A Mini Project report on

THE EFFECT OF AGRICULTURAL WASTE ADDITIVES ON GEOTECHNICAL PROPERTIES OF EXPANSIVE SOIL

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ABSTRACT

Soil is one of the most important construction materials in the world & has been effectively exploited for various purposes, such as building social infrastructures, roads etc. The expansive type of soil is the most problematic soil and causes damage to the foundations of roads and buildings as expansive soil has property of swelling when moisture content increases and shrinking when water gets evaporated. Additional problems associated with expansive soils are high compressibility, plasticity, poor permeability & low bearing strength makes the practical use of such soil problematic for construction purposes.

Agricultural wastes are widely & easily available and are also a serious problem for the environment and its ecosystem. Therefore, improving the property of problematic soil by using sustainable, locally available, and low-cost agricultural waste materials might be a viable option.

This paper aims to review the existing knowledge and practices from the recently published journals related to expansive soil stabilization by agricultural waste additives. The effect of using agricultural waste additives such as coffee husk, rice husk, sawdust, wheat husk & sugarcane bagasse was carefully evaluated in terms of geotechnical characteristics and strength parameters. As a result of the review, agricultural waste additives had significant improvement in California bearing ratio (CBR), Plastic Index (PI), Unconfined Compressive Strength (UCS), compressibility parameters & swelling.

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LIST OF ABBREVIATIONS

Abbreviations	Full-form
RHA	Rice husk ash
SBA	Sugarcane Bagasse ash
SDA	Sawdust ash
WHA	Wheat husk ash
CHA	Coffee husk ask
MDD	Maximum dry density
OMC	Optimum moisture content
LL	Liquid limit
PL	Plastic limit
PI	Plasticity index
CBR	California bearing ratio
UCS	Unconfined compressive strength

CONTENT

CHAPTER 1
INTRODUCTION

2.1 Background:

Expansive soils pose a significant hazard to building foundations. Swelling clays from residual soils may exert pressure to elevate due to the presence of swelling clay minerals. As they get wet, the clay minerals absorb and expand; on the other hand, as they dry, they shrink, leaving large vacuums in the soil. This creates cyclic shrink/swell behavior in the upper portion of the soil column, and cracks can extend to much greater depths than imagined by most engineers. The most profound swelling properties are found in soils with smectite clay minerals, such as montmorillonite. In the field, the deep cracks, in roughly polygonal patterns, on the ground surface can easily recognize expansive clay soils in the dry season. Additional problems associated with high compressibility, plasticity, poor permeability & low bearing strength makes the practical use of such soil problematic for construction purposes.

Agricultural waste is sustainable, low cost, and can be considered a potential alternative material for soil stabilization because of the availability of easy & large quantities of waste. Hence, utilizing waste materials for soil stabilization is viewed positively for several reasons, such as improving the bearing capacity of the soil, increasing the shear strength, and reducing the permeability, reducing compressibility & shrink-swell behaviour. Stabilization of expansive soil with agricultural waste additives has immense significance in terms of the utilization of agricultural wastes, reducing environmental pollution that could harm human safety and health, advocating the geotechnical researchers to widely consider the use of it for soil stabilization.

CHAPTER 2

LITERATURE REVIEW

Adajir et al. (2019) indicated that rice husk ash (RHA) has been effectively used in soil stabilization. Studies have demonstrated improvements in the Atterberg limits and reductions in swelling potential when RHA is incorporated into soil mixtures. While the incorporation of RHA can reduce the swelling potential of expansive soils, the study's findings suggest that it may not significantly improve the moisture-density relationship or the overall strength parameters of the treated soils. This study aims to investigate the effectiveness of RHA in mitigating the swelling potential of expansive soils and improving their strength properties. It evaluated the engineering properties of soil-RHA mixtures, including Atterberg Limits, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Unconfined Compressive Strength (UCS), and Expansion Index (EI).

Singh et al. (2017) focused on the safe disposal and utilization of such waste, specifically wheat husk ash (WHA) and sugarcane straw ash (SCSA), to improve soil quality. The main objective was to enhance the shear strength and reduce the compressibility of expansive soils, particularly black cotton soil. explored the use of bagasse ash from the sugarcane industry for soil stabilization. This research highlighted the fibrous nature of bagasse ash, which contains silica, and demonstrated that a 6% replacement of soil with this ash significantly improved the soil's chemical, physical, and geotechnical properties. The findings indicated that the addition of bagasse ash enhances the compressibility and bearing capacity of black cotton soil, thus providing a solution to poor geotechnical properties of expansive soil & safe the disposal issues faced by the sugarcane industry.

Oguche et al. (2022) highlighted the potential of using sawdust ash, a byproduct of local sawmills, as a stabilizing agent for road construction. The research involved mixing clayey soil with varying percentages of sawdust ash (2%, 4%, 6%, 8%, and 10%) to assess its impact on key geotechnical properties such as optimum moisture content (OMC), maximum dry density (MDD), California bearing ratio (CBR), and unconfined compressive strength (UCS). The results demonstrated that 6% SDA provided optimal stabilization, improving the soil's strength and reducing its plasticity index. The findings suggest that sawdust ash is a viable and economical stabilizing agent for clayey soils.

Atahu et al. (2020) focused on the challenges posed by expansive soils and the potential of coffee husk ash (CHA) as a stabilizing agent. The addition of CHA to expansive soil resulted in notable improvements in various geotechnical properties. Specifically, the study found that the soil treated with 20% CHA exhibited a three-fold reduction in swelling capacity compared to untreated soil, indicating enhanced stability under moisture fluctuations. The combination of CHA with lime was found to be more effective than lime alone in reducing plasticity and swelling while improving the bearing capacity of the soil. This suggests that the combined effect of CHA and lime can lead to better stabilization outcomes for expansive soils.

