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Eco-Friendly Soil Stabilization Using Glass Powder, Sawdust Ash, and Guinea Corn Husk Ash for Improved Geotechnical Properties in Highway Construction

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ABSTRACT

This study explores the use of glass powder, guinea corn husk ash, and sawdust ash in stabilizing weak soils for highway pavement. Conducted in two phases, it first examined how different blend ratios affect soil strength and density. The second phase assessed how these admixtures influence key geotechnical properties, including Atterberg limits, compaction, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS). Tests followed BS 1377 (1990) standards. Admixtures were added at 1%, 2%, and 3% individually, totalling 6% combined by weight. Both treated and untreated samples were tested. Results showed that the blend significantly improved strength, reduced plasticity, and increased load-bearing capacity. These effects are due to pozzolanic reactions that enhance particle bonding. The findings suggest strong potential for using these waste materials in eco-friendly soil stabilization for road construction. However, further studies are needed to optimize mix ratios for different soil types.

Keywords: Soil Stabilization, Compaction, Glass Powder, Sawdust Ash, Guinea Corn Husk Ash, Geotechnical Properties.

1 Introduction

The strength, stability and durability of any structure are heavily dependent in the quality of the soil upon which it is built. Soil plays a key role in determining the long-term performance and safety of any structure, and it is one of the major challenges faced by civil engineers in highway construction. Natural soil with high clay content, poor grading, and excessive moisture content often lacks the geotechnical characteristics needed for construction purposes. Such soil is a weak soil with poor bearing capacity, low shearing strength, poor compaction and tendency to shrink or swell with a change in moisture content. These problems have necessitated the use of soil stabilization techniques to improve soil performance before construction begins

To address these challenges, soil stabilization typically involves the use of materials such as cement, bitumen, and synthetic polymers. While effective, these methods are not environmentally friendly due to high carbon footprint associated with their production and use. Due to the high cost of these conventional stabilizer in many developing regions, they limit their use, mainly in rural infrastructure development. This has led construction industry to be encouraged to adopt eco-friendly practices and utilise waste materials in a resource-efficient manner. This has led researchers to explore alternative materials affordable and sustainable for soil stabilization.

Among these alternatives, glass powder, which is a by-product of the glass recycling process, contains a significant amount of silica. It exhibits pozzolanic activity similar to fly ash when ground into powder.

Guinea corn husks, known as sorghum, are a widely cultivated cereal crop especially in Africa, waste such as husk and stalks are generated, when burned under controlled condition the ash produce contain mineral compound and rich in silica and alumina. These chemical properties make guinea corn ash a potential pozzolanic material that can interact with soil particles to improve strength and reduce plasticity in soil.

Soil stabilization involves enhancing the engineering properties of soil to make it suitable for construction and other engineering applications. This can be achieved through various methods, including soil-cement stabilization, lime stabilization, and fly ash stabilization. Researcher such as Ogundipe and Adekanmi (2019), Balogun (1991) and Ola (1974) have successfully utilized these conventional stabilizers for soil stabilization and confirmed their efficacy.

In the light of that this research focused on assessing the geotechnical properties of one sample by combing Glass powder GP, Sawdust Ash SDA, and Guinea Corn Hush Ash GCHA.

This research investigates the combined effect of glass powder, guinea corn ash and saw dust ash on the geotechnical properties of poor-quality soil found in highway subgrades. By adding different percentage in ratio 1:2:3, for glass powder, guinea corn ash and saw dust respectively. The aim is to evaluate whether this eco- friendly mixture can offer a sustainable and effective solution for improving soil performance in road construction. The soil sample were subjected to standard laboratory test, the research investigates changes in Atterberg limits, compaction characteristics, and bearing capacity, to measure the improvement in soil behaviour after treatment.

The choice of combing the three-waste material not only to offers an environmentally solution to soil stabilization but also addresses the problem of waste disposal.

