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Soil Stability: An Experimental Investigation Utilizing Bagasse Ash in Combination with Guar Gum and Xanthan Gum Biopolymers

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Abstract - This study presents an experimental investigation aimed at enhancing soil stability through the synergistic application of bagasse ash in conjunction with Guar gum (GG) and Xanthan gum (XG) biopolymers. Soil stabilization is a critical aspect of construction and land management, especially in regions where red soil predominates. Due to its pozzolanic qualities, the by-product of sugarcane processing known as bagasse ash has demonstrated potential as a soil stabilizer. Guar gum (GG) and Xanthan gum (XG), natural biopolymers, have demonstrated promise in improving soil engineering characteristics. This research contributes to the evolving field of sustainable soil stabilization techniques, offering insights into the potential of bagasse ash and biopolymers in mitigating soil-related challenges. In the current study, Xanthum gum (XG) and Guar gum (GG) in varied percentages was employed in experimental experiments on red soil as a material for soil improvement. In this investigation, soil was also replaced with Bagasse ash up to 10% of its volume and its strength attributes were assessed. It was found through studies utilizing different Biopolymers concentrations (XG & GG) the soil's strength was improved.

Index Terms – Red Soil, Bagasse Ash (BS), Xanthum Gum (XG), Guar Gum (GG)

1. Introduction

Soil stability is a critical concern in various industries and applications, including agriculture, construction, and environmental conservation. In order to use land sustainably and build infrastructure, soil must be able to withstand erosion, preserve its structure, and support plant growth. However, many regions face challenges related to soil degradation and erosion due to natural factors such as rainfall and wind, as well as anthropogenic activities like deforestation and construction. Researchers and engineers have been investigating novel techniques and materials to increase soil stability to solve these issues. One such strategy uses biopolymers, organic or biodegradable polymers generated from microorganisms or plants, to improve the characteristics of soil. In comparison to conventional chemical additives, biopolymers provide a number of benefits, such as lower environmental impact and eco-friendliness.

This study focuses on the experimental investigation of soil stability improvement using a combination of two biopolymers, guar gum and xanthan gum, in conjunction with bagasse ash. Bagasse ash, a waste product from the manufacturing of sugarcane, has drawn interest as a possible soil stabilizer because of its wide availability and pozzolanic qualities. When incorporated into soil, bagasse ash has the potential to undergo a chemical reaction with calcium hydroxide to form cementitious compounds, which enhance soil strength and stability. Guar gum and Xanthan gum are natural biopolymers with proven effectiveness in soil stabilization. Guar gum is derived from guar beans and is recognized for its capacity to enhance soil cohesion, reduce erosion, and improve water retention. Xanthan gum, produced by Xanthomonas bacteria, exhibits excellent thickening and binding properties, making it suitable for enhancing soil structure.

The aim of this research was to evaluate the engineering performance and efficacy of soil that has been biopolymer-treated with Xanthan and Guar gums. The strength-related characteristics of soil samples that had been enriched with bagasse ash and treated with these biopolymers were examined through a series of experimental tests. The study examined the impact of XG and GG treatment on various soil characteristics, including consistency limits, compaction behavior, permeability, unconfined compressive strength, aging resistance, and long-term durability. Different proportions of XG and GG replacements, specifically at 4% and 6%, were analyzed in this investigation. The outcomes of this research demonstrate the promising potential of

XG and GG as sustainable and cost-effective alternatives for enhancing soil properties.

2. Literature Review

Mustafa Tahseen etal [2] in his study they explored whether the addition of GG, an organic, environmentally benign biopolymer ingredient, may improve cohesive soil. The biopolymer-added soils have undergone a number of laboratory experiments for this reason, including the compaction test, the Atterberg limits test, and the UCC strength test. For comparison, the tests performed on improved soils have also been conducted on the untreated cohesive soil. For a comprehensive evaluation, scanning electron microscopy analyses (SEM analyses) was conducted on some samples.

Dehghan, H., Tabarsa, A., Latifi, N., Bagheri, Y [3] in his study investigates whether xanthan gum and guar gum are suitable as biodegradable additions for collapsible soil stabilization. In this work, triaxial tests measuring permeability, compaction, consolidation, and unconsolidated-undrained soil were used to assess the engineering qualities of soil treated with varied biopolymer concentrations and curing durations. To evaluate the changes on the morphological properties of the stabilized soil SEM was used. The findings show that biopolymers reduce the collapsible soil's maximum dry density and permeability. The results also indicate that quantity of biopolymer and curing time affect strain-stress curves.