Gidebo et al. (2023) highlighted the potential of agricultural waste, such as rice husk, coffee husk, and sugarcane bagasse, as sustainable and low-cost alternatives for soil stabilization. These materials are abundant and can help mitigate environmental pollution caused by waste disposal. Agricultural waste additives significantly improve key geotechnical properties of expansive soils, including California bearing ratio (CBR), unconfined compressive Strength (UCS), and plasticity index (PI). The review organizes and discusses these findings systematically, showcasing the effectiveness of different additives. The review concludes that using agricultural waste for soil stabilization not only provides economic advantages due to the low cost of these materials but also promotes environmental sustainability by reducing waste and enhancing resource utilization.

Zaika et al. (2020) The study investigates the effectiveness of combining lime and rice husk ash (RHA) as a stabilization method for expansive soils. The combination of lime and RHA shows improved durability compared to using lime or RHA alone. This indicates that the treated material can withstand environmental changes better, which is crucial for applications in pavement structures. The study found that a curing period of 7 days significantly enhances the California Bearing Ratio (CBR) of the stabilized soil. This suggests that allowing adequate time for the lime and RHA to bond with soil minerals is essential for achieving maximum strength and reducing swell potential.

- **Hasan et al. (2016)** presents several significant findings regarding the use of bagasse ash in the remediation of expansive soils, particularly in the context of road construction. The study found that the addition of bagasse ash, when combined with lime, resulted in a notable increase in the unconfined compressive strength (UCS) of expansive soils. The UCS of bagasse ash-lime treated soil was comparable to that of lime-treated soil alone, indicating that bagasse ash can effectively enhance soil strength while also reducing the cost associated with lime usage.The incorporation of bagasse ash significantly reduced the shrink-swell capacity of expansive soils. This is crucial as expansive soils can cause substantial damage to road pavements due to their volume changes with moisture content.

- **Yasir et al. (2023):** provided a comprehensive evaluation of the chemical properties of sawdust ash and its impact on the geotechnical and mechanical properties of both stabilized and non-stabilized soils. This included a detailed analysis of how different percentages of SDA influenced soil characteristics. The addition of SDA resulted in a notable reduction in the liquid limit (LL) from 62% to 52% as the SDA content increased from 0% to 10%. This reduction indicates a decrease in the soil's plasticity, which is beneficial for mitigating compressibility and swelling characteristics. The plasticity index also decreased significantly from 35% to 16% with the same increase in SDA content, demonstrating improved soil stability. The study found a consistent increase in CBR values with higher percentages of SDA, reaching a peak of 14.4% when 6% SDA was used. This suggests that sawdust ash effectively enhances the load-bearing capacity of expansive soils, making it a viable alternative to traditional stabilizers like cement and lime. The research indicated that as the proportion of SDA increased, there was a concurrent rise in maximum dry density and a reduction in optimum moisture content. The highest recorded MDD was 2269 kg/m^3 at 6% SDA, which further supports the effectiveness of SDA in soil stabilization.

2.2 Summary:

Overall, the literatures demonstrate the viability of SDA, WHA, RHA, SBA & CHA as a cost-effective, environmentally sustainable solution for stabilizing expansive soils, reducing dependency on conventional stabilizers, and mitigating waste disposal challenges. This research reviews the role of RHA, CHA, SBA, WHA & SDA in improving geotechnical properties, making it suitable for enhancing the properties of expansive soils.

2.3 Objective of the study:

The paper studies the effect of different agricultural wastes on the geotechnical properties of expansive soil and the practical viability of their use in soil enhancement. The paper draws out the advantages & disadvantages of such agricultural wastes.

CHAPTER 3
AGRICULTURAL WASTES FOR SOIL STABILIZATION

3.1 Introduction:

This chapter discusses the use of five agricultural wastes materials namely Rice Husk Ash (RHA), Sugarcane Bagasse Ash (SBA), Coffee Husk Ash (CHA), Wheat Husk Ash (WHA) & Sawdust Ash (SDA) and their effects on stabilizing expansive soils.

3.1.1 Expansive Soil:

Expansive soil, is a type of clay-rich soil that undergoes significant volume changes in response to moisture variations. It swells when wet and shrinks when dry, posing serious challenges to construction and infrastructure development. The primary constituents of expansive soils are clay minerals, such as montmorillonite, illite, and kaolinite. Montmorillonite is the most active mineral, capable of absorbing large amounts of water and exhibiting extreme swelling behavior. The key characteristics of expansive soils include a high plasticity index, high compressibility, high shrink-swell potential, low permeability, low bearing strength and the development of deep cracks during dry periods. These soils also exhibit significant variability in strength, becoming weaker when wet and stronger when dry. The combination of these traits makes expansive soils particularly challenging for soil engineering. They can cause structural damage, road distress, and foundation failures. For example, swelling soil can exert upward pressure on structures, leading to uneven settlement and cracking in buildings and pavements. Roads and highways built on expansive soil often experience heaving and surface irregularities, compromising safety and durability.

Fig 3.1 Expansive Soil

Additionally,the low permeability of these soils leads to drainage issues, which further exacerbate swelling and associated structural problems.