2 Material Methodology

2.1 Soil

The soil material used for this research was obtained from a road construction borrow pit near The Federal Polytechnic, Ado-Ekiti. Samples were taken to the Soil Mechanics Laboratory of the Civil Engineering Department to determine geotechnical properties such as Atterberg limits, compaction, California Bearing Ratio (CBR), and unconfined compressive strength (UCS)..

2.2 Sawdust and Guinea Corn Husk Ash (GCHA)

Sawdust was obtained from a sawmill located at Oke Ureje, along Federal Polytechnic Road, Ado-Ekiti, while guinea corn husk was sourced from a local market in Ago, along Ijan-Ekiti Road, Ekiti State. Both materials were air-dried for 14 days and subsequently converted to ash by controlled open-air burning. The ash obtained was then sieved using a 600 µm sieve, in accordance with Ogundipe et al. (2019), to ensure uniform particle size for stabilization purposes.

2.3 Glass Powder (GP)

Waste glass was collected from a local glass seller adjacent to the Immigration Office along Federal Polytechnic Afe Babalola Road, Ado-Ekiti. The material was cleaned, dried, and ground into powder before being sieved through a 600 µm sieve.

2.4 Mix Proportions

For this study, the soil was stabilized with a ternary blend of glass powder (GP), sawdust ash (SDA), and guinea corn husk ash (GCHA). The total additive content was fixed at 6% by dry weight of soil. The mixtures were prepared in three different permutations of the 1:2:3 ratio, in addition to the control sample, as shown below:

S0: 0% additives (natural soil only).

S1: 1% GP + 2% SDA + 3% GCHA (total 6%).

S2: 3% GP + 1% SDA + 2% GCHA (total 6%).

S3: 2% GP + 3% SDA + 1% GCHA (total 6%).

In each case, the additive percentage was calculated by weight relative to the dry soil mass, GP, SDA, and GCHA according to the specified proportions. This gave a total additive content of 6% by dry weight of soil.

3 Results and Discussion

Summary results of geotechnical properties of untreated soil and treated are presented in table 1 while graphs are shown in the figures 1.

Properties of Untreated Soil

The result of geotechnical properties test carried out shows the soil can be classified as (A-7-6) having processed the following properties, liquid limit of 42.8%, plastic limits 25.6% and percent passing sieve 0.075mm, 63.4%, all these parameters shows that the soil fulfills the criterial to be classified as (A-7-6) i.e clay present >30% and PI> 14%. These parameters also show that the soil is a (CL) soil. Soil in soaked state and loses up to > 75% ucs strength with high shrinkage.

Table 1: Untreated Soil Properties

	Untreated soil	**Treated soil**
Soil Properties	**values**	**Values**
Moisture content	13.4%	---
Specific gravity	2.59	2.61
% passing sieve 0.075mm	63.4%	63.4%
Liquid limits	42.8%	21.4%
Plastic limits	25.6%	10.2%
Plasticity index	17.2%	11.2%
Soil type USCS	CL	ML (silt clay)
Soil type AAHTO	A-7-6	A-4
Maximum dry density	1785kg/m^3	1921kg/m^2
Optimum moisture content	20.2%	17.3%
CBR soaked	4%	13.1%
UCS	165.5KN\M^2	398KN\M^2

3.1 Effect on Atterberg Limit

Effect the additives were examined on geotechnical properties of the weak soil liquid limit (LL) test results shows that treatment with combined glass powder, sawdust ash, and guinea corn husk ash reduced the (LL) from 42.8% to 21.4% (a 50% decrease) and the plasticity index from 17.2% to 11.2% (a 34% decrease) these reductions indicate a substantial, decrease in soil plasticity and moisture susceptibility. Figure 1 shows the Atterberg Limit