Pouyan Bagheri, Ivan Gratchev and Maksym Rybachuk [4] in his work explained about the number of environmental risks brought on by global warming have been on the rise, necessitating the application of sustainable engineering approaches. The aim of the research is to examine the effectiveness of xanthan gum biopolymer as a sustainable solution for improving soil qualities. The impact of XG on the strength and plasticity of the soil was investigated using the Atterberg limits, unconfined compression, CU, and UU triaxial tests. Additionally, moisture susceptibility and the resilience of soils treated by and without biopolymers were evaluated. The findings demonstrated that increasing XG content and curing duration enhanced soil's compressive strength, which peaked after a particular curing period.

3. Materials

A. Soil: A combination of organic material, minerals, gases, liquids, and living things make up soil, which is where life can coexist. The strength and geotechnical characteristics of soil samples taken from Bannur in the Mysore district are examined.

B. Bagasse ash: Bagasse ash is a residue that results from the combustion of sugarcane in sugar factories; typically remaining after all economically viable sugar has been obtained from the sugarcane. The management and disposal of this material have already begun to pose environmental challenges in the vicinity of sugar processing facilities. In numerous tropical regions, significant amounts of bagasse ash are available, and its high amorphous silica content suggests that it possesses pozzolanic characteristics.

C. Xanthan Gum: Xanthan gum is a biopolymer, commonly referred to as a polysaccharide that is produced through the fermentation of bacteria called Xanthomonas campestris. It is utilized in diverse sectors, encompassing food, pharmaceuticals, and cosmetics, as a thickening, stabilizing, and emulsifying agent. Xanthan gum is valued for its ability to create a viscous and gel-like consistency in aqueous solutions, making it a versatile and widely used additive in many products. It is particularly favored in the food sector due to its involvement in improving texture and shelf stability in a variety of food and beverage products. Additionally, its biodegradable and biocompatible nature has led to its application in environmentally friendly products and processes.

D. Guar Gum: Another biopolymer that is frequently utilized in a variety of industries, including the food, drug, cosmetic, and oil and gas sectors is guar gum. It is a naturally occurring polysaccharide that is obtained from the seeds of the guar plant (Cyamopsis tetragonoloba). The galactomannan polysaccharide known as GG, also known as guaran, is obtained from guar beans and possesses thickening and stabilizing qualities that are helpful in food, feed, and industrial applications. The thickening, stabilizing, and binding abilities of guar gum are well known. GG is prized for having a natural origin and for working as a flexible biopolymer that can degrade naturally in a variety of applications.

Methodology

- Step 1: Suitable soil sample will be collected for Testing.
  (The soil contents should be having the particles as 50% Sand + 20% Clay + 15% Gravel and + 15% Silt).
- Step 2: Basics tests are directed on the materials to know its index and engineering properties.
- Step 3: Examine the strength and stability of a cohesive soil blend by incorporating 10% Bagasse Ash by mass, along with either XG or GG in proportions ranging from 4% to 6% of the dry soil mass, as separate treatments.
- Step 4: Soil mixture containing 10% Bagasse Ash is further treated with a combination of Xanthan Gum and Guar Gum, specifically in two different proportions: 2% Xanthan Gum and 2% Guar Gum, as well as 3% Xanthan Gum and 3% Guar Gum.

Table 3.1: Tests conducted on Materials

Soil	Bagasse Ash	Xanthum Gum	Guar Gum
Specific gravity ConsistencyLimits Dry density &OMC Unconfined Compression Test CBR	• Specificgravity	• Specificgravity	• Specificgravity

Table 3.2: Tests conducted on Mix Proportions

Index properties	Engineering properties
ConsistencyLimits	Dry density &OMC Unconfined Compression Test CBR

Table 3.3: Specific gravity of materials

Material	Soil	Bagasse ash	Xanthum Gum	Guar Gum
Specific gravity	2.45	2.42	2.13	2.00

Table 3.4: Index & Engineering characteristics of soil

Tests conducted	Results
Specific gravity	2.45
Liquid limit	21%
Plastic limit	38.21%
Shrinkage limit	29.6%
Proctor test (OMC)	19%
Proctor test (Max dry density) g/cc	1670
Cohesion (C) kN/ m^2	0.33
Angle of friction (ϕ)	8^0
CBR for 2.5 mm	5.3%
CBR for 5.0 mm	4.9%

4. Results & Discussion

Cohesive soil that has been treated with varied amounts of Xanthan Gum (4% to 6%) and Guar Gum (4% to 6%) separately and blended with 10% bagasse ash exhibits an excellent improvement in the soil's strength metrics. Additionally, Xanthum Gum and Guar Gum are used in combination to remediate the soil that contains 10% Bagasse Ash.

