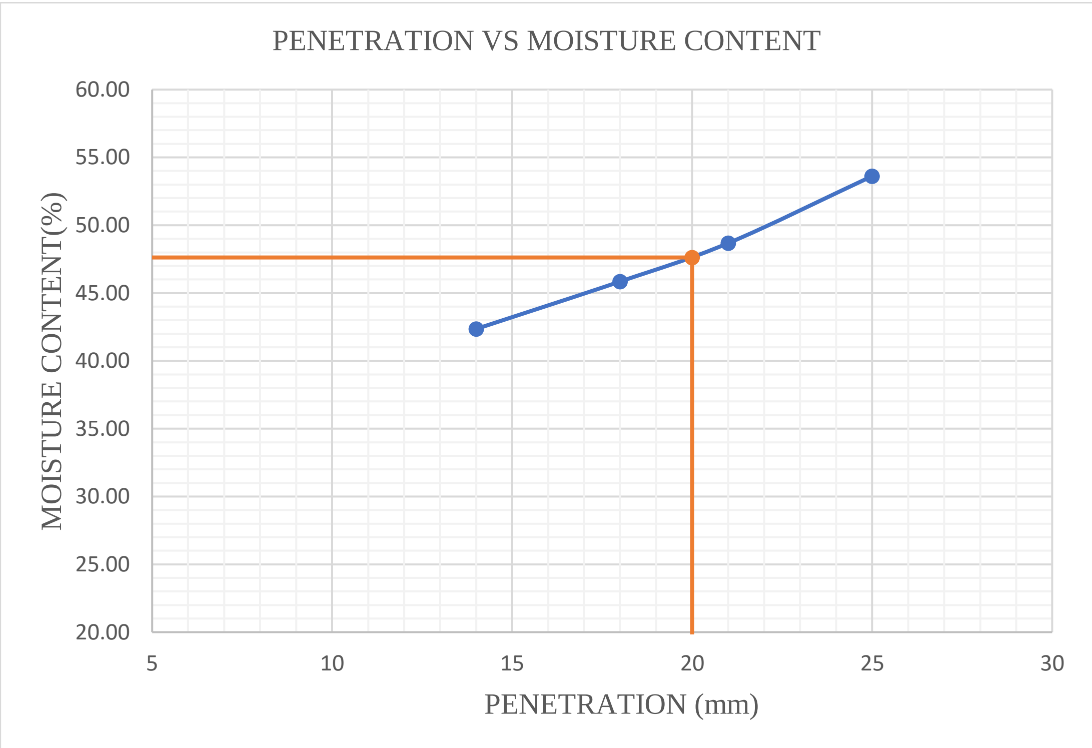

Fig 5.11 Penetration Vs moisture curve for soil with 10% ESP

5.15 **Plastic Limit test** for soil with 10% ESP

Table 5.14 Values for plastic limit method of soil with 10% Egg shell powder

Empty weight of container (w0) g	Weight of container and wet soil (w1)g	Weight of container and oven dried soil(w2)g	Weight of water (w1-w2)g	Weight of oven dried soil (w2-w0)g	Water content (w)= (w1-w2/w2-w0)*100
9.69	12.60	11.99	0.61	2.30	26.52
6.61	10.61	9.77	0.84	3.16	26.58
8.86	11.65	11.06	0.59	2.20	26.82
		PLASTIC LIMIT	26.64		

Plastic Limit for soil with 10% ESP = 26.64

5.16 Liquid limit test for soil with 15% ESP

Table 5.15 values for liquid limit of soil with 15% Egg shell powder in soil sample

Weight of container and dry soil (W3)gm	Weight of moisture W4=(W2-W3)gm	Weight of dry material W5=(W3-W1)gm	Cone Penetration(mm)	Moisture content (W=100*W4/W5)%
18.31	3.59	8.62	14	41.65
16.24	3.18	7.14	18	44.54