To mitigate the challenges posed by expansive soils, various strategies can be employed. Soil stabilization techniques, such as lime or cement treatment, are commonly used to reduce plasticity and improve strength. Eco-friendly alternatives, such as fly ash or sawdust ash, can also be effective. Proper drainage systems are essential to manage water infiltration and prevent excessive swelling. Maintaining consistent moisture levels around structures through landscaping, moisture barriers, or controlled watering is also crucial. Expansive soils present significant risks in soil engineering due to their unpredictable behavior, but understanding their composition and characteristics allows for effective mitigation. By combining material treatments and engineering solutions, it is possible to address the challenges of expansive soils and ensure the safety and durability of infrastructure.

3.1.2 Coffee Husk Ash (CHA):

Coffee husk ash (CHA) is an agricultural by-product derived from the combustion of coffee husks, a residue generated during coffee processing. The husks are the outer coverings of coffee beans, typically removed during the milling process. Due to the high global coffee production, significant amounts of coffee husk are generated annually, leading to challenges in waste management. Burning the husks produces ash rich in pozzolanic materials, making CHA a potential resource in various industrial and environmental applications.

CHA has been increasingly investigated for use in stabilizing expansive soils, which undergo significant volumetric changes with moisture variation. When mixed with problematic soils, CHA enhances their strength, reduces plasticity, and limits swelling and shrinkage potential. This has proven particularly useful in infrastructure projects such as road construction, where expansive soils are common.

Fig 3.2: Coffee husk

3.1.3 Rice Husk Ash (RHA):

Rice husk ash (RHA) is a by-product obtained from the combustion of rice husks, the protective outer covering of rice grains. Globally, rice is a staple crop, and its milling generates significant quantities of husks, which are often treated as waste. Burning rice husks under controlled conditions produces RHA, a material rich in silica and other pozzolanic compounds. Its unique chemical properties and abundance make RHA a versatile material in various industrial, environmental, and agricultural applications.

RHA has proven effective in stabilizing expansive and problematic soils. It improves the soil's physical and mechanical properties by reducing its plasticity index, increasing compressive strength, and minimizing swelling potential. This makes it particularly valuable in geotechnical applications.

Fig 3.3: Rice husk

3.1.4 Sugarcane Bagasse Ash (BA):

Sugarcane Bagasse ash (BA) is a by-product of the combustion of sugarcane bagasse, the fibrous residue left after extracting juice from sugarcane. Sugar industries produce large quantities of bagasse ash, which poses significant disposal challenges. However, the ash is rich in silica and other pozzolanic compounds, making it a promising material for various applications, including soil stabilization. In geotechnical engineering, SBA has gained attention as a sustainable and cost-effective stabilizing agent for improving the properties of expansive and problematic soils. The high silica content contributes to the pozzolanic behavior of SBA, allowing it to react with calcium hydroxide to form cementitious compounds. This chemical reaction enhances the engineering properties of soils, making SBA a viable material for stabilization.

Expansive soils such as those containing montmorillonite exhibit significant volumetric changes with moisture variations. Adding SBA improves their load-bearing capacity and reduces settlement issues, making them suitable for road subgrades and foundations.

Fig 3.4: Sugarcane Bagasse

3.1.5 Wheat Husk Ash (WHA):

WHA has a good pozzolanic property. It is the staple food produced in large quantity for living and non-living beings. Its by-product is often found in the fields because waste is burned by the farmers after extracting grains. In this research, the effect of WHA on the soil is studied. Wheat husk is taken from the agriculture fields and burned at 600°C to convert into fine ash yielding high amount of silica & pozzolanic properties which helps in enhancement of expansive soil. Wheat husk ash, basically a waste material, is produced by burning crops waste while processing wheat from paddy. About 20 – 22% wheat husk is generated from paddy and about 25% of this total husk become ash when burn. It is non – plastic in nature& its properties also varied depending on its burning temperature.

Fig 3.5 Wheat husk

3.1.6 Sawdust Ash (SDA):

Sawdust ash, a byproduct of burning sawdust, has emerged as a sustainable and cost-effective material for soil stabilization. Soil stabilization improves the engineering properties of soil, making it more suitable for construction and agricultural purposes. The use of sawdust ash aligns with environmentally friendly practices by repurposing waste materials and reducing dependency on conventional stabilizers like cement or lime. Sawdust ash primarily contains silica, calcium oxide, and trace amounts of other minerals. Its chemical composition varies depending on the type of wood burned and combustion conditions. The presence of calcium oxide and silica makes it reactive with soil, enhancing its stabilizing properties. When mixed with soil, sawdust ash interacts chemically with water and the soil particles. The calcium and silica compounds contribute to pozzolanic reactions, forming cementitious products like calcium silicate hydrate (C-S-H). These products bind soil particles together, improving properties.

Fig 3.6 Sawdust

CHAPTER 4

EFFECT ON GEOTECHNICAL PROPERTIES OF EXPANSIVE SOILS

4.1 Introduction:

The chapter discusses the effect of agricultural admixtures on the geotechnical properties of expansive soils.

4.1.1 Rice Husk Ash (RHA):

4.1.1.1 Atterberg's Limits:

The Atterberg Limits are important parameters which determine the amount of water needed to transform the soil's consistency from one state to another & affects the plasticity characteristics. Based on test results, the decrease in the soil's LL and PI were observed at the increasing amount of added RHA. This is due to the reduction of clay particles by rearrangement & repalcemement of clay minerals which mainly contains Montmorillonite, Illite , and Kaolinite that are responsible for the clay's high plasticity. Through the introduction of RHA, a non-plastic material, the Atterberg limits of soil mixture were improved.

