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Enhancing Soil with Low-Cost Pozzolanic Materials: Rice Husk Ash and Groundnut Shell Ash Compared to Cement

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ABSTRACT

This study investigates whether low-cost pozzolanic materials such as rice husk ash, groundnut shell ash can improvement soil used in the study that are classified as Low-plasticity clays (cl) and activity of it equal to 1.05 as a replacement for traditional, costly additives. the percentage are used be 4%, 6%, 8%, and 10% of weight soil for each additive. chemical properties were studied for rice husk ash, groundnut shell ash, and cement Portland such as CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, and Na_2O. Also, pre- and post-mixture soil was tested for Atterberg's Limit, Activity, Shrinkage Limit, Clay value, Proctor Standard Compaction, and Unconfined Compressive Strength. Untreated soil samples were compared to treated ones. Adding 8% cement OPC, 10% groundnut shell ash, and 10% rice husk ash enhanced soil cohesiveness from 21 to 57.5, 52, and 45 kPa, respectively, also the optimal soil moisture content dropped from 15% to 8%, 10.5%, and 10% for mixes. Increased mixer percentages lead to reduced maximum dry unit weight and optimized water content. Based on these observations aims to develop effective solutions for treatment expensive soil in engineering and construction projects.

1. INTRODUCTION

The foundation of a building is the most important part of the structure, as this is where the construction process starts. A variety of factors, including the accumulation of moisture in the subsoil, uneven settlement of the subsoil, uneven settlement of the workmanship, horizontal development of the subsoil, lateral pressure on the divider, air activity [1]. The present studies examine the risks associated with traditional methods of enhancing base soil properties and their corresponding financial implications. Additionally, the research commenced to demonstrate alternative approaches for enhancing the characteristics of the underlying soil through the utilization of recycled environmental waste. This serves as a viable alternative to the conventional methods employed to improve the base soil, which typically incur financial expenses. Particularly, the inclination towards sustainability. [2]. The exploration of pozzolanic materials has presented a notable obstacle to the advancement of national development. The considerable significance of laterite soil as a dependable and long-lasting construction material stem from its ample local accessibility, rendering it a prominent choice for construction purposes throughout an extended duration [3-5]. The implementation of waste management and waste recycling practices is still in its nascent phase but is increasingly receiving significant recognition in the Global South. These approaches are more comprehensive and ecologically sustainable compared to traditional methods, and they have a beneficial impact on both human well-being and the environment [6]. Numerous research studies have investigated the viability of incorporating industrial waste as a potential input material in various phases of the Portland cement production process [7]. The utilization of pozzolanic materials is a chemical stabilization technique employed to enhance soil stability by the augmentation of soil particle size, reduction of plasticity index, and mitigation of swelling and consolidation tendencies [8]. Traditionally, soil reinforcement involves the incorporation of pozzolanic materials, such as cement [9], but improvement soil with cement is more costly [10]. Iskandar et al. [11] directed to soil treatment using cheap pozzolanic materials as substitutes for expensive pozzolanic materials such as peanut shells after conversion, its content [12], where it was observed that CaO is relatively less than what was observed in ordinary Portland cement, which has a higher total composition [13]. Grinding peanuts results in the generation of peanut shell ash (GSA) which refers to the residue from the burning of peanut shells. Ash will remain. Which will act as a stabilizer for highly expanded clay soils. This investigation was motivated by the expensive nature of conventional stabilizers and the necessity to use industrial and agricultural wastes economically [14]. Rice husk ash (RHA) is recognized for its significant reactivity as a pozzolanic material [15]. The production of RHA involved controlled burning at temperatures ranging from 400 to 500°C, as reported by Paul and Sarkar in 2023 [16]. Furthermore, it is important to acknowledge that the incorporation of Rie Husk Ash (RHA) as a supplementary substance has the potential to yield dual advantages. The utilization of 10% of rice peel ash (RHA) has the potential to decrease the overall expenses while maintaining comparable outcomes. Furthermore, the use of

RHA serves to augment environmental consciousness, a pivotal facet in guaranteeing enduring sustainability. In the year 2021, Ali et al. [17] made notable contributions in their respective fields. The focus of our research project is to conduct a comparative analysis of soil treatment employing three distinct additives, namely rice husk ashes, groundnut ashes, and cement OPC, individually. Nevertheless, the low-cost nature of peanut crust ashes and rice crust ashes renders them comparable to the considerably expensive Portland cement, a highly priced pozzolan. The primary aim of this study is to investigate the feasibility of employing waste leftovers as alternative options for traditional methods of soil treatment, such as cement, lime, and gypsum. The main objective is to reduce the costs related to soil remediation while concurrently advancing environmental sustainability.