17.65	4.21	8.79	22	47.90
19.44	5.46	10.38	27	52.60

Liquid limit of soil with 15% ESP = 46.51

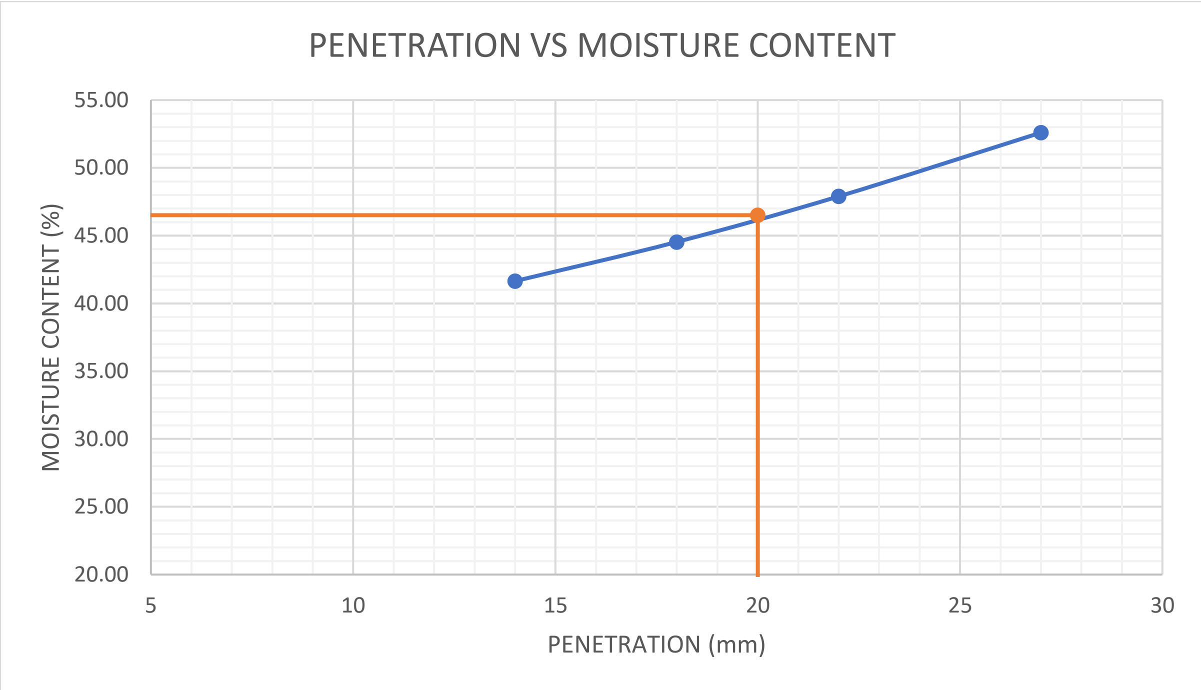

Fig: 5.12 Moisture content vs penetration curve for 15% ESP

5.17 Plastic limit test for soil with 15% Egg shell powder

Table 5.16 values for plastic limit with 15% Egg shell powder in soil sample

Empty weight of container (w0) g	Weight of container and wet soil (w1)g	Weight of container and oven dried soil(w2)g	Weight of water (w1-w2)g	Weight of oven dried soil (w2-w0)g	Water content (w)= (w1-w2/w2-w0)*100
9.01	10.45	10.18	0.27	1.17	23.08
6.60	8.70	8.22	0.48	1.62	29.63

11.43	13.27	12.94	0.33	1.51	21.85
plastic limit		24.85			

5.18 Specific Gravity of Egg shell powder

Table 5.17 values for specific gravity of Egg shell powder

Density bottle no.	Weight of empty density bottle (w1)g	Weight of density bottle+ ESP and soil(w2)g	Weight of density bottle+ ESP, soil and distilled water(w3)g	Weight of density bottle, and distilled water(w4)g	Specific Gravity(G)
1	35.32	45.36	93.29	88.89	1.77
2	24.28	34.53	78.49	74.14	1.73
3	27.14	37.31	80.98	77.45	1.53
	SPECIFIC GRAVITY	1.67			

