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Strength and Compressibility Behaviours of Expansive Soil Treated with Coffee Husk Ash and Xanthan Gum

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Abstract

The strength of the sub-grade, the caliber of the subbase and base course, the surrounding conditions, and the characteries of the soil utilized are some of the variables that might impact how long a road lasts. Because expansive soil swells and shrinks in response to variation in moisture content, roads constructed on it are especially vulnerable to early deterioration. Buildings with black cotton soils have experienced different settlement due to regular alternating swelling and shrinking. Adding stabilizers to poor soil is the most common way to improve its quality. The utilization of waste components to enhance the expanding soil's characteristics is a recent discovery in soil stabilization. In this article, consequences of coffee husk ash with xanthan gum on soil improvement are examined. In this work, xanthan gum and ash from coffee husks were employed to Replace some of the black cotton soil. The percentages of xanthan gum were 0.50% while the amounts of coffee husk ash were 2%, 4%, 6%, 8%, 10 and 10%. The behaviors of soil specimens were measured using the liquid limit (LL), compaction test, CBR test, specific gravity test, and plastic limit test (PLT).

Keywords: Black cotton soil, coffee husk ash, soil stabilization, CBR test, liquid limit, and xanthan gum

INTRODUCTION

Before using soil in any kind of construction process, it is crucial to understand its qualities and viability because soil is a nice and comfortable building material [4]. Behavior and retention the ground is necessary for every structure because it support loads from larger structures volcanic ash and magma refer to as regur. The word regur is derived from the word 'Reguda' from the Telugu language. These can be found in lava-covered areas and are utilized to grow cotton. are considered the primary component of soil used for black cotton in Telugu. which can be found in Karnataka, Telangana, Andhra Pradesh, and Tamil Nadu. Known as normal soil or tropical chernozems in most other parts of the world, black cotton soil is the third most common type of soil in India. Black cotton contributes approximately 25% of the soil in Andhra Pradesh and 15% of total soil in India due to its high moisture content. Black cotton soils are notorious for having occasional shrinkage and swelling issues. capacity and challenging to work with in projects involving civil engineering. One technique for stabilizing soil is mixing with stabilizing additives like cement and lime. Such materials include lime, fly ash, cement, rice husk ash, waste ceramic dust, nano silica, calcium carbide residue, microbial biopolymers,[3] and more additives used for soil stabilizations. Globally, alkali-activated binders have seen a significant surge in application in the past few years. Concrete and geotechnical applications frequently use alkali-activated

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binders. These binders were created using an amorphous alumina-silicate source. Materials such as metakaolin, fly ash, rice husk ash, petroleum fuel ash from palm oil, calcium carbide residue, and powdered granulated blast furnace slag are mixed with alkali solutions, which include alkali earth metals and typically sodium or potassium hydroxide. There are other ways to accomplish this as well. Cement and lime have been in high demand [8] expanding in the building sector, which drives up their price. These soils frequently contain over 60% clay, which dramatically boosts the soil swelling potential to get better unwanted qualities include soil swelling potential and shear strength stabilization is implemented Black cotton soils have often been exposed to alternating swelling shrinkage, which causes buildings to settle differently furthermore, the amount of water present has a considerable impact on its low bearing capacity. The most common soil in Odisha is red soil, which has significant concentrations of the mineral’s elite and kaolinite [5]. Mixed red and yellow soil is the next most common type of soil. Many districts occasionally have expansive soil that contains the mineral montmorillonite Building is therefore difficult. Some soil varieties can be chemically and physically stabilized to improve and strengthen the earth's natural qualities. Soil remediation involves the use of various wastes. current days to lessen soil settling and stabilize the soil. One of the most common and frequently problematic forms of soil in the world is expanding soil. Poor subgrade and expansive soil are more likely to expand and compress when exposed to moisture [7] The high concentration of montmorillonite minerals in clay is thought to be the reason for this characteristic. In arid and semi-arid areas, this kind of soil expands differently, which can be very troublesome for pavement projects. Pavements with clayey soil subgrade are especially sensitive to severe pavement degradation because of their low subgrade support values and moisture-induced volume fluctuations. In geotechnical engineering, expanding soils are a concern because they can occur on construction sites [2]. Because of their tendency to inflate and shrink, these soils are not appropriate for use in their original state. When expansive soils dry out, they become robust and hard, but as the moisture content rises, they swell and become softer the presence of the clay mineral montmorillonite, which shrinks during dry seasons and can absorb water during monsoons, is the primary cause of ground movement problems.

