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Effect Of Rice Husk Ash On The Plasticity Characteristics Of Jamshoro Shale

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ABSTRACT

This study investigates the effect of rice husk ash (RHA) on the plasticity characteristics of Jamshoro shale. Shale samples were treated with RHA at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by weight, and Atterberg limits were determined for each blend. Results showed that the Liquid Limit decreased progressively from 51% at 0% RHA to 43% at 12% RHA, while the Plastic Limit increased from 29% to 37% over the same range. Consequently, the Plasticity Index decreased markedly from 22% at 0% RHA to 6% at 12% RHA, representing a reduction of approximately 73%. These findings indicate that RHA treatment substantially reduces the plasticity of Jamshoro shale, likely due to cation exchange and flocculation-agglomeration reactions between the shale particles and the pozzolanic RHA, improving the soil's suitability for use in geotechnical applications such as subgrade and embankment construction.

Keywords: Rice Husk Ash, Jamshoro Shale, Plasticity Index**.**

INTRODUCTION

Shale is a fine grained sedimentary rock composed predominantly of clay minerals, and is frequently encountered in geotechnical engineering practice across Sindh, including in the vicinity of Jamshoro. Owing to its clay mineralogy, shale often exhibits high plasticity, significant moisture sensitivity, and a marked tendency

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toward volumetric instability, expanding when wetted and shrinking upon drying. These characteristics pose considerable challenges for construction on or with shale, including reduced bearing capacity, differential settlement, and distress in overlying pavement and foundation structures. Consequently, shale is frequently classified as a problematic soil requiring stabilization before it can be reliably used in embankments, subgrades, or as a foundation material.

Soil stabilization techniques aim to improve the engineering behavior of such problematic soils, most commonly by reducing plasticity and moisture sensitivity while enhancing strength and volumetric stability. Traditional stabilizers such as lime and ordinary Portland cement (OPC) have long been employed for this purpose, typically acting through cation exchange, flocculation-agglomeration of clay particles, and pozzolanic reactions that bind soil particles into a more stable matrix. However, the production of lime and cement is energy-intensive and associated with substantial carbon dioxide emissions, prompting growing interest in sustainable, low-cost alternatives derived from agricultural and industrial waste streams.

Rice husk ash (RHA), obtained through the controlled combustion of rice husk, a major agricultural by product in rice-producing regions such as Sindh, Pakistan, is one such material. RHA is rich in amorphous silica and exhibits pozzolanic characteristics, enabling it to react with clay minerals in a manner similar to conventional stabilizers. When blended with clayey or shaley soils, RHA has been reported to alter the soil's Atterberg limits, typically reducing the Liquid Limit and Plasticity Index while increasing the Plastic Limit, indicating a reduction in plasticity and an improvement in workability. Given the large quantities of rice husk generated annually as agricultural residue, its beneficial reuse in soil stabilization offers both an environmentally sound disposal route and an economical alternative to conventional stabilizers.

Despite encouraging findings for RHA-based stabilization of various clayey soils, research specifically addressing its effect on the plasticity behavior of Jamshoro shale remains limited. This study aims to address this gap by experimentally evaluating the influence of RHA, at varying percentages, on the Liquid Limit, Plastic Limit, and Plasticity Index of Jamshoro shale, with the objective of assessing its suitability as a sustainable stabilizing additive for this locally significant geomaterial.

MATERIALS AND METHODOLOGY

Soil

Jamshoro shale was collected from the vicinity of Mehran University of Engineering and Technology (MUET), Jamshoro, Sindh, Pakistan. The soil retained on the No. 40 sieve was discarded, and the remaining material was thoroughly mixed to ensure uniform testing conditions.

Table 1: Engineering Properties of Untreated Jamshoro Shale

Property	Standard	Value
Natural Moisture Content (%)	AASHTO T265	3.81
Specific Gravity	ASTM D854	2.69
Liquid Limit (%)	ASTM D4318	51

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Plastic Limit (%)	ASTM D4318	29
Plasticity Index (%)	ASTM D4318	22
USCS Classification	ASTM D2487	CH (high plasticity clay)
AASHTO Classification	—	A-7-6
Group Index (GI)	—	17

The Group Index of 17 exceeds the maximum allowable value of 10 for highway subgrade material, classifying the untreated Jamshoro shale as a poor subgrade material and confirming the need for stabilization.