5.19 Specific Gravity of soil with 5% Egg shell powder

Table 5.18 values for Specific Gravity of soil with 5% Egg shell powder

Density bottle no.	Weight of empty density bottle (w1)g	Weight of density bottle+ ESP and soil(w2)g	Weight of density bottle+ ESP, soil and distilled water(w3) g	Weight of density bottle, and distilled water(w4)g	Specific Gravity(G)
1	23.34	34.81	79.72	73.35	2.24

2	37.58	49.14	97.43	90.63	2.43
3	20.29	31.85	75.82	69.56	2.18
		SPECIFIC GRAVITY	2.28		

5.20 Specific Gravity of soil with 10% Egg shell powder

Table 5.19 values for Specific Gravity of soil with 10% Egg shell powder

Density bottle no.	Weight of empty density bottle (w1)g	Weight of density bottle+ ESP and soil(w2)g	Weight of density bottle+ ESP, soil and distilled water(w3)g	Weight of density bottle, and distilled water(w4)g	Specific Gravity(G)
1	37.11	47.75	96.59	90.66	2.25
2	35.77	45.68	93.92	88.82	2.05
3	31.83	42.33	88.48	83.08	2.05
			SPECIFIC GRAVITY		2.11

5.21 Specific Gravity of soil with 15% Egg shell powder

Table 5.20 values for specific gravity of soil with 15% Egg shell powder

Density bottle no.	Weight of empty density bottle (w1)g	Weight of density bottle+ ESP and soil(w2)g	Weight of density bottle+ ESP, soil and distilled water(w3)g	Weight of density bottle, and distilled water(w4)g	Specific Gravity(G)
1	23.01	33.87	78.22	73.16	1.87
2	26.11	37.17	80.80	75.97	1.77
3	23.95	32.85	77.72	72.47	2.43
		SPECIFIC GRAVITY		2.02	