The significant swell shrink tendency of these soils results in unanticipated movement that severely damages above structures or splits pavements resting on them. The degree of pavement degradation and cracking drives up the cost of rehabilitation and repairs. Billions of dollars have been calculated as the price of the harm that expansive soils have brought to global civil engineering structures. Coffee husk is one by product of the coffee processing industry. Among the goods manufactured and sold most widely worldwide is coffee. Ethiopia is a producer of coffee. In a 5.32 ~ 109 m2 area, 3.93 ~ 108 kg of coffee were produced in 2017 and 2018. During the processing phase, between 30 and 50 percent of the mass of the coffee produced is squandered. This is a considerable quantity of agricultural waste. Problems with disposal and the environment may arise if this solid residue is not applicable. There are financial and environmental advantages to using this waste material properly [1]. There hasn't been much study done on using CHA to stabilize clay soils overall. Coffee husk ashes have only been used for the previous five years to stabilize the soil for black cotton soil for the past five years [6]. This study aims to investigate the impact of applying CHA, a leftover from industry and agriculture, on the geotechnical properties of clay soil. The physical (Atterberg limits and the typical Proctor compaction test) and mechanical (UCS and direct shear tests) [8]. Numerous geotechnical lab tests were used to evaluate the properties of the CHA–soil mixture. It is well known how CHA content affects clay soil and whether waste is used as a geomaterial for construction. For create new materials with distinctive features and better new products for a variety of uses, biopolymers have been added to soil mixes at a certain percentage in numerous geotechnical experiments conducted recently [8]. Because biopolymer is made from agricultural non-food crops that are always available, it is a carbon- neutral material that is permanently recognized as renewable.

For this study, expansive soil samples were collected and treated with varying proportions of coffee husk ash (CHA) and xanthan gum (XG) to investigate their effects on soil stabilization. The primary materials used in the study include expansive soil samples obtained from the study area, coffee husk ash sourced from local coffee processing units, and xanthan gum purchased from a commercial supplier.

Other materials such as distilled water for sample preparation and testing, and standard laboratory equipment including ovens, sieves, and molds were also used shown in table 1. The proportions of CHA and XG mixed with the soil samples were varied to determine their optimal ratios for improving the strength and compressibility behaviors of the expansive soil. The materials section provides a detailed account of the preparation process, including mixing procedures, curing conditions, and testing methods employed to assess the treated soil samples' engineering properties.

Table 1. characteristics of the soil in black cotton

Soil property	value
Gravel	0
Sand	5
Clay and silt	90
Specific gravity	48
Liquid limit	69
Plastic limit	72
Shrinkage limit	25
Plasticity index	45
Type of soil	Expansive soil
OMC	2.65
MDD	2.6
CBR Soaked Unsoaked	1.01.25
Unconfined compressive test	125.85kpa
Permeability soil	0.0092

BLACK COTTON SOIL

Expansive soil, sometimes referred to as vertosol (shrink-swell soils), or black cotton soil. The Latin word "Vert ere" which meaning to invert, is where the name "vertosol" comes from. Expansive soil is a type of clayey soil with high expansivity and shrinkage characteristics. In geotechnical terms, it poses specific challenges due to its behaviors in response to moisture changes. It is rich in clay minerals, particularly montmorillonite, which gives the soil its unique properties. The clay content can make it highly expansive and prone to swelling when wet. Although black cotton soil is rich and can sustain the growth of a variety of crops, its tendency to become extremely sticky when wet and hard when dry poses difficulties. This kind of soil can be found in arid climates, such as some portions of Africa, India, and the United States. It is often associated with the Deccan Plateau. Black cotton soil's expansive nature presents difficulties for building projects and can harm structures. By adding stabilizers or reinforcing components, the soil's engineering properties can be improved and its susceptibility to volume changes can be reduced.

Coffee Husk Ash

Coffee husk ash is a byproduct obtained from burning coffee husks, the outer layers of coffee beans. The coffee husk ash is produced by burning coffee husks in an unregulated manner. Following total combustion, the ash cooled for another 24 hours. Coffee husk ash waste collected from continental coffee private limited. it is located to the Duggirala mandal, Guntur district, Andhra Pradesh, India.

Xanthan gum

Xanthan gum collected from online organic grocery shopping near plot no 25, ground floor, kanaka Durga gazette officer's colony, Vijayawada, Andhra Pradesh. Xanthan gum, which is generally used as thickening agent in the food and pharmaceutical industries is used in this as a binding material. Xanthan gum is a chemical that may be made synthetically or through bacterial fermentation and functions as a thickening and gelling agent in food. The bacteria Xanthomonas campestris produces xanthan gum, a biopolymer glucuronic acid (C6H1007), Mannoses (C6H12O6) and glucoses (C6H12O6) make up the repeating composition of XG, a polysaccharide. Water viscosity is greatly increased by a modest amount of XG because to the hydrophilic water adsorption and after XG'S hydrogel production. For this reason, XG is frequently employed in the food, cosmetics, Pharmaceutical, agricultural and petroleum engineering industries as a viscosity thickening agent. A lot of people have been using XG for drilling muds, agricultural irrigation and dust management and Excavation slurries due to its viscous elastic rheology. XG has excellent potential for stabilizing and reinforcing soil from a geotechnical engineering standard point.

