ENVIRONMENT FRIENDLY USE OF BAGASSE ASH FOR THE STABILIZATION OF HIGH PLASTIC CLAYS

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CERTIFICATION

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SUSTAINABLE DEVELOPMENT GOALS

SDG NO	DESCRIPTION OF SDG	SDG NO	DESCRIPTION OF SDG
SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	**SDG 11** ✓	**Sustainable Cities and Communities**
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

ABSTRACT

High plastic clays present challenges in geotechnical engineering due to low shear strength and high compressibility in construction of road subgrade. This study investigates the environment-friendly stabilization of high plastic clays using waste agricultural material i.e., bagasse ash which is a byproduct of sugarcane processing. Comprehensive laboratory tests including sieve analysis, Atterberg's limits, modified compaction, free swell, unconfined compressive strength (UCS), and unconsolidated undrained (UU) triaxial strength tests, were performed on non-stabilized and stabilized clay by using 2%, 4%, 6%, 8%, and 10% bagasse ash. Results show that 8% bagasse ash can help to achieve optimum geotechnical properties of stabilized clay i.e., enhancement of UCS and elastic modulus (E) as 59% and 76% respectively whereas swell potential was decreased by 125%. This study demonstrates the effectiveness of using bagasse ash for the sustainable stabilization of high plastic clays. Results of this research can be utilized for the stabilization of road subgrades comprising high plastic swelling clays to limit the settlement of subgrade and decrease in road cracks during heavy traffic volume. This research meets the Sustainable Development Goal (SDG) No. 11 (Sustainable Cities and Communities) as this research contributes to sustainable pavement subgrade construction.

UNDERTAKING

I certify that the project **Environment Friendly Use of Bagasse Ash for the Stabilization of High Plastic Clays** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged.

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ABBREVIATIONS

UCS	Unconfined Compression Test
UU	Unconsolidated Undrained
BA	Bagasse Ash

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CHAPTER 1

1 INTRODUCTION

1.1 GENERAL

Numerous parts of Pakistan include high plastic clays, which are distinguished by high water content and poor shear strength. They are frequently found in places with alluvial deposits and river deltas, such the Indus River Basin, which includes sections of the provinces of Punjab and Sindh. Due to sedimentation processes, coastal regions like the Makran coast and the Indus River Delta also have high flexible clay soils. High flexible clay soils are also frequently found in floodplains along significant rivers and estuaries, notably the delta regions close to Karachi. When loaded, these soils are prone to settlement, needing stabilization techniques. Chemical techniques that make use of materials like lime, cement, or industrial waste items like sugarcane bagasse ash have gained popularity. Bagasse ash combines with free lime in the soil to create stable compounds that increase strength and decrease compressibility. Amorphous silica makes up the majority of bagasse ash, along with other mineral compounds. A viable option for building, bagasse ash provides a long-term and affordable solution for enhancing the engineering qualities of high plastic clay soils.

1.2 PROBLEM STATEMENT

Due to their high compressibility, poor shear strength, and settling issues, high plastic clay soils cause difficulties in building. Environmentally damaging compounds are used in traditional stabilizing techniques, adding to pollution worries. The issue is how to stabilize high plastic clays while preserving the environment and promoting the growth of sustainable infrastructure.

1.3 RESEARCH OBJECTIVES

The objectives of the research are as follows.

1. Evaluation of Unconfined Compressive Strength, Compressive Strength in Triaxial Test, Swell Pressure, and Initial Elastic Modulus of Non-stabilized and Bagasse Ash Stabilized Soil will be used to investigate the efficacy of employing Bagasse Ash to Stabilize High Plastic Clays.
2. Use bagasse ash as an environmentally friendly stabilizer to examine the characteristics of High Plastic clays.

1.4 SCOPE OF RESEARCH

The purpose of this study is to evaluate the viability of using bagasse ash (BA) to stabilize high plastic clays. Through a thorough laboratory testing program, the study focuses on comparing the geotechnical characteristics of the soil before and after stabilization with BA. The goal of the study is to establish the best BA ratio for boosting soil stability and strength. The findings of this study will advance ecologically friendly geotechnical procedures by shedding light on the use of BA as a high plastic clay stabilizing option. The study's focus is only on assessing BA's effectiveness; other potential stabilization strategies are not included. Additionally, the research did not address the stability of High plastic over time.

1.5 THESIS ORGANIZATION

This thesis has been divided into five chapters. Details of each chapter are given below.

Chapter 1: Introduction

The project's scope, methods, and thesis aims are all covered in this chapter's overview. Along with laying out the format and substance of the following chapters, it also presents the thesis organization.

Chapter 2: Literature Review

A thorough analysis of contemporary studies and research on cement-based overlays is presented in this chapter. It provides a strong basis for the project by examining the challenges, successes, and important discoveries in the discipline.

Chapter 3: Methodology

The approach for doing tests and experiments on diverse samples is detailed in this chapter. It describes the steps taken to gather pertinent data and produce reliable results, as well as the tools and methods used.

Chapter 4: Results and Analysis

This chapter includes a thorough compilation of test findings and data, along with perceptive remarks and observations. It provides a thorough analysis of the findings and contains quantitative results in the form of data tables and graphs.

Chapter 5: Conclusion and Recommendations

Drawing on the findings and analysis offered in the earlier chapters, the project's conclusions are summarized in the last chapter. It also provides suggestions based on the findings, emphasizing areas that require additional research and development.

A reference section that lists the sources from which pertinent facts and theories were gathered and evaluated is included at the end of the thesis.

CHAPTER 2

2 LITERATURE REVIEW

By giving a synthesis of the research work on repairs, this chapter presents the main research results on the subject. The list of works presented does not pretend to be exhaustive, but nevertheless, it covers the subject from old works to recent ones.

2.1 GENERAL

We give a broad review of the underlying ideas and historical context for using bagasse ash to stabilize high plastic clays in an environmentally responsible manner in this section. This background information provides context for understanding the particular research emphasis and highlights the significance of looking into sustainable solutions for clay stabilization.

Geotechnical engineering and building projects have a sizable challenge in stabilizing high plastic clays. Due to their high water content, these clays have negative engineering characteristics, including high compressibility, low shear strength, and significant volume variations brought on by moisture fluctuations. These unfavorable characteristics may cause structural instability, settling problems, and potential infrastructure damage.

Traditional methods of stabilization for Cement, lime, or chemical additions have typically been used with high plastic clays. These traditional techniques do a good job of enhancing the clay's engineering qualities, but they frequently have negative environmental effects, such as excessive energy use, greenhouse gas emissions, and resource depletion. As a result, in recent years, there has been an increase in interest in the need for environmentally sustainable solutions.

Utilizing bagasse ash, a byproduct of sugarcane processing, is one such option. Bagasse ash has been investigated for its ability to function as a pozzolanic material in a variety of processes, including the creation of concrete and soil stabilization. Bagasse ash works as a pozzolan when combined with calcium hydroxide in the presence of water, generating cementitious compounds that aid in the growth of strength and improved stability.

There are various benefits to using bagasse ash for clay stabilization. First of all, it offers an environmentally sound and sustainable option by making use of a plentiful agricultural waste product that would otherwise be thrown away. This strategy supports waste reduction and adheres to the sustainability and circular economy tenets. The engineering qualities of High plastic clays, such as greater shear strength, decreased swelling potential, and improved overall stability, could also be enhanced by bagasse ash.

Although previous research has looked at the use of bagasse ash for soil stabilization in general, only a small amount of study has concentrated on its usage for High plastic clays. By assessing the body of information already in existence and studying the efficacy of bagasse ash as a stabilizing agent for High plastic clays, this literature review seeks to fill this research gap. We can get important insights into the potential advantages and restrictions of using bagasse ash for ecologically friendly clay stabilization by examining the key findings and techniques of earlier studies.

We will explore more deeply into particular facets of bagasse ash stabilization in the following sections of this literature review, including its effects on the geotechnical qualities of High plastic clays, ideal proportions and mix designs, curing conditions, and long-term durability. These elements will help us gain a thorough understanding of how bagasse ash is used to stabilize High plastic clays in an eco-friendly manner and will serve as the basis for future study.

Overall, the background information offered in this part highlights the need for environmentally benign clay stabilization options and provides bagasse ash as one such possibility. The effectiveness and possible uses of bagasse ash in this situation will be assessed in more detail in the next sections of the literature review.

Great plastic clays are a particular form of clay soil that exhibits high plasticity and considerable volume changes in response to changes in moisture content. They are also referred to as expansive clays or shrink-swell soils. These clays are distinguished by their capacity for water absorption and retention, which causes great expansion upon wettability and substantial shrinkage with drying. Construction projects including road construction, subterranean infrastructure, and building foundations may suffer as a result of these volumetric changes.

The dominating mineral in these clays, montmorillonite, a form of swelling clay mineral, is principally responsible for their remarkable plasticity. Due to their layered structure and strong cation exchange capacity, montmorillonite clays can absorb water molecules and increase their interlayer gaps. Because of this, the clay particles have the potential to inflate and put a lot of pressure on nearby buildings.

High flexible clays' engineering characteristics present difficult geotechnical engineering problems. These clays experience volume fluctuations in response to variations in moisture content, which cause uneven settlements, foundation movements, and structural cracking. These clays have a high clay content, which raises the possibility of excessive deformation and instability, as shown by their high plasticity index (PI).

High plastic clays' geotechnical qualities are frequently improved using stabilizing procedures to address these issues. Cement, lime, or chemical additives are typically added as part of traditional stabilization techniques to change the characteristics of the clay and improve its engineering behavior. These techniques, nevertheless, frequently raise environmental issues and could not be long-term viable.

In recent years, there has been increased interest in using alternate ingredients, like as bagasse ash, to stabilize High plastic clays. Researchers hope to create environmentally friendly alternatives that can lessen the harmful effects of High plastic clays while reducing the reliance on conventional stabilizers with greater environmental implications by investigating the potential of bagasse ash as a stabilizing agent.

We will go more deeply into the studies on the stabilization of High plastic clays utilizing bagasse ash in the following sections of this literature review. We seek to analyze the effectiveness of bagasse ash as a stabilizing agent and assess its impact on the geotechnical properties of High plastic clays by reviewing the findings of previous studies. This investigation will shed light on the viability and possible advantages of using bagasse ash to address the problems posed by high plasticity clays, opening the way for ecologically friendly and sustainable geotechnical engineering methods.

The section on high plasticity clays emphasizes their special qualities, difficulties, and the demand for efficient stabilizing methods. The use of bagasse ash as a viable remedy for enhancing the geotechnical characteristics of these clays will be further explored in the sections that follow, giving readers a thorough understanding of its application and advantages in the context of stabilizing high plastic clays.