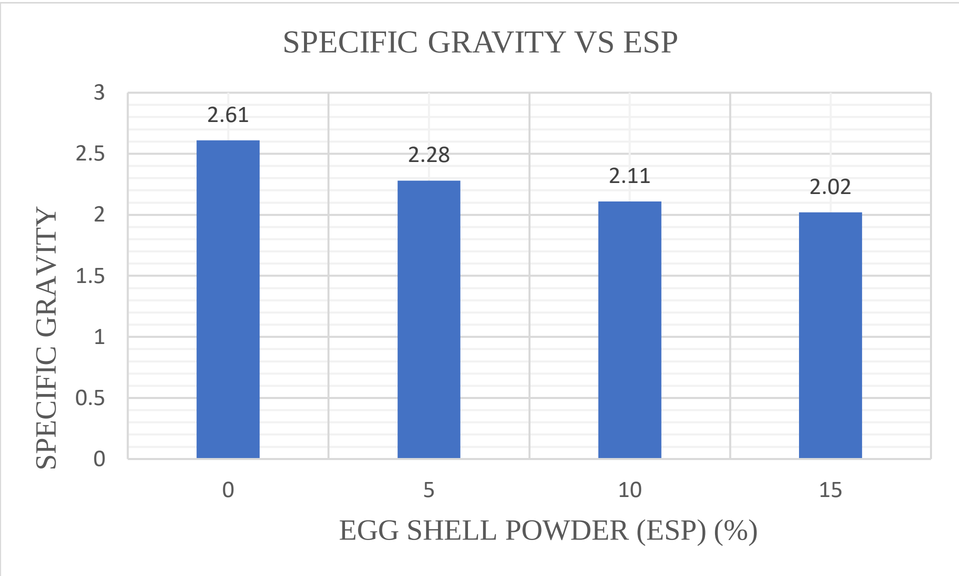

Fig 5.13: variation of specific gravity of CH soil with addition of ESP

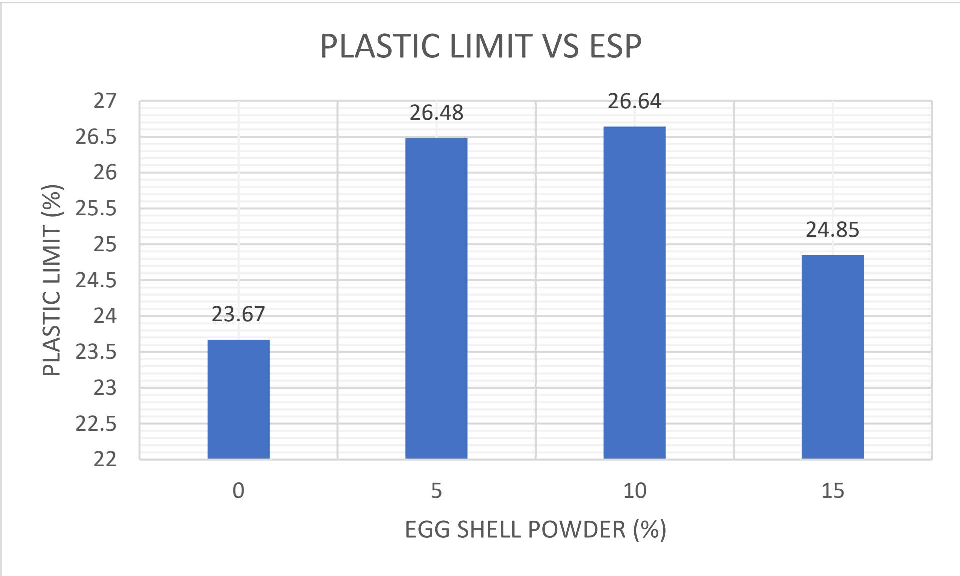

Fig 5.14: Variation of plastic limit of soil after addition of ESP