2. METHODOLOGY

The Methodology work involves collocation of sample and sample preparation, The experimental work and analysis, and, result with discussion. illustrating the methodology adopted in this study as well as Figure 1.

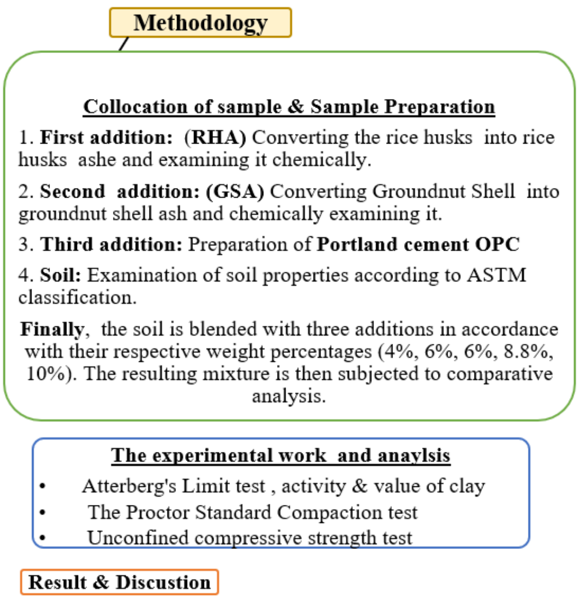

Figure 1. Methodology chart

The selection of cost-effective alternative materials such as groundnut shell ash and rice husk ash, followed by their comparison with higher-cost pozzolanic materials like ordinary Portland cement. Different proportions of additives Portland cement, groundnut shell ash, and rice husk ash will be incorporated into soil samples, namely 4%, 6%, 8%, and 10% by weight. Portland cement, groundnut shell ash, and rice husk ash will all be analyzed chemically, with a focus on ingredients like CaO, SiO_2, Al_2O_3, FeO_3, MgO, and K_2O as in Appendix A American Society for Testing and Materials (ASTM) Standards [18]. Lastly, physical tests, the soil classified according to the Unified Soil Classification System (USCS) to analyze the soil effect it is necessary to know the clay's physical properties will be carried out to compare the elasticity characteristics of treated and untreated soil samples. The experimental work that are used to compare between of the groundnut shell ash and rice husk ash, and cement such as Atterberg's Limit test, the activity, shrinkage limit, and clay value of the soil samples as in ASTM 2000 [19]. Also, the Proctor Standard Compaction test will be utilized to ascertain the maximum dry unit weight and the optimal moisture content, also as in ASTM D1557-07-2007 [20]. And also, an unconfined compressive strength test by ASTM D2166-16-2016 [21] will be performed.

2.1 Sample collocation and preparation

The materials used in the tests were soil, rice husk Ash groundnut Shell Ash, ordinary Portland cement OPC, and Water. Below the collection and preparation for all.

2.1.1 Cement OPC

The cement is obtained from the local market. In order to get soil samples ready for testing, the oven-dried soil was sieved with a mesh size of 4.75 millimeters (ASTM - D422–2004).

2.1.2 Rice husk ash

The rice husk ash utilized in this study was acquired from a nearby rice mill facility. The following table presents the results of numerous laboratory tests regarding the characteristics of clay soil samples that were conducted without the addition of admixtures such as rice husk ash. Additive preparation of rice husk ash, groundnut shell ash by burning it in the oven at a temperature of 500 degrees Celsius for 4 hours after grind it in the mill [22].

2.1.3 Groundnut shell ash GSA

The milling of groundnuts results in the generation of an agricultural byproduct known as groundnut shell. Groundnut shell ash is the name given to the ash that is produced when groundnut shells are burned (GSA). The burned ash would be put through a BS filter (75 microns), and the portion that made it through the sieve would meet the specified degree of fineness of 0.063mm or less [23].

2.1.4 Soil

The soil samples that were gathered are subjected to the process of air-drying, followed by sieving to exclude any particles with a size above 2 mm [18]. The samples are then mixed thoroughly to ensure uniformity. Soil samples are collected from the study area and transported to the laboratory for analysis. it is necessary to know the clay's physical properties. Each test is presented in Table 1 [19-21, 24-28].