4.1.1.2 Compaction Characteristics:

The moisture-density relationship is an important property which is generally associated with soil compaction - a common practice in improving the strength characteristics and the overall stability of the soil. Soil-RHA mixtures experienced a decrease in the maximum dry density and an increase in the optimum moisture content. The decrease in the MDD can be attributed to the presence of RHA, which has a significantly low specific gravity. The high number of voids present in the RHA contributed to the reduction of the soil's MDD. The increase in the OMC is due to the increased porosity of soil mixtures with RHA. A significant number of voids are present in RHA which increases the capacity of water a sample can intake. In turn, the increase of the OMC indicates that more water is needed to effectively compact the soil.

4.1.1.3 Unconfined Compressive Stress (UCS):

The unconfined compressive strength test is a widely performed test to quickly obtain the soil's unconfined compressive strength, (q_u), a strength parameter of the soil which does not consider confining pressure. It can be observed the soil's UCS decreases at the increasing amount of RHA added. Due to the introduction of RHA, a non-cohesive material, the decrease in the soil's UCS was observed. The presence of RHA prevented the soil's strength to develop over time. Though RHA contains pozzolanic property, its content was not enough to produce cementitious mixture preventing the soil-RHA mixture from developing a strong chemical bond.

4.1.1.4 California Bearing Ratio (CBR):

It can be seen that, there is an enhancement in CBR values with increasing content of RHA up to 12% of RHA and after that a decrease is observed. The rise of CBR with addition of RHA from 0-12% may be attributable to the high amount of silicates causing pozzolanic reactions within soil leading to the formation of cementious material within the soil mass causing an increase in strength characteristics. The later on decrease in CBR indicates that surplus of silica does not react with soil particles and negatively influence the binding of the particles.

4.1.2 Coffee Husk Ash (CHA):

4.1.2.1 Atterberg's Limits:

The improvement of CHA treated soil could be attributed to the chemical reaction between CHA and the soil. This includes the replacement of naturally occuring cations on clay surfaces with Ca2+ cations. The increased Ca2+ concentration in pore solution also causes flocculation and agglomeration of clay particles. This interplay reduces the water absorption of the soil particles, making them less plastic. The reduction in the plasticity of the soil indicates that it became less sensitive to water, leading to less expansive and better compactable. Consequently, the treated soil gains stability with respect to the deformations due to the seasonal variations of water content. In addition, the decrease in the PI of treated samples indicates an improvement in the workability of the soil, and the lower the PI, the smaller the swelling potential.

4.1.2.2 Compaction Characteristics:

It can be seen that the MDD increased and the OMC decreased as the amount of CHA increases. The reduction in the OMC of CHA treated samples could be attributed to the amount of water needed to reach an optimum state is lower for CHA-treated samples compared to untreated samples; this could be due to the lower affinity of CHA particles for water.

4.1.2.3 Unconfined Compressive Strength:

The addition of CHA to soil samples shows considerable improvement in UCS. As the percentage of CHA increases from 0 to 15% the UCS value increases upto a maximum CHA content of 15%. The decrease in the UCS after 15% CHA content may be due to excess CHA that was not mobilized in the reaction, which consequently occupies spaces within the sample and therefore reducing bond in the soil–CHA mixtures. The UCS of soil treated with 15% CHA increase by more than double compared to that of the untreated soil. The strength gain of CHA treated samples is primarily caused by the formation of cementation material by pozzolanic reactions within soil mass. In addition, this improvement could be due to better interlocking of soil-CHA particles consequently yielding a higher load. For further addition the UCS values decreases.

4.1.2.4 California Bearing Ratio (CBR):

After stabilization, it can be concluded that the CBR value increases as the percentage of CHA increases. It is observed that the stabilization of soil with CHA improves the CBR value, which is an indicator for the load carrying capacity improvement. The addition of CHA showed a significant improvement in both soaked and un-soaked conditions. With a concentration of 20% CHA, the soaked CBR value increased by around 205% and the un-soaked CBR value increased by around 28%. From these results, it can be observed that CHA is more effective for soaked condition. The improvement can be attributed to the reaction between the soil and CHA, forming cementitious material. The formation of these cementitious material bounds the particles together, by covering the soil grain and filling the inter-aggregate pores. The result indicates that the soil treated with CHA performs better as a sub-grade material; which requires lower thickness of the pavement structure compared to the untreated soil.

4.1.2.5 Compressibility:

It can be seen that the initial void ratio of samples decreased as the CHA concentration increases for the same loading and saturation conditions. Further, as the load increases, continued reduction in void ratio is observed for all samples. The reduced void ratio of CHA treated samples could be attributed to the closer of voids by CHA constituents and due to joined particles by the formation of cementitious compounds. The main reason behind performing odometer test is to examine the effect CHA on the compression, recompression and swelling characteristics of expansive soil as applied pressure changes. The compression index (Cc), recompression index

(Cr) and swell index (Cs) values of the soil-CHA mixture were determined from consolidation curves. The addition of CHA leads to a significant change in these curves for similar loading conditions. The values of Cc, Cr and Cs decreased as the added percentage of CHA increases. The reason behind the decrement in consolidation parameters (Cc, Cs and Cr) may be due to the addition of CHA, filling the inter-aggregate pores and resulting in reduced compressibility characteristics. The decrement in Cc values of treated samples shows a better tendency of treated samples to resist the external load in comparison to the untreated samples.

The coefficient of compressibility and volume change are determined respectively. The coefficient of volume compressibility (m_v) is defined as the volume change per unit increase in effective stress for a unit volume of soil. The test shows m_v decreases as the pressure increases. Both coefficients of compressibility and volume change of CHA treated samples are decreased as the effective stress and concentration of CHA increases. This might be attributed to a reduction in volume of voids due to rearrangement of the soil particles and decrease in plasticity behavior as CHA increases, thus, making the soil particles more compact and less compressible.