Rice Husk Ash (RHA)

Rice husk, obtained from the local market, was burnt under controlled conditions at 600°C for 2 hours to produce rice husk ash (RHA). The resulting ash was characterized by EDS to confirm its pozzolanic potential prior to use in stabilization.

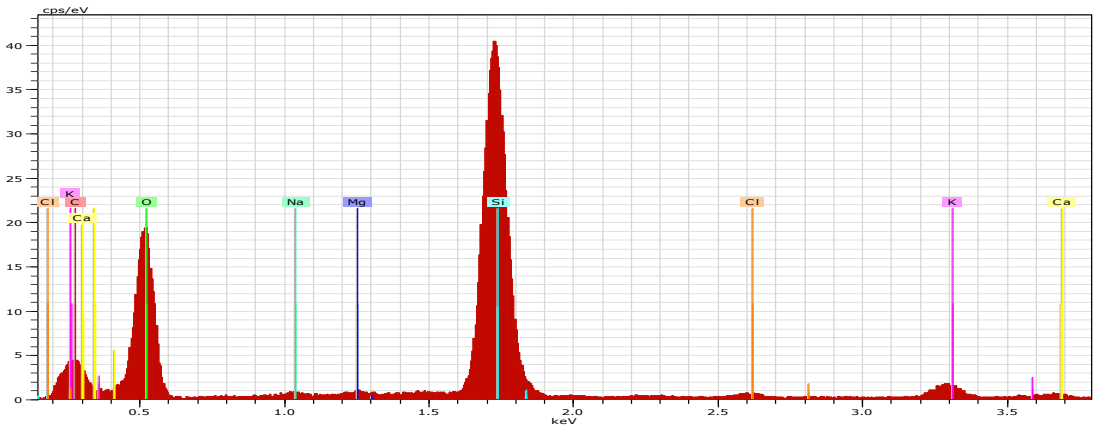


Figure 1: Energy Dispersive Spectrometer EDS of RHA at 600 C-2hr

Table 2. Weight % of elements in RHA(600^{o}C-2hr)

Elements	Series	wt %age	Error %age
Silicon	K-series	35.7	0.6
Aluminium	K-series	0.79	0.3
Magnesium	K-series	0.53	0.1
Calcium	K-series	1.78	0.4
Sodium	K-series	0.47	0.1
Potassium	K-series	3.17	0.1

The high silicon content (35.70%) confirms the amorphous silica-rich, pozzolanic nature of the RHA produced under these calcination conditions.

Soil Ash Blending and Testing Program

RHA was thoroughly blended with untreated Jamshoro shale at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by dry unit weight. Each blended sample was tested for Liquid Limit and Plastic Limit in accordance with ASTM D4318, and the Plasticity Index was

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calculated as the difference between the two (PI = LL − PL).

RESULTS AND DISCUSSION

Effect of RHA on Liquid Limit

Table 3: Effect of RHA Content on Liquid Limit, Plastic Limit, and Plasticity Index

RHA (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	51	29	22
2	48	32	16
4	47	33	14
6	46	34	12
8	45	35	10
10	44	36	8
12	43	37	6

Figure 2 shows the variation of Liquid Limit with RHA content. The Liquid Limit of the Jamshoro shale decreased progressively with increasing RHA content, from 51% at 0% RHA to 43% at 12% RHA, a reduction of approximately 15.7%. This reduction can be attributed to cation exchange reactions between the calcium ions present in RHA and the exchangeable cations on the clay particle surfaces, promoting flocculation and agglomeration of the finer clay particles into coarser aggregations. This reduces the specific surface area available for water adsorption, thereby lowering the Liquid Limit.