2.2 FACTORS AFFECTING HIGH PLASTIC CLAYS

Numerous elements that have a substantial impact on stability and performance can affect the behavior and technical characteristics of high plastic clays. It is essential to comprehend these aspects in order to stabilize these clays and minimize their detrimental consequences. We examine some of the major elements that High plastic clays are affected by in this section:

Mineralogy and Composition: High plastic clays' engineering qualities are greatly influenced by their mineralogy and composition. High plastic clays frequently contain montmorillonite, a form of swelling clay mineral, at high concentrations. Illite or kaolinite, two other clay minerals in the composition, may also have an impact on how they behave.

Moisture Content: Moisture content plays a crucial role in how High plastic clays change in volume and how they behave as industrial materials. These clays have the capacity to absorb and hold onto water, which causes them to significantly expand when wet and significantly contract when dried. The clay particles may swell or shrink as a result of variations in moisture content, causing volume fluctuations and ensuing structural instability.

Consolidation Stress: Another significant element affecting their behavior is the consolidation stress, also known as the effective stress given to High plastic clays. These clays consolidate when a weight is applied, which reduces their volume by forcing water out of the crevices between the particles. High plastic clays' consolidation rate, compression properties, and settling behavior are all influenced by the consolidation stress.

Potential of Swell: High plastic clays have a tendency to undergo volumetric expansion when exposed to water, which is referred to as their "swell potential." The clay particles absorb water molecules, which causes swelling, which separates the layers and increases the volume. Mineralogy, moisture content, and the presence of certain ions are some of the variables that affect swell potential.

High plastic clays are a complex and difficult material to work with because of how these elements interact and affect the material's overall behavior. Researchers and engineers can create efficient solutions to enhance the engineering qualities and decrease the negative effects of High plastic clays by taking these elements into consideration when designing stabilizing techniques.

2.3 OCCURRENCE OF HIGH PLASTIC CLAYS IN PAKISTAN

High plastic clays are very common throughout Pakistan, especially in coastal and riverine locations. High plastic clay is frequently found in substantial amounts in river deltas, estuaries, and floodplains. Additionally, several regions of the provinces of Punjab, Sindh, and Balochistan are known for having sizeable areas of High plastic clay soils. High flexible clays present geotechnical difficulties for construction projects, including the foundations of roads and buildings, in these areas.

High plastic clay presented difficulties for a number of significant Pakistani construction projects:

- Lahore Ring Road, Lahore: High polymeric clay layers made building of the Lahore Ring Road difficult. In order to lessen the effects of the High plastic clay, settlements and deformations along the road required additional measures, such as soil stabilization procedures.
- Islamabad International Airport, Islamabad: High plastic clay layers were found during the construction of Islamabad International Airport, which caused settling problems. To stabilize the soil and guarantee the structural integrity of the airport, numerous ground improvement techniques were used, such as the use of stone columns and surcharge loading.
- Aga Khan University Hospital, Karachi: Due to the High plastic clays' presence, the hospital's foundation in Karachi had settlement issues. To reduce settlement and assure the stability of the building, specialized foundation design and construction techniques were used.

These illustrations emphasize the need of solving the geotechnical issues High Plastic Clays provide in construction projects. Engineers can successfully reduce the negative effects of High Plastic Clays and assure the long-term stability and performance of structures by employing appropriate soil stabilizing procedures and adopting specialized foundation designs.

2.4 PROPERTIES OF HIGH PLASTIC SOILS

High plastic soils have distinctive characteristics that add to their peculiar behavior and engineering difficulties. For high plastic soils to be effectively stabilized and their negative impacts to be reduced, it is essential to comprehend their qualities. We examine some of the essential characteristics of high plastic soils in this section.

- Plasticity Index (PI): High plastic soils have a high PI, indicating a broad range of moisture content which can result in considerable volume fluctuations.

- Swelling Potential: When exposed to water, high plastic soils frequently experience volumetric expansion that results in swelling. This characteristic is impacted by the soil's composition, which contains minerals that cause swelling in the clay, including montmorillonite.

- Liquid Limit (LL) and Plastic Limit (PL): The plastic limit denotes the moisture content below which soil can no longer be deformed, whereas the liquid limit describes the moisture content at which a soil changes from a liquid to a plastic condition. The plasticity index (PI), which measures the difference between the liquid limit and plastic limit, is used to describe the soil's plastic behavior.

- Consolidation Characteristics: High plastic soils may consolidate significantly when loads are applied. Consolidation is the process of squeezing water out of the gaps between soil particles, which leads to a decrease in volume. Structures' settling and structural stability may be impacted by the consolidation behavior of high plasticity soils.

- Shear Strength: In stability assessments, the shear strength of High Plastic Soils is significant. Mineralogy, moisture content, and effective stress are influencing factors. Designing secure and stable slopes and foundations requires an understanding of the shear strength characteristics.

- Permeability: Low permeability is a characteristic of high plastic soils, which makes them less permeable to water movement. The possibility for pore water pressure building as well as drainage and consolidation properties can all be impacted by this attribute.

- Engineering Challenges: The unique properties of High plastic soils present various engineering challenges, including excessive settlement, differential movement, cracking, and reduced bearing capacity. These challenges necessitate appropriate stabilization techniques to mitigate potential hazards.

For effective geotechnical engineering procedures and the creation of environmentally friendly solutions for stabilization and construction in locations with high plastic soils, it is essential to comprehend and characterize these qualities.

2.5 PROBLEMS CAUSED BY HIGH PLASTIC CLAYS

Due to their special characteristics, high plastic clays provide a number of difficulties in geotechnical engineering and building. For High plastic clay risks to be successfully managed and reduced, it is crucial to comprehend these issues. We go over a few of the major issues raised by high plastic clays in this section:

- Volume Changes: With changes in moisture content, high plastic clays are vulnerable to substantial volume fluctuations. These clays have the ability to expand when exposed to water, increasing in volume, and shrink when exposed to dry air, decreasing in volume. The structural instability brought on by these volume variations may include foundation movement, fissures, and differential settlements.
- Soil Erosion: Due to their tiny particle size and cohesive nature, high plastic clays have poor erodibility resistance. These clays are quickly eroded by water flow or hydraulic forces, which can result in soil loss, embankment failure, and channel instability. High plastic clays can promote soil erosion, which can have a negative impact on hydraulic structures like dams, canals, and riverbanks.
- Poor Drainage: Low permeability is a characteristic of high plastic clays, which makes them less permeable to water movement. Because of this insufficient drainage capacity, water may build up and the soil mass's ability to regulate moisture may be inadequate. Increased pore water pressure, decreased shear strength, and potential slope instability can all be effects of excessive water content.
- Geotechnical Hazards: These clays' strong swelling and plasticity potential might result in geotechnical risks such landslides, slope failures, and slope instability. The stability of both built and natural slopes can be jeopardized by the expanding properties of high plastic clays and variations in moisture content.
- Construction Difficulties: Due to their cohesive nature and volume variations, high plastic clays pose difficulties during construction. Because these clays have a propensity to clump together and attach to construction equipment, excavation and earthwork tasks become more difficult. For a construction project to be successful, high plasticity clays must be taken into account specifically and the proper engineering methods must be used.
- Structural Damage: Clays with a high plasticity can put a lot of pressure on buildings, causing structural harm and decreased stability. These clays' swell and contract nature can put stress on foundations, leading to fissures, uneven settlements, and even structural failure. It is frequently important to take stabilization procedures in order to reduce the possible harm that High plastic clays may cause.

Engineers and geotechnical experts can create suitable stabilization strategies, design suitable foundations, and implement efficient soil management practices by understanding the issues brought on by High plastic clays. This will ensure the secure and long-lasting construction of infrastructure projects in areas with High plastic clays.

Figure 2.1. Foundation Failure Due to Presence of Untreated High Plastic Clays

2.6 STABILIZATION OF HIGH PLASTIC CLAYS

High plastic clays must be stabilized in order to enhance their engineering qualities and lessen the difficulties brought on by their behavior. These clays have been stabilized using a variety of methods and substances in an effort to increase their durability, lessen volume changes, and make them more suitable for use in building. In this section, we'll talk about some typical techniques and materials for stabilizing high plastic clays:

2.6.1 Chemical Stabilization

In order to change the characteristics of High plastic clays and enhance their engineering qualities, chemical stabilization is a frequently utilized technique. Chemical stabilizers for High plastic clays are routinely added to cement, fly ash, lime, and cement. As a result of the reaction between these stabilizers and the clay particles, strength, plasticity, and durability are all improved. Chemical stabilization is frequently used as an ingredient in soil-cement or soil-lime combinations or for in situ stabilization.

2.6.2 Mechanical Stabilization

In order to increase the stability and strength of the soil, mechanical stabilization procedures entail changing the soil's physical characteristics. For high plasticity clays, common mechanical stabilizing techniques include compaction, preloading, and soil reinforcement. Compaction improves stability and lowers settlement by increasing soil density and reducing compressibility. Before building, preloading includes putting a load on the ground to compact the soil and hasten the settlement process. The shear strength and stability of the soil can be improved by using soil reinforcement techniques like the use of geosynthetics or soil nails.

2.6.3 Thermal Stabilization

Heat is used in thermal stabilization techniques to change the characteristics of high plasticity clays. Heat drying and thermal treatment are used in these techniques. Heat is applied to the clay to reduce its moisture content, which reduces its plasticity and limits volume fluctuations. This process is known as thermal drying. Thermal treatment, on the other hand, includes heating the clay, which triggers chemical processes and modifies its mineralogical makeup. The outcome is an increase in the clay's strength and a decrease in its swelling potential.

2.6.4 Geosynthetic Stabilization

For High plastic clays, geosynthetics like geotextiles, geogrids, and geocells provide efficient stabilizing options. These materials can be used to strengthen the soil's structure, increase its tensile strength, and reduce erosion. In order to increase shear resistance and give tensile strength, geosynthetics are carefully positioned within the soil mass. They effectively reduce the risk of slope failures this way, and they also help to maintain the stability of retaining walls and embankments. Geosynthetics also make drainage easier and stop soil particles from migrating, improving the soil's overall stability.

2.6.5 Innovative Stabilization Techniques

New stabilizing techniques designed specifically for high plastic clays have recently been introduced as a result of recent developments in geotechnical engineering. One such strategy entails the use of waste resources as additives or stabilizers, such as recycled materials and industrial by-products. An illustration of this is the use of bagasse ash, a byproduct of the sugarcane industry, which has shown promise in stabilizing High plastic clays. This novel stabilizing method not only improves stabilization but also promotes environmental sustainability. Engineers can enhance the engineering features of high plastic clays, reduce their negative impacts, and guarantee the stability and durability of construction projects carried out in places with these challenging soil conditions by using the appropriate stabilization procedures.