Sampling Techniques

The model approach utilized in this investigation was purposeful sampling, a non-probability method. Considering information that aids in determining the strength of the black cotton soil, this sample technique was recommended.

STUDY VARIABLES

Independent variable

The study independent variables were.

- Dosage of Coffee husk ash
- Dosage of Xanthan gum
- Plastic limit, MDD, OMC, LL and CBR.

Dependent variable

Impact of xanthan gum and coffee husk ash on expanding soil.

Sample Perpetration

The sample was produced utilizing the AASHTTO T87-86 procedure before processing and testing, which includes.

- Air and oven drying the samples;
- Getting ready uniform samples for testing such California Bearing Ratio, compaction, and Atterberg limits.
- Mixing manually soil, xanthan gum and coffee husk ash to get.

RESULT AND DISCUSSION

Untreated Expansive Soil's Engineering Properties

The specific gravity, the California bearing ratio, the limit test, and the compaction test were the tests that were used to determine the sieve analysis and the mechanical and physical features of the soil's Atterberg. This complied with AASHTO guidelines are presented in Table.2.

Table 2. Geotechnical properties of untreated expansive soil

S.N.	Property	Observed values
1	Classification	
	AASHTO (group index)	A-7-5
	USCS (group symbol)	CH
	USCS (group name)	High plastic clay
2	Specific gravity	2.3
3	Particle size analysis	
	Gravel content% (20 to 4.75mm)	0.525
	Sand content% (4.75 to 0.075mm)	5.35
	Silt and clay content % (below 0.075mm)	90.842
4	Atterberg's limits %	
	Liquid limit (LL)	80.15
	Plastic limit	36.55

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	Plasticity index	60.25
5	Proctor test	
	Optimum moisture content (OMC) %	30.50
	MDD (g/cm^3)	1.3
6	CBR value % soaked	1.6

Properties of coffee husk ash

This study's main objective was to ascertain whether expanding soil might be made better by using coffee husks. Road construction uses coffee husk ash, which enhances the benefits for the environment and the economy. The coffee husk waste was retrieved from a near Continental coffee private limited it is located to Duggirala mandal, Guntur district, Andhra Pradesh as shown in Figure.1. Following the coffee husk was 300 to 400 degree celsius burned and then cooled for twenty-four hours. Sieve, plastic limit Tests for specific gravity and liquid limit analysis were conducted.

Figure 1. Coffee husk

Table 3. Properties of CHA

Properties		**Observed value**
Particle size gradation	Gravel %	0
	Sand %	75.2
	Fine %	20.92
Consistency	Liquid limit %	25.64
	Plastic limit %	23.50
	Plastic index %	0.80
Specific gravity		2.45

This Table 3 presents the key properties of coffee husk ash (CHA) used in the study. CHA was obtained from local coffee processing units and used as a partial replacement for cement in the soil stabilization process. The properties listed in the table include chemical composition, specific gravity, fineness, and loss on ignition (LOI). These properties are essential for understanding the reactivity and effectiveness of CHA as a supplementary cementitious material in soil stabilization. The specific gravity of CHA indicates its density compared to water, while the fineness provides insight into the particle size distribution, which can affect its pozzolanic activity. The chemical composition, including the percentage of silica, alumina, and other oxides, influences the reactivity and strength development of CHA in the treated soil. Additionally, the loss on ignition value indicates the amount of organic matter and unburned carbon present in CHA, which can affect its pozzolanic reactivity and overall performance in soil stabilization applications shown in Table 3.

Compaction Test

The above Table 4 Comparison of MDD And OMC In different proportions of soil samples. Demonstrates the differences between various soil types and the OMC, and MDD. Maximum dry density coffee husk ash and xanthan gum percentages in the soil decreases as CHA grows. In the soil without CHA and XG, The maximum dry density is 1.482 g/cc fell to 1.351g/cc in soil with 8% CHA and XG. In the meanwhile, the ideal soil moisture content without CHA and XG IS 17.5% soil with 8% CHA and XG decreased to 23.7%. Cause of the decline in the organic nature of the material and water may be related to the highest dry and OMC rise.