4.1.3.6 Free Swell Index (FSI) & Volumetric Shrinkage (V_s):

Soil swelling is an expansion in volume that causes significant problems leading to serious damage and economic consequences in construction sectors, mainly in road construction. The FSI was determined using Equation 4.1.

FSI (%) = $(V_f - V_i) / V_i * 100$ --Equation 4.1

The volumetric shrinkage (V_s) is the decrease in volume of a soil mass when the water content is reduced from a given percentage to the shrinkage limit and it is expressed as percentage of dry volume of the soil mass. The VS of soil and soil-CHA mixtures is determined using Equation 4.2.

V_s (%) = $(V_w - V_d) / V_d * 100$--Equation 4.2

The addition of CHA on soil samples shows significant change on both swelling capacity and volumetric shrinkage. The FSI value decreases almost by half by adding 10% CHA. The V_s value decreases from 143% to 84% by adding 20% CHA, which indicates about a two-fold reduction compared to the soil.

4.1.3 Sawdust Ash (SA):

4.1.3.1 Atterberg's Limits:

The findings presented reveal a notable reduction in the liquid limit, decreasing from 62% to 52% as the proportion of SDA increased from 0% to 10%. This decline can be attributed to the reduced water affinity exhibited by SDA, resulting in diminished soil plasticity. Consequently, the observed decrease in the liquid limit signifies a substantial mitigation of the compressibility and swelling characteristics of the soil. The plasticity index reduced from 35% to 16% when SDA was increased from 0% to 10%.

4.1.3.2 Compaction Characteristics:

Maximum dry density decreases with the increase in SDA content 23.65% to 14.3% which may be due to low specific gravity of SDA content. The MDD value decreases virtually on every increase of SDA content added to the natural soil. The optimum moisture content increases with increase in the SDA content 9.7% to17.2%. This phenomenon could be attributed to the addition of SDA with lower specific gravity than the one of the soil used. On the other hand, the reason behind the increase in OMC with growth in the different proportion of sawdust and decrease in the proportion of the soil in the mix is that the SDA causes absorption of a high amount of water which takes away the clay particles, thus more water is needed to occupy the place for the clay particles.

4.1.3.3 California Bearing Ratio (CBR):

Sawdust has shown a significant increase in the CBR value of expansive soil, especially on the unsoaked soil samples. The peak unsoaked and soaked CBR values obtained at 56 blows compaction are 20.53%, and 7.16%. It was observed that all the CBR values for the soaked samples are relatively smaller than the unsoaked samples, this is attributed to the presence of water in the saturated samples that do not have shear strength for engineering purposes. Based on the results obtained from the samples, the CBR after substituting the soil with 3% sawdust, at the same compaction effort (56 blows), the soaked CBR value increased to 7.16% from previous 4%.

4.1.3.4 Unconfined Compressive Strength:

There is an increase in UCS value with increase in SDA addition due to pozzolanic reactions. It shows that addition of SDA improved the soft clayey soil by reducing such coefficients especially compression index with no noticeable effect in swelling index. The growth could be attributed to the formation of cementitious compounds between the calcium hydroxide present in the soil and the pozzolans present in the sawdust.

A slight decrease in the UCS values at the composition of 5% SD and 95% soil, and 7% SD and 93% soil may be due to the excess SDA introduced to the soil, hence forming weak bonds between the soil and the cementitious compounds formed. Moreover, the sudden decrease may be due to decrement in the content of silt and clay present in the soil which reduces the cohesion of the sample**.**

4.1.4. Sugarcane Bagasse Ash (SBA):

4.1.4.1 Atterberg's Limits:

The LL & PL decreased with the gradual increase of additive content. The decrease in plasticity index indicates an improvement in the workability of the soil.

- When black cotton soil treated with 5% bagasse ash the plasticity index decreased from a natural soil value of 41% to 39.7% for stabilized sample.
- While the addition of 10%bagasse ash the plasticity index decreased from a natural soil value of 41% to 11.33% for stabilized soil sample
- For similar type addition of 15% bagasse ash the plasticity index decreased from the natural soil value of 41% to 10.7% for the stabilized soil sample.
- While the addition of 20% of bagasse ash the plasticity index decreased from the natural soil value of 41% to 4.7% for stabilized soil sample.

Significant reduction in plasticity associated with addition of bagasse ash and also this effect could be attributed to the combined action of partial replacement of plastic soil particles with non-plastic particles of bagasse ash & lower water affinity of SDA compared to clay minerals. These led to flocculation and agglomeration of the clay particles which in turned reduced the plasticity of the treated soil.

4.1.4.2 Compaction Characteristics:

The compaction tests were performed at moisture content 36.5% (the optimum moisture content of untreated soil) for all various combinations of soil & bagasse ash. Results indicate that with an increase in the admixture content, the dry density slightly decreases. As expected, the lower specific gravity of bagasse ash may be the reason of the reduction in dry density, in comparison to the compacted natural soil.

- For the addition of 5% bagasse ash the maximum dry density decreases from the natural soil sample 2.19g/cm3 to 1.77g/cm3 for stabilized soil sample.
- While the addition of 10% bagasse ash the maximum dry density decreases from the natural soil sample 2.19g/cm3 to 1.66g/cm3 for the stabilized soil sample.
- For the addition of 15% bagasse ash the maximum dry density decreases from the natural soil sample 2.19g/cm3 to 1.59h/cm3 for the stabilized soil sample.