2.6.6 Types of Ash

Due to its pozzolanic capabilities and capacity to improve soil characteristics, ash is frequently used as a stabilizing agent for high plastic clays. Ash of many varieties that comes from various sources can be used to stabilize soil. We go over a few commonly utilized ash types below:

- Fly Ash: A fine, powdery byproduct of coal combustion in thermal power plants is called fly ash. Silica, alumina, and iron oxide make up the majority of its composition, along with other inorganic mineral materials. Due to its pozzolanic reactivity, which allows it to react with calcium hydroxide and produce cementitious compounds, fly ash is frequently used for soil stabilization. Improved soil strength and decreased plasticity are the results of this response.

- Bottom Ash: Another by-product of burning coal is bottom ash, which is gathered from the bottom part of the furnace. Compared to fly ash, it has a coarser texture and bigger particle size. Bottom ash can nonetheless help stabilize soil by adding granular material and improving mechanical qualities like drainage and load-bearing capacity, while having a lesser pozzolanic reactivity than fly ash.

- Rice Husk Ash: The waste product of the rice milling industry, rice husks, are burned to produce rice husk ash. It has pozzolanic properties and contains a considerable amount of silica. As a soil stabilizer, rice husk ash can be utilized to strengthen and lessen the plasticity of high plasticity clays. Its use not only provides a sustainable option, but also helps with the disposal of rice husk trash.

- Bagasse Ash: Bagasse ash is a byproduct of burning bagasse, the fibrous material left over after sugarcane juice is extracted. It has pozzolanic characteristics and is silica-rich. High plastic clays can now be stabilized with bagasse ash, which offers a more affordable and environmentally responsible alternative.

- Other Ash Types: For soil stabilization, various different ash types, including coal ash, wood ash, and palm oil ash, can also be used. These ashes may vary in composition and pozzolanic characteristics, but when employed properly, they can help High plastic clays' technical qualities.

The best ash type to use for stabilizing soil will rely on a number of variables, including what is available locally, the kind of soil, the needed engineering features, and the project specifications. To successfully stabilize High plastic clays, the ideal dosage and the right ash type must be determined through careful examination and testing.

2.6.7 Bagasse Ash

Bagasse ash is produced by burning bagasse, the fibrous byproduct of sugarcane juice extraction. It is good for soil stabilization since it is silica-rich and has pozzolanic properties. We go through the characteristics and advantages of bagasse ash for stabilizing High plastic clays in this subsection.

- Because of its high silica content, bagasse ash is recognized for being pozzolanic reactive. Bagasse ash can react with calcium hydroxide, which is frequently present in soil, to create cementitious compounds thanks to the presence of silica. The High plastic clays get stronger and lose some of their flexibility as a result of this reaction.
- Bagasse ash has pozzolanic qualities, which means that when lime and moisture are present, they can react to produce compounds having cementitious capabilities. This pozzolanic reaction improves the High Plastic Clays' binding and stability, leading to better technical qualities.
- Benefits for the environment: Using bagasse ash for soil stabilization has advantages for the environment. Bagasse ash helps to promote sustainability by reducing trash disposal. A decrease in carbon emissions may also result from the substitution of bagasse ash for cementitious materials in soil stabilization.
- Bagasse ash is frequently regarded as a cheaper option for stabilizing soil. It is easily

accessible in regions where sugarcane is produced because it is a by-product of the sugarcane industry. When used as a soil stabilizer, it can be more cost-effective than other stabilizing chemicals.

- Bagasse ash has showed potential in stabilizing high plastic clays, making it suitable for high plastic clays. High plastic clays' pozzolanic reactivity, high silica content, and cementitious qualities help to lessen their flexibility and increase their strength and stability. For best outcomes, proper dosing and mixing procedures are necessary.

It may be advantageous to use bagasse ash as a soil stabilizer to enhance the engineering qualities of high plastic clays. To define standards and optimize the use of bagasse ash for efficient stabilization in various soil conditions and engineering applications, more study and testing are required.

Figure 2.2. Bagasse Ash

2.6.8 Physical Properties of Bagasse Ash

When assessing bagasse ash's acceptability and effectiveness as a stabilizing agent for high plastic clays, its physical characteristics are crucial. Understanding these characteristics is crucial for determining its capability for stabilizing soil. The essential physical characteristics of bagasse ash are covered in the following section:

- Particle Size Distribution: Bagasse ash often includes both tiny particles and larger aggregates, exhibiting a wide range of particle sizes. The packing density, workability, and permeability of the stabilized soil are all impacted by the particle size distribution. The performance of the stabilized soil can be improved overall by using proper grading and particle size distribution of the bagasse ash.

- Specific Surface Area: The overall surface area per unit mass of the ash particles is referred to as the specific surface area of bagasse ash. It is a significant factor that affects the ash's pozzolanic reactivity and cementitious qualities. Greater reactivity and a higher capacity for interacting with the soil particles are often indicated by a higher specific surface area.

- Bulk Density: Taking into consideration the vacuum spaces between the particles, the bulk density of bagasse ash indicates its mass per unit volume. The stabilized soil's strength and compaction are influenced by bulk density. An increase in the bulk density of bagasse ash can help the soil retain more stability and load-bearing capability.

- Bagasse ash particles can have a variety of forms, many of which are distinguished by irregularity. The overall strength and stability of the stabilized soil are affected by the interlocking and bonding between particles, which is influenced by particle form. Bagasse ash's porosity, which refers to the void spaces within the particles, has an impact on soil properties like permeability and moisture retention.

- Bagasse ash typically has a greyish appearance, though this can change depending on the combustion process and the presence of contaminants. Bagasse ash can have a powdery or somewhat grainy appearance. The look and usability of the stabilized soil may be affected by these aesthetic characteristics.

Bagasse ash's ability to stabilize high plastic clays is influenced by its pozzolanic qualities, chemical makeup, and physical characteristics taken together. It is crucial to fully comprehend and characterize these qualities in order to choose the ideal dosage and mix design for soil stabilization initiatives.

2.6.9 Chemical Properties of Bagasse Ash

Understanding bagasse ash's action and how well it stabilizes High plastic clays depends heavily on its chemical characteristics. These characteristics affect the pozzolanic reactivity and the way that ash and soil interact. The essential chemical characteristics of bagasse ash are presented in the section below:

- Bagasse ash has a high silica content, which adds to its pozzolanic activity and is one of its distinguishing characteristics. Calcium silicate hydrates are created when silica and calcium hydroxide, which is frequently present in soil, combine. High plastic clays undergo this reaction, which increases strength while decreasing flexibility.
- Bagasse ash may have different concentrations of alumina and iron oxide, which affect the ash's overall chemical makeup. These substances may have an impact on the ash's reactivity and how it interacts with soil particles, which may have an effect on the stabilizing process.
- Bagasse ash can contain leftover carbon because the bagasse was not completely burned. The carbon content may need to be taken into account when stabilizing applications since it can affect the pozzolanic reactivity of the ash.
- Bagasse ash's chemical composition can change based on a number of elements, including the bagasse's source, the combustion process, and the presence of contaminants. To make sure bagasse ash is appropriate for soil stabilization purposes, it is essential to analyze the exact chemical makeup of the substance.

- The bagasse ash and the soil minerals interact chemically when it is combined with high plastic clays. These reactions produce cementitious compounds such calcium silicate hydrates and other pozzolanic products, which help the stabilized soil become stronger and less flexible.

Bagasse ash's effectiveness as a stabilizing agent for High plastic clays is determined by both its physical and chemical characteristics. In order to evaluate the applicability and maximize the application of bagasse ash in soil stabilization projects, it is critical to accurately characterize and comprehend these properties:

Table 2.1.Chemical Properties of Bagasse Ash

Chemical Property	**Value (%)**
Silica Content	60.94
Alumina Content	14.28
Iron Oxide Content	12.81
Calcium Oxide Content	3.05
Others	8.92

The bagasse combustion method, the bagasse source, and the presence of contaminants are few examples of the variables that might affect the chemical composition of bagasse ash. To verify that bagasse ash is suitable for soil stabilization purposes, it is crucial to analyze the exact chemical makeup of the substance. Chemical interactions occur between the ash particles and the soil minerals when bagasse ash is combined with High plastic clays. These interactions lead to the development of cementitious compounds, which improve the soil's strength and decrease its flexibility.

Bagasse ash's ability to stabilize High plastic clays depends on its chemical characteristics in addition to its physical characteristics. For determining the acceptability and maximizing the use of bagasse ash in soil stabilization projects, it is essential to accurately characterize and comprehend these qualities.

2.6.10 Utilization of Sugarcane Bagasse Ash in Organic Soil Stabilization

The study discussed in the paper looks into the use of sugarcane bagasse ash (SCBA) as an alternative, environmentally friendly binder for stabilizing organic soil. In the study, SCBA was coupled with different additions to stabilize peat soil, including Ordinary Portland Cement (OPC), calcium chloride (CaCl2), and silica sand. It was discovered through a series of experiments on stabilized peat samples that the ideal mix design included a partial substitution of OPC with SCBA 1 and SCBA 2 of 20% and 5%, respectively. According to the findings, compared to peat-cement (PC) specimens, stabilized peat specimens had better unconfined compressive strength (UCS).

The scientists came to the conclusion that SCBA 1, which has finer particle size, performed better as a material for peat stabilization. The study also brought to light the environmental issues surrounding the use of cement in soil stabilization, especially as a result of its high carbon dioxide emissions. The use of SCBA in soil stabilization was suggested as a promising alternative that can assist lower energy consumption and pollution in order to address these challenges and encourage sustainable practices.

An innovative strategy that can support waste management and sustainable building practices is the use of sugarcane bagasse ash in organic soil stabilization. A consequence of burning bagasse, the fibrous residue left over after extracting the juice from sugarcane, is sugarcane bagasse ash (SCBA).

By adding natural elements, organic soil stabilization seeks to improve the engineering qualities of soil, such as strength, durability, and load-bearing capacity. Due to its pozzolanic characteristics, SCBA is regarded as a good organic material for soil stabilization. Pozzolanic materials generate cementitious compounds when they react with calcium hydroxide in the presence of water, improving the properties of the soil.

When SCBA is combined with soil, it combines with the soil's lime concentration to create more cementitious compounds, increasing the strength and stability. Expansive soils can have their flexibility and swelling potential reduced by SCBA, improving their suitability for construction. The SCBA increases the stabilized soil's resilience to erosive forces, moisture damage, and other environmental conditions. Sugarcane waste can be disposed of in an environmentally acceptable manner by using SCBA. Bagasse ash can be used successfully rather than being thrown away or burned, minimizing waste accumulation and its related environmental effects.

The study also emphasized the significance of looking into bagasse residues' possible uses, which are substantial waste products of the sugar industry. There is currently a dearth of data supporting their use in stabilizing soil, especially organic soil. Therefore, it is deemed advantageous to develop eco-friendly alternative binders for sustainable soil management.