Table 4. Comparison of max. dry density and optimum moisture content in different proportions of soils samples

Soil Type	**Max. dry density MDD, gm/cc**	**Optimun Moisture content OMC, %**
Black Cotton Soil	1.485	17.5
Soil + 0.50 % X G + 2% CHA	1.423	18.6
Soil + 0.50 % X G + 4% CHA	1.410	20.5
Soil + 0.50 % X G + 6% CHA	1.365	21.2
Soil + 0.50 % X G + 8% CHA	1.351	23.7
Soil + 0.50 % X G + 10% CHA	1.321	24.3

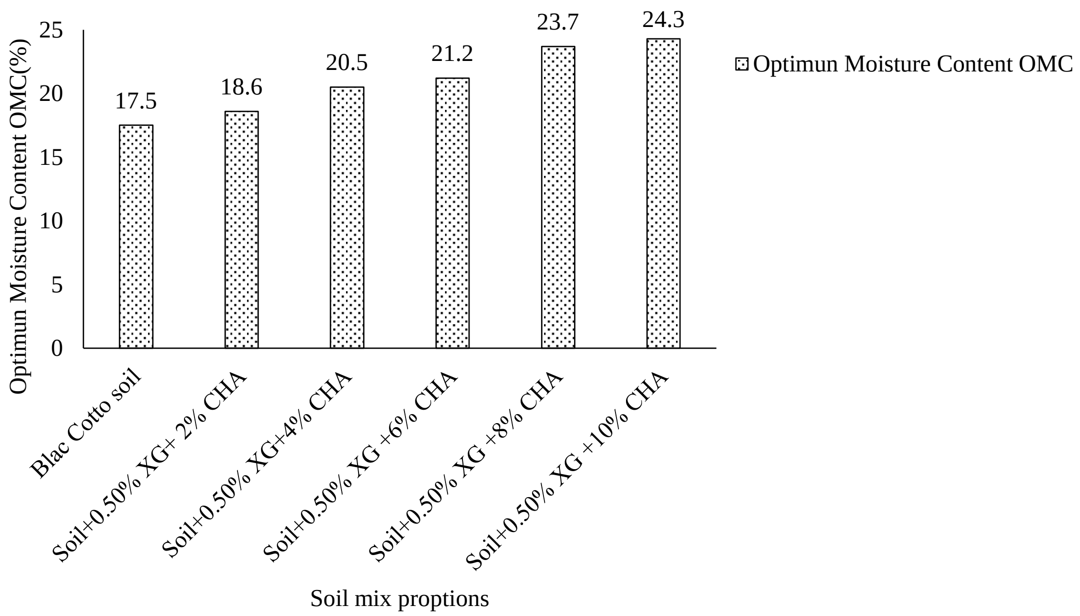

Figure 2. Comparison of OMC in different proportions of soils samples respectively.

These Figures are essential for understanding the impact of CHA and XG on the compaction characteristics of the soil. In Figure 2, the OMC values for various mixtures are plotted against the percentage of CHA and XG added to the soil. The OMC represents the moisture content at which the soil exhibits maximum compaction under standard compaction efforts. The figure illustrates how the OMC changes with different proportions of CHA and XG, indicating their influence on the workability and compaction of the soil.

Figure 3, on the other hand, shows the MDD values for the same mixtures. The MDD represents the maximum density achieved by the soil when compacted at the OMC. The figure demonstrates the effect of CHA and XG on the density of the soil, with higher percentages of additives generally resulting in higher MDD values. These figures provide valuable insights into the compaction characteristics of the treated soil samples, helping to determine the optimal proportions of CHA and XG for achieving the desired engineering properties.