The effects of bagasse ash on the optimum moisture content for the soil-bagasse ash mixture for stabilized soil samples are as follows:

- For the addition of 5% bagasse ash the optimum moisture content increases from the natural soil sample 14.8% to 18% for stabilized soil sample.
- For the addition of 10% bagasse ash the optimum moisture content increases from the natural soil sample 14.8% to 20% for stabilized soil sample.
- For the addition of 15% bagasse ash the optimum moisture content increases from the natural soil sample 14.8% to 23% for stabilized soil sample.
- For the addition of 20% bagasse ash the optimum moisture content increases from the natural soil sample 14.8% to 25% for stabilized soil sample

4.1.4.3 California Bearing Ratio (CBR):

Results also show that the strength enhancement of expansive soil treated with bagasse ash. The normal CBR value increases for all mixes from a natural soil value of 0.91% to 2.45%, respectively. The increase in CBR value could be attributed to the progressive cementation of soil-SBA as a result of hydration and the pozzolanic reaction. The improvements in the CBR values of samples satisfy the minimum requirements that qualify them as road construction materials and showed that the soil sample was very effectively improvements in the CBR values of samples satisfy the minimum requirements that qualify them as road construction materials and showed that the soil stabilized with bagasse ash.

4.1.4.4 Unconfined Compressive Strength (UCS):

The UCS was conducted with a mixture of soil, SBA & lime. It was be seen that the UCS increased when the bagasse ash was 6%, 10%, 18% and 25%, respectively. The UCS of treated soil with 25% of SBA was 3.2 times greater than the untreated sample. The increase in UCS can be related to the hydration and pozzolanic reaction between soil, bagasse ash and lime forming CSH and CAH, thus fills the void space, and binds the particles together improving the strength of the mass.

4.1.4.5 Free Swell Index (FSI):

The FSI values slightly decrease as the percentage of bagasse ash increases. The minimum FSI belongs to the samples with 18.75% SBA-6.25% Lime. The FSI values decreased as the percentage of bagasse ash and lime increased. Combination of bagasse ash with lime was more effective in reducing the FSI than the lime only. This is because of bagasse ash can provide an adequate array of divalent and trivalent cations (Ca^{2+}, Al^{3+}, Fe^{3+}, etc) which have lower water affinity & that increase cation exchange and flocculation. In addition, SBA non-expansive material replaces the expansive clay contributing to a notable reduction in FSI. Addition of bagasse ash to expansive soil decreases its swelling because bagasse ash is non plastic material. The free swell index (FSI) decreases as percentage of bagasse ash increases. The use of bagasse ash with lime is more effective than lime only in curtailing the swelling tendency of soil.

4.1.5 Wheat Straw Ash (WHA):

4.1.5.1 Atterberg's Limits:

The addition of wheat husk ash influences the plasticity of the soil. As WHA is introduced, the plasticity index tends to decrease, indicating a reduction in the soil's plasticity. The optimal enhancement was observed at a 7% addition of WHA, which improved the soil's plasticity and made it more suitable This suggests that the soil becomes less plastic and more stable with the incorporation of WHA, indicating improved workability which is beneficial for construction purposes. This could be attributed to the combined action of partial replacement of plastic soil particles with non-plastic particles of bagasse ash & lower water affinity of SDA compared to clay minerals.

4.1.5.2 Compaction Characteristics:

The compaction characteristics of the soil are affected by the addition of WHA. The maximum dry density (MDD) of the soil generally decreases with increasing percentages of wheat husk ash. The study found that the optimal percentage for compaction was around 7%, which effectively enhanced the soil's density and reduced its void ratio. This is likely due to the lightweight nature of the ash compared to traditional soil particles. Conversely, the optimum moisture content (OMC) tends to increase, indicating that more water is required to achieve maximum compaction as WHA is added.

4.1.5.3 California Bearing Ratio (CBR):

The CBR values improved with the addition of wheat husk ash up to a certain percentage. The study indicated that the CBR value increased with the addition of WHA, peaking at a 7% enhancement level. This increase in CBR value suggests that the addition of WHA significantly improves the soil's load-bearing capacity, making it more suitable for construction applications. This could be due to cementious material formed due to hydration & pozzolanic reactions due to WHA. However, beyond the optimal point, the CBR value began to decline, indicating the importance of precise dosage in soil stabilization.

4.1.5.4 Unconfined Compressive Strength (UCS):

The UCS of the soil also shows an increase with the addition of wheat husk ash, particularly at specific percentages (e.g., 5% to 7%). The UCS test results demonstrated a notable increase in the strength of the soil with the addition of WHA. The maximum strength was achieved at a 7% addition of WHA, indicating significant enhancement of the soil's structural integrity. This increase in strength suggests that WHA acts as a stabilizing agent, enhancing the overall strength of the soil, which is essential for supporting structures.

CHAPTER 5
RESULTS

5.1 Introduction:

This section discusses the effect which each of the agricultural waste had on each of the geotechnical properties of an expansive soil.

5.1.1 Effect of each agricultural additive on the geotechnical properties of expansive soil:

1. **Coffee Husk Ash:** Using coffee husk ash results in improved geotechnical properties, including a high California Bearing Ratio (CBR) value, reduced liquid limit and plasticity index, and lowered compressibility parameters (C, Cc, and Cr). It also reduces swelling (Free Swelling Index or FSI) and volumetric changes while enhancing the unconfined compressive strength (UCS). Additionally, it increases the Maximum Dry Density (MDD) and decreases the Optimum Moisture Content (OMC).