Table 1. Properties of soil

Properties		
% G	2.1	[20] ASTM: C136/C136M − 19
% S	46.9	
% M	12	
% C	40	
Soil Type	**Cl**	
W%	8.95	[24] ASTM: D2216 − 19
Gs	2.72	[25] ASTM: D854 – 02
FSI	50%	[26] ASTM: D7928
L.L	62%	
P.L	21%	[19] ASTM: D4318 - 00
P.I	42%	
A	1.05	
OMC	15%	[21] ASTM: D1557-07
MDD	1.65 g/cc	
CU	21KPa	[27] ASTM: D3080/D3080M – 11
UCS	65 KPa	[28] ASTM: D2166-16

3. TEST RESULTS AND DISCUSSIONS

3.1 The chemical characteristics

The percentage quantitative analysis of composition for (cement OPC, GSA, RHA) of silica oxide and other chemical compound such as P_2O_5, SO_3, K_2O, MnO, Fe_2O_3 and so on, were carried out on the coconut husk ash at Laboratories, the following table presents the chemical and pozzolanic characteristics of the additives.

Table 2. The chemical characteristics

The Chemical Characteristics	GSA (%)	RHA	Cement (OPC) (%)
CaO	10.91	1.5	62
SiO_2	34	72.3	22
Al_2O_3	12	4.4	5
Fe_2O_3	14	1.2	4
MgO	4.72%	1	1
K_2O+Na_2O	2.04	4.3	-

Table 2 shows the oxide composition of the (GSA, RHA and OPC cement) respectively. From Table 1, GSA contains 34% SiO_2, 12 Al_2O_3 and 14% Fe_2O_3. This gives 60% of SiO_2+ Al_2O_3+Fe_2O_3 which is pozzolanic properties. also has some cementitious properties in line with ASTM C 618-78. And GSA contain 72% SiO_2, 4.4 Al_2O_3 and 1.2% Fe_2O_3. This gives 77.9% of SiO_2+ Al_2O_3+Fe_2O_3 which is pozzolanic properties in line with ASTM C 618-78, while cement OPC is contains 22% SiO_2, 5 Al_2O_3 and 4% Fe_2O_3. This gives 31% of SiO_2+ Al_2O_3+Fe_2O_3.

3.2 The additives effect on the Atterberg limits

Atterberg's Limits experiments were carried out in the laboratory at percentages of 0%, 4%, 6%, 8%, and 10% for cement OPC, GSA, and RHA. Each additive is being studies individually and the results obtained are as follows:

Figure 2 shows the plastic limit of soil- cement OPC, GSA, and RHA at 4%, 6%, 8%, and 10%. cement improved soil stability the most at 22%, followed by groundnut shell ash at 32.5 and rice husk ash at 34%. Cement had the highest plasticity index increase of 9%, followed by groundnut shell ash (10%) and rice husk ash (11%). As clay fraction dropped, soil plasticity index decreased and vice versa.

Figure 3 shows the liquid limit between soil, OPC cement, GSA, and RHA with percentages. OPC cement improved soil stability the most at 31%, followed by groundnut shell ash (42%), and rice husk ash (45%).

In Figure 4, it was discovered that the plastic index of the soil decreased from (52% to 9.5%, 11%, and 14%) with increasing percentages of (8%, 10%, 10%) respectively of (cement OPC, GSA, and RHA) respectively.

Figures 5 and 6 show the shrink limit and soil activity between soil- cement OPC, GSA, and RHA) respectively. Cement stabilized best with a 9% increase, followed by groundnut shell at 13% and rice husk ash at 14.5%. It has reduced activity with moisture content, reducing soil linear shrinkage, cement OPC, GSA, and RHA, and respectively mix and improving soil volume stability. Figure 7 shows the relationship of clay in soil between soil- cement OPC, GSA, and RHA with percentage (0 4%, 6%, 8%, and 10%). In conclusion, the best soil foundation material depends on the soil condition. Cement, groundnut shell ash, and rice husk ash performed well at the liquid and plastic limits, respectively. It also performed well at the plasticity index and was the best stabilizer.