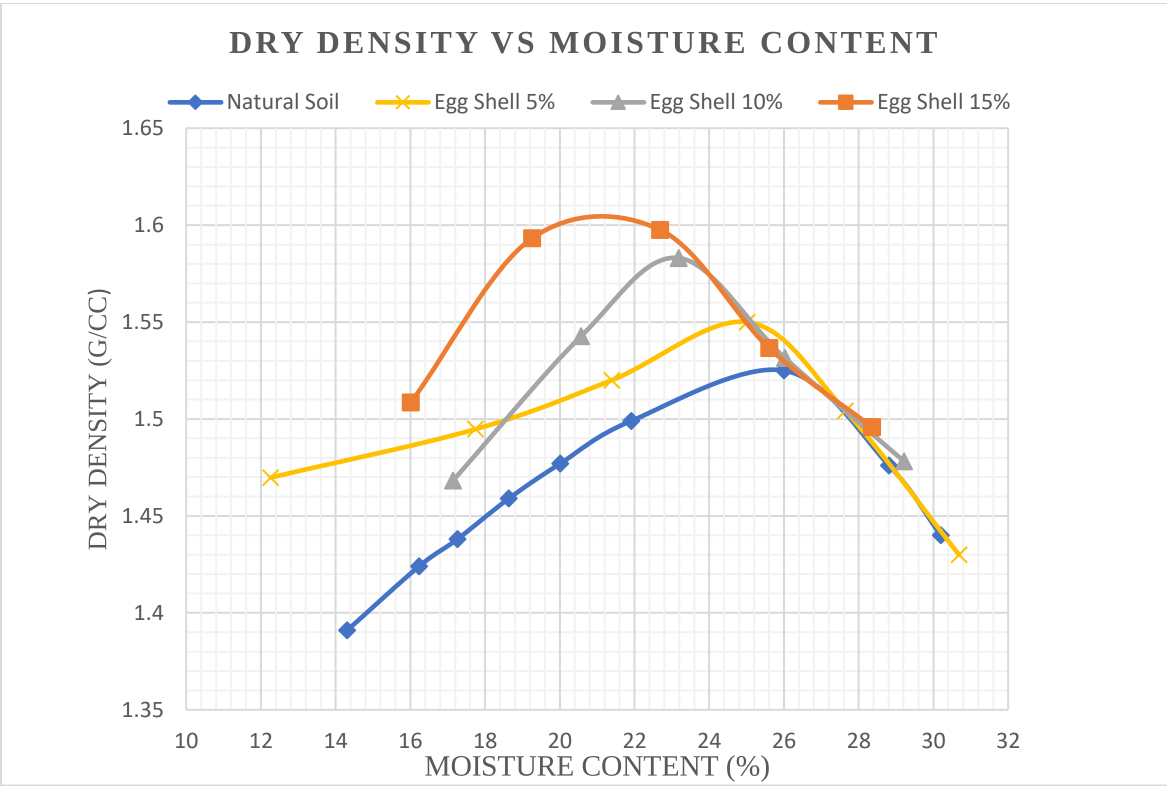

Fig 5.15: Combined curve showing variation in Dry density vs Moisture content

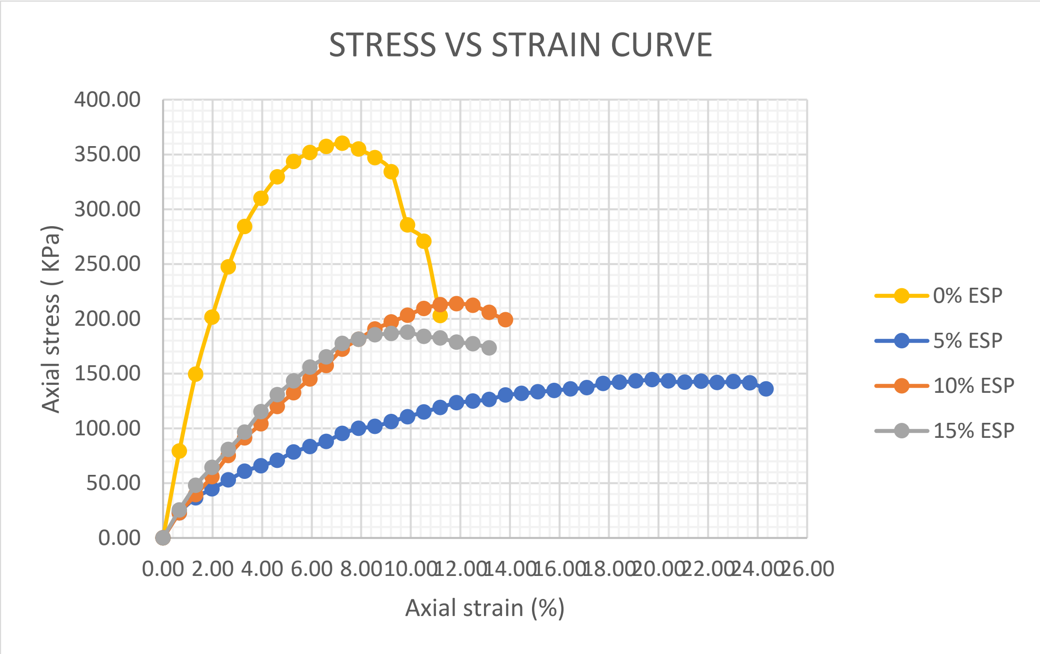

Fig 5.16: Combined graphs showing variation of UCS value for varying percentage of ESP.