2. **Rice Husk Ash**: The addition of rice husk ash increases the CBR value but decreases UCS. It reduces the liquid limit and plasticity of the soil. Moreover, it increases the OMC while decreasing the MDD.

3. **Sawdust Ash:** Sawdust ash improves the CBR value and UCS of soils, lowers liquid limit and plasticity index, and increases OMC. It also reduces MDD and enhances compressibility and swelling properties.

4. **Sugarcane Bagasse Ash:** This agricultural waste increases the CBR and UCS values, reduces the plasticity index, and significantly lowers swelling potential (FSI). It also decreases both MDD and OMC.

5. **Wheat Husk Ash:** Wheat husk ash contributes to reduced plasticity index and shrinkage limit, improves UCS and CBR, and lowers MDD and OMC.

5.1.2 Advantages & Disadvantages of Agricultural Wastes:

Advantages:

- **Sustainability:** Agricultural waste is a renewable resource that can be utilized for soil stabilization, promoting sustainable practices in construction and reducing reliance on non-renewable materials
- **Cost-Effectiveness:** The use of agricultural waste is often more economical compared to traditional soil stabilization methods. These materials are locally available and can significantly lower construction costs.
- **Environmental Benefits:** Utilizing agricultural waste helps in waste management by reducing the amount of waste that would otherwise contribute to environmental pollution. This practice can mitigate air and water pollution and promote a healthier ecosystem.
- **Improvement in Soil Properties:** Agricultural waste additives have been shown to enhance various geotechnical properties of expansive soils, such as increasing the California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), and reducing plasticity index (PI).This leads to improved bearing capacity and reduced permeability of the soil .
- **Biodegradability:** Agricultural waste materials are biodegradable, making them an eco-friendly option for soil stabilization. This characteristic contributes to the sustainability of construction practices.

Disadvantages:

- **Durability Concerns:** Natural fibers from agricultural waste are prone to decay and decomposition, which may affect the long-term durability of the stabilized soil. Further studies are needed to assess the durability of these materials in various environmental conditions.
- **Variability in Effectiveness:** The effectiveness of agricultural waste additives can vary significantly based on the type of waste used, the soil type, and the specific testing methods employed. This variability can lead to inconsistent results in soil stabilization efforts.
- **Limited Research:** There is a lack of comprehensive studies on the advantages and disadvantages of various agricultural waste types. Some materials have not been extensively researched, which may limit their application in soil stabilization.
- **Potential for Health Risks:** While agricultural waste can be beneficial, improper handling and disposal can lead to health problems for humans and animals, particularly if the waste is

contaminated.

Therefore, while the use of agricultural waste for soil stabilization offers numerous benefits, it is essential to consider the potential drawbacks and conduct further research to optimize its application in geotechnical engineering.

CHAPTER 6

CONCLUSION

6.1 Introduction:

The agricultural wastes additives to expansive soil add a positive effect on nearly each of geotechnical properties of soil. A brief conclusion is drawn in this chapter based on each of the agricultural waste additive focusing on the geotechnical properties.

6.1.2 Rice husk ash (RHA):

I. A significant decrease of about 27.23% and 33.87% in the soil's Liquid Limit and Plasticity Index respectively were observed when RHA was added in the expansive soil. This classifies RHA as effective in terms of improving the soil's Atterberg limits.

II. A decrease of as much as 230 kg/m3 in the soil's maximum dry density (MDD) and an increase of 47.41% in the soil's optimum moisture content (OMC) were observed. This classifies RHA as ineffective in terms of improving the soil's Moisture-Density relationship.

III. A decrease of as much as 194.2 kPa in the soil's unconfined compressive strength (UCS) was observed as the amount of added RHA increases. This classifies RHA as ineffective in terms of improving the soil's Unconfined Compressive Strength.

IV. The addition of RHA reduced the expansion index value of the soil of as low as 0 (no expansion). This classifies RHA as effective in improving the expansion index of the soil.

V. There is an enhancement in CBR values up to 12% dosage of RHA and after that a decrease is observed. The rise of unsoaked CBR with addition of RHA from 0-24% may be attributable to the calcium silicates formation following a soil silica reaction. The later on decrease in the unsoaked CBR indicates that surplus of silica does not react with soil particles and negatively influence the binding of the particles.

6.1.2 Coffee husk ash (CHA):

I. The obtained result reveals that the addition of CHA reduces the plasticity of the soil. The LL and PI decreased as the amount of CHA increased (reduction in LL from 93% to 71%, and PI from 52% to 22%, respectively, were observed for addition of 20% CHA). Since PI is a good indicator of the swelling behavior of soils, the reduced PI helped to decrease the swell potential of treated soil.

II. The results of swell-shrink tests indicated that CHA is effective in controlling the swell potential of an expansive soil.

III. From the compaction test results, the MDD of CHA treated samples increased and OMC decreased as the amount of CHA increased. The MDD of lime-treated samples slightly decreased and the OMC increased as the lime content increased. In contrast, the addition of CHA on lime treated soil, slightly increases the MDD and decreases the OMC.

IV. The addition of CHA improved the bearing capacity of the BC soil. CBR-values of the BC soil increased with the increase in CHA content from 5% to 20%. Both lime and lime-CHA treated samples also shows increment in CBR value as the amount of additives increases.

V. The unconfined compressive strength (UCS) of samples treated with CHA increased with the increase in CHA content from 5% to 15%. Above 15% CHA (eg. 20%), decrease in the UCS value was observed. The addition of lime and lime-CHA together increased the UCS and the strength gain values of the BC soils. The strength gain of samples treated with the mixture of lime and CHA was higher compared to the addition of lime and CHA separately.

