

SOIL STABILIZATION USING PLASTIC WASTE AND FLY ASH

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering in
Civil Engineering
By

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**DEPARTMENT OF CIVIL ENGINEERING
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Nirmalya Das** (Reg no. 39200028) and **Nikhil Kumar Singh** (Reg no. 39200027) who carried out the project entitled "**Soil Stabilization Using Plastic Waste And Fly-Ash**" under my / our supervision from June 2022 – April 2023

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DECLARATION

We **NIRMALYA DAS (39200028)** and **NIKHIL KUMAR SINGH (39200027)** hereby declare that the Project Report entitled “**Soil Stabilization using Plastic Waste and Fly Ash**” done under the guidance of **Dr. S Packialakshmi** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Civil Engineering.

DATE : 13.04.2023

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1.



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ABSTRACT

The structure's stress should be borne by the soil bed. However, weak soil is unable to bear heavy loads, and thus requires reinforcement and stabilization. Improved soil quality generally enhances the soil's capacity to distribute the weight over a larger area. Soil stabilization aims to improve soil engineering properties by modifying soil characteristics through proportioning or admixtures. Various techniques, including mechanical or chemical stabilization, can be used for soil stabilization. One economical approach is to use plastic waste and fly ash to stabilize the soil. The benefits of using fly ash include their low cost, local availability, and its engineering properties. A study was conducted to examine the soil's strength by adding randomly distributed fly ash and plastic waste with different percentages of reinforcement (ranging from 25 to 35% for fly ash and (0.5, 0.7 and 0.9%) for plastic waste by conducting various tests such as compaction, CBR, specific gravity, and UCC. The test results were compared and conclusions were drawn on their usefulness and effectiveness for different geotechnical applications as a cost-effective approach. The samples were prepared at their respective maximum dry density and optimum moisture content. The plastic fiber dimensions used were (12mm length and 8mm width). The soil sample was passed through a 4.75mm BIS sieve. Among the different proportions, the proposed system of adding 30% fly ash and 0.7% plastic waste stabilized the soil sample to the optimum level. The study aimed to enhance soil stability in an eco-friendly way without harming groundwater levels.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Construction of roadways, pavement and foundation on soft and expansive soil can be problematic because these type of soil typically have no shear strength and high compressibility to avoid such problem the soil is stabilized chemically using various types of admixtures or the soil is stabilized mechanically by mixing various types of material in the soil such as rice husk, fly ash , coir fiber .

Adding these constituent materials ultimately includes the various properties of soil such as CBR value, Liquidity Index, Shear strength, unconfined compressive strength and bearing capacity, so that the soil can be used for various construction purposes.

Typically, when building roadways over organic soil subgrades, the most common method involves taking out the organic soil to an adequate depth and substituting it with crushed rock, a process known as "cut and replace." Another option is to apply preloading to enhance the engineering characteristics.

The Earth has been negatively impacted by the excessive use of non-renewable natural resources and the generation of waste from human activities. To attain sustainable development, the construction industry has implemented the usage of by-products or waste as one of its methods.

1.2 Uses of stabilization

The design of pavements is established on the principle that every layer of material in the pavement system will meet the minimum specified structural requirements. Each layer must be able to resist shear and prevent excessive deflections that lead to fatigue. Since soil properties can differ significantly, the construction of structures

relies heavily on the soil's bearing capacity. Improving the load-bearing capacity of the soil can be achieved through soil stabilization.

Stabilizing the soil results in increasing the mechanical strength of various soil properties. Enhancing the bearing capacity of soil is a more cost-effective and energy-efficient approach compared to opting for deep foundation or raft foundation. This method can also offer additional stability to the soil in areas such as slopes or other similar terrains.

Stabilized soil can help prevent the leaching of harmful chemicals and pollutants into the surrounding environment, minimizing the risk of contamination.

1.3 Selection of Additives

When choosing a stabilizer, there are several factors that must be taken into consideration, such as:

1. The type of soil which we need to stabilize.
2. Durability of stabilized layer.
3. Environmental impact of the additive.
4. The cost of stabilizing agent is also an important factor.
5. The method which will be used to apply the stabilizer.
6. The cost of stabilizing material.

1.4 Objective

- To study and interpret the importance of soil compacting and strengthening concept in construction engineering.

- To study the effectiveness of selected materials (fly ash, plastic waste) for improving the characteristics property of the soil.
- To determine the characteristics properties of soil by adding different proportions (i.e., plastics waste and fly-ash) respectively.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a detailed explanation of previous research on stabilizing soil using different additives. It aims to emphasize the significance of studying this topic and the methodologies employed in conducting such research.

Hussein Jalal Aswad Hassan et al (2020) conducted a study which was carried out to examine how plastic waste affects the geo-technical properties of clayey soil. The soil used in the study was classified as clay soil, and polyethylene terephthalate (PE) and polypropylene were used as fiber stabilizers. To create the plastic fibers, waste plastic bags and bottles were cut into pieces measuring 1-2cm in length and 2.5-3mm in width. The fiber content was added to the soil in amounts ranging from 1% to 4% of the soil's dry weight. The addition of plastic fibers led to a decrease in both the optimum moisture content and maximum dry density, with the greatest decrease occurring at a fiber content of 4%. The unconfined compressive strength (UCS) test showed that the addition of stabilized soil strength increased up to a fiber content of 1%, after which the strength was no different from that of ordinary unconfined soil. The increased percentage of fiber content created more friction between the soil particles and fibers, which caused the medium between the soil and plastic fiber to increase.

Mallikarjuna and Bindumani (2016) conducted a research project was conducted to investigate the use of plastic for soil compaction. Black cotton soil was selected for the study and the plastic strips used were obtained from discarded plastic chairs. The plastic strips had a density of 0.42gm/cc and were added to the black cotton soil in increasing percentages of 2, 4, 6, and 8. Results showed that the CBR (California Bearing Ratio) value increased with the addition of plastic waste, with the highest value observed at 4% plastic content. However, the CBR value decreased after this optimum percentage. Therefore, the study concluded that the most effective amount of waste plastic to use for soil stabilization is 4%. The study also

concluded that the use of waste plastic as a soil stabilizer is an efficient way to make use of the waste plastic and improve the properties of the soil.

Tarun kumar et al (2018) conducted the study involved conducting a series of standard and CBR tests on clayey soil mixed with varying proportions and lengths of plastic strips. The soil was reinforced with low-density polyethylene (LDPE) strips that were obtained from waste plastic, which may have caused other environmental issues. Results indicated that the maximum dry density of the plastic-mixed soil decreased as the amount of LDPE strips increased. The CBR value increased as the percentage of plastic strips increased up to a certain limit, after which it started to decrease. The optimum length of plastic strips to be used was identified as 2cm.

Partha Sarathi et al (2018) experimented the study involved mixing alkali-activated fly ash with expansive soil in varying percentages of 20%, 30%, and 40%. The soil was collected from Nagpur district and classified as black cotton soil. It was air-dried and sieved (4.75mm). The fly ash used was of class F grade. Results showed that the maximum strength was achieved when the activator-alkali ratio ranged between 0.3 and 0.6. The Unconfined Compressive Strength value varied based on the curing period and the concentration of activated alkali. The study concluded that the mixture containing a lower activator-ash ratio exhibited more strength than higher proportions of ash and activator, which is both economical and stronger..

Abdus Salaam Cadersa et al (2014) investigated the use of bottom ash as a mechanical soil stabilizer in subgrade soil. Three samples of subgrade soil and bottom ash were used, with percentages of 15%, 30%, and 40%, respectively. Results from laboratory tests showed that adding bottom ash improved the mechanical properties of the subgrade soil, with the highest CBR value obtained at 30% weight of bottom ash. The addition of bottom ash also considerably reduced the swelling potential of the subgrade soil. Based on these findings, the study concluded that bottom ash can be used as a soil stabilizer to enhance the mechanical stability of soil.

