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Evaluating the Effectiveness of Rice Husk Ash and Lime in Subgrade Soil Enhancement

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Abstract. This study explored the use of Rice Husk Ash (RHA) and lime as soil stabilizers for subgrade soil. RHA, a by-product of rice milling, poses environmental hazards if improperly disposed of. The optimal RHA content for subgrade stabilization is 15%, combined with 3% lime. The research found that RHA not only improves subgrade properties but also mitigates environmental pollution and offers a cost-effective stabilization method. The study evaluated engineering properties like plasticity index, maximum dry density (MDD), optimum moisture content (OMC), and California Bearing Ratio (CBR). Results showed a significant decrease in plasticity index and an increase in MDD with RHA addition up to 15%. However, further increase in RHA content led to a decrease in MDD. The combination of 15% RHA and 3% lime exhibited the highest CBR improvement (61.48%), indicating enhanced soil strength. This research suggests that RHA may be a sustainable and cost-effective subgrade stabilization material that improves pavement performance and waste utilization. RHA is abundant, easy to obtain, and economical as compared to cement as a soil stabilizer, reducing disposal issues and environmental impact.

Keywords: Soil, Rice husk Ash, Lime, Maximum dry density, Optimum moisture content & CBR

INTRODUCTION

Research suggests that soil stabilization is crucial for the maintenance and improvement of engineering characteristics of structures like roads, trains, and airport runways [1]. In India, waste production and pollution are major challenges, and subgrade stabilization can help address these issues [2]. A combination of RHA and lime can strengthen and reduce soil flexibility, making it construction-ready. Wood ash can also be used for clay stabilization, reducing plasticity and increasing CBR value and strength [3]. Road construction subgrades using RHA, lime, and fly ash can lower pavement thickness and project costs [4]. RHA can also improve index values in Lateritic soil, and experiments on black soil with 5% RHA and Lime showed increased unconfined compressive strength and CBR [5].

MATERIALS

The study tested virgin soil from Kalanwali, Haryana, India having high clay content and low bearing capacity. The soil's high compressibility necessitates stabilization for engineering use [6]. The soil's geotechnical properties were determined in a laboratory setting, with the results showing a liquid limit of 41%, a plastic limit of 30.54%, a plasticity index of 10.46%, water content of 9.59%, dry density of soil 1.789 g/cc and maximum moisture content of 18.95%. The soil's high clay content and compressibility result in low bearing capacity, making it unsuitable for engineering use [7]. The soil can be stabilized using RHA and lime to improve its properties [8].

Table 1: Geotechnical Properties of Soil Sample. (Source: Author)

Property	Value
Liquid limit (WL)	41%
Plastic limit (WP)	30.54%

Plasticity index (Ip)	10.46%
Water content (W)	9.59%
Soil classification	CI
Maximum Dry Density (MDD)	1.789 g/cc
Optimum Moisture Content (OMC)	18.95%
CBR Value (Soaked)-2.5mm	3.56%
CBR Value (Soaked)-5.0mm	3.53%

Rice husk, a by-product of rice processing, is used as fuel in rice factories to generate steam during boiling [9]. After burning, 25% RHA is produced, posing a significant environmental threat to India, a major rice-producing nation [10]. India produces about 20 million tonnes of RHA annually, posing significant ecological risks if not properly utilized [11]. This husk, high in silica, is an effective soil stabilizer due to its pozzolanic properties (Table 2). Despite its potential commercial use, improper disposal of RHA poses significant ecological risks [12]. Various methods are being explored to commercially utilize RHA, but proper disposal is crucial [13].

Table 2: Chemical Composition of RHA [10]

Composition	SiO ₂	Fe ₂ O ₃	MgO	Al ₂ O ₃	CaO	Loss on ignition
Amount (%)	85	1.98	0.41	3.7	3.9	4.9

Lime (CaO), known for its caustic and alkaline properties, was procured from a local market for this study [14]. This study used lime (CaO), a white, caustic, alkaline crystalline solid at room temperature, to prepare soil samples. Rice Husk Ash was used in different percentages, with a constant percentage (3%) of lime in every mix. The soil, RHA, and lime samples were analyzed using different mix proportions. The results are shown in Figure 1, and the mix proportions are tabulated in Table 3. The soil, RHA, and lime samples were categorized into subgrade soil, graded sand, and graded lime [15]. The study aimed to understand the effects of different mix proportions on soil quality and nutrient content.

SAMPLE PREPARATION

Samples were prepared with varying RHA contents (0%, 5%, 10%, 15%, 20%, and 25%) and a constant lime content (3%), presented in Table 3.

Table 3: Mix Proportions of Soil, RHA, and Lime. (Source: Author)

Sample ID	Soil (%)	RHA (%)	Lime (%)
CS	100	0	0
SP0	98	0	3
SP5	92	5	3
SP10	87	10	3
SP15	82	15	3
SP20	77	20	3
SP25	72	25	3

EXPERIMENTAL WORK

Plasticity Index: The Plasticity Index (Ip) was determined according to BIS: 2720 (Part-5), 1985 [16]. Results are shown in Table 4 and Figure 1.