Bagasse ash is created by gathering and burning bagasse, a waste product of the sugarcane industry. For the purpose of determining the SCBA's appropriateness for soil stabilization and the ideal mix proportions, its physical and chemical properties are examined. In predetermined ratios, the SCBA is combined with the soil. To guarantee an even dispersion of the ash, mixing can be done mechanically using tools like a soil mixer or a pug mill. For a set amount of time, the stabilized soil must cure in order for SCBA and lime in the soil to undergo a pozzolanic reaction. To maximize the reaction, curing variables like temperature and moisture can be managed.

Laboratory tests are performed on the stabilized soil mixture to evaluate its engineering qualities, including compressive strength, permeability, and stability. These tests aid in determining how well SCBA stabilizes soil. It is crucial to remember that using SCBA for soil stabilization requires adherence to the appropriate engineering standards and norms. The kind of soil, intended use, and desired engineering features are only a few examples of the variables that affect the SCBA dosage and design parameters.

In conclusion, the study examines the use of SCBA as an alternative binder and evaluates its usefulness in peat stabilization. It underlines the need to look for alternate binders for sustainable soil management and the advantages of integrating SCBA. [1]

Overall, the use of sugarcane bagasse ash in organic soil stabilization offers a sustainable waste management option while enhancing the soil's engineering qualities. We may lessen our influence on the environment and work toward a more sustainable future by encouraging the use of agricultural byproducts in construction methods.

2.7 USE OF BAGASSE ASH IN ROAD PROJECTS

High plastic clays have been stabilized with success using bagasse ash in road construction projects. It can be added to subgrade layers to improve the soil's mechanical qualities, such as its shear strength, compressibility, and resistance to damage brought on by moisture. The use of bagasse ash in road construction projects has a number of potential advantages, including affordability, sustainability, and environmental friendliness.

Global study into efficiently using waste materials for engineering uses is a result of the rising expenses of waste disposal and soil stabilization. Industrial and agricultural waste products need to be properly disposed of, which calls for quick and affordable solutions. Researchers have concentrated on using potentially cost-effective materials that are locally accessible from industrial and agricultural waste in order to make deficient soils useable and meet the design requirements of geotechnical engineering. The goal of this research is to improve the qualities of poor soils.

Even though industrial waste has been used to improve soil, its high cost makes it challenging to construct roads at an affordable cost, particularly in developing and poor countries that struggle to construct highways that are accessible for their primarily rural populations. Researchers have turned to agricultural waste like bagasse ash, which has the potential to substantially cut construction costs, in order to counter the environmental dangers brought on by such trash.

An agricultural byproduct of sugarcane milling is bagasse ash. The estimated yearly production of bagasse ash in Ethiopia is 72,000 tons, and the five-year plan is expected to expand that amount to 0.94 million tons. Pozzolana is the name given to the ash produced from bagasse, which contains 1.78 percent calcium oxide (CaO), 5.78 percent iron oxide (Fe_2O_3), 1.23 percent magnesium oxide (MgO), 65.58 percent silicon oxide (SiO_2), and 5.78 percent aluminum oxide (Al_2O_3).

By giving poor nations access to affordable and easily accessible building materials, the use of this pozzolana as a replacement for conventional stabilizers like cement and lime will greatly help them realize their objectives. As a partial substitute for cement, bagasse ash has been used in concrete.

High plastic soils are common and well-known for being ideal for growing cotton. The primary component of these soils is montmorillonite, which exhibits significant volume fluctuations throughout the wet and dry seasons. During dry seasons, field layers of black cotton soil frequently experience severe cracking that can extend up to 1.5 meters in depth.

Bitumen, lime, and cement are the three main stabilizers utilized for high plasticity soils. But they are economically unappealing as stabilizing agents due to their high costs. Recent studies in the fields of geotechnical engineering and building materials have become more and more interested in investigating the possible stabilizing properties of low-cost, readily accessible materials such bagasse ash, sugarcane straw ash, fly ash, rice husk ash, coconut husk ash, etc. The engineering properties of soils are frequently altered by the combination of various waste components.

This literature analysis has highlighted the importance of locating affordable options for garbage disposal and soil stabilization. It emphasizes how important it is to use locally accessible resources for engineering reasons. Other agricultural waste products, such as bagasse ash, have also been discovered as possible stabilizing agents that could partially or entirely replace more conventional stabilizers like cement and lime. [2]

2.8 UTILIZATION OF BAGASSE ASH AS A STABILIZER MATERIAL

In the realm of building roads, the use of industrial and agricultural waste materials has drawn more and more attention. Due to its excellent engineering features, sugar cane bagasse ash (SCBA), one of these materials, has been researched as a subgrade layer stabilizer. Pozzolana materials, such as bagasse ash, are distinguished by their capacity to react with water and lime to form cementitious compounds.

Advantages of employing bagasse ash to stabilize the subgrade layer have been the subject of numerous studies. Based on the dry weight of the soil, laboratory tests involved stabilizing soil samples with increasing amounts of bagasse ash (3 percent, 5 percent, 7 percent, 10 percent, 15 percent, 20 percent, 25 percent, and 30 percent). According to the AASHTO soil classification system, the soil employed in these investigations is classified as A-7-6, which normally denotes low engineering appropriateness.

The geotechnical characteristics of the soil stabilized by bagasse ash have slightly improved, according to analysis of the data. Similar to this, the soil's initial MDD is 1.59 gm/cm3, and after bagasse ash is added up to 30 percent, it drops to 1.11 gm/cm3, representing a reduction of 30.2 percent. The plasticity index, liquid limits, and plastic limits of the sample.

Despite bagasse ash's availability and high silica content, no research has been done to determine whether it may be used alone to stabilize soil. Although prior research has supported its appropriateness as an additive with cement and lime, its effectiveness as a stand-alone substance is still debatable. Determining the possible advantages of employing bagasse ash as a stand-alone material for subgrade layer stabilization is the purpose of this paper.

In summary, earlier research shows that the addition of bagasse ash can improve the geotechnical qualities of soil, providing a possible substitute for conventional stabilizing agents. To fully investigate the potential of bagasse ash as a stand-alone stabilizing substance for the subgrade layer, more research is necessary. [3]

2.9 CURRENT RESEARCH WORK ON BAGASSE ASH

Further understanding of the potential of bagasse ash as a stabilizing component for high plastic clays is the focus of ongoing study. Its long-term performance, ideal mix design, compatibility with other materials, and the impact of environmental conditions on its efficiency are all constantly being researched. The objective of the current investigations is to improve knowledge and application of bagasse ash in geotechnical engineering procedures.

In building projects utilizing fine-grained soil, expansive soils, recognized for their propensity to expand or consolidate depending on the imposed structural stress, present considerable issues. Structures built on expansive soils in Australia, where about 20% of the surface soils are, may endure significant settlements under heavy traffic over time.

Researchers specifically looked at the effects of lime and bagasse ash, both separately and together, on the capabilities of vast soil to consolidate. The findings revealed that the soil's swelling pressure dropped as lime or bagasse ash concentration increased, and that adding bagasse ash to soil that had already received lime treatment produced better results. The study showed that stabilizing High Plastic Clay with Bagasse Ash and Lime significantly reduced the compression and swelling indices. [4]

This study aims to look at the potential for utilizing bagasse ash as a supplement for expanding soil stabilization. Hence, finding ways to utilize bagasse ash can address the environmental problems caused by its disposal.

In this study, the researchers examined the geotechnical properties of stabilized soil specimens that underwent treatment with various bagasse ash and lime concentrations. A description of the geotechnical features of the stabilized Unconfined compressive strength (UCS) tests for various curing times were used to analyze the soil. With the use of scanning electron microscope (SEM), a vast study of the growth of the microstructure in untreated and treated soils was also conducted. [5]

Expansive soils are known for exhibiting volumetric changes against changes in moisture content. This phenomenon often occurs near the ground surface, where soil is directly exposed to environmental and seasonal variations. As a result, constructing civil engineering structures on this type of soil can be very risky as the soil is susceptible to significant deformations due to drying and wetting cycles. Different measures have been put in place to combat the adverse effects of expansive soil. These measures include replacing expansive soil with non-expansive soil, maintaining constant moisture content, and using various ground improvement techniques such as granular pile-anchors, sand cushion technique, belled piers, and soil stabilization with chemical agents like lime and cement.

This study focuses on an experimental investigation of improving the geotechnical properties of expansive soil stabilized with bagasse fiber and ash, with or without lime stabilization. The agricultural waste by-products of bagasse ash and fiber were obtained from the crushing of sugarcane for juice extraction, and the expansive soils were collected from Queensland, Australia. With varying additive amounts and curing durations of 3, 7, 28, and 56 days, several laboratory studies were carried out on expansive soil samples that were both untreated and treated. The evolution of the microstructure in expansive soils that had not been treated and that had been treated was assessed using scanning electron microscopy (SEM), pH measurements, and Fourier transform infrared (FTIR) methods.

According to the experimental investigations, adding bagasse ash to expansive soils increased their compressive strength at failure and corresponding strain by 48 percent, which resulted in a significant reduction in linear shrinkage of 47 percent, a reduction in free swell potential of about 10 percent to less than 0.5 percent, a reduction in swelling pressure of about 60 percent from 80 kPa to 35 kPa, and a significant increase in swelling pressure of about 60 percent. In the meantime, the use of bagasse ash and lime to stabilize soils led to a notable increase in compressive strength of 815 percent and the secant modulus of elasticity from 7.2 MPa to 107.2 MPa, as well as a significant 84 percent reduction in linear shrinkage, a decrease in free swell potential to less than 0.5 percent, a decrease in the amount of permeability, and a decrease in the amount of water retention. [6]

Expansive soils are problematic in civil engineering due to their high swelling and shrinkage potential. The use of soil reinforcement techniques has been explored as a means of mitigating these issues. In this paper, the authors investigate the mechanical characteristics of expansive soil reinforced with bagasse fibre and lime.

Bagasse fiber, has the ability to act as an expanding soil's reinforcement. Standard compaction and consolidation tests, as well as other laboratory studies, were carried out by the authors, on untreated soil and soil samples blended with varying quantities of bagasse fiber ranging from 0 percent to 2 percent and a specific amount of 2.5 percent lime.

So, bagasse fiber has the potential to be a low-cost, environmentally friendly fill material for the treatment of expansive soils in the field of civil infrastructure foundations. However, more research is required to fully understand the mechanical properties of bagasse fibre-reinforced soils and to optimize the mix design for specific applications.

In conclusion, the authors' investigation highlights the significant benefits of using bagasse fibre as a reinforcing component for expansive soils. The research findings contribute to the development of sustainable construction practices and can potentially lead to the utilization of bagasse fibre in civil engineering applications. [7]

Due to their tendency for soil expansion or consolidation depending on the amount of structural stress present, expansive soils pose substantial building issues on fine-grained soil. Structures built on expansive soils in Australia, which make up about 20% of the total surface soils, may experience considerable settlements under long-term traffic loads (Karunarathne et al., 2013). Due to their propensity for soil expansion or consolidation depending on the amount of structural stress present, expansive soils pose substantial building issues on fine-grained soil. Structures built on expansive soils in Australia, which make up about 20% of the total surface soils, may experience considerable settlements under long-term traffic loads (Karunarathne et al., 2013).