Erdem O. Tastan et al (2011) investigated the stabilization of organic soils with fly ash. Three types of organic soft soils, namely Lawson (low plasticity organic sandy

clay), Markey (silty, sandy peat), and Theresa (moderately plastic organic clay), were used in the study along with six types of fly ash and Type-1 Portland cement as binders. Fly ash mixtures were made at varying percentages of 10%, 20%, and 30% based on dry weight. In addition, soil-cement mixtures were made with 10% cement at very wet conditions. The study revealed that the unconfined compressive strength of soil with organic properties can be improved by the use of fly ash, but the extent of improvement depends on the characteristics of the fly ash and the type of soil.

Anil Kumar Singhai and Sudhanshu Shekhar Singh(2014) demonstrated a laboratory study which was conducted to investigate the use of fly ash and rice husk ash for soil stabilization. Black cotton soil was used for the study, with the aim of improving its performance. Fly ash was added to the soil in varying percentages of 5%, 10%, 15%, 20%, and 25%, and the samples were examined after 28 days of curing. The results showed that the liquid limit was reduced to 55% for the sample with 20% fly ash and 25% rice husk ash, and the plasticity index was reduced to 86% for the same mix. The differential free swell was reduced to 75% for the sample with 15% fly ash and 20% rice husk ash, and the specific gravity content was also reduced.

Shiva Prashanth Kumar and Darga Kumar Nandyala(2019) conducted a study to investigate the effect of randomly mixed coir fibers and fly ash on the stabilization of clayey subgrade. The study involved several tests, including unconfined compressive strength, CBR, standard proctor compaction, and specific tests of the soil. The results showed that as the percentage of fly ash increased from 0 to 30%, the liquid limit of the soil decreased linearly. The plasticity index also decreased with an increase in fly ash percentage, with a lower rate of decrease beyond 20% fly ash. Additionally, the high point of compaction curves decreased as the percentage of fly ash increased. The study suggested that blending 20% fly ash and 1% coir fiber with the clayey soil could result in improved strength and CBR of the clay subgrade.

Robert M. Brooks(2009) performed a study on soil stabilization using fly ash and rice hulk ash, it was observed that an increase in fly ash content from 0% to 25% resulted in a 106% increase in stress and a 50% increase in strain in the unconfined

compressive strength test. The compaction level of soil affects a number of engineering properties, such as compressibility, stiffness, permeability, and CBR value, as well as shrink and swell potential. For the purpose of improving the strength of expansive subgrade soil, a fly-ash content of 25% and an RHA content of 12% are recommended, whereas for reducing swell potential, a fly-ash content of 15% blended with RHA is recommended.

Hamza Gullu (2015) investigated the study which involves the mixing of bottom ash, lime, and superplasticizer with fine-grained soil, specifically low plasticity clay sourced from a nearby thermal power plant. The researchers found that the addition of stabilizers increased the strength of the clay. Furthermore, the combination of bottom ash, superplasticizers, and lime demonstrated a relatively enhanced resistance to disintegration of various specimens under different loading conditions.

Afaf Ghais (2014) formulated a study focused on the use of fly ash for soil stabilization, with varying proportions of 5% to 20% by weight added to the soil. Results showed a 50% reduction in soil plasticity after adding 20% fly ash, while the soil's bearing capacity increased with the addition of 15% fly ash. The researchers discovered that the primary function of fly ash is to fill the air voids between materials, allowing it to act as a binding agent. The optimum moisture content of the soil also increased, leading to the conclusion that the soil is suitable for constructing new pavement structures.

Aditya pandey et al (2018) conducted an investigation where methodology was developed to investigate the stabilization of soil for pavement and foundation by adding fly ash collected from thermal power plants to black cotton soil. The addition of fly ash resulted in a decrease in liquid limit by up to 25%, causing the soil to behave like sand and increase in rigidity. This decrease in liquid limit indicates that fly ash can be used to address issues such as swelling, shrinkage, and uneven settlement. Additionally, the addition of fly ash could lead to a cost reduction of 25% to 35% for pavement and foundation related work. Soft and expansive soils, which typically have no shear strength and high compressibility, can pose challenges in the construction of roadways, pavement, and foundation. To address this problem, soil can be chemically stabilized using different admixtures, or mechanically

stabilized by mixing materials such as rice husk, fly ash, and coir fiber into the soil. By incorporating these materials, the various properties of the soil, such as CBR value, liquidity index, shear strength, unconfined compressive strength, and bearing capacity, are improved to make the soil suitable for various construction purposes.

Lekha et al (2015) conducted an experimental study to examine the effectiveness of Electrolyte Lignin and Fly Ash in stabilizing Black Cotton Soil, with a dynamic load test performed on both treated and untreated soil samples to study their fatigue behavior. Results showed an increase in dry density, UCS value, and CBR value for the treated soil, with significant improvements in the basic geotechnical properties of soil, such as Atterberg limit and compaction characteristics. The addition of fly ash led to a three-fold increase in UCS enhancement compared to normal black cotton soil. Furthermore, the soaked CBR value in the soil mixes was found to improve by 2 to 12 times more than normal soil. These test results suggest that the stabilized soil can be used as a construction material for pavement sections, as it meets the required limits.

Sourav Ghosh et al (2020) designed an experimental study on improving pavement subgrade material by mixing fly ash with lime and gypsum. Two samples were prepared: one consisting of fly ash mixed with locally available soil, and the other consisting solely of locally available soil. The test results showed that the local soil can be replaced with the soil mixed with fly ash, as the latter demonstrated improved characteristic properties. The desired changes were achieved, such as a reduction in the swelling index and an increase in the CBR value.

Salman Asrar and Malik Shoeb (2022) investigated the impact of reinforcement on the strength behavior of fly ash. The researchers concluded that weak subgrade soil could be replaced by fly ash reinforced with reinforcement. They performed an unsoaked CBR test on the fly ash reinforced soil and obtained satisfactory results. The soil sample exhibited good bearing strength characteristics, with the strength of the subgrade soil increasing by 55%-58% after the addition of fly ash. Consequently, the researchers concluded that fly ash could serve as a reinforcing material for the construction of subgrade layers.

Songyu Liu et al (2008) studied the stabilizing expansive soils with fly ash, it was observed that immediate treatment with fly ash did not result in any significant change in the unconfined compressive strength of the soil. However, after a curing period of approximately 7 days, the treated soil exhibited a substantial increase in unconfined compressive strength. The fly ash used was sourced from a thermal power plant and comprised around 70% quick lime. The content of fly ash was incrementally increased from 0% to 15%. It was noted that as the fly ash content increased, the optimum moisture content and maximum dry unit weight decreased. Based on these findings, it was concluded that fly ash can be employed as a soil stabilizer.

Erdem O. et al (2011) studied the effectiveness of fly ash in stabilizing organic soil and the factors that affected the soil stabilization. They figured out that increase in organic content of soil leads to reduction of soil strength exponentially. They used three different samples of organic soil with varying content of organic materials in it. They figured out that increase in unconfined compressive strength depends on the type of soil and characteristic of fly ash. They concluded that fly ash can be used to increase the strength of the soil sample by keeping the various proportions in mind.

Amin esmaeil (2012) conducted a study which aimed at stabilizing soil using inexpensive methods. During the study, they employed various materials including Portland cement, lime, fly ash, and scrap tires for soil stabilization. The purpose of using Portland cement was to transform the soil into a cemented mass, while fly ash was used to enhance the dry density and decrease the optimal moisture content of the soil sample. Subsequently, the individual carried out several tests to analyze the soil's properties, and ultimately determined that this approach was an efficient method for stabilizing the soil while also making productive use of waste tires.

Maha Hatem Nsaif (2013) studied how soil reacted to the inclusion of plastic waste materials. They performed an initial test by adding plastic fibers and observed an increase in shear strength parameters. Both sandy and clayey soil types were

utilized in their experimental work. The individual carried out grain size distribution, specific gravity, and direct shear tests. As anticipated, the angle of internal friction increased significantly, and the desired soil property was achieved.

A. Burman et al (2016) investigated the utilization of plastic waste in soil improvement. They utilized silty soil for the study and conducted several tests, such as the CBR test and direct shear test, on the soil sample to analyze any changes in the soil properties. As a result, they observed an increase in the cohesion and internal friction of the soil. Ultimately, the individual concluded that the impact of plastic addition is contingent upon the number of plastic strips added.