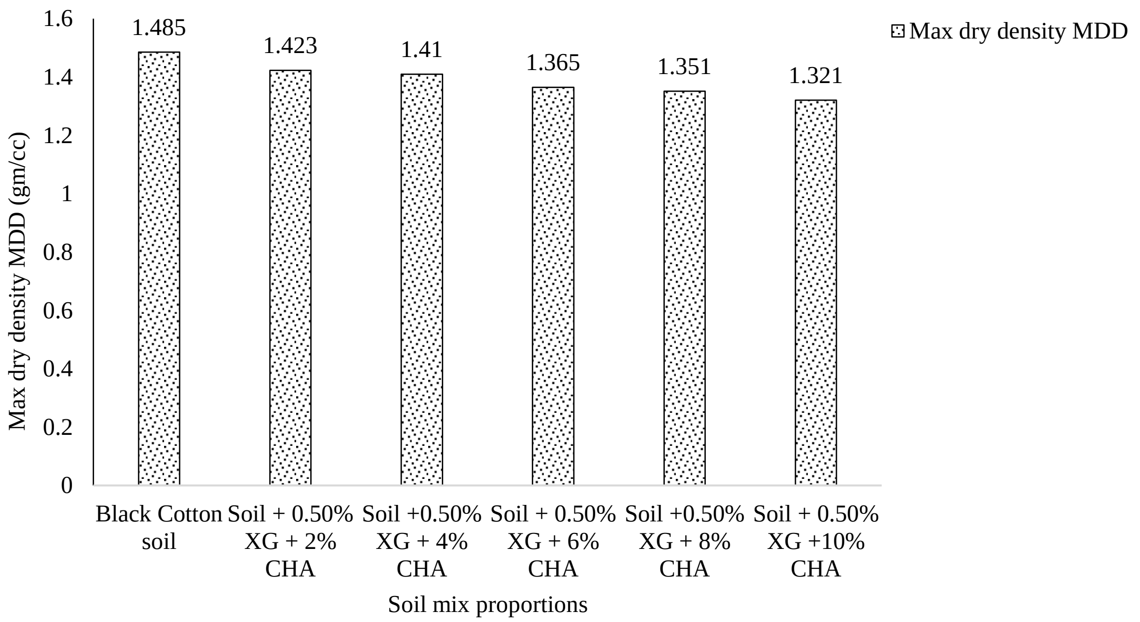

Figure3. Comparison of OMC And MDD in different proportions of soils samples respectively

Effect Of CHA And XG On Atterberg's Limit

Table 5 shows how different combinations' consistency limits change because of looking at how the soil expands when more XG and CHA are added. When the liquid limit rises observations have revealed that there is a decrease in the proportion of XG and CHA and an increase in the plastic limit of up to 6% CHA. The flexibility index therefore dropped as the amount of CHA increased.

Table 5. Atterberg's limit test

Symbol	Liquid limit, %	Plastic limit, %	Plasticity index, %	Swelling potential
Black cotton soil	70.25	24.23	60.23	Very high
Soil + 0.50 % X G + 2% CHA	75.45	26.15	58.35	Very high
Soil + 0.50 % X G + 4% CHA	68.39	35.26	48.71	High
Soil + 0.50 % X G + 6% CHA	65.48	30.40	38.21	Medium
Soil + 0.50 % X G + 8% CHA	58.51	28.25	33.26	Medium
Soil + 0.50 % X G + 10% CHA	50.29	22.15	28.36	Medium

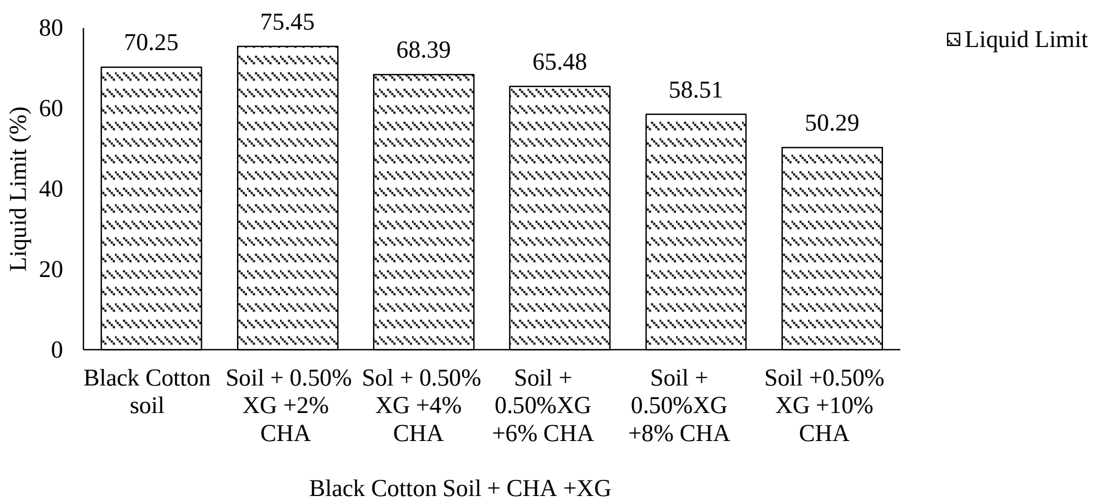

Figure 4. Comparison of Liquid Limit Index in Black cotton soil, CHA and XG.