One conventional method used to improve the geotechnical properties of expansive soils is the chemical stabilization of clay with lime, which has been shown to effectively reduce soil consolidation, and swelling potential, and improve the strength of clayey soil (Amiralian et al., 2012; Kolay and Ramesh, 2016; Ouhadi et al., 2014; Pal and Ghosh, 2013; Salehi and Sivakugan, 2009; Taiyab et al., 2015). The ion exchanges and pozzolanic reaction resulting from the chemical reaction between clay particles and lime leads to short-term modification and long-term stabilization of the soil (Karunarathne et al., 2013).

Another solution that can minimize the cost of the project while reducing the size of landfills and the adverse effects on the environment is the use of waste material in ground modification (Eberemu, 2011; Mir and Sridharan, 2014; Nalbantoglu and Tuncer, 2001; Okoro et al., 2011; Sureban, 2011). For instance, bagasse ash, derived from the ignition of sugarcane waste at electrical power stations, has been considered as a discarded material, and its use in soil stabilization has been investigated in several studies (Alavéz-Ramírez et al., 2012; Dang et al., 2016; Manikandan and Moganraj, 2014; Osinubi et al., 2009). The use of bagasse ash has been found to increase the efficiency of lime or cement in soil stabilization and contribute to reducing the swell characteristics of expansive clay samples (Phanikumar and Sharma, 2007).

In this study, the researchers investigated the effect of lime and bagasse ash, both individually and in combination, on the consolidation characteristics of expansive soil. The results indicated that the swelling pressure of the soil decreased with an increase in bagasse ash or lime, and better results were obtained when bagasse ash was added to soil treated with lime. The study showed that the compression and swelling indices decreased significantly when soft clay was stabilized with bagasse ash and lime (Karunarathne et al., 2013). [8]

CHAPTER 3

3 METHODOLOGY

3.1 GENERAL

The work scope and methodology used in this study to accomplish the study's goals are summarized in this chapter. Phases of the project included gathering soil samples, getting remolded samples ready, and putting laboratory testing processes into action. This chapter presents thorough explanations of the testing processes used together with the names of the related ASTM standards. A work flow chart that details the sequential stages taken during the research process is also offered.

3.2 COLLECTION OF SOIL SAMPLES

A soil sample was taken for examination as part of our research project, "Environmentally Friendly Use of Bagasse Ash for High Plastic Soil Stabilization," which was carried out at the University of Engineering and Technology (UET) in Lahore, Pakistan. To assure the integrity of the sample, the soil sample was collected from Nandipur, Pakistan, by adhering to stringent processes. The surrounding region was cleaned of any potential contaminants before many sub-samples were taken with the proper equipment. Then, a representative composite sample of the High Plastic clay soil was made by combining these sub-samples.

The disturbed soil sample was delivered unaltered to the UET lab, keeping every aspect of its original composition. The composition, behavior, and geotechnical properties of the soil sample were thoroughly examined in the laboratory. Testing was done in order to completely comprehend the characteristics of the soil for upcoming study and evaluation about the usage of bagasse ash for soil stabilization.

3.3 COLLECTION OF BAGASSE ASH SAMPLE

For our research project, Kamalia Sugar Mills provided a 30 kg sample of bagasse ash. The sample was painstakingly taken to guarantee representativeness, and it was then taken to the lab for examination. Impurities were removed as part of the preparations. To evaluate the ash's capabilities for stabilizing soil, extensive testing and analysis were done in the lab.

Figure 3.1. Bagasse Ash Sample Obtained from Kamalia Sugar Mills

3.4 LABORATORY TESTS PERFORMED

3.4.1 Determination of Natural Moisture Content

The steps for Determining Natural Moisture Content are as follows:

1. Sample preparation: The samples were delivered to the lab with their original moisture content intact. The removal of any discernible organic matter, rocks, or rubbish.
2. Weighing the container: Empty containers were weighed with their tight-fitting lids (W1).
3. Weighing the soil and the containers: Samples of the High plastic clay were divided into representative quantities, and the containers were weighed (W2).
4. Oven drying: The soil sample containers were put in an oven set at 105-110°C (221-230°F) and left there until the weight remained constant.
5. Weighing the dried sample: The containers containing dried dirt were weighed after cooling (W3).
6. Calculation: The formula NMC = [(W2 - W3) / (W3 - W1)] 100 was used to determine the NMC.

3.4.2 Atterberg's Limits (ASTM D 4318)

Atterberg's limits can be described by liquid limit, plastic limit and plasticity index that are explained below:

1. The water content at which the soil transitions between states is known as the liquid limit. It was decided to take a sample of the High Plastic Clay and put it in a moisture container. The soil sample container was weighed (W1). The soil sample was thoroughly blended with distilled water to create a consistent consistency. A portion of the soil-water mixture was put into a Casagrande cup or another liquid limiter. A

groove was formed in the soil sample using a grooving tool, and it was then sealed by lightly hitting the cup. Repeating the previous process until the groove's two walls contacted for a distance of 13 mm. It was measured and noted how many strikes it took to completely seal the groove (N). Calculated was the average number of blows necessary (N). A separate part of the soil sample was dried in an oven and weighed to estimate the moisture content of the soil (W2). The formula LL = (W2 - W1)x100 was used to determine the liquid limit (LL).

2. The soil's plastic limit is the water content at which it transitions from a semi-solid to a plastic condition. More High plastic clay was taken as a representative sample, and it was air-dried until it attained a constant weight. To eliminate large particles, the dry soil sample was ground into a fine powder and sieved with a 425-micron mesh. The weight of an empty moisture container (W3) was measured. The container was filled with about 10 grams of the sieved soil sample, which was then weighed (W4).The soil sample in the container was extensively combined with distilled water to create a paste-like consistency. A tiny amount of the dirt paste was rolled into a 3 mm-diameter thread. The thread was rolled until it disintegrated and split into tiny pieces. h. Until reliable findings were obtained, steps (f) and (g) were repeated. A separate quantity of the dirt paste was dried in an oven and weighed to assess the moisture content (W5). The plastic limit (PL) was calculated using the formula: PL = (W4 - W5) × 100
3. Plasticity Index (PI) Calculation: PI = LL - PL
4. Mixing with Optimum Bagasse Ash Percentage: A typical Proctor compaction test was used to evaluate the High Plastic Clay sample's Optimum Moisture Content (OMC). At the OMC, the High Plastic Clay sample was combined with the ideal Bagasse Ash Percentage. On a mixture of high plastic clay and bagasse ash, the LL, PL, and PI experiments were conducted once more as previously mentioned.

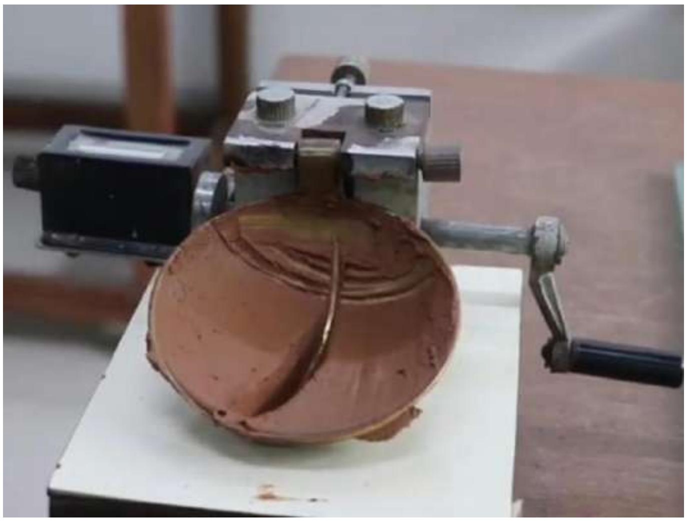

Figure 3.2. Determination of Liquid Limit Using Casagrande Cup Apparatus

Figure 3.3. Determination of Plastic Limit

3.4.3 3.4.3 Sieve Analysis (ASTM D6913)

Following are the steps of sieve analysis:

1. To ensure the sample's representativeness, the High plastic clay sample was initially obtained and gathered in a clean, dry container.
2. To get rid of any extra moisture and preserve consistency throughout the examination, the acquired High plastic clay sample was air-dried in a lab setting.
3. Following the removal of moisture, a pan and a series of sieves measuring 4.75mm, 2mm, 0.425mm, 0.15mm, and 0.075mm were set up. The sample is put on a 4.75mm sieve, and after giving each sieve a good shake, all the retained weights are documented. Particle size distribution curves were plotted by analyzing the retained weights on each sieve.

Our study, which focuses on High plastic soil stabilization utilizing bagasse ash, places the utmost priority on determining the particle size distribution using sieve analysis. We may learn more about the soil's engineering qualities, such as its permeability, compaction traits, and shear strength, by analyzing the particle size distribution of the High plastic clay sample. These characteristics are essential for comprehending the behavior of high plasticity soils and creating powerful stabilization strategies. Furthermore, the sieve analysis enables us to comprehend how the addition of this ash affects the particle size distribution of the High plastic clay, assisting in the evaluation of its potential for soil development and stability. Bagasse ash is used for soil stabilization.

3.4.4 Hydrometer Analysis (ASTM D7928)

Following is the procedure for hydrometer analysis:

1. To get rid of extra moisture and keep consistency throughout the examination, the High plastic clay sample was air-dried in a lab setting.
2. To assure precision in the analysis, a precise quantity of the air-dried High plastic clay sample was weighed using an analytical balance.
3. In order to make a homogenous solution, distilled water was poured to the weighted High plastic clay sample in the container and forcefully stirred.
4. For a fixed amount of time, the suspension was allowed to settle, with the coarsest

particles settling first and the finer particles settling later, in accordance with their settling velocities.

5. A hydrometer was carefully put into the suspension once the settling time had passed, making sure it was submerged to the necessary depth without disturbing the settled particles.
6. The hydrometer was allowed to reach a steady reading on the hydrometer scale by being unaltered for a predetermined amount of time.
7. It was noted the final hydrometer measurement, which represents the depth of suspension in relation to the hydrometer.
8. The suspension was then examined at regular intervals in order to determine the hydrometer's reading for the suspension's settling depth. At each interval, the hydrometer readings were recorded until the suspension achieved a specific minimum hydrometer measurement.

In our study, which focuses on High plastic soil stabilization utilizing bagasse ash, the assessment of particle size distribution using hydrometer analysis is crucial. We learned a lot about the fine-grained component of the soil by analyzing the settling velocities of the particles in the High plastic clay sample.

Figure 3.4. Hydrometer Analysis

3.4.5 Modified Proctor Test (ASTM D1557)

To determine the soil sample's degree of compactness, modified Proctor tests are used. In other words, the modified proctor test is used to determine the sample's optimal water content (OMC) and maximum dry density (MDD).