6.1.3 Sugarcane Bagasse ash (SBA):

I. The Liquid limit is slightly decreased for the black cotton soil due to the addition of different contents of bagasse ash. The plasticity index slightly reduced with an increase in bagasse ash content has also an insignificant effect on the plasticity of the expansive soil.

II. Addition of bagasse ash to expansive soil decreases its swelling, because bagasse ash is non plastic material. The free swell index (FSI) decreases as percentage of bagasse ash increases. The use of bagasse ash with lime is more effective than lime only in curtailing the swelling tendency of soil. The swelling property reduces with the increase in the percentage of BA and with increasing curing period. The swelling index found to be zero for 10 % addition of SSA.

III. The CBR value also increases with the increase in the curing period. The maximum CBR value is obtained for 10 % addition of BA and decreases with further increase in the percentage of BA.

IV. With the increase in the curing period, the UCS value increases. The increase of the UCS value is more significant for 10 % addition of BA. On treatment with bagasse ash, plastic nature of soil decreases and contributes to gain in strength. Bagasse ash effectively stabilized BC soil and has led to tremendous increase in compressive strength of soil.

V. The maximum dry density (MDD) decreased & optimum moisture content (OMC) increased whiles the increment of bagasse ash content.

6.1.4 Wheat husk ash (WHA):

I. WHA significantly affects the plasticity index of black cotton soil. The optimal enhancement was observed at a 7% addition of WHA, which improved the soil's plasticity and made it more suitable for embankment applications. The results indicated that the plasticity index of untreated black cotton soil was high, but the addition of WHA reduced this index, indicating improved workability and stability of the soil.

II. The maximum dry density (MDD) of the soil generally decreases with increasing percentages of wheat husk ash & the optimum moisture content (OMC) tends to increase, indicating that more water is required to achieve maximum compaction as WHA is added. The study found that the optimal percentage for compaction was around 7%, which effectively enhanced the soil's density and reduced its void ratio.

III. The study indicated that the CBR value increased with the addition of WHA, peaking at a 7% enhancement level and then further decreases. This decline is basically due to certain increase and decrease in OMC which is responsible for decrease in CBR value.

IV. The compressive strength increases slowly with the addition of ashes and then maximum strength is at 7% addition. The maximum strength was achieved at a 7% addition of WHA, indicating significant enhancement of the soil's structural integrity.

6.1.5 Sawdust ash (SDA):

I. Reduction in the plasticity index as the proportion of sawdust ash (SDA) in the soil increased. Notably, the optimum plasticity index of 16% was achieved when 10% SDA was incorporated. Similarly, the shrinkage limit exhibited a decreasing trend with the addition of higher percentages of SDA, reaching its lowest point of 2% when 10% SDA was employed.

II. The addition of Saw dust ash to the soil in order to treat it resulted to increase the OMC and decreases the MDD. This phenomenon could be attributed to the addition of SD with lower specific gravity than the one of the soils. On the other hand, the reason behind the increase in OMC with growth in the different proportion of sawdust and decrease in the proportion of the soil in the mix is that the SD causes absorption of a high amount of water which takes away the clay particles, thus more water is needed to occupy the place for the clay particles.

III. The CBR value increases from 6.45 to 8.8% then suddenly reduce to 1.4% at 6%. The CBR achieved its maximum strength at 6% SDA. Therefore 6% is the Optimum value for stabilization. It was observed that all the CBR values for the soaked samples are relatively smaller than the unsoaked samples this is attributed to the presence of water in the saturated samples. The CBR value increases from 6.45 to 8.8% then suddenly reduce to 1.4% at 6%. The increase in CBR value may be as a result of pozzolanic effect of SDA while the decrease may be due to the low strength exhibited by the SDA.

IV. The unconfined compressive strength (UCS) and shear strength increased by 1.4 times one of the un stabilized soil. The increase occurred after the soil was replaced with the sawdust at 3% and 5% SD of the dry unit weight of the soil, and then decreases after the soil was replaced with 7% SD. A slight decrease in the UCS values at the composition of 5% SD and 95% soil, and 7% SD and 93% soil may be due to the excess SD introduced to the soil, hence forming weak bonds between the soil and the cementitious compounds formed.

6.2 Summary:

This study has revealed many untouched possibilities of using agricultural waste for soil stabilization purposes. A substantial amount of waste is being generated globally and polluting the environment and its ecosystem causing health problems for humans. Indeed, on the other hand, it could be a useful resource in terms of engineering per spectives, resource utilization aspects, and economic benefits. Moreover, this review article explored the enormous importance of agricultural plant-based waste additives for soil stabilization and concluded with the following points. In this review, the testing techniques and test results for agricultural waste additives were well organized, matriculated, and accurately addressed from different researchers' perspectives. It is believed that agricultural waste additives are economically viable, locally available, bio-degradable, and eco-friendly. The sustainability practice was thoroughly assessed and discussed in response to utilizing the waste material for soil stabilization. It examined the significant improvement in CBR, UCS, PI, shear strength, and other important engineering properties in the treated soil, however, the results varied from one additive to another due to the soil type and employed testing mechanisms.

The expansive soil stabilized with agricultural waste additives has shown significant improvements in terms of strength development, compressibility, and reduction in cracking. However, recommendations would be given for the careful selection of plant resources, and microstructural and mineralogical formations in soils in future studies. Natural additives are prone to decay and decomposition hence, the article would suggest further study on durability of additives in terms of applicability and current construction practice.

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