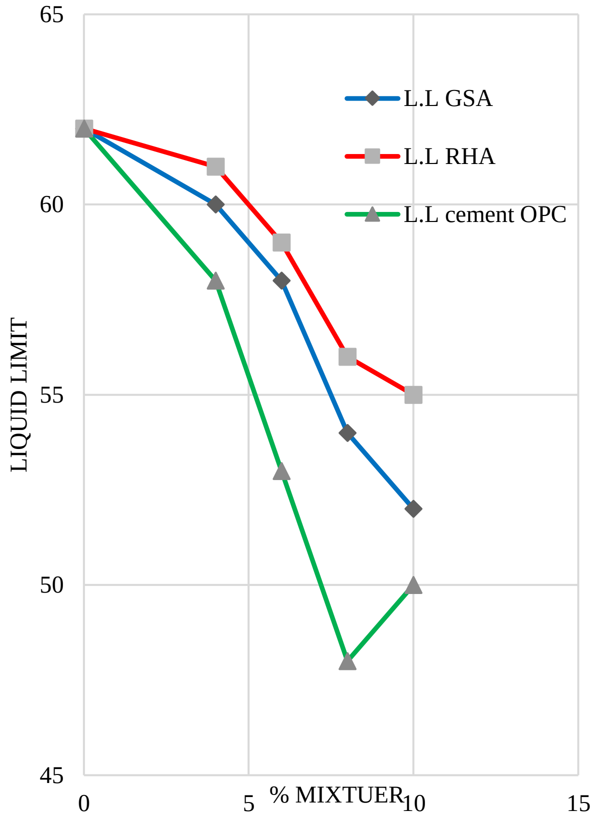

Figure 2. The mixture effect on liquid limit

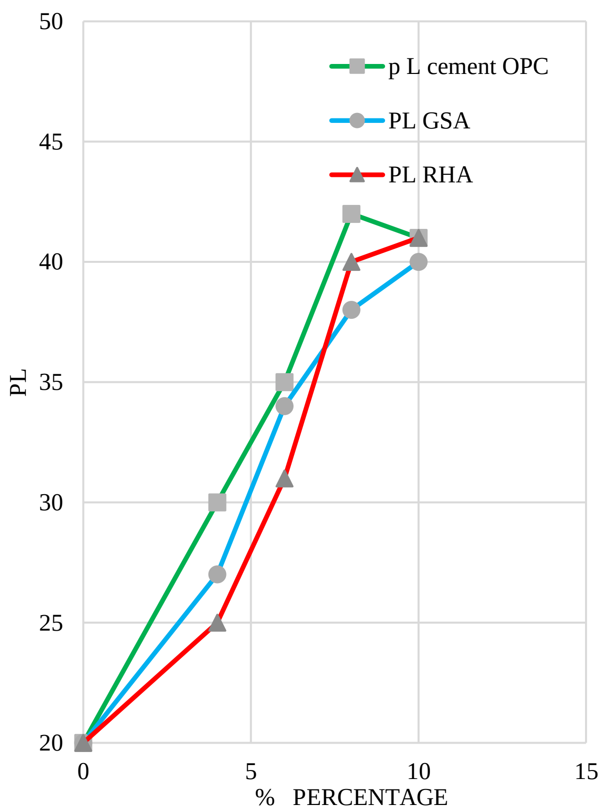

Figure 3. The mixture effect on the plastic limit

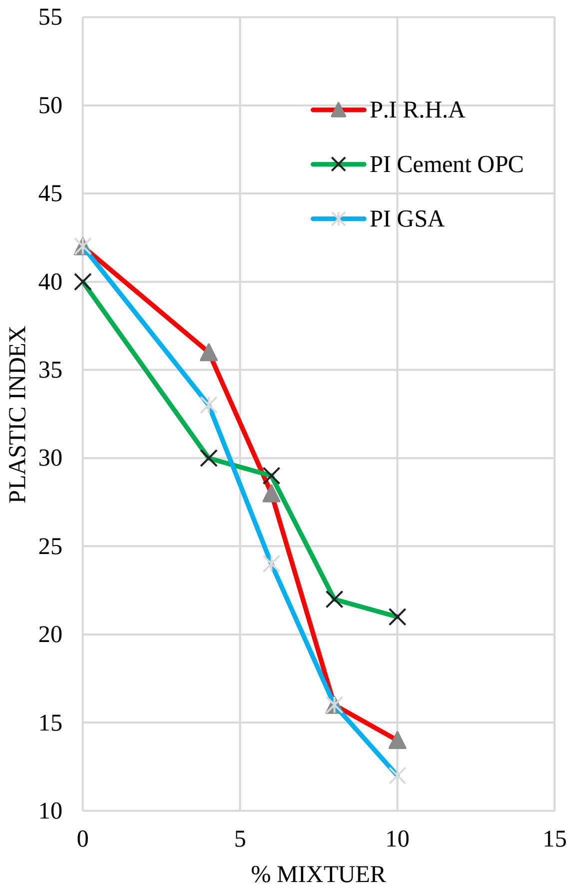

Figure 4. The mixture effect on the plastic index

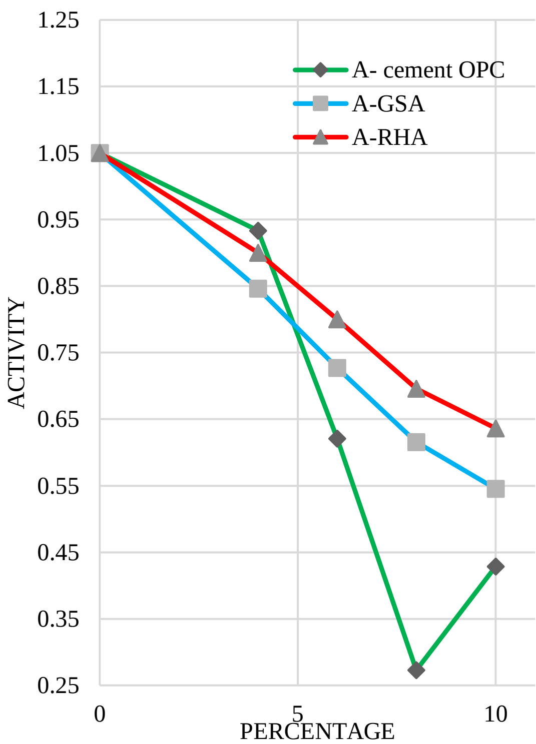

Figure 5. The mixture effect on the activity

3.3 The additives effect on the standard proctor's compaction

The research encompassed the incorporation of varying quantities of groundnut shell ash, rice husk ash, and cement into the soil, with each additive being examined