Rowad Esameldin Farah and Zalihe Nalbantoglu (2019) formulated a study evaluated the effectiveness of plastic waste for improving soil performance. Results indicated that mixing sand with plastic chips of waste material increased the shear strength of the sand. The optimum percentage of plastic chips was found to be 0.75%, with the critical internal friction angles and peak values increasing with a rise in plastic chip percentage (up to 0.75%). However, incorporating plastic chips beyond 0.75% decreased the peak internal friction angle, suggesting that the reinforcing effect of plastic waste on the shear strength of sand diminishes. The CBR number exhibited a positive improvement with 0.75% plastic chip reinforcement, with reinforced sand demonstrating greater resistance to penetration. The study recommended using different sizes and percentages of plastic waste to determine whether the 0.75% of small plastic chips of waste material is an optimum percentage for resistance penetration, as it is for shear strength, and only 1% of plastic chips (optimum percentage of shear strength) were used to evaluate the CBR values.

Pooja Lamba et al (2021) conducted a study on the reuse/recycling of plastic waste as construction material for sustainable development. The study found that waste plastic can be utilized in the construction of bricks, blocks, tiles, and concrete for road construction. Additionally, the study explored the use of admixtures of plastic waste and medical plastic waste with waste rubber in construction materials. Various types of plastic waste, including PVC, PET, LDPE, PU, HDPE, HDPE, and nylon 66, can be effectively combined with sand, fly ash, cement, and other

materials to produce bricks, blocks, and tiles. However, PET waste is a preferred replacement material.

Amit Kumar Rai et al (2020) the study analyzed the use of discarded materials such as glass powder, plastic, and e-waste for soil stabilization. These materials contain inert chemical compounds and have a slow rate of degradation, making them non-biodegradable. The researchers found that adding waste glass powder (at 4%, 8%, and 12% by the dry weight of the soil) to loose soil acted as a stabilizer, and the reinforced soil achieved a CBR value of 6% with the addition of 25 mm by 5 mm PET scrap strip reinforcement. Different proportions of the waste materials were blended with the soil, and it was observed that the addition of these materials enhanced various engineering properties of cohesive loose soils up to a certain extent, providing the necessary constructional strength to the soil.

Agus Setyo Muntohar (2013) et al performed a study to investigate the impact of lime and rice husk ash (RHA) on the engineering properties of silty soil when reinforced with waste plastic fibers. Results showed that the addition of RHA and lime improved the tensile and compressive strength of the soil up to four and five times, respectively. Incorporation of plastic waste fibers contributed to a significant increase in the tensile strength and strength ratio of the stabilized soil, as well as an increase in curing age due to the enhancement of compressive strength. The shear strength of the soil increased with the addition of the lime RHA mixture, while the friction angle decreased with the inclusion of fibers. Initially, the cohesion of the fiber-reinforced lime/RHA/soil mixtures increased and then decreased as the fiber content increased, with the maximum value observed at a fiber content of 0.4%. Plastic fibers had a greater impact on the cohesion than the friction angle of the soil when added to the lime/RHA mixture. The CBR value of the soil increased up to 3.6 times by mixing RHA/lime, but the addition of plastic-waste fibers resulted in a considerably greater increase, up to 8.7 times.

Gowtham S et al (2018) investigated the use of glass and plastic waste powder for stabilizing clay soil. The research revealed that the most effective mix for enhancing the geotechnical characteristics of the expansive soil consists of 6% plastic waste and glass powder. The optimal proportion of glass powder and plastic waste

required to achieve the best results in terms of clay soil properties ranges from 4% to 6% of the soil's mass. The expansive soil was subjected to tests for liquid limit, plastic limit, and plasticity index.

2.1 Inference from the literature review:

From the literature study, the various proportion and the optimum percentage of plastic and fly-ash usage was found . In most of the studies the plastic proportion was used in varying percentage of (0.5,0.7,0.9) percentage and fly-ash in (25,30,35) percentage .The basic test to understand the characteristics of materials were identified from the earlier study, the test includes Specific gravity, Optimum moisture content, Unconfined Compressive test(UCC), California Bearing Ration (CBR). After going through all the literature reviews a convenient methodology was derived.

CHAPTER 3

METHOD AND MATERIAL

3.1 Materials Used

3.1.1 Soil

For the experimental purpose, the soil sample was taken from the Thalambur region in Chennai. The soil was left to dry for a period of five days and was subsequently broken down into small, fine pieces. Following this, the soil was passed through an IS 4.5 mm sieve to obtain a consistent texture. Only the soil that passed through the sieve was used for the remaining experiments.



FIG: 3.1: Soil Sample



FIG:3.2: Breaking of soil into fine pieces

3.1.2 Fly Ash

Fly ash is a by-product that is generated during the process of coal combustion, typically in electric power plants. When fly ash is introduced to soil, it has an initial effect like that of Portland cement, causing flocculation and agglomeration of clay particles through ion exchange at the surface of soil particles. This reaction leads to improved workability and an immediate reduction in the soil's tendency to swell, shrink, and become plastic. Class F fly ash was used for the experiment.

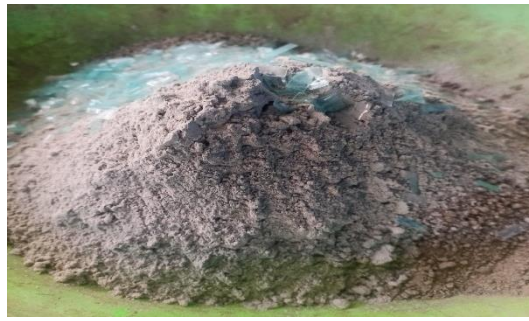


FIG:3.3: Test Sample

Application of Fly Ash

Fly ash is commonly used as a partial replacement for cement in the production of concrete. It improves the workability of concrete, reduces water demand, and enhances long-term strength and durability. Fly ash is used as a soil amendment to improve soil fertility, pH balance, and water retention. Fly ash can be used for mine reclamation and stabilization of mining waste materials. Fly ash has excellent thermal insulation properties due to its low thermal conductivity. It is used as an insulating material in the construction of walls, roofs, and floors. Fly ash has low levels of heavy metals and other toxic compounds, making it a safe material to use in various applications. It also reduces the permeability of concrete, which makes it an effective barrier against corrosive chemicals and gases.

3.1.3 Plastic Waste

Plastic is a significant invention that has greatly impacted various aspects of life, including the scientific field. However, with the increasing use of plastic, it has become a major environmental pollutant due to its "use and throw" mechanism. In the current scenario, it is essential for everyone to think about limiting the use of plastic to prevent severe consequences for both humans and the environment soon. Since plastic is non-degradable, there is a growing need to recycle or reuse it to

reduce its wastage. In this study, polyethylene terephthalate (PE) (water bottles) was used. Plastic fibers were prepared by cutting waste bottles into 12mm length and 4mm width. They were used in varying percentage of 0.5,0.7 and 0.9 percentage. The use of plastic in soil stabilization can make the soil more resistant to water, reducing the likelihood of erosion and improving its ability to retain moisture, use of plastic in soil stabilization is often less expensive than other methods such as chemical stabilization, which can require expensive materials and equipment.



Fig:3.4: Plastic Bottles Cut into Small Pieces

3.2 Application of Soil Stabilization

The process of soil stabilization is useful due to following reasons:

- Decreasing the permeability of foundation soil.
- Increasing the bearing capacity of soil.
- Enhancing the ability to withstand harsh moisture and stress conditions to increase durability.

- Soil stabilization can enhance natural soils to make them suitable for the construction of highways and airfields by controlling soil and aggregate grading. It can also be used in the construction of bases and sub-bases for these projects.