1. The samples were processed by clearing them of any debris or organic matter that could be seen.

2. In order to account for both dry and wet circumstances, a variety of moisture contents were used. The OMC might be precisely estimated within this range.
3. Five layers of the high plastic clay sample were applied to a compaction mold. Using a compaction hammer that weighed 10 pounds, each layer was compressed using a predetermined amount of strokes.
4. By adding water or letting a portion of the sample to partially dry, the moisture content of each layer was adjusted to the desired amount. By doing this, the moisture content of the sample was confirmed to be within the acceptable limit.
5. With each increase in moisture content, the compaction procedure was repeated. Layers of the sample were compressed until the mold was completely filled. It was noted how many blows each layer received.
6. The compacted sample was taken out of the mold after compaction, weighed, and the mold was carefully removed.
7. The extracted sample was divided into representative pieces, each of which was dried in an oven to a constant weight. The extracted sample's moisture content was then determined using the following formula: Moisture Content = [(Wet weight - Dry weight) / Dry weight] × 100.
8. The formula was used to determine the compacted sample's dry density: Dry Density (g/cm^3) = (Dry weight / Volume of mold).
9. To create the compaction curve, the dry density and moisture content values for each moisture level were plotted on a graph.
10. The optimal moisture content (OMC) for the High Plastic Clay sample was determined to be the moisture content corresponding to the greatest dry density on the compaction curve.

3.4.6 Swell Potential Test (ASTM D5333)

The free swell test was conducted on High plastic clay soil at the optimum moisture content (OMC) to ascertain the free swell ratio. The procedure followed was as follows:

1. To get rid of any large debris or coarse particles, the soil sample was air dried before being put through sieves.
2. A free swell test was conducted. A predetermined portion of the soil sample from OMC was extracted and put in a measuring tool, like a swell cone.
3. To ensure there were no gaps or air pockets, the soil sample was carefully packed into the measuring equipment.
4. The soil sample was placed in the measurement equipment with distilled water added and thoroughly covered the soil surface. In order to avoid disturbing the soil, the water was applied gradually and consistently.
5. For a set amount of time, usually 24 hours, the soil was allowed to soak in the water to allow full saturation and swelling.
6. The final volume of the soil sample was measured following the soaking period, taking into account the volume that swelled. The swollen volume was the volume that was recorded.
7. In order to express the result as a percentage, the free swell ratio was then determined

by dividing the expanded volume by the soil sample's original volume.

8. The High Plastic Clay Soil at OMC was combined with Bagasse Ash at a concentration of 8% by weight in the following phase of the experiment. To guarantee homogeneity, the soil sample and bagasse ash were carefully mixed.
9. The method outlined earlier was applied to the soil-bagasse ash mixture in the free swell test. The swollen volume and free swell ratio were also determined.

3.4.7 Unconfined Compression Test (ASTM D2166)

Procedure for Unconfined Compression Test:

1. A modified Proctor compaction test was performed to estimate the Optimum Moisture Content (OMC), which was then utilized to create the High Plastic Clay sample.
2. A cylindrical mold with a 1.5-inch diameter and 3-inch height was made. The High plastic clay sample was inserted into the mold and uniformly compressed. The High Plastic Clay Sample Mold was then put into the Unconfined Compression Testing Device. Up to failure, the axial load was applied continuously. Axial deformation measurements were taken during the test.
3. Various amounts of bagasse ash, including 2 percent, 4 percent, 6 percent, 8 percent, and 10 percent, were added to the sample of high plastic clay. Each mixture was made by completely combining the High plastic clay sample with the bagasse ash. At the OMC, the mixed samples were compressed.
4. For each combined sample, cylindrical molds with the identical dimensions were created. The mixed samples were poured into the molds and evenly compressed. The combined sample molds were put within the unconfined compression testing equipment. Up to failure, the axial load was applied continuously. Measurements of axial deformation were made during the test.
5. The ideal percentage of bagasse ash was established using the findings from the UCS tests conducted on mixed samples. The most effective mixture was discovered to contain 8% bagasse ash.
6. The following curves were obtained from the UCS testing on the High plastic clay sample alone and the mixed samples with various amounts of bagasse ash: Axial deformation-compressive stress curve and the stress-strain curve. Compressive strength (qu) and modulus of elasticity are two of the strength metrics that were determined from these tests (E).

Figure 3.5. Soil Plus Bagasse Ash

Figure 3.6. UCS Y-Shaped Failure Plane

3.4.8 Unconsolidated and Undrained Triaxial Test (ASTM D285

Procedure for Unconsolidated Undrained Triaxial Test:

1. The Optimum Moisture Content (OMC), as measured by the common Proctor compaction test, was used to prepare the High Plastic Clay sample.
2. A cylindrical mold with a height of 3 inches and a width of 1.5 inches was created to perform the unconsolidated undrained (UU) test on the High Plastic Clay Sample. The High plastic clay sample was inserted into the mold and uniformly compressed. The High plastic clay sample mold was then put into the triaxial testing device. The sample was subjected to the confining pressure, and the cell pressure was set to zero. Up to failure, the axial load was applied continuously. Pore water pressure readings were taken during the test.

3. Various amounts of bagasse ash, including 2 percent, 4 percent, 6 percent, 8 percent, and 10 percent, were added to the sample of high plastic clay. Each mixture was made by completely combining the High plastic clay sample with the bagasse ash. At the OMC, the mixed samples were compressed. For each combined sample, cylindrical molds with the identical dimensions were created. The mixed samples were poured into the molds and evenly compressed. The mixed sample-containing molds were set up in the triaxial testing device. The cell pressure was set to 0, 50, and 100 kPa while the confining pressure was applied. Up to failure, the axial load was applied continuously.
4. The ideal percentage of bagasse ash was established using the findings from the UU tests conducted on mixed samples. The most effective mixture was discovered to contain 8% bagasse ash.
5. Obtained curves and strength parameters: The following curve was discovered from the UU experiments on the High plastic clay sample alone and the mixed samples with various amounts of bagasse ash: Strain-stress curve. These tests produced the following strength parameters:
    (a) Cohesion (c)
    (b) Internal friction Angle (phi)
    (c) Undrained shear strength (su)

By analyzing stress-strain curve and using the proper mathematical model, these parameters were established.

Figure 3.7. UU Test Sample Failure Planes

CHAPTER 4

4 RESULTS AND DISCUSSION

4.1 GENERAL

The laboratory test findings and the conversations that follow them are reported in this section. The experiments were carried out to assess the soil's geotechnical characteristics both before and after stabilization with bagasse ash (BA) and plastic strips (PS). Below are the findings from a number of tests, including the determination of natural moisture content, sieve analysis, hydrometer analysis, Atterberg's limits, specific gravity test, modified compaction test, free swell test, unconfined compression test (UCS), and unconsolidated undrained triaxial test, along with the pertinent discussions for each test.

4.2 Laboratory Test Results

4.2.1 Test Results of Virgin Soil

4.2.1.1 Natural Moisture Content

The virgin soil's natural moisture content was found to be 16 percent.

4.2.1.2 Specific Gravity Test

The soil's 2.75 specific gravity was found to be accurate.

4.2.1.3 Sieve Analysis

Three gradation curves were developed after the soil samples underwent sieve analysis testing. No gravel was found in the samples, however there was 7% of sand.

4.2.1.4 Hydrometer Analysis

To ascertain the amount of clay and silt in the soil, hydrometer tests were performed. The findings showed a high degree of flexibility and a silt content of 36% and a clay content of 57%.

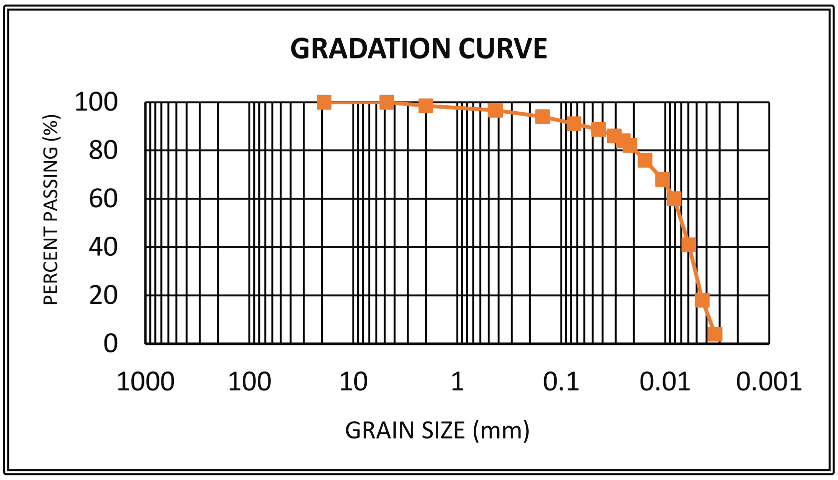

Figure 4.1. Gradation Curve of Soil

4.2.1.5 Atterberg's Limits

The soil's liquid limit was determined to be 60%, its plastic limit to be 24%, and its plasticity index to be 36%. Due to the liquid limit exceeding 50% and the plastic limit exceeding 25%, these results categorize the soil as High expansive (CH).

Table 4.1. Properties of Virgin Soil

PROPERTIES OF SOIL	DESCRIPTION & VALUES
Colour	Grey Brownish
Natural Moisture Content (%)	7
Specific gravity	2.75
Gravel Content (%)	0
Sand Content (%)	7
Silt Content (%)	36
Clay Content (%)	57
Liquid Limit (%)	60
Plastic Limit (%)	24
Plasticity Index	36
Unified Classification Symbol	CH (Fat Clay)

4.2.1.6 Modified Compaction Test

The improved compaction test yielded a maximum dry density of 1.9158 g/cm3, with an ideal moisture content of 13.5 percent.

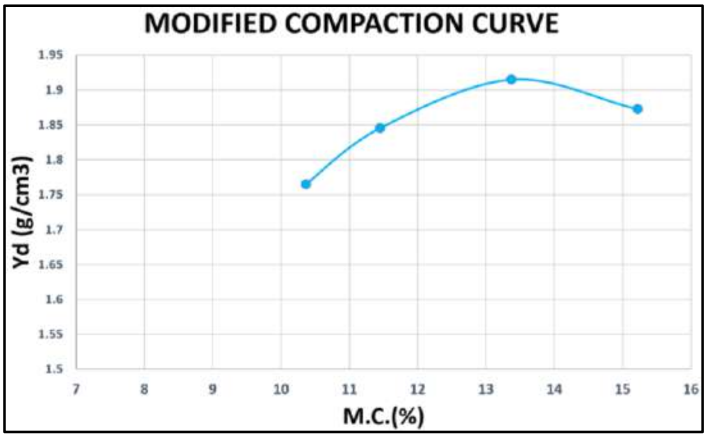

Figure 4.2. Modified Compaction Curve

4.2.1.7 Unconfined Compression Test

Three samples of the virgin soil were tested for unconfined compression; the results showed peak strengths of 40.5 kPa, 42 kPa, and 43 kPa, respectively.