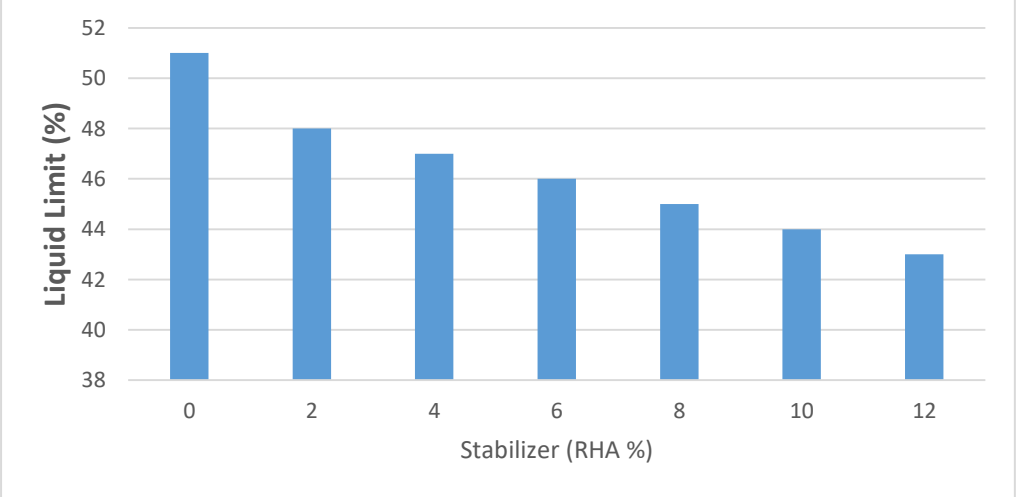


Figure 2: Liquid Limit vs. RHA Content (%)

Effect of RHA on Plastic Limit

Figure 3 presents the trend of Plastic Limit with increasing RHA content. In contrast to the Liquid Limit, the Plastic Limit increased steadily with RHA content, from 29% at 0% RHA to 37% at 12% RHA, an increase of approximately 27.6%. This increase is consistent with the coarser, more granular texture imparted by RHA particles, which alters the soil-water interaction at the plastic state and requires additional moisture for the blended material to reach a workable, plastic consistency.

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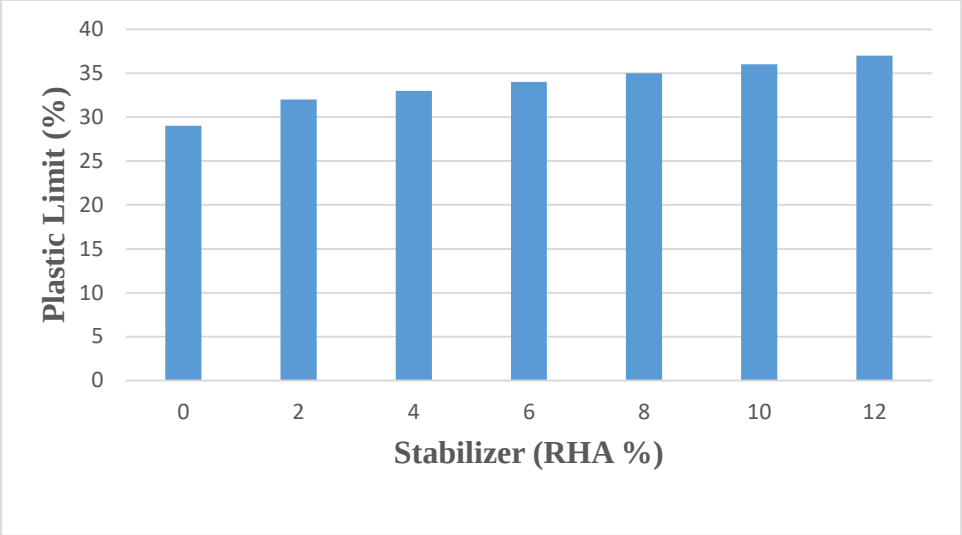
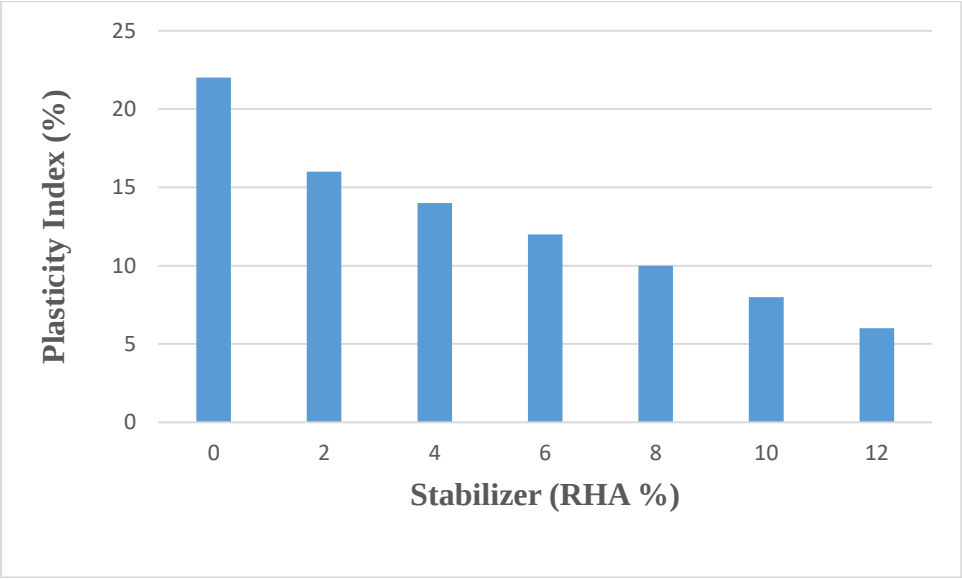