3.3 Reason for Choosing the materials

- The main reason for choosing plastic was to find an effective way to utilize the waste plastic and to minimize the plastic waste disposal. If the usage of plastic gives beneficial result than further study can be carried out to find more efficient method of plastic waste usage.
- Fly ash is used for the experiment because it is a good binding agent. It acts as a binding medium between soil and the plastic waste particles. In some states fly ash is also regarded as a waste material because it is produced in surplus quantity and as byproduct after burning of coal in power plant. The pozzolanic nature of fly ash make it more suitable for usage.
- Both the materials used in the experiment are either produced in surplus quantity or are regarded as waste materials. Hence using these materials will prove beneficial from the economical point of view. When we look upon the other methods of Soil Stabilization, we observe that they are not cost effective therefore from the economical aspect also the materials used in the experiment are beneficial.
- The materials used in this experiment serve two purposes: they improve the mechanical properties of soil, including bearing capacity and compressibility, and they are considered waste materials that can be used in a more cost-effective and environmentally friendly manner. By utilizing these materials, the experiment achieves both objectives and offers a sustainable approach

to soil stabilization that enhances its engineering properties while reducing waste.

3.4 Methodology

Methodology describes the complete procedure from surveying of literatures to comparison of results of conventional soil and stabilized soil. The given figure shows the methodological framework.

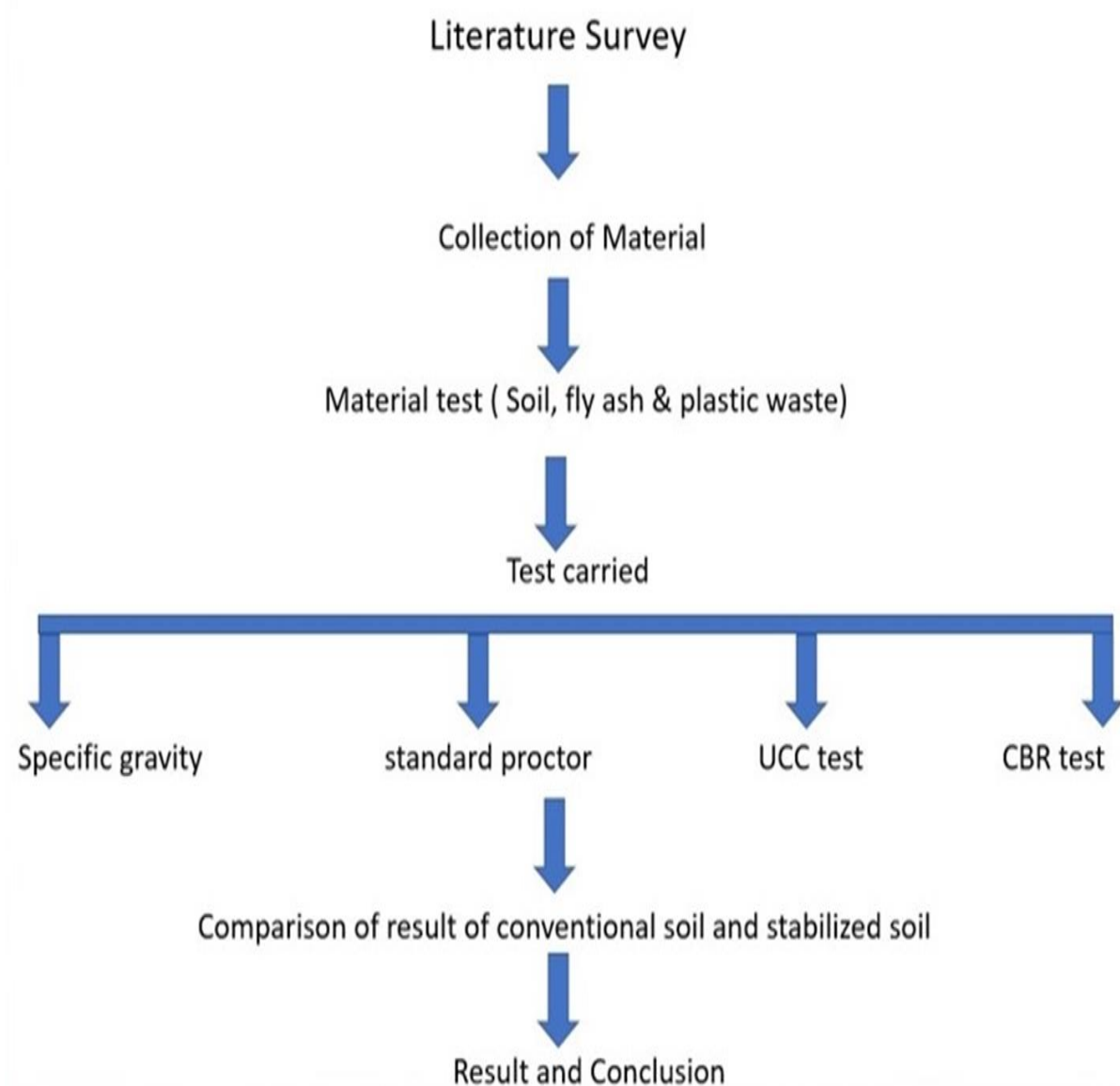


Fig:3.5: Methodological Frame-Work

3.5 Testing procedure for Soil

3.5.1 Specific gravity of soil

Definition

Specific gravity is the ratio of the density of a substance to the density of a reference substance, usually water at a standard temperature and pressure. It is a dimensionless quantity that compares the weight or mass of a given substance to an equal volume of water, which is assigned a specific gravity of 1.

Procedure

- Weigh the empty pycnometer or specific gravity bottle (W1).
- Transfer the soil specimen into the pycnometer or specific gravity bottle and weigh it (W2).
- Add enough distilled water to fill the pycnometer or specific gravity bottle about three-fourths full and weigh it (W3).
- Remove any trapped air by subjecting the contents to a partial vacuum.
- Fill the pycnometer or specific gravity bottle completely with distilled water up to the mark and weigh it (W4).
- Remove all soil particles from the pycnometer or specific gravity bottle and wash it thoroughly with distilled water.



Fig:3.6: Pycnometer with soil

3.5.2 Standard proctor test

Definition

The Standard Proctor Test is a laboratory test used to determine the maximum dry density and optimum moisture content of a soil sample for a given compaction effort. The test involves compacting a soil sample using a standard amount of energy applied through a standard compaction mold with a controlled number of blows from a standard hammer. The results of the test can be used to assess the engineering properties of the soil, including its ability to withstand deformation and support heavy loads, and to design earthworks such as embankments, foundations, and retaining structures.

Procedure

- Prepare four separate mixing pans and label them as 1, 2, 3, and 4. Weigh out 2200 g of soil for each pan and estimate the natural moisture content of the soil.
- Estimate the optimum moisture content for the soil and determine the amounts of water needed to bracket the optimum moisture content. Ensure that there is a spread of two percent in moisture content between the samples.
- Start adding water to sample No. 3 and mix the soil thoroughly. Check if the

moisture content is within the optimum range. If it is below the optimum range, add more water and adjust the water quantity for the remaining samples accordingly.

- If sample No. 3 has excess moisture, consider it as sample No. 4 and reduce the water quantity for the remaining samples.
- Assemble mold with a collar and base plate, along with an insert leucite liner, and place it on the compaction base.
- Fill the mold with the mixed sample in five equal layers and compact each layer with 25 blows from the rammer. Avoid bouncing the weight off the handle and distribute the blows uniformly.
- After compacting, remove the collar and trim the soil even with the top using a straight-edge. Remove the mold and liner, weigh the specimen, and record the weight to the nearest gram.
- Slice the sample vertically and remove 100 g of soil from the central section for moisture content determination.
- Weigh the sample and place it in a tared aluminum can. Oven dry it at 110°C and determine the difference between the wet and dry weights to calculate the moisture content.
- Repeat the entire process for the remaining samples. Figure 3.8 illustrates the compacting of soil and weighing the cylinder with compacted soil.
- Plot a graph with dry density on the y-axis and moisture content on the x-axis. The maximum dry density and optimum moisture content are obtained from the peak of the curve.



Fig:3.7: Compacting soil by giving blows



Fig:3.8: Soil after compaction

3.5.3 UNCONFINED COMPRESSIVE STRENGTH TEST

DEFINITION

The unconfined compressive strength test is a laboratory method used to determine the mechanical strength of cohesive soils. It measures the maximum axial compressive stress that an undrained soil specimen can withstand before failure. The test is performed on a cylindrical soil specimen that is not confined by any external pressure, hence the name "unconfined."