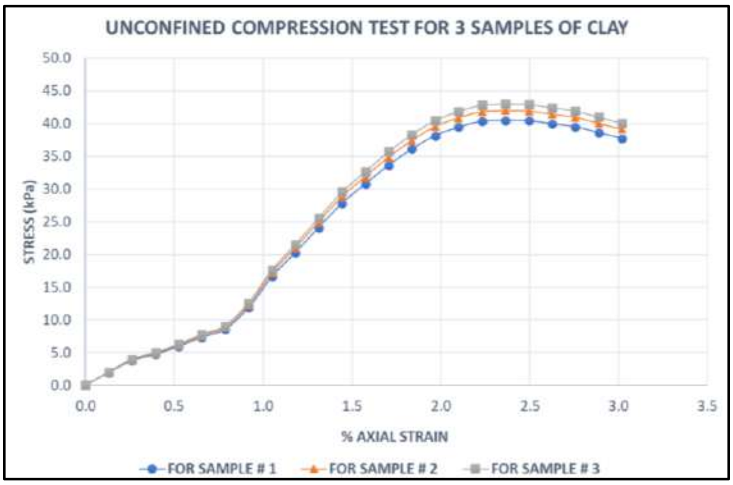

Figure 4.3. Unconfined compression Test for 3 Samples of High Plastic Clay

4.2.1.8 Unconsolidated Undrained Triaxial Test

On the virgin soil, unconsolidated undrained triaxial tests were carried out at three various confining pressures. 52 kPa, 63 kPa, and 81 kPa were the peak deviator strengths attained.

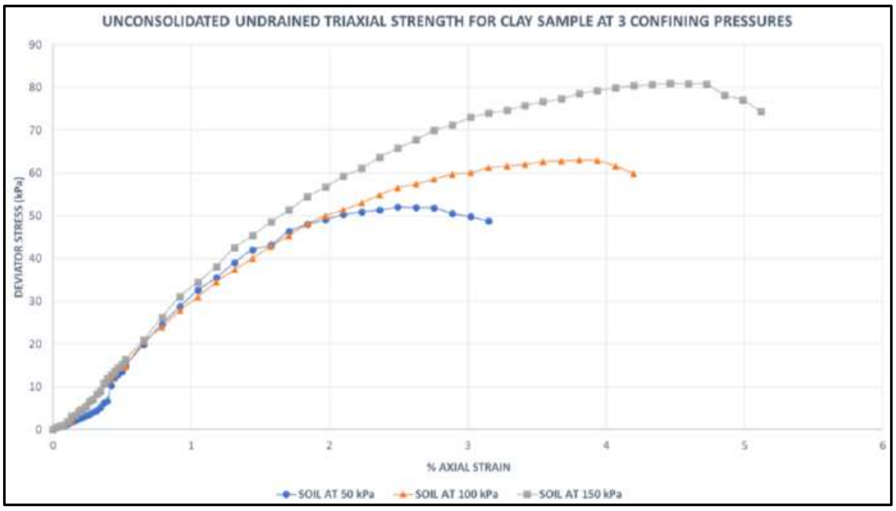

Figure 4.4. Unconsolidated Undrained Triaxial Strength For Clay Sample At 3 Confining Pressures

For the virgin soil, it was found that the cohesiveness and internal friction angle were 17 kPa and 7.14 degrees, respectively.

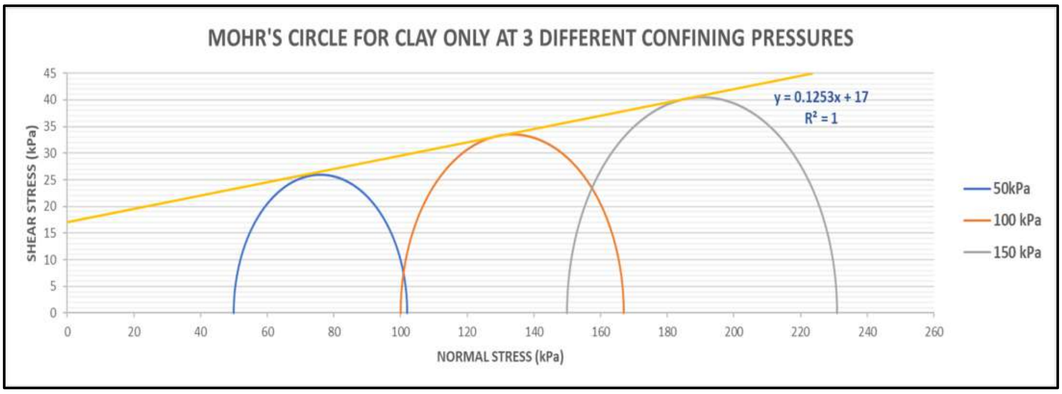

Figure 4.5. Mohr’s Circle for Clay Only At 3 Different Confining Pressures

4.2.1.9 Free Swell Test

The virgin soil's free swell ratio was discovered to be 5.2 percent.

4.2.2 Test Results after Stabilization with Bagasse Ash

4.2.2.1 Unconfined Compression Test for BA

Unconfined compression tests were performed on soil samples stabilized with different proportions of bagasse ash (2%, 4%, 6%, 8%, and 10%). The peak strengths obtained were as follows:

Soil+2% BA: 56 kPa

Soil+4% BA: 65 kPa

Soil+6% BA: 71 kPa

Soil+8% BA: 79 kPa

Soil+10% BA: 67 kPa

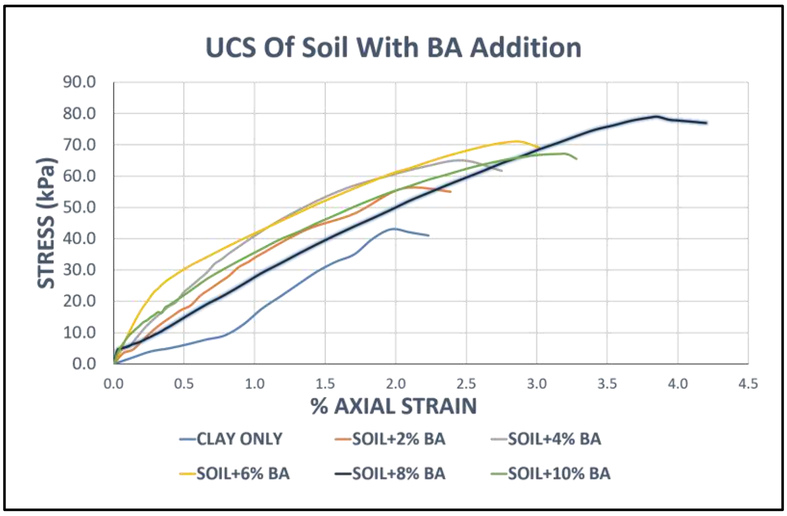

Figure 4.6. Effect of Percentages of Bagasse Ash on UCS of High Plastic Clays

The findings showed that 8 percent bagasse ash was the ideal amount for stabilizing soil.

4.2.2.2 Effect of Soil Stabilized by 8% BA on UU Triaxial Strength

Unconsolidated undrained triaxial tests were carried out at confining pressures of 50 kPa, 100 kPa, and 150 kPa by incorporating 8% bagasse ash into the soil. Peak deviator strengths of 106 kPa, 143 kPa, and 184 kPa were the outcomes.

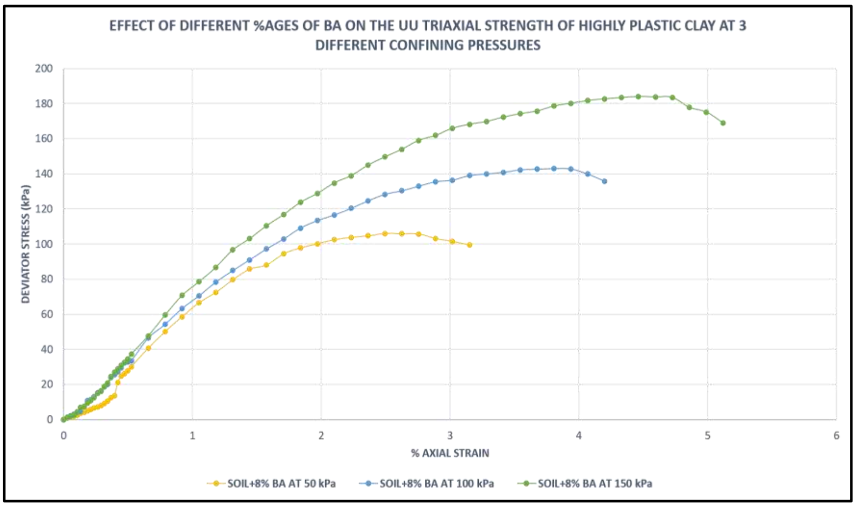

Figure 4.7. Effect of Percentages of Bagasse Ash on UCS of High Plastic Clays

For the soil stabilized by 8% bagasse ash, the cohesiveness and angle of internal friction were found to be 24.8 kPa and 16.52 degrees, respectively.

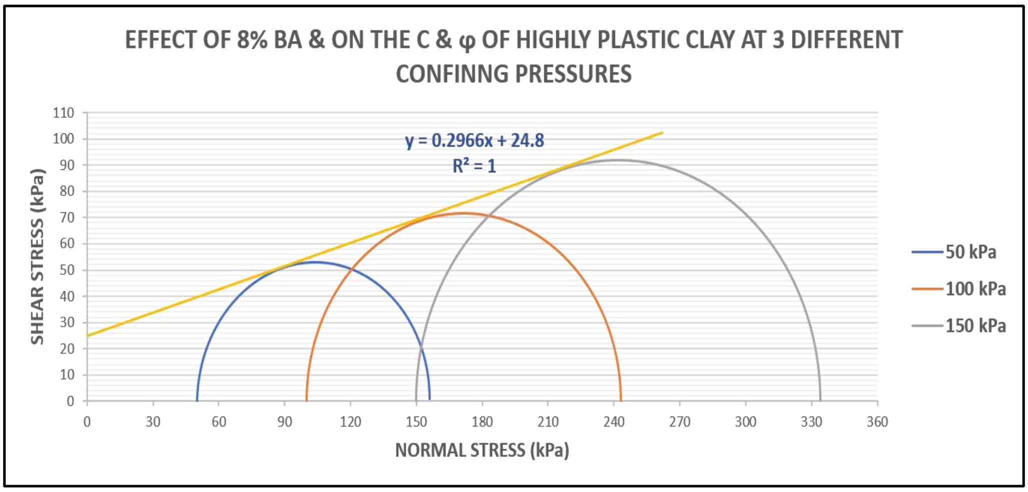

Figure 4.8. Effect of 8% BA on the c & ϕ of High plastic clays at 3 Different Confining Pressures

4.2.2.3 Effect of Soil Stabilized by 2%, 4%, 6%, 8%, and 10% BA on UU Triaxial Strength

The soil stabilized with various amounts of bagasse ash was subjected to unconsolidated undrained triaxial tests at three confining pressures. The following table shows the peak deviator strengths that were obtained:

Table 4.2. UU Peak Strength at Different Confining Pressures

Confining Pressures	Units	50kPa	50kPa	50kPa
UU Peak Strength for Clay only	kPa	52	63	81
UU Peak Strength for 2% BA kPa	kPa	64	117	137
UU Peak Strength for 4% BA kPa	kPa	76	130	160.5
UU Peak Strength for 6% BA kPa	kPa	88	136.5	175
UU Peak Strength for 8% BA kPa	kPa	106	143	184
UU Peak Strength for 10% BA kPa	kPa	88	122	167

4.2.2.4 Effect of Soil Stabilized by BA on Cohesion of Soil

The cohesion of soil increases from 17 kPa to 62 kPa at 8 % BA and after that decreases to 58 kPa at 10 % BA.