individually. The Standard Proctor's Compaction Test determined each soil mixture's OMC and MDD. Cement increased MDD values the most, followed by groundnut shell and rice husk ash.

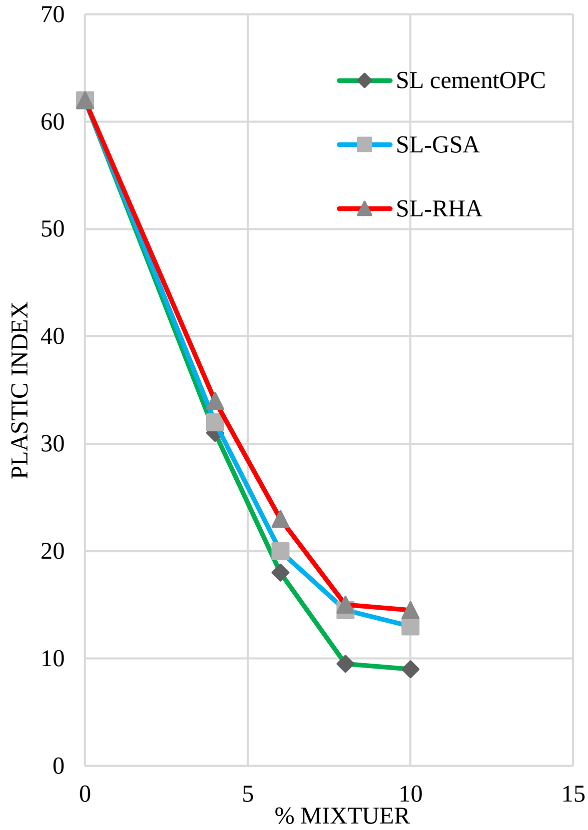

Figure 6. The mixture effect on the shrinkage limit

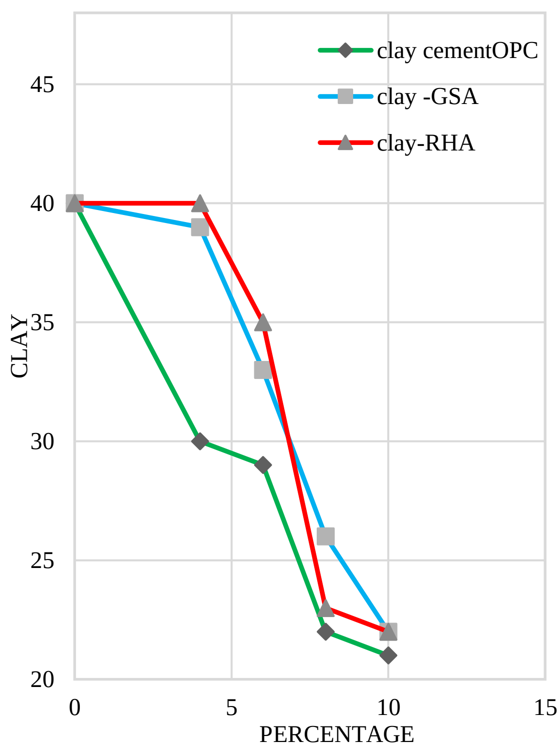

Figure 7. The mixture effect on the percent the clay

In Figure 8, it was discovered that the Optimal Moisture

Content (OMC) of the soil decreased from (15% to 8.1%, 9%, and 10.5%) with increasing percentages of (8%, 10%, 10%) respectively of (cement OPC, GSA, and RHA) respectively.