PROCEDURE

- The first step of the procedure is to examine the loading frame, which is the device used to apply the load to the soil sample.

- The person conducting the test needs to learn how to read the load and deformation dial gauges by turning the crank.
- It is important to determine the calibration constant for the proving ring and the units of the deformation dial gauge.
- The calibration constant is used to convert the load indicated on the dial gauge to actual load applied to the soil sample.
- The deformation dial gauge is used to measure the vertical deformation of the soil sample.
- Since the soil samples will be sheared at a strain rate of 1% per minute, it is necessary to determine the deformation at 1% strain from the length of the soil sample.
- Depending on the units of the vertical deformation dial gauge, it is also important to determine the number of dial divisions per 1 strain.
- This information is required to ensure that the soil sample is not sheared faster than the specified rate of 1% per minute.
- To measure the initial height and diameter of the soil sample, calipers are used. It is unlikely that the sample will be a perfect right cylinder, so it is necessary to find the average height and diameter by taking several measurements in different places along the soil sample.
- The measurements should be taken by more than one lab team member to ensure accuracy, and if there are any questions about using calipers, the laboratory instructor should be asked for instruction.
- The weight of the soil sample should be recorded, and the total unit weight

should be determined.

- This information is required to calculate the density of the soil sample.
- Once the soil sample is placed in the loading frame and the proving ring is seated, the dials are zeroed.
- During the lab, the load applied at specified strain values should be recorded.
- It is recommended to take readings at strains of 0, 0.1, 0.2, 0.5, 1, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, and 20 percent.
- The vertical deformation dial readings should also be prerecorded at these strain values.
- With the measured initial height of the sample (H_0), the desired percent of vertical deformation can be calculated.
- This information is useful for determining when to take load readings during the test.
- By following these steps, the unconfined compressive strength of the soil sample can be determined, which is important for the design and analysis of earthworks such as foundations, slopes, and embankments.



Fig:3.9: UCC Machine

3.5.4 CALIFORNIA BEARING RATIO TEST

DEFINITION

The California Bearing Ratio (CBR) is a test method used to evaluate the strength of subgrade and base course materials for flexible pavements. It is a measure of the pressure required to penetrate a soil sample with a standard piston at a standard rate, relative to the pressure required to penetrate. This value is used to determine the load-carrying capacity of the soil and the thickness of the pavement layers needed to support the anticipated traffic loads.

PROCEDURE

- Place the mold assembly, including the surcharge weights, onto the penetration test machine.
- Position the penetration piston at the center of the specimen with the smallest possible load, but no more than 4 kg, ensuring that the piston makes full contact with the sample.
- Adjust the stress and strain dial gauge to read zero. Apply the load on the

piston at a rate of approximately 1.25 mm/min.

- Record the load readings at intervals of 0.5 mm of penetration up to 12.5 mm, and note the maximum load and corresponding penetration if it occurs before 12.5 mm.
- Detach the mold from the loading equipment and collect a soil sample of 20 to 50 g from the top 3 cm layer to determine the moisture content.

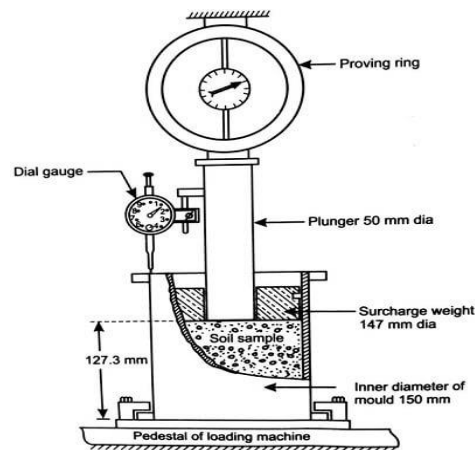


Fig:3.10: CBR Test Apparatus

CHAPTER 4

ANALYSIS AND RESULT

This chapter provides in-depth information about the different parameters discovered during the soil sample testing, as well as the various combinations of fly ash and plastic waste.

Table 4.1 provides information on the values obtained during the soil sample's specific gravity test.

Table 4.1: Specific gravity of soil

S.NO	DESCRIPTION	Trial 1
1	Weight of pycnometer bottle (W_1) g	610
2	Weight of the bottle + soil (W_2) g	1470
3	Weight of the bottle + soil + water (W_3) g	1960
4	Weight of the bottle + water (W_4) g	1466
5	Specific gravity	2.34

$$\begin{aligned}\text{Specific gravity} &= (W_2 - W_1) / ((W_2 - W_1) - (W_3 - W_4)) \\ &= (1470 - 610) / ((1470 - 610) - (1960 - 1466)) \\ &= 2.34\end{aligned}$$

Table 4.2 provides information on the values obtained during the specific gravity test for the soil sample mixed with 30% fly ash and 0.7% plastic waste.

Table 4.2 Specific gravity of Soil + 30% fly ash + 0.7% plastic waste

S.NO	DESCRIPTION	TRAIL 1
1.	Weight of pycnometer bottle (W_1)g	610
2.	Weight of the bottle + soil + fly-ash + plastic waste	1484
3.	Weight of the bottle + soil + fly-ash + plastic waste	1985
4.	Weight of the bottle + water (W_4)g	1466
5.	Specific gravity	2.44

$$\begin{aligned}
 \text{Specific gravity} &= (W_2 - W_1) / (W_2 - W_1) - (W_3 - W_4) \\
 &= (1484 - 610) / (1484 - 610) - (1985 - 1466) \\
 &= 2.44
 \end{aligned}$$

Table 4.3 shows the comparative study of the specific gravity values of soil sample along with various proportions.

Table 4.3: Comparative study of specific gravity values

S.NO	DESCRIPTION	SPECIFIC GRAVITY
1.	Clay	2.34
2.	Clay + fly ash (25 %) + plastic waste (0.5 %)	2.39
3.	Clay + fly ash (30 %) + plastic waste (0.7 %)	2.44
4.	Clay + fly ash (35 %) + plastic waste (0.9 %)	2.41