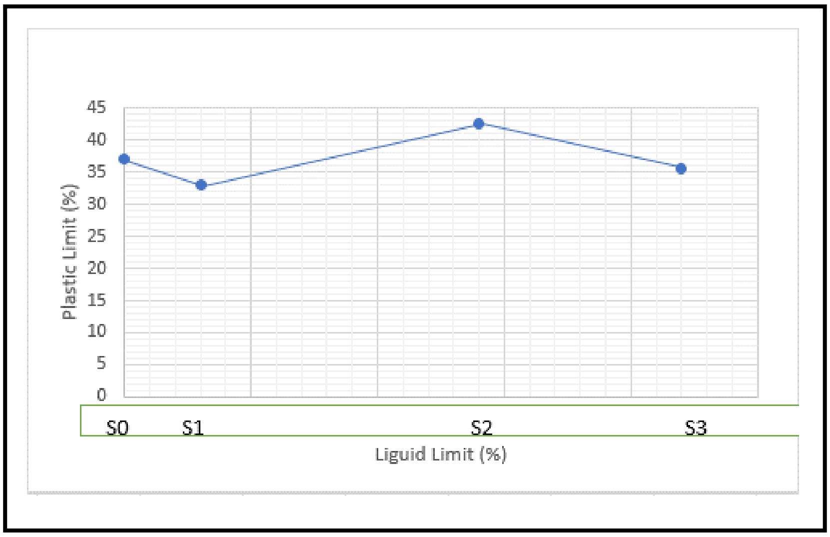
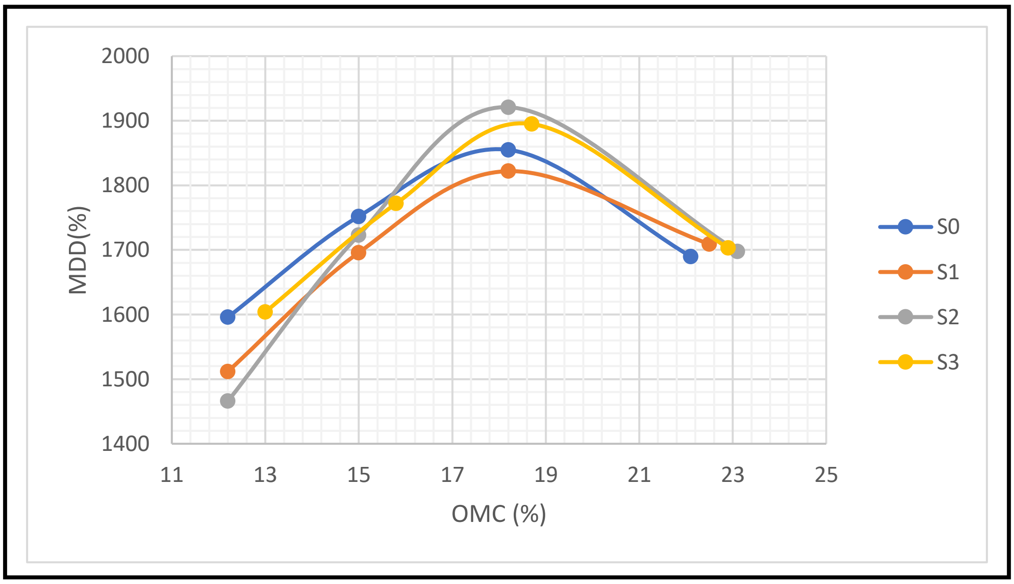


Figure 1: Attterberg Limit

3.2 Effect on Compaction Characteristic

Effect of combined additive were examined on the compaction characteristics, test conducted to find optimum moisture content (OMC) and maximum density (MDD) , result for Untreated soil are shown in figure 2, together with treated soil, the Untreated MDD 1785 kg/m3 and OMC 20.2%. result obtained for treated soil indicate increasing trend in MDD with decreased in OMC values mix proportion 1% Sawdust ash (SDA), 2%,Guinea corn husk ash (GCHA) and 3% Glass powder (GP) combined have the highest MDD 1921 kg/m3 with decreased in OMC 17.3% this may be due to pulverized loss are denser than the natural soil particles. The reduction in OMC was due to flocculation and agglomeration reaction of soil to the additives or involvement of glass powder that has low absorption capacity which can lead to reduction in the OMC. Figure 2 shows effect of SDA, GCHA and GP on MDD and OMC



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The Figure 3 show that the inclusion of glass powder (GP), sawdust ash (SDA), and guinea corn husk ash ($GCHA_2$) in varying proportions generally increased the maximum dry density (MDD) compared to the untreated soil (1785 kg/m³, OMC = 18.2%). The highest MDD (1921 kg/m³) and optimum moisture content (OMC = 19.9%) were recorded for the mix with 1% SDA, 2% $GCHA_2$, and 3% GP, indicating improved soil compaction and potential load-bearing capacity.