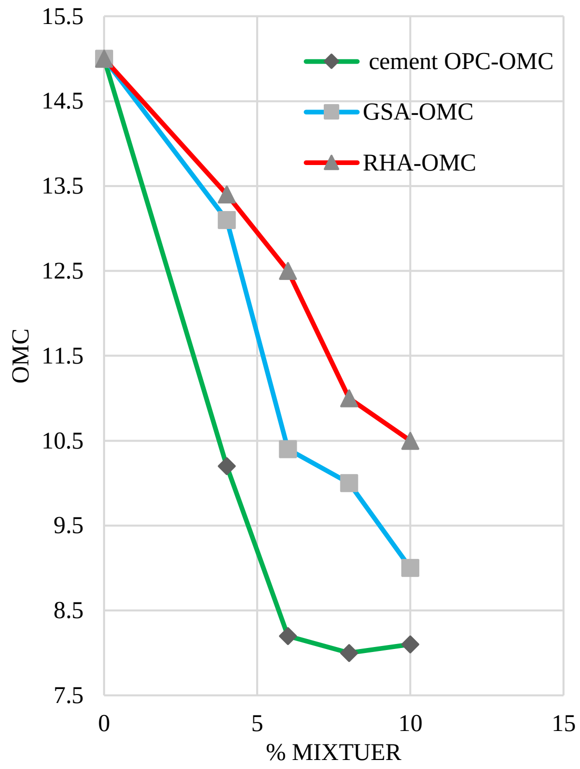

Figure 8. The mixture effect on the OMC

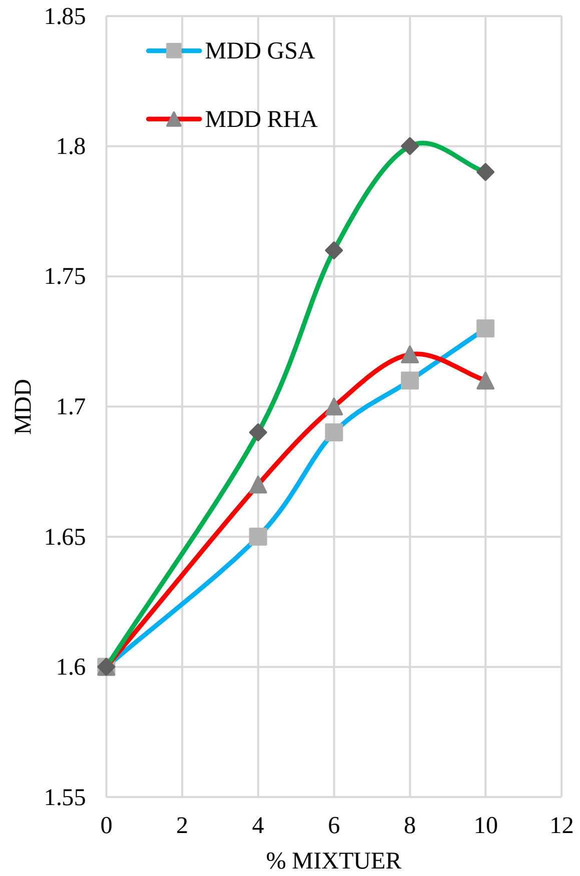

Figure 9. The mixture effect on the MDD

While Figure 9 shows that the Optimal Moisture Content (OMC) of the soil increased from (1.6 to 1.8 1.75, and 1.71 with increasing percentages of (8, 10, 10) % respectively of (cement OPC, GSA, and RHA) respectively.

3.4 The additives effect on the unconfined compressive strength USC

The USC test was carried out for each additive individually, and the procedure of examining and analyzing the outcomes was beginning in the following manner.

In Figure 10, the USC of the soil increased from (65% to 129.7, 120, and 100) with increasing percentages of (8, 10, 10) % respectively clay cement OPC, GSA, and RHA).