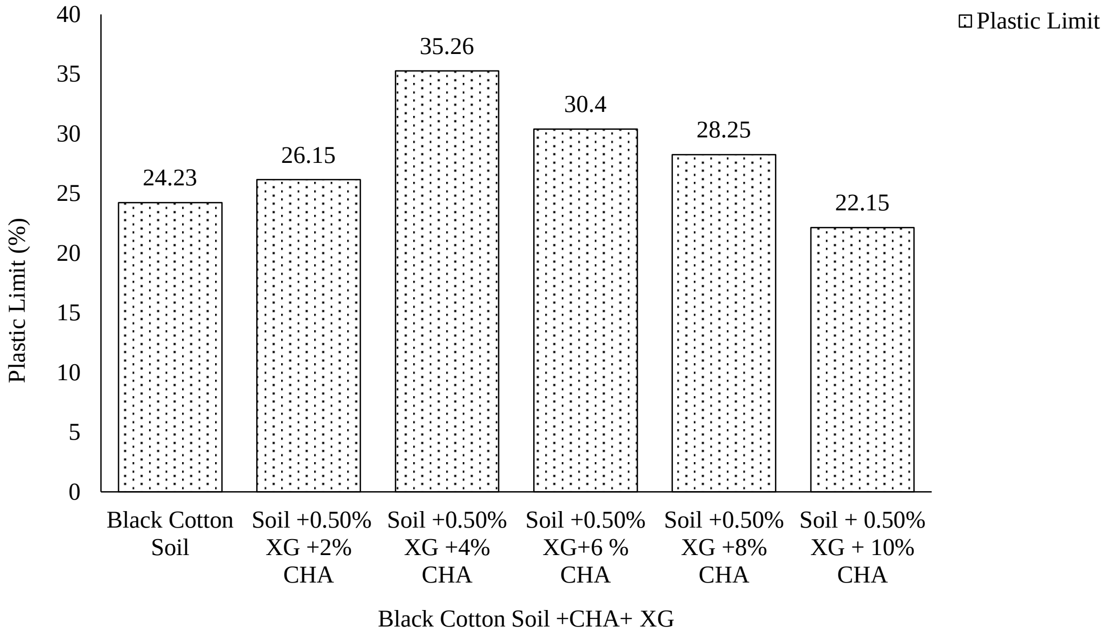

Figure 5. Comparison of Plastic Limit Index in Black cotton soil, CHA and XG

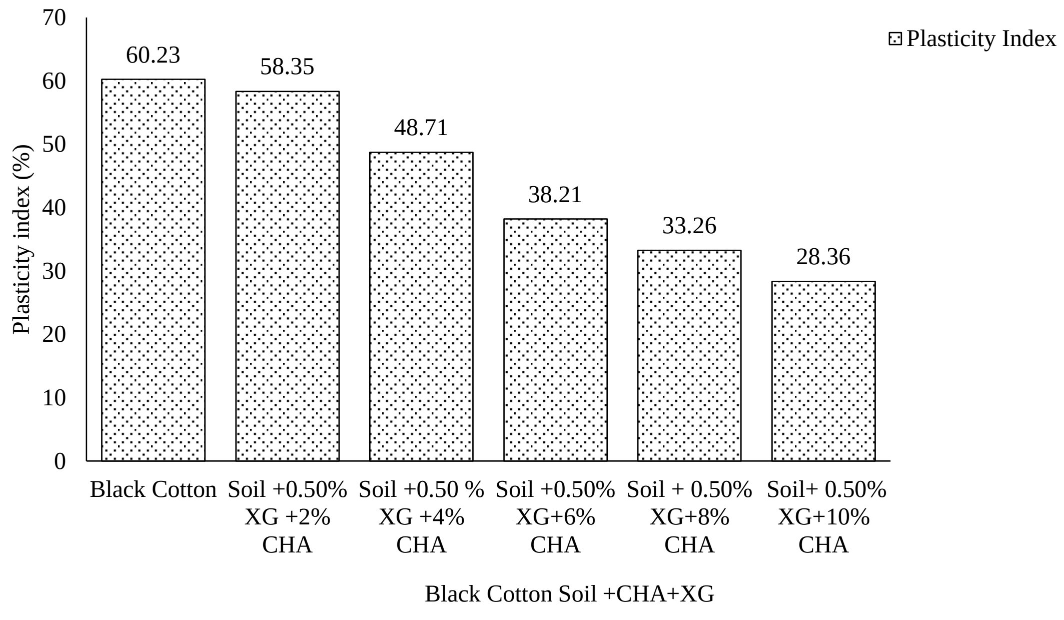

Figure 6. Comparison of Plasticity Index in Black cotton soil, CHA and XG.

The liquid limit, plastic limit, and plasticity index of black cotton soil (BCS) are compared with soils treated with increasing amounts of xanthan gum (XG) and coffee husk ash (CHA) in Figures 4, 5, and 6. These characteristics are essential for determining a soil's workability and plasticity, particularly in expansive soils like black cotton soil. The liquid limit of soil treated with XG, CHA, and BCS is shown in Figure 4. The moisture content at which soil changes from a plastic to a liquid condition is known as the liquid limit. The graph illustrates how the addition of XG and CHA alters the soil's liquid limit, revealing variations in its flexibility.