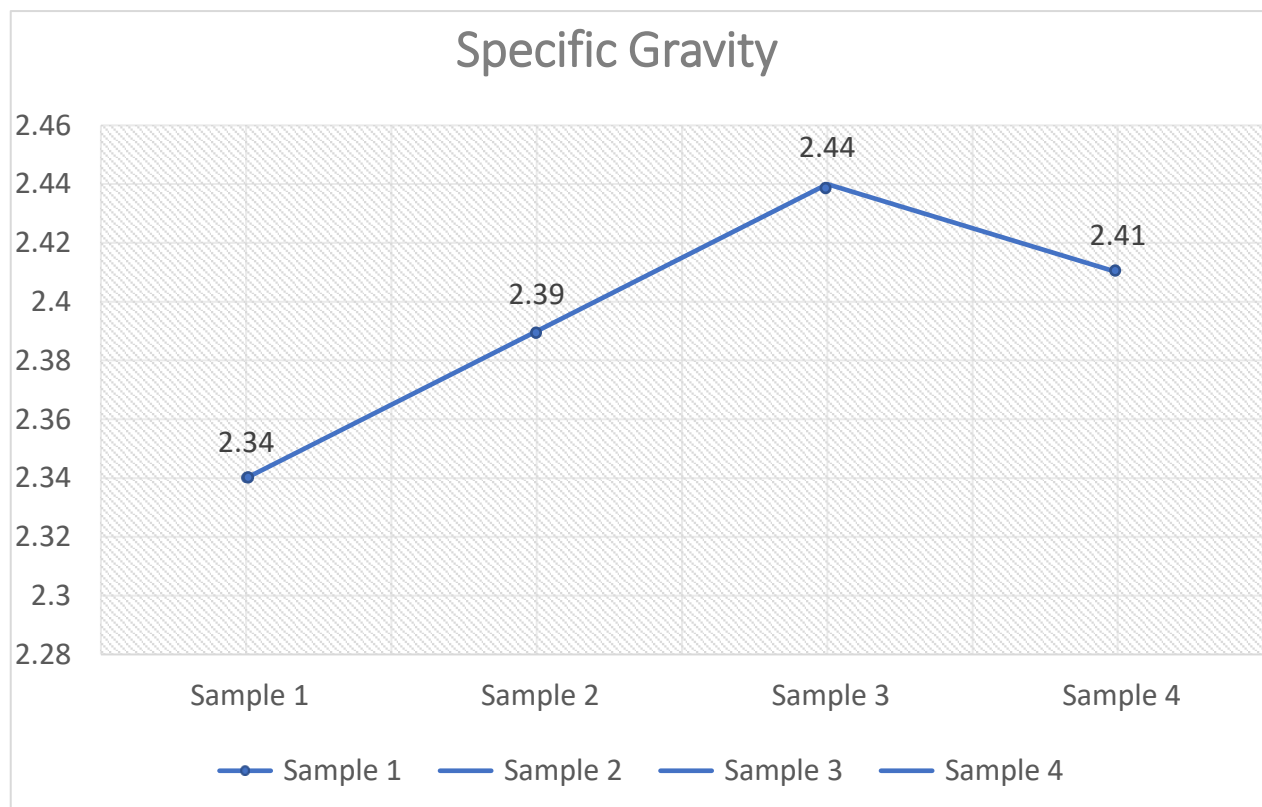


Fig:4.1: Specific Gravity Graph

It can be concluded that higher values of specific gravity gives more strength to road and pavement layers which is in accordance with Surendra Roy (2017) .

Table 4.4 shows the various parameters found out while performing Standard proctor test for the soil

Table 4.4: Standard proctor test for soil.

S.NO	DESCRIPTION	TRIAL 1
1.	Empty Mould wt, Kg (W_1)	2.000
2.	Mould wt + Sample, Kg (W_2)	3.992
3.	Sample wt, Kg ($W_2 - W_1$), W_3	1.992
4.	Mould dia, cm	10.0
5.	Mould length, Cm	12.7
6.	Mould volume, $\text{cm}^3(W_4)$	997.80
7.	Wet density, g/cm^3 (W_3/W_4), W_5	1.996
8.	Wet wt, gram (W_6)	205
9.	Dry Wt, Gram (W_7)	188
10	O.M.C(W_8)= $(W_6 - W_7)/W_7 \times 100$	9.04%
11.	M.D.D $(100 \times W_5)/(100 + W_8)$	1.830 g/cm^3

Table 4.5 shows the various parameters found out while performing Standard proctor test for the soil sample with 30% fly ash and 0.7% plastic waste.

Table 4.5: Standard Proctor Test for Clay+ Fly ash (30%) +Plastic Waste (0.7%)

S.NO	DESCRIPTION	TRIAL 1
1.	Empty Mould wt, Kg (W_1)	2.000
2.	Mould wt + Sample, Kg (W_2)	4.106
3.	Sample wt, Kg ($W_2 - W_1$), W_3	2.106
4.	Mould dia, cm	10.0
5.	Mould length, Cm	12.7
6.	Mould volume, cm^3 (W_4)	997.80
7.	Wet density, gm/cm^3 (W_3/W_4), W_5	2.110
8.	Wet wt, gram (W_6)	205
9.	Dry Wt, Gram (W_7)	182.6
10	O.M.C ($(W_6 - W_7)/W_7 \times 100$) W_8	12.267%
11.	M.D.D ($(100 \times W_5)/(100 + W_8)$) g/cm^3	1.872 g/cm^3

CALCULATION

$$\text{OPTIMUM MOISTURE CONTENT} = (W_6 - W_7)/W_7 \times 100$$

$$= (205 - 182.6) / 182.6$$

$$= 12.267\%$$

$$\text{MAXIMUM DRY DENSITY} = (100 \times W_5)/(100 + W_8)$$

$$= (100 \times 2.110) / (100 + 12.267)$$

$$= 1.872 \text{ g/cm}^3$$

Table 4.6: COMPARITIVE VALUES OF OMC AND MDD

Table 4.6 shows the comparative study of the OMC and MDD values of the soil along with various proportions.

S.NO	DESCRIPTION	OMC (%)	MDD g/cm ³
1.	Clay	9.04	1.830
2.	Clay + fly ash (25 %) + plastic waste (0.5 %)	10.356	1.845
3.	Clay + fly ash (30 %) + plastic waste (0.7 %)	12.267	1.872
4.	Clay + fly ash (35 %) + plastic waste (0.9 %)	11.47	1.748