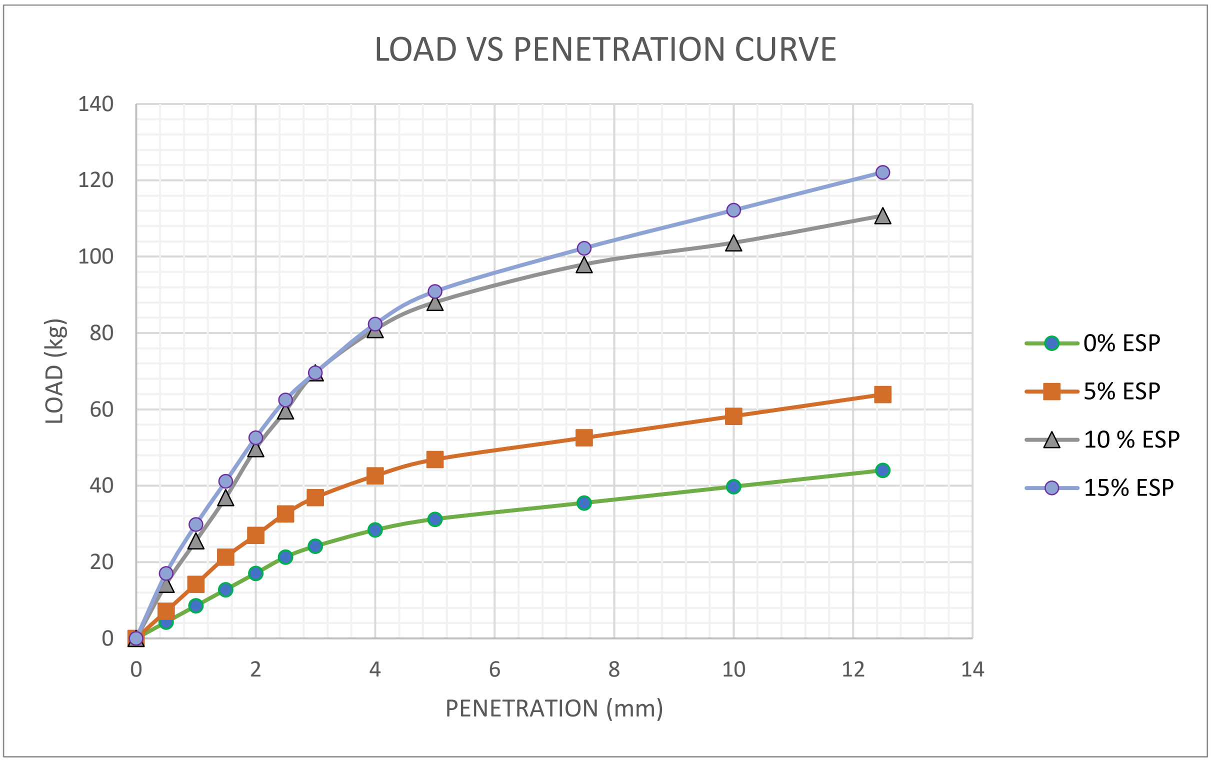

Fig 5.17: Combined graphs showing variation of CBR value for varying percentage of Egg shell powder in soil sample .

CHAPTER -6
CONCLUSIONS

- The soil sample collected is found to be clay with high plasticity .
- With the addition of the Egg shell Powder at (5%,10%, 15%) the specific gravity of the soil decreases.
- Addition of ESP shows considerable decrease in Liquid limit , while there is an increase of plastic limit with increase of egg shell powder .
- The maximum dry density of the soil increases with increase in ESP corresponding to it the optimum moisture content decreases.

CHAPTER -7

SCOPE FOR FUTURE STUDY

- A comparative study between egg shell powder and cement can be conducted when cement as an additive is also added at varying percentages to the dry weight of the respective clay soil sample .
- A comparative study can be conducted between marble dust and Egg shell when added to the CH soil at varying percentages.
- A detailed study can be conducted by adding egg shell powder to the soil particles by keeping the admixture mixed with soil for curing for different number of days and the variation in test results can be evaluated.

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