The plastic limit of soil treated with XG, CHA, and BCS is displayed in Figure 5. The moisture level at which soil becomes too dry to mold is known as the plastic limit. The graph illustrates the differences in the soil's plasticity and workability by comparing how the addition of XG and CHA affects the soil's plastic limit. The plasticity index of the soil treated with XG, CHA, and BCS is shown in Figure 6. The range of moisture content over which the soil behaves plastically is represented by the plasticity index, which is the numerical difference between the liquid limit and the plastic limit. This figure illustrates how the addition of XG and CHA alters the soil's flexibility index, changing its engineering qualities and construction appropriateness.

CALIFORNIA BEARING RATIO TEST (CBR)

The steps necessary to test black cotton soil combined with xanthan gum and CHA utilising the California Bearing Ratio (CBR) test methodology are described in this method. The CBR test results for xanthan gum and CHA together in black cotton soil are shown here. The results of many CBR tests using different concentrations of CHA (2%, 4%, 6%, 8%, and 10%) and 0.50 percent Xanthan gum (XG) are shown for BCS in Table 6.

Table 6. California bearing ration for Natural and treated soil

Mix proportions	**CBR (%)**	
	Unsoaked	**soaked**
Black cotton soil	2.41	2.35
Soil + 0.50 % X G + 2% CHA	5.50	5.30
Soil + 0.50 % X G + 4% CHA	6.31	6.2
Soil + 0.50 % X G + 6% CHA	3.26	3.16
Soil + 0.50 % X G + 8% CHA.	2.85	2.40
Soil + 0.50 % X G + 10% CHA.	2.55	2.28

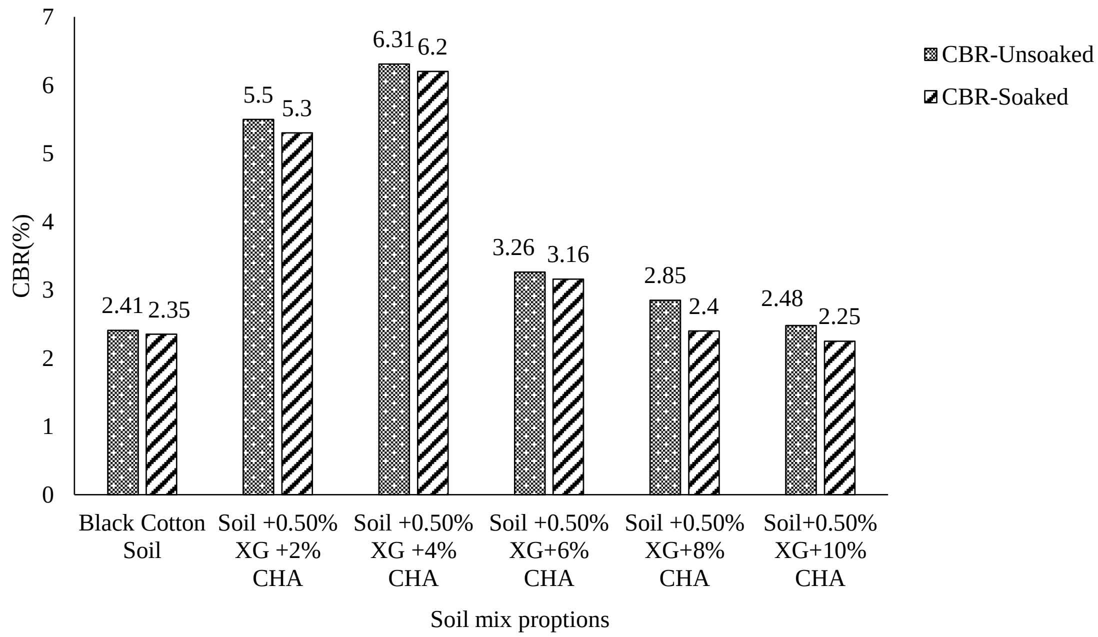

Figure 7. Comparison of CBR Soaked and Unsoaked Condition for different mix proportion of Black cotton soil, CHA and XG

The comparison of California Bearing Ratio (CBR) values for varying mix proportions of black cotton soil (BCS), coffee husk ash (CHA), and xanthan gum (XG) under wet and unsoaked circumstances is shown in Figure. 7. The CBR test, which is frequently used in pavement design and geotechnical engineering, is an essential indicator of soil strength and load-bearing capability. The graph illustrates how the CBR values of BCS under drenched and unsoaked conditions change with the addition of CHA and XG. The mix proportions of CHA and XG are represented by the x-axis, and the CBR values are represented by the y-axis. The graph's lines each indicate a distinct mix proportion, making it possible to compare the CBR values of various mix designs visually.

It is crucial to compare soaked and unsoaked circumstances since this gives information about how the soil behaves at varying moisture levels. Understanding how the soil stabilizing additives function in various environmental settings is essential for informing the design and development of long-lasting, sustainable infrastructure.