Table 2: Showing the result of the compaction test

Figure 2: OMC vs MDD

SAMPLE CODE	mix ratio	Types of Admixtures	MDD Kg/m3	OMC (%)
S0	0%	0	1785	20.2
S1	1% 2% 3%	GP SDA GCHA	1822	19.1
S2	1% 2% 3%	SDA GCHA GP	1921	17.3
	1%	GCHA		

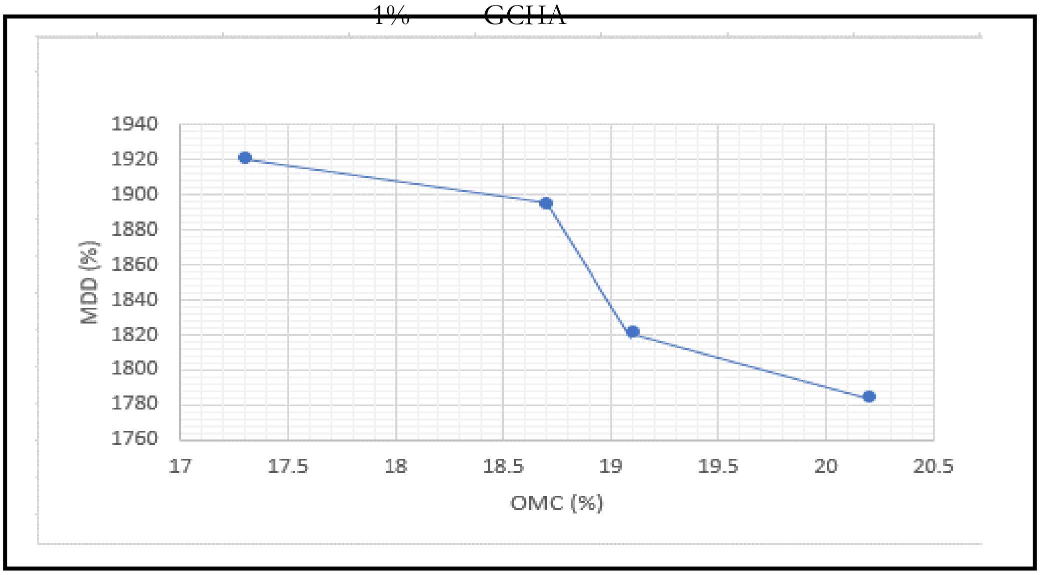

Figure 3: Showing the effect of the listed additives on the soil samples

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3.3 Effect on California Bearing Ratio (CBR)

The soaked CBR value of untreated soil was 4%, which is considerably below the minimum requirement of 8% for subgrade material in most highway design specifications (AASHTO, 1993). After treatment with the blended additives (1% SDA, 2% GCHA, 3% GP), the CBR increased to 13.1%, representing an approximate 227.5% improvement. This significant gain indicates that the pozzolanic reaction between the additive blend with soil minerals enhanced particle bonding and load-bearing capacity, making the treated soil suitable for use in road subgrades and lightly trafficked pavements.