Table 4.1: Soil subjected to varying levels of concentration of XG and 10% BA

Test conducted	Soil	10% Bagasse Ash + 4% Xanthum Gum	10% Bagasse Ash + 6% Xanthum Gum
Liquid limit	38.2%	35.4%	32.7%
Plastic limit	21%	23%	26%
Shrinkage limit	29.6%	29.2%	29.3%
Proctor test (OMC)	19%	22%	24%
Proctor test (Max dry density) g/cc	1670	1720	1820
Cohesion (C) kN/ m^2	0.33	0.54	0.61
Angle of friction (ϕ)	8^0	10^0	13^0
CBR for 2.5 mm	5.3%	5.8%	6.5%
CBR for 5.0 mm	4.9%	5.3%	5.9%

Table 4.2: Soil subjected to varying levels of concentration of GG and 10% BA

Test conducted	Soil	10% Bagasse Ash + 4% Guar Gum	10% Bagasse Ash + 6% Guar Gum
Liquid limit	38.2%	39.8%	40.6%
Plastic limit	21%	26%	29%
Shrinkage limit	29.6%	31.9%	34.8%
Proctor test (OMC)	19%	22%	25%
Proctor test (Max dry density) g/cc	1670	1830	2240
Cohesion (C) kN/ m^2	0.33	0.56	0.64
Angle of friction (ϕ)	8^0	9^0	14^0
CBR for 2.5 mm	5.3%	10.4%	11%
CBR for 5.0 mm	4.9%	8.6%	9%

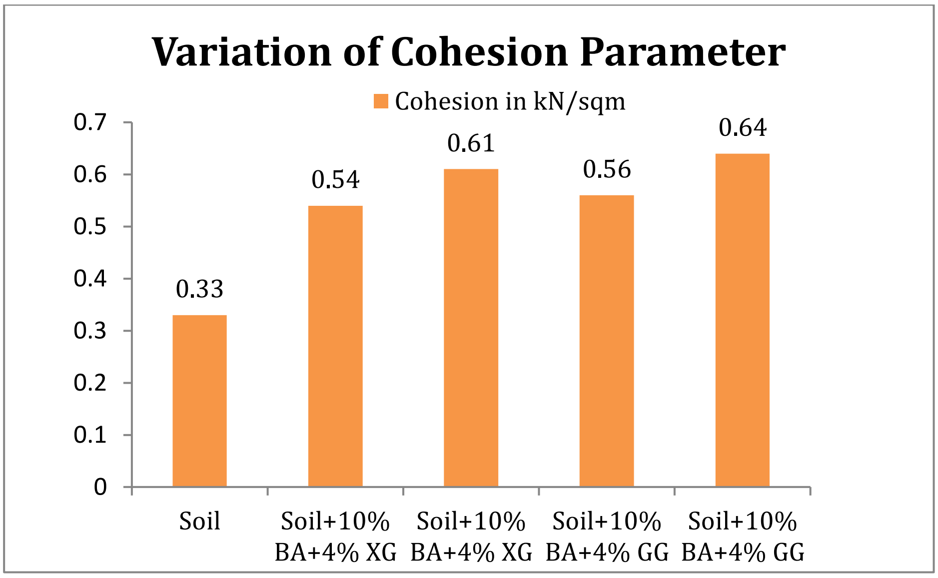

Figure 4.1: shows the variation of cohesion parameter for the soil subjected to varying level of concentrations of Xanthum Gum, Guar Gum and 10% bagasse ash.

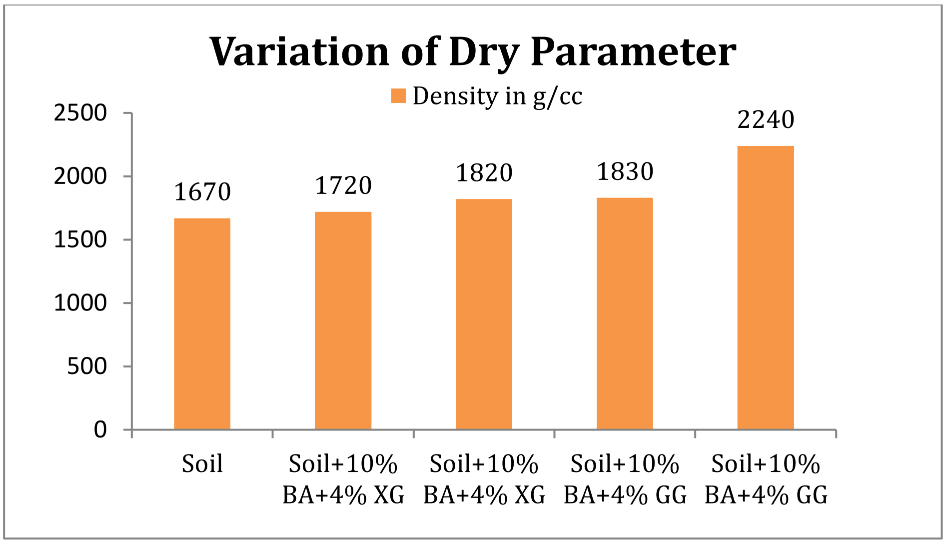

Figure 4.2: shows the variations of density parameter for the soil subjected to varying level of concentrations of Xanthum Gum, Guar Gum and 10% bagasse ash.