Unconfined Compressive Strength Test

The unconfined compressive strength test (UCC), sometimes referred to as the uniaxial test, is used to assess the shear strength of the soil. Expansive soil, coffee husk ash, and xanthan gum were tested details were illustrated in table 7.

Table 7. Unconfined compressive strength for natural and treated soil.

S.NO	Soil description	UCC (Kpa)
1	Black cotton soil	60.32
2	Soil + 0.50 % X G + 2% CHA	95.25
3	Soil + 0.50 % X G + 4% CHA	80.75
4	Soil + 0.50 % X G + 6% CHA	75.39
5	Soil + 0.50 % X G + 8% CHA	68.15
6	Soil + 0.50 % X G + 10% CHA	65.13

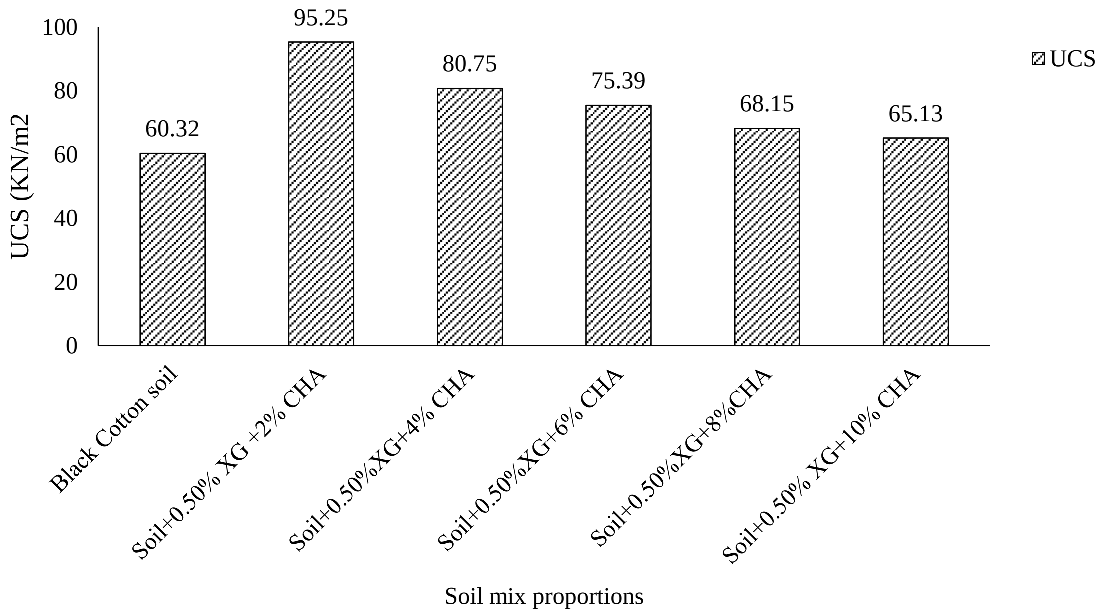

Figure 8. unconfined compressive strength test for different mix proportion of Black cotton soil, CHA and XG

Figure 8 illustrates the results of unconfined compressive strength (UCS) tests conducted on samples of black cotton soil treated with varying mix proportions of coffee husk ash (CHA) and xanthan gum (XG). The graph depicts the relationship between the UCS values and the different mix proportions, showing how the addition of CHA and XG affects the strength characteristics of the soil. The figure provides valuable insights into the optimal mix proportions that enhance the strength of black cotton soil, highlighting the potential of CHA and XG as soil stabilizers for improving the geotechnical properties of expansive soils.

CONCLUSION

1. The addition of coffee husk ash (CHA) improves the characteristics of black cotton soil. In rare circumstances, CHA can be used in place of black cotton soil. The attributes that black cotton soil enhanced are listed below.
2. Due to its high levels of swelling and expansion, black cotton soil need stability in order to perform properly.
3. The natural soil will have less MDD and more OMC in the composite mixture when Xanthan gum (XG) and coffee husk ash are added.
4. In proportion to the percentage of coffee husk ash, the OMC rises from17.5 to 24.3. MDD decreases from 1.485 to 1.321.
5. The UCS value rises 60.32 from to 95.25.UCS value drop with additional CHA added.
6. The CBR value rises in the drenched condition from 2.35% to 6.2% and in the unsoaked condition from 2.41% to 6.31%. CBR values drop with additional of coffee hush ash.
7. 2%,4%,6%,8%,10% was found to be an effective substitute for coffee husk ash. A desirable mix of research is black cotton soil + 0.50% Xanthan gum + 2%,4%,6%,8%,10% CHA which is economical.

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