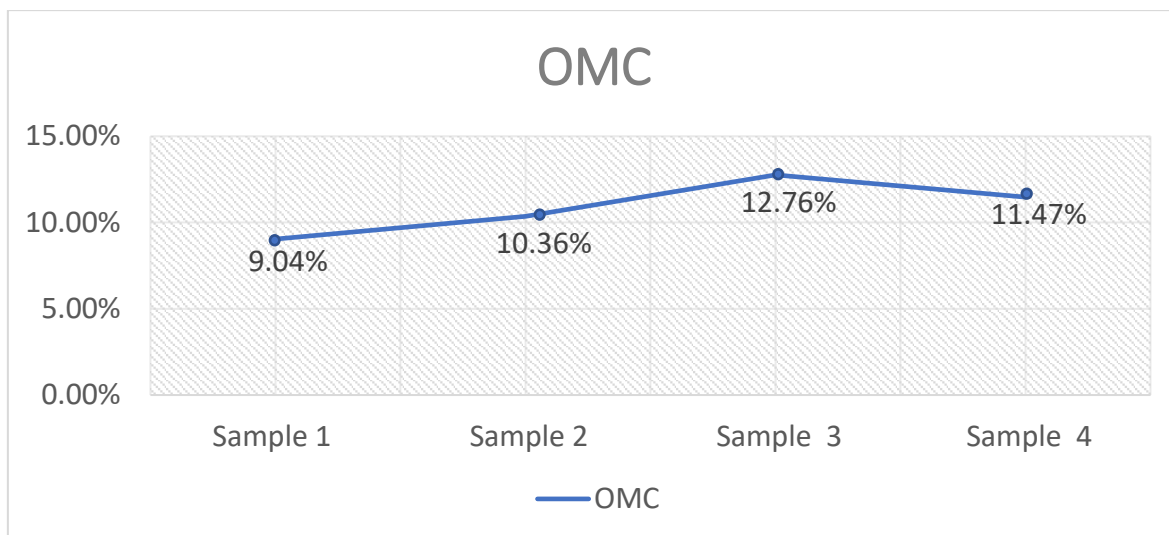


Fig:4.2: OMC Graph

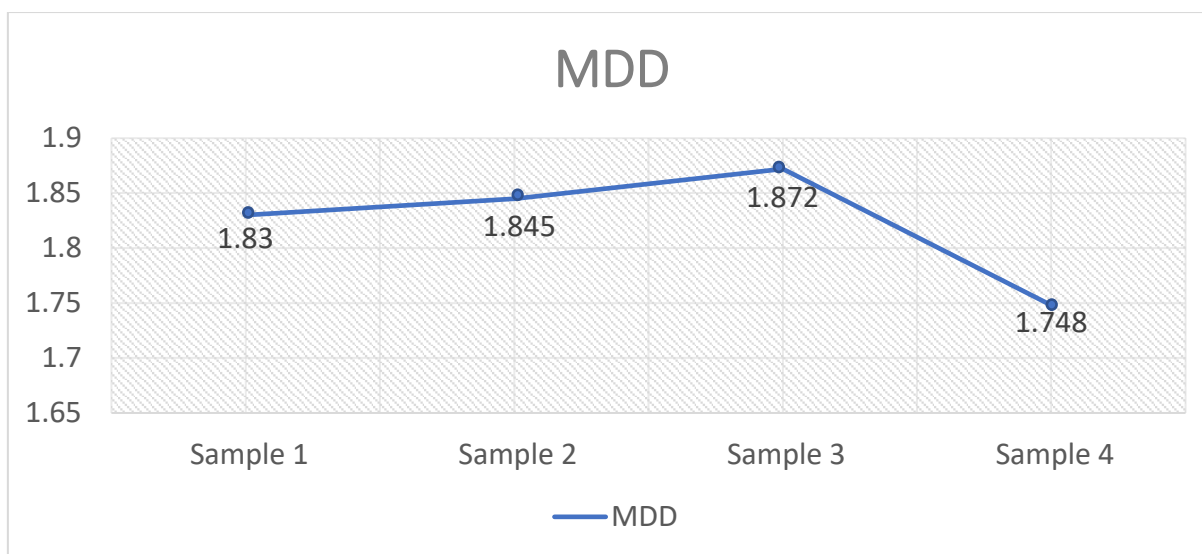


Fig:4.3: MDD Graph

The Standard Proctor compaction test allows us to determine the values of maximum dry density (MDD) and optimum moisture content (OMC). The table presents the maximum dry density (MDD) and optimum moisture content (OMC) values for the soil sample at various proportions. As the percentage of additives increased, the values for optimum moisture content (OMC) and maximum dry density (MDD) also increased. However, failure occurred for the soil sample that contained 35% fly ash and 0.9% plastic waste. The best values for optimum OMC and MDD were obtained for the soil sample with 30% fly ash and 0.7% plastic waste, which are 12.267% and 1.872 g/cm³ respectively. This pattern is similar to that found by Havanagi and Kaniraj (2015).

Table 4.7 gives the information of the values of various parameters found while performing the Unconfined compression strength for the soil sample.

Table 4.7: Unconfined Compression Strength for soil sample

S.NO	ELAPSED TIME (min)	AXIAL STRAIN	C/S AREA (MM ²)	DEFORMATION DIAL GAUGE READING LC =0.01mm	LOADING (kg)	UCC VALUE, Kg/mm ²
1.	0.5	0.0059	1142.78	0.39	3.9	3.4x10 ⁻³
2.	1	0.0103	1148.35	0.71	7.8	6.7x10 ⁻³
3.	1.5	0.0278	1169.73	1.81	10.1	8.6x10 ⁻³
4.	2	0.0346	1178.79	2.29	12.6	10.6x10 ⁻³

5.	2.5	0.0419	1189.77	2.71	15.8	13.2x10 ⁻³
6.	3	0.0613	1213.60	3.99	19.9	16.39x10 ⁻³
7.	3.5	0.0867	1247.68	5.79	17.7	14.18x10 ⁻³
8.	4	0.097	1252.87	6.62	17.61	14.0x10 ³

Diameter of sample =39mm

Height of sample= 67mm

CALCULATION

UCC = load /area

$$= 3.9 / 1142.78$$

$$= 3.4 \times 10^{-3} \text{ kg/mm}^2.$$

Table 4.8 gives the information of the values of various parameters found while performing the Unconfined compression strength for the soil sample with 30% fly ash and 0.7% plastic waste.

Table 4.8: Unconfined Compression Strength for Fly ash

30 % + Plastic waste 0.7% :

S.NO	ELAPSE D TIME (min)	AXIAL STRAIN	C/S AREA(MM ²	DEFORMATIO N DIAL GAUGE READING LC =0.01mm	LOADIN G (kg)	UCC VALUE, Kg/mm ²
1.	0.5	0.0096	1145.12	0.61	2.1	1.83x10 ⁻³
2.	1	0.0134	1149.73	0.86	4.8	4,17x10 ⁻³
3.	1.5	0.0285	1167.63	1.80	7.9	6.76x10 ⁻³
4.	2	0.0319	1172.84	2.07	12.5	10.65x10 ⁻³
5.	2.5	0.0458	1189.76	2.99	15.8	13.27x10 ⁻³

6.	3	0.0587	1205.78	3.83	19.6	16.25x10 ⁻³
7.	3.5	0.0741	1226.13	4.81	20.8	16.96x10 ⁻³
8.	4	0.0818	1235.74	5.31	19.9	16.10x10 ⁻³

UCC = load /area

$$= 2.1 / 1145.12$$

$$= 1.83 \times 10^{-3} \text{ kg/mm}^2$$

Table 4.9 gives the comparative study of the UCC values of the soil along with various proportions.

Table 4.9: UCC Values

S.NO	DESCRIPTION	UCC
1.	Clay	16.39x10 ⁻³ kg/mm ²
2.	Soil + fly ash (25 %) + plastic waste (0.5 %)	16.58x10 ⁻³ kg/mm ²
3.	Soil + fly ash (30 %) + plastic waste (0.7 %)	16.96x10 ⁻³ kg/mm ²
4.	Soil + fly ash (35 %) + plastic waste (0.9 %)	15.26x10 ⁻³ kg/mm ²

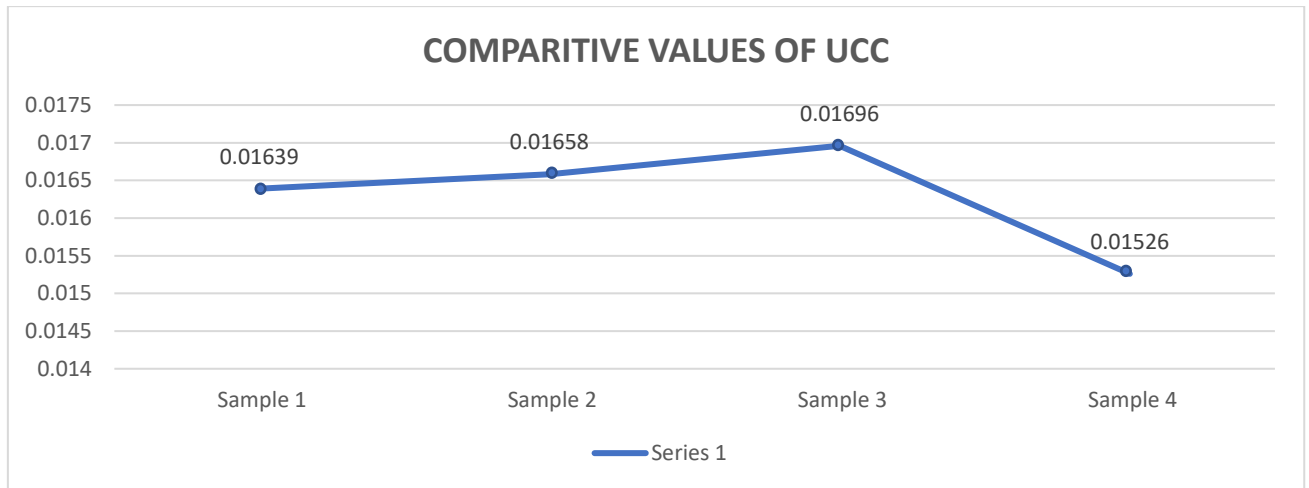


Fig:4.4: Comparative Graph of UCC

The UCC values for the soil sample with different proportions are presented in the table above. Initially, the UCC value for clay was $16.39 \times 10^{-3} \text{ kg/mm}^2$. However, with the introduction of additives, the UCC value for the soil gradually increased. The ideal UCC value was achieved by adding 30% fly ash and 0.7% plastic waste resulting in a UCC value of $16.96 \times 10^{-3} \text{ kg/mm}^2$.

Table 4.10 shows the values of various parameters noted down while performing the CBR test for the soil sample.

Table 4.10: CBR Test for normal soil sample

S.NO	UNSOAKED (%)			SOAKED (%)		
	DEFLECTION	LOAD	CBR(%)	DEFLECTION	LOAD	CBR(%)
1.	0.5	49.97		0.5	28.02	
2.	1	54.86		1	36.43	
3.	1.5	62.02		1.5	39.04	
4.	2	69.89		2	45.88	
5.	2.5	79.21	5.78	2.5	48.52	3.54

6.	3	82.96		3	50.73	
7.	4	93.02		4	57.23	
8.	5	102.02	4.96	5	67.31	3.27

For 2.5mm penetration

$$\begin{aligned}
 \text{CBR} &= (\text{load applied} / \text{standard load}) \times 100 \\
 &= (79.21/1370) \times 100 \\
 &= 5.78
 \end{aligned}$$

For 5mm penetration

$$\begin{aligned}
 \text{CBR} &= (\text{load applied} / \text{standard load}) \times 100 \\
 &= (102.2/2055) \times 100 \\
 &= 4.96
 \end{aligned}$$

Table 4.11 shows the values of various parameters noted down while performing the CBR test for the soil sample with 30% fly ash and 0.7% plastic waste.