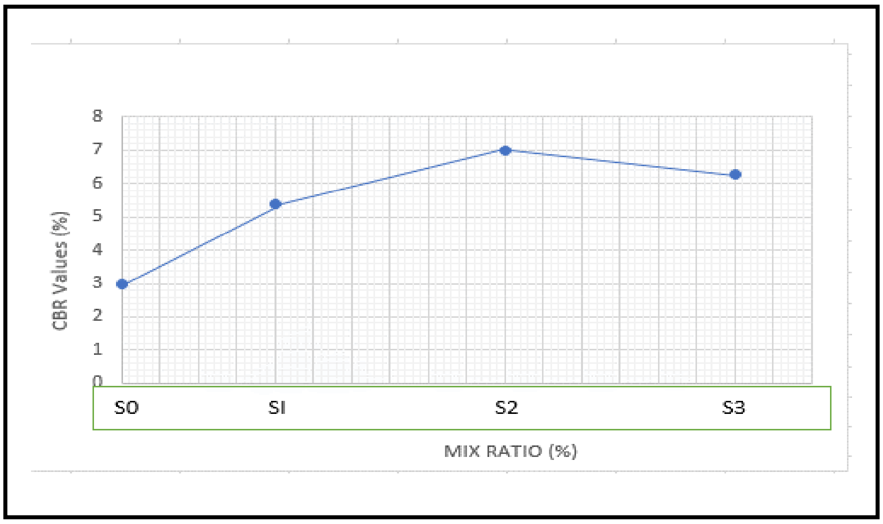

Figure 4: showing the effect of listed additives on the soil samples

3.4 Effect on Unconfined Compression Strength

GP, SDA, GCHA and soil were prepared using the OMC obtained from the compaction test. Samples were treated and cured for 28 days; results are presented below in figure 5. The different mix proportion reacted positive improved USC strength. The maximum dosage of the additives was observed at 1% SDA, 2% GCHA and 3% GP blended together give UCS value 398 KN\M2.

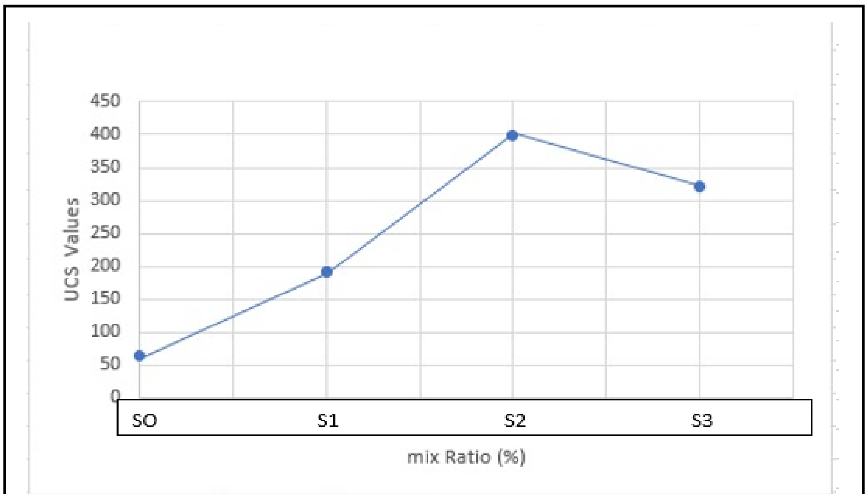

Figure 5: GP, SDA, GCHA on qu

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4 Conclusion

This study investigated the stabilization of weak subgrade soil using a ternary blend of glass powder (GP), sawdust ash (SDA), and guinea corn husk ash (GCHA). Laboratory tests including Atterberg limits, compaction, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) were performed to evaluate performance.

The results showed that the addition of the waste-derived pozzolanic materials improved the geotechnical properties of the soil. Specifically, the CBR value increased from 4.0% in the natural soil to a maximum of 13.1% with the blended additives, representing a 227.5% increase. Similarly, the UCS improved from 165.6 kN/m² to 398 kN/m², confirming the strength-enhancing potential of the additive blend.

While these results demonstrate clear improvements, it is important to note that the maximum CBR value obtained (13.1%) is still below the 15–20% typically required for subbase layers. Therefore, the treated soil is considered more suitable for subgrade applications, rather than for higher pavement layers.

The study concludes that waste-derived materials such as GP, SDA, and GCHA can serve as sustainable, eco-friendly alternatives to conventional stabilizers. Further research is recommended to optimize mix proportions, curing conditions, and long-term durability under field conditions.

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