Table 4.3: Soil subjected to treatment with GG and XG while incorporating 10% Bagasse Ash

Test conducted	Soil	10% Bagasse Ash + 2% GG + 2% XG	10% Bagasse Ash + 3% GG + 3% XG
Liquid limit	38.2%	41%	43%
Plastic limit	21%	31%	32%
Shrinkage limit	29.6%	35%	37%
Proctor test (OMC)	19%	26%	20%
Proctor test (Max dry density) g/cc	1670	2360	1700
Cohesion (C) kN/ m^2	0.33	0.68	0.42
Angle of friction (ϕ)	8^0	16	8^0
CBR for 2.5 mm	5.3%	10.5%	5.6%
CBR for 5.0 mm	4.9%	8.6%	5%

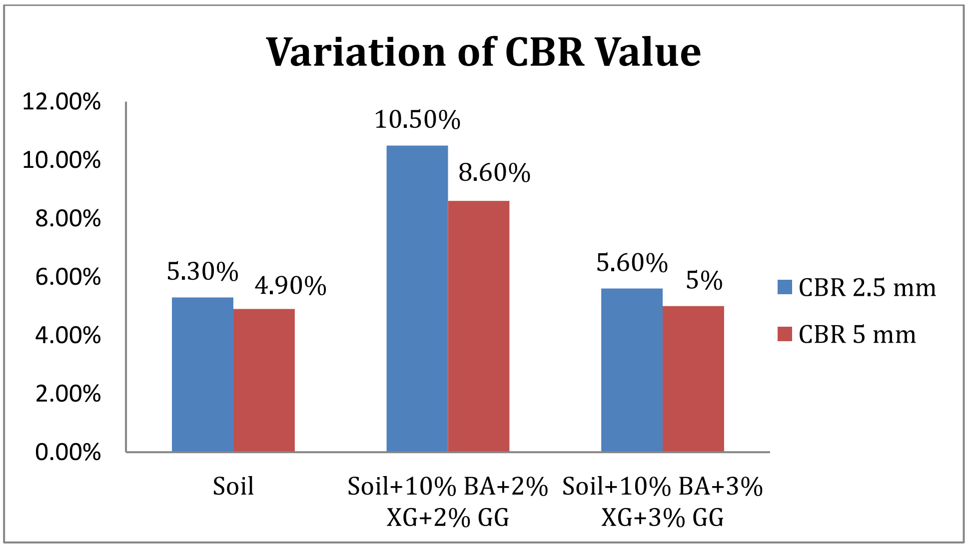

Figure 4.3: shows the variation of CBR value the soil subjected to varying level of concentrations of Xanthum Gum, Guar Gum and 10% bagasse ash

❖ **Observations and Comments Based on the Results**

1. From the above experimental data, both Xanthum Gum and Guar Gum increases the parameter related to strength of soil.
2. The Bio-Polymers has to be limited to 6% beyond which it reduces the parameter related to strength, because of its moisture enhancing property.
3. Soil with Bagasse treated with 6% Guar Gum increases the Dry density of soil mix by 34% and cohesion by 94% in contrast with natural soil which indicates mix being denser and mix being more resistant to shear deformation and sliding.
4. The combination of both Guar Gum and Xanthum Gum has to be limited to 2%+2% were slight increase in the mass reduces the strength of the soil.
5. The combination of both XG & GG (2%+2%) enhances the cohesion by 106% which is highest among all the mixes.

5. Conclusion

1. Pozzolanic substances such as Bagasse Ash undergo a reaction with calcium hydroxide when moisture is present, resulting in the formation of calcium silicate hydrates. These compounds have the capacity to occupy voids within the soil and enhance its strength.
2. Xanthan Gum is a natural biopolymer produced by bacteria. When added to soil, it acts as a binding agent and improves the soil's water retention capacity. It creates a gel-like network that enhances the cohesion and adhesion of soil particles. This improved bonding between soil particles leads to increased shear strength and stability.
3. Guar Gum acts as a binding agent, effectively connecting soil particles. This interlocking effect increases resistance to shear forces, which is crucial for soil stability and strength.
4. The strength gain in soil can be ascribed to the formation of hydrogels that are cementitious in nature. Strength is also improved through the ionic / hydrogen bonds that are formed by biopolymer addition [11].
5. Biopolymers can improve the workability of the soil, making it easier to handle during construction or engineering projects. This can lead to better compaction and increased soil strength.

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