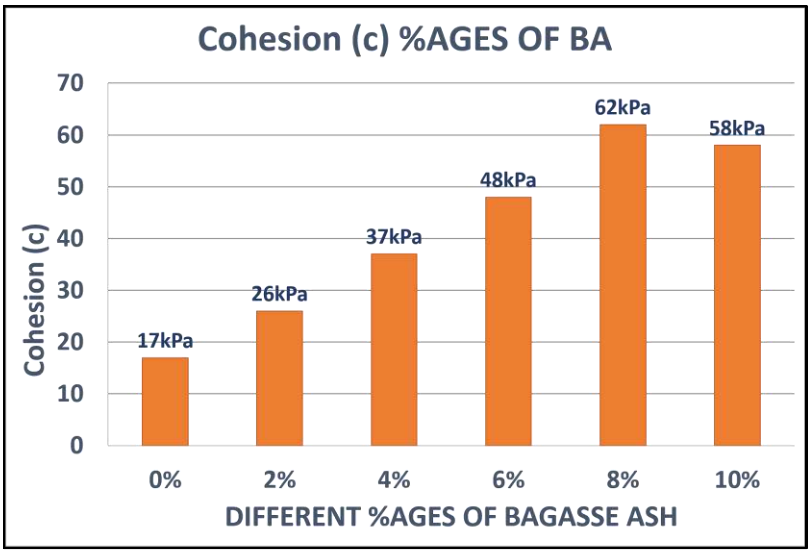

Figure 4.9. Cohesion Vs %Ages of Bagasse Ash

4.2.2.5 Effect of Soil Stabilized by BA on Angle of Internal Friction of Soil

At 8% BA, the soil's Angle of Internal Friction rises from 4 degrees to 21 degrees before falling back to 19 degrees at 10% BA.

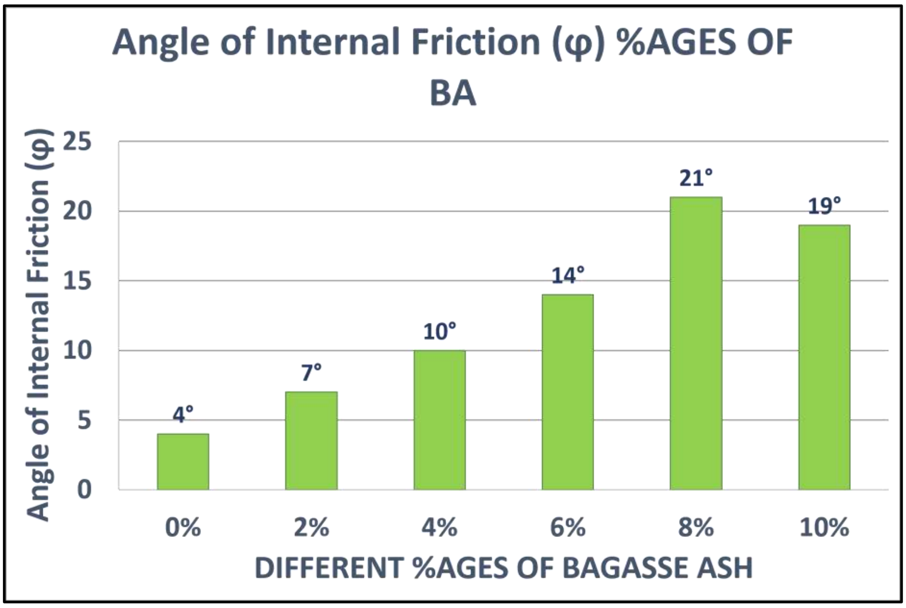

Figure 4.10. Angle of Internal Friction Vs %Ages of Bagasse Ash

4.2.2.6 Free Swell Ratio with Soil + Different Percentages of BA

For soil samples that had various amounts of bagasse ash mixed in, the free swell ratio was calculated. The results were 5.2 percent, 4.5 percent, 3.5 percent, 2.9 percent, and 2 percent, respectively, for soil+2 percent BA, soil+4 percent BA, soil+6 percent BA, soil+8 percent BA, and soil+10 percent BA.

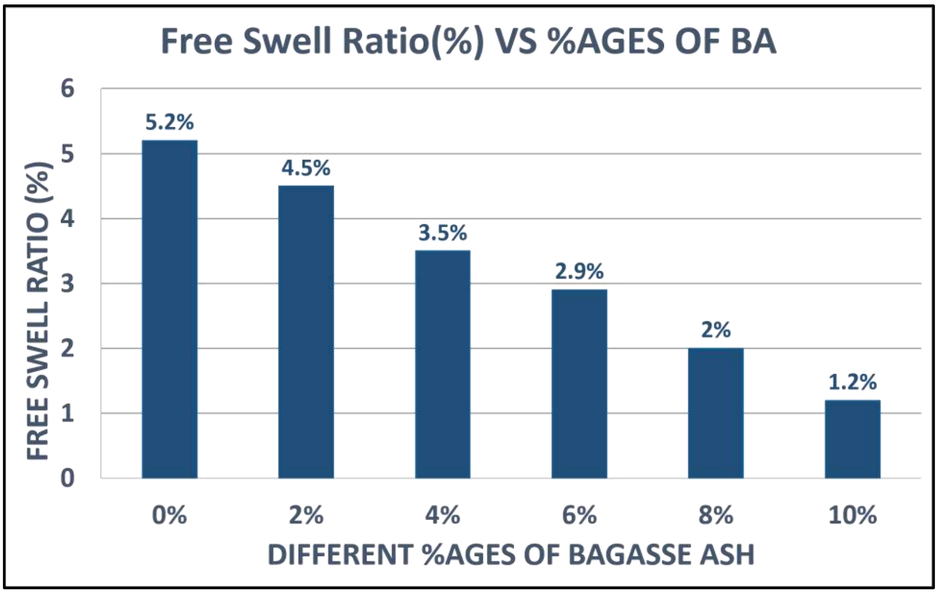

Figure 4.11. Free Swell Ratio Vs %Ages of Bagasse Ash

4.2.2.7 Effect of Addition of BA on Elastic Modulus of Soil at 50kPa

Elastic Modulus (50 kPa) increases from 2.3 MPa to 5.1 MPa with the addition of Bagasse Ash from 0% to 8%. The value drops to 4.2 MPa, or declines, for the addition of 10% bagasse ash. It demonstrates that soil + 8% bagasse ash, or 5.1 MPa, yields the highest elastic modulus value at 50 kPa.

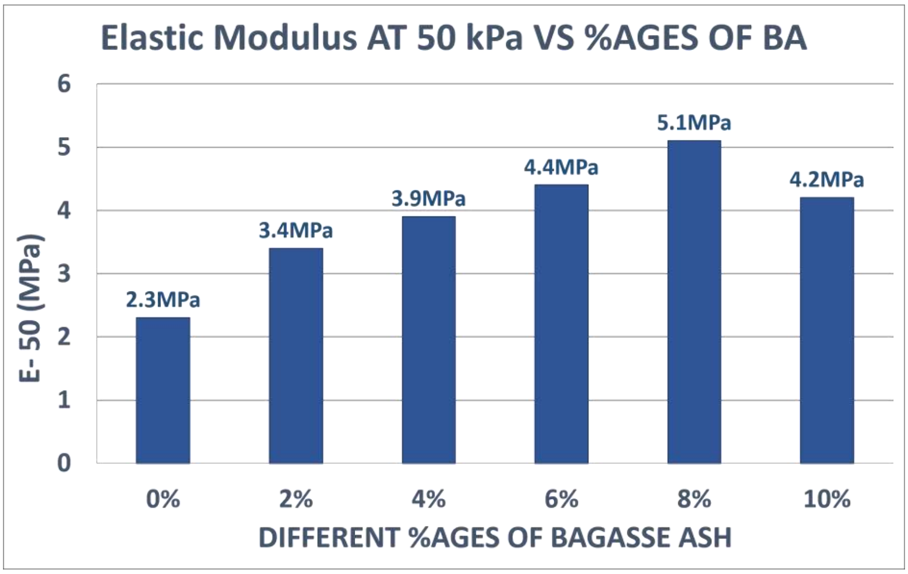

Figure 4.12. Elastic Modulus at 50 kPa Vs %Ages of Bagasse Ash

CHAPTER 5

5 CONCLUSIONS & RECOMMENDATIONS

5.1 GENERAL

To determine the effects of adding bagasse ash (BA) on the stability of High plastic clays collected from Nandipur, Pakistan, an optimal investigation was carried out in this study. The best BA percentages that can be integrated into the soil for optimum stabilization were determined through a variety of tests in the geotechnical laboratory. The findings from the laboratory study that was done form the basis for the conclusions that are presented here.

5.2 CONCLUSIONS

1. In comparison to the virgin soil, the addition of 8% BA increased the unconfined compressive strength by 59%.
2. When compared to virgin soil, the cohesion value from the triaxial (UU) test increased by 114 percent after the injection of 8 percent BA. The angle of internal friction value increased from 4 degrees to 21 degrees as a result of the addition of 8 percent BA.
3. The elastic modulus increased as the percentage of BA increased, and the value increased by 76 percent with the addition of 8 percent BA, indicating an increase in soil stiffness.
4. The free swell ratio declined as the percentages of BA increased, and the value dropped by 125% when the percentages of aged BA were added.

5.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the results and conclusions, the following recommendations are suggested for future re- search:

1. It is advised to gather soil samples from other cities in Pakistan and carry out similar examinations in order to support the research's conclusions.
2. The impact of different bagasse ash sizes and lengths on soil stability should be investigated in more detail.
3. Examine the impact of bagasse ash on the stabilization of High plastic clays at various curing times.

With future research opportunities to build on the findings of this study, these recommendations seek to increase knowledge and understanding of High Plastic Clay Stabilization.

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