Figure 11 explains that cohesion of the soil increased from (21 to 57.5, 56, and 52) with increasing percentages of (8, 10, 10) % respectively (cement OPC, GSA, and RHA). The additive and percentage affected improvement. The strongest substance was cement. Unconfined compressive and cohesive strengths were highest in 8% cement samples. Cement stabilizes soil, according to study. Cement strengthened more than groundnut shell and rice husk ash. Samples with 10% groundnut shell and rice husk ash were weaker than those with 8% cement. In conclusion, cement is the best solution to boost soil's unconfined compressive and cohesive strength. If cement is unavailable or expensive, groundnut shell and rice husk ash can also increase.

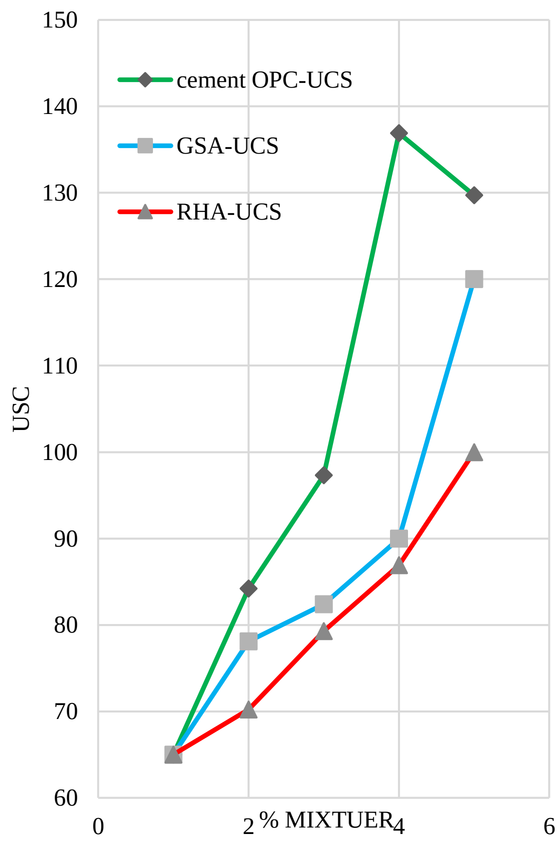

Figure 10. Mixture effect on the UCS

After conducting a comparative analysis of the findings obtained in the current study and previous studies, it was seen that there exist notable resemblances between the outcomes of the current investigation and previous scholarly inquiries pertaining to RAH. Previous studies have utilized rice husk ash as a sole component, with a ratio ranging from 10%-15% depending on the soil type [17, 29-32]. However, another study has found that a 10% proportion of rice husk ash as a partial replacement for cement in aerated concrete yields beneficial effects on the strength and durability properties of the concrete. Various studies have incorporated additional substances, such as lime or cement, into their researches [16, 33]. However, the utilization of chemical stabilizers like cement and lime, which are commonly employed at present, typically entails significant costs and has environmental sustainability concerns due to their unclean nature. Additionally, it has been observed that the utilization of rice husk ashes as a substitute for cement in Portland has shown improved effectiveness, especially when the cement content and cement levels in the mixture are not less than 20% and 35%, respectively. The concentration of crucial constituents within the totality of cement materials, which function to enhance the overall strength of the composite, may surpass 50 percent. According to a study conducted by Jongpradist et al. [34], it was observed that rice corsage ash exhibits higher effectiveness compared to fly ash of same grain size. This increased efficiency was discovered to occur when the content of rice husk ash applied above 15 percent.