Table 4.11: CBR Test for soil +Fly ash (30%) + Plastic waste(0.7%)

S.NO	UNSOAKED(%)			SOAKED(%)		
	DEFLECTION	LOAD	CBR(%)	DEFLECTION	LOAD	CBR(%)
1.	0.5	21.20		0.5	12.43	
2.	1	50.96		1	28.80	

3.	1.5	59.35		1.5	43.98	
4.	2	79.80		2	58.60	
5.	2.5	99.02	7.22	2.5	78.80	5.81
6.	3	105.01		3	88.1	
7.	4	120.98		4	98.7	
8.	5	129.56	6.30	5	105.6	5.13

For 2.5mm penetration

$$\begin{aligned}
 \text{CBR} &= (\text{load applied} / \text{standard load}) \times 100 \\
 &= (99.02/1370) \times 100 \\
 &= 7.22
 \end{aligned}$$

For 5mm penetration

$$\begin{aligned}
 \text{CBR} &= (\text{load applied} / \text{standard load}) \times 100 \\
 &= (129.56/2055) \times 100 \\
 &= 6.30
 \end{aligned}$$

Table 4.12 presents a comparison of the CBR values for the soil sample with different proportions. The CBR values were measured at 2.5mm and 5mm for both soaked and unsoaked samples. The most favorable CBR values were obtained with the addition of 30% fly ash and 0.7% plastic waste. For the unsoaked sample, the optimum CBR values were 7.22% and 6.30%, while for the soaked sample, they were 5.81% and 5.13%. The CBR value tends to increase as the surface becomes harder. High CBR percentage means harder surface which is same as found by Kasia Zamara (2022).

Table 4.12 : CBR Values

S.NO	DESCRIPTION	UNSOAKED		SOAKED	
		2.5mm	5mm	2.5mm	5mm
1.	Clay	5.78	4.96	3.54	3.27
2.	Soil + fly ash (25 %) + plastic waste (0.5 %)	6.89	5.99	5.12	4.85
3.	Soil + fly ash (30 %) + plastic waste (0.7 %)	7.22	6.30	5.81	5.13
4.	Soil + fly ash (35 %) + plastic waste (0.9 %)	6.50	5.89	4.61	4.72

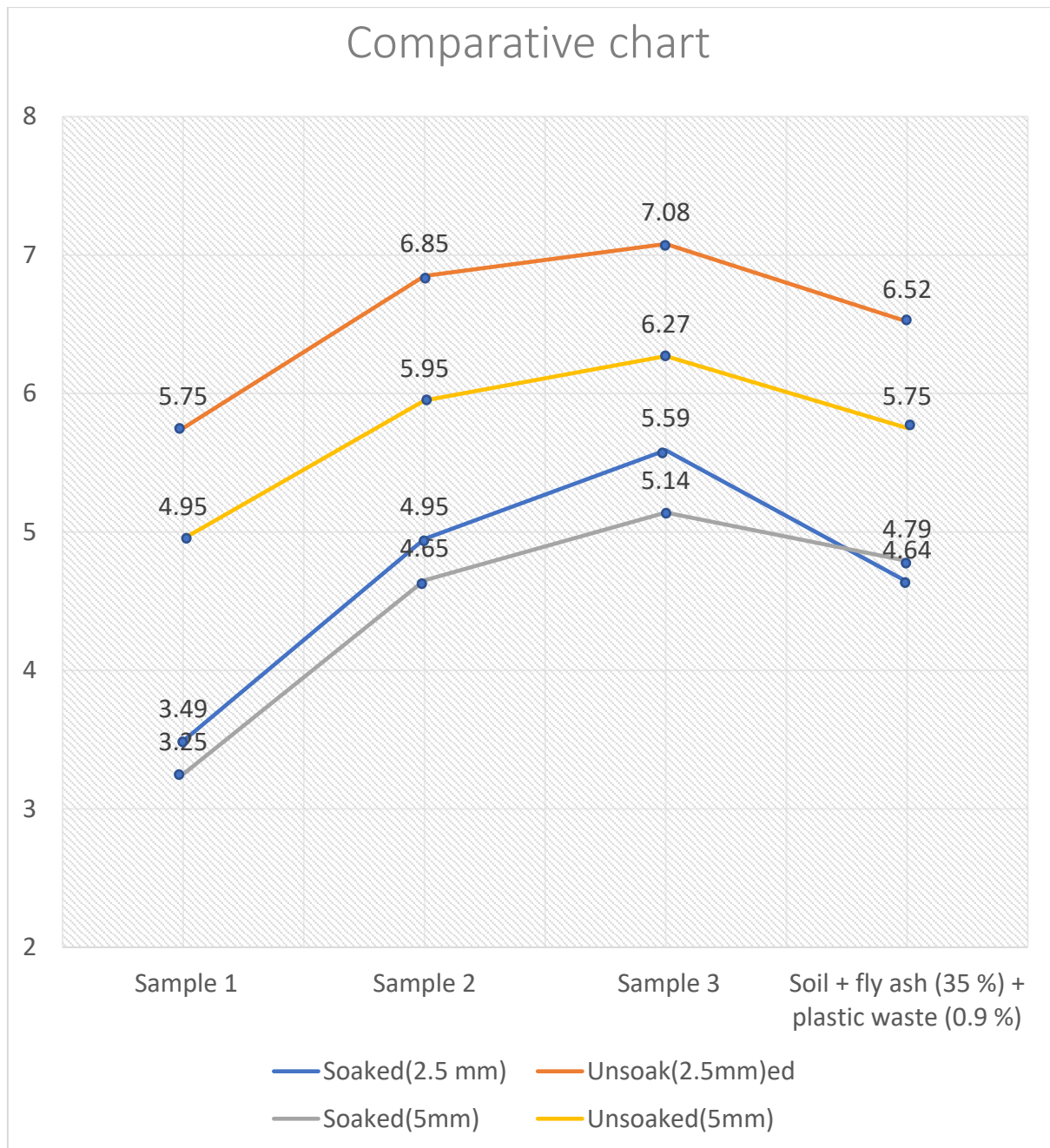


Fig:4.5: Comparative Graph of CBR

Chapter 5

SUMMARY AND CONCLUSION

5.1 Summary

The article below discusses the variations observed in different engineering properties of soil resulting from tests performed on mixes of clay soil, fly ash and plastic waste.

The maximum specific gravity of 2.44 was obtained at a combination of 30% fly ash and 0.7% plastic waste. Specific gravity is an important factor as far as the qualitative behavior of soil is taken account. It can be concluded that higher value of specific gravity gives more strength to road and pavements layer.

When Fly ash and plastic waste are added, both the maximum dry density and the optimum moisture content of the clay increase. The clay soil reaches optimal values of 12.267% and 1.872 gm/cc for optimum moisture content and maximum dry density, respectively, when 30% of fly ash and 0.7% of plastic waste are added. This pattern is similar to that found by Havanagi and Kaniraj and is mainly due to agglomeration and flocculation.

With the addition of crumb rubber and coir fiber, the CBR (California Bearing Ratio) and UCC (Unconfined Compressive Strength) values increase until 30% fly ash and 0.7% plastic waste, respectively, after which they begin to decrease. At this proportion, the UCC value is $16.96 \times 10^{-3} \text{ kg/mm}^2$.

5.2 CONCLUSION

The following conclusions are made while performing the experimental study on soil stabilization using Plastic waste and fly ash.

- In this study, soil stabilization was carried out by adding Plastic Waste and fly ash at different percentages, and the results were compared to those obtained from a normal soil sample.
- The study has demonstrated that the strength of soil increases when 30% fly ash and 0.7% plastic waste are added.

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