Figure 3: Plastic Limit vs. RHA Content (%)

Effect of RHA on Plasticity Index

Figure 4 illustrates the combined effect of RHA content on the Plasticity Index. The combined effect of decreasing Liquid Limit and increasing Plastic Limit produced a marked reduction in Plasticity Index, from 22% at 0% RHA to 6% at 12% RHA, representing an overall reduction of approximately 73%. This substantial decrease indicates a considerable improvement in the workability of the shale and a reduced range of moisture contents over which the soil remains plastic, lowering its susceptibility to volume change and improving its suitability as a subgrade material. The results indicate that plasticity reduction is progressive and does not show a clear reversal or optimum within the tested range (0–12%), suggesting that RHA continues to improve the plasticity characteristics of Jamshoro shale up to at least 12% replacement.



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Figure 4: Plasticity Index vs. RHA Content (%)

CONCLUSION

The untreated Jamshoro shale was classified as CH (inorganic clay of high plasticity) under the USCS and as A-7-6 under the AASHTO classification system, with a Group Index of 17, indicating a poor subgrade material requiring stabilization.

Rice husk ash (RHA), produced by burning rice husk at 600°C for 2 hours, was confirmed to be silica rich (35.70% Si by EDS) and pozzolanic in nature.

The Liquid Limit of the Jamshoro shale decreased progressively with increasing RHA content, from 51% at 0% RHA to 43% at 12% RHA, a reduction of approximately 15.7%.

The Plastic Limit increased with increasing RHA content, from 29% at 0% RHA to 37% at 12% RHA, an increase of approximately 27.6%.

The Plasticity Index decreased markedly, from 22% at 0% RHA to 6% at 12% RHA, a reduction of approximately 73%, indicating a substantial improvement in the workability and moisture stability of the shale.

These trends are attributed to cation exchange and flocculation agglomeration reactions between the RHA and the clay fraction of the shale, which reduce the soil's affinity for water and its tendency toward plastic deformation.

The results demonstrate that RHA is an effective and sustainable additive for reducing the plasticity of Jamshoro shale, improving its suitability for use as a subgrade or embankment material in highway construction.

Given the progressive nature of the improvement observed up to 12% RHA, further studies extending beyond this range are recommended to identify whether an optimum RHA content exists beyond which no further plasticity reduction occurs.

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