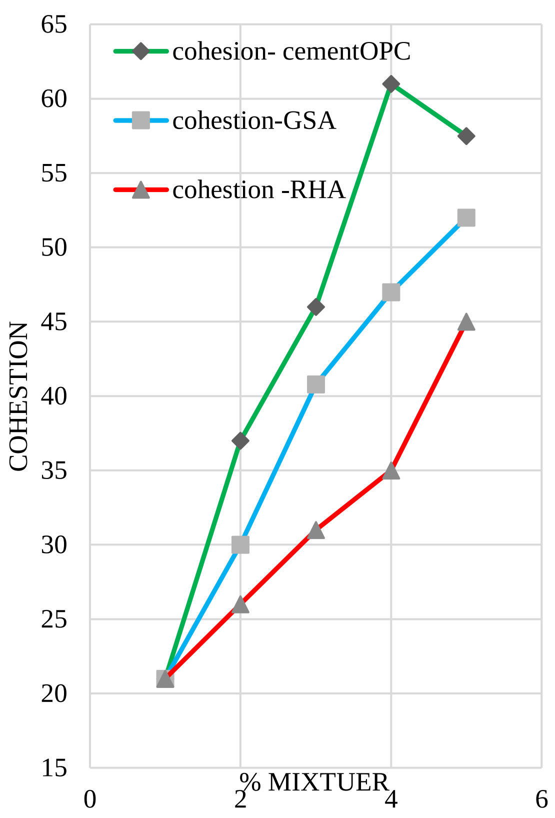

Figure 11. The mixture effect on the cohesion

Regarding the additional additive known as GSA, it has been seen in various studies that its application might enhance soil quality. The optimal ratio of GSA to soil varies between 4% and 12%, depending on the specific soil type [4, 5, 35]. According to Mujedu and Adebara [13], it has been observed that groundnut shell ash can be used as a substitute for up to 30% of regular Portland cement in concrete, as stated by Albert et al. in 2015 and reiterated by Mujedu and Adebara [13, 23]. Furthermore, it has been employed as a supplementary component in conjunction with another additive, as indicated by Adetayo et al. [36] in 2021, and Ikumapayi [12]. The replacement of groundnut shell ash (GSA) with ordinary Portland cement (OPC) is expected to enhance the resistance of the resultant concrete against chloride ion penetration. Previous studies have demonstrated that incorporating both 4% GSA and 12% GSA in concrete leads to an improvement in its resistance to chloride ion penetration.

Cement is an addition commonly employed in traditional ways to enhance the qualities of the underlying soil [37-39]. However, it is worth noting that cement might be economically costly. However, the production of cement and lime requires a considerable amount of thermal energy and has the capacity to release a huge amount of carbon dioxide. Hence, the application of these commonly used soil binders to improve soil quality may result in negative consequences, encompassing environmental ramifications and increased construction costs [40].

The objective of this study is to conduct a comparative analysis of RAH and GAS as environmental waste materials. These materials are known for their cost-effectiveness and their ability to aid in waste management. The study also aims to evaluate the performance of a third cement addition, which shares similar characteristics with the aforementioned additives, as indicated in Table 2. It has been shown that the adoption of GAS can result in a 10% reduction in cement usage compared to an 8% reduction when dealing with expansive clay soils. This finding also applies to (RHA).

4. CONCLUSION

From the tests result, after conducting a variety of laboratory experiments on the clay soil while varying the proportion of clay cement OPC, GSA, and RHA it was discovered that the various properties of the soil sample improved with the addition of these admixtures. This was discovered Following are some of the conclusions that may be taken from the experimental inquiry that was carried out, which are as follow, the primary findings can be inferred as follows:

- Based on the results obtained by conducting Atterberg's limits test, it can be noted that there is a minor drop in the liquid limit and a slight increase in the plastic limit when the amount of rice husk ash increases. A notable reduction in the plasticity index was seen as the GSA or RHA increased.
- The optimal percentage to be added to the soil is 8% for cement, 10% for groundnut shell ash, and 10% for rice husk ash. These findings could be helpful in selecting the most suitable material and percentage for soil stabilization in construction projects, also can used GSA, or RHA instead of cement OPC in improve the physical properties of the swollen clay soil.
- The undrained shear strength derived from the unconfined compression test demonstrates a positive correlation with the concentration of (GSA) and (RHA). Specifically, the shear strength exhibits a linear increase up to 2.1 times greater than that of the clayey soil when GSA is utilized, and up to 2 times greater when RHA is employed. This indicates that both GSA and RHA play a significant role in enhancing the inter-particle tension within the soil-fiber mixture.
- Moreover, the use of recycling should be in soil based

remediation to reduce waste in the environment. Sustainable construction practices involve the incorporation of agricultural waste materials such as rice husk ash and groundnut shell ash, which contribute to the promotion of sustainability by repurposing waste resources that would otherwise be discarded. This is consistent with environmentally sustainable construction methods, which aim to minimize the negative effects on the environment caused by waste management. This is consistent with sustainable construction methods, which aim to mitigate the environmental consequences linked to waste.

- The relevance of these cost-effective soil treatment approaches is particularly significant in rural and developing regions characterized by limited resources. They facilitate cost-effective construction and infrastructure development in locations characterized by limited financial resources.

- It can be suggested that the study treatment soil with groundnut shell ash and rice husk ash. For (7, 14, and 28) day is the most effective in increasing the stability and strength of the soil foundation.

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NOMENCLATURE

L.L	Liquid Limit
P.L	Plastic Limit
PI	Plastic Index
USC	The Unconfined Compressive Strength
OPC	Ordinary Portland Cement
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
A	Activity
GSA	Groundnut Shell Ash
RHA	Rice Husk Ash
G	Gravel
S	Sand
M	Silt
C	Clay
Gs	Specific Gravity
Cu	Cohesion
W%	Natural Moisture Content
FSI	Free Swell Index