Table 4: Plasticity Index of Samples (Source: Author).

Sample ID	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
CS	41	30.54	10.46
SP0	39.5	30.95	8.55
SP5	38.7	31.45	7.25
SP10	37.7	31.84	5.86
SP15	36.9	32.42	4.48
SP20	36.1	32.69	3.41
SP25	35.7	33.21	2.49

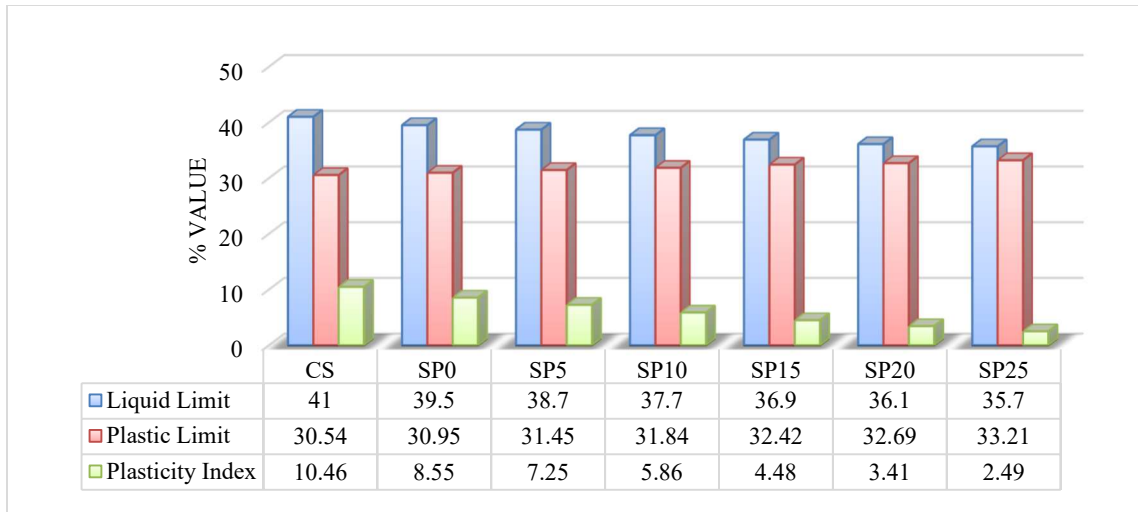


Figure 1: Graph of Liquid limit, Plastic limit & Plasticity Index of different Soil Samples. (Source: author)

MDD and OMC: Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined using the Standard Proctor Test according to BIS: 2720 (Part-8), 1984 [17]. Results are shown in Table 5. The graph shown in Figure 2 displays the MDD and OMC of various soil samples.

Table 5: MDD and OMC of different soil samples (Source: Author).

Sample ID	MDD (g/cc)	OMC (%)
CS	1.789	18.95
SP0	1.812	18.10
SP5	1.824	17.59
SP10	1.894	16.95
SP15	1.912	15.21
SP20	1.906	16.26
SP25	1.856	16.06

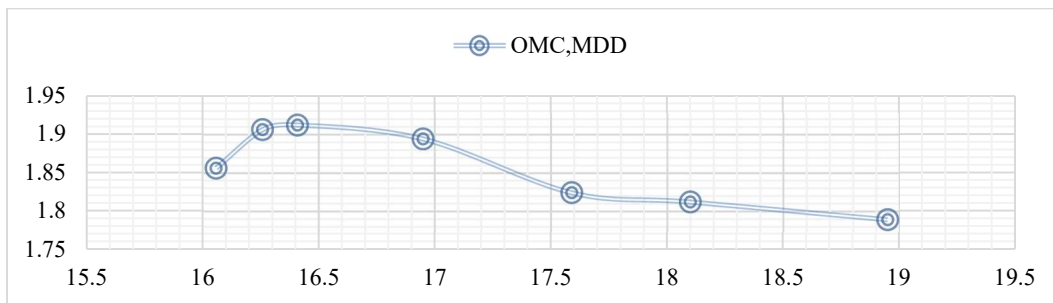


Figure 2: Graph of MDD and OMC of different soil samples. (Source: author)

California Bearing Ratio (CBR): CBR tests, as per BIS: 2720 (Part-16), 1987 [18], were conducted to determine soil strength. Results are shown in Table 6 and Figure 3.

Table 6: CBR Values of different Soil Samples (Soaked & Unsoaked) (Source: Author).

Soil Sample	CBR (Unsoaked)	
	2.5 mm	5.0 mm
CS	3.56	3.53
SP0	4.21	4.11
SP5	4.87	4.58
SP10	5.21	5.04

SP15	5.79	5.67
SP20	5.42	5.31
SP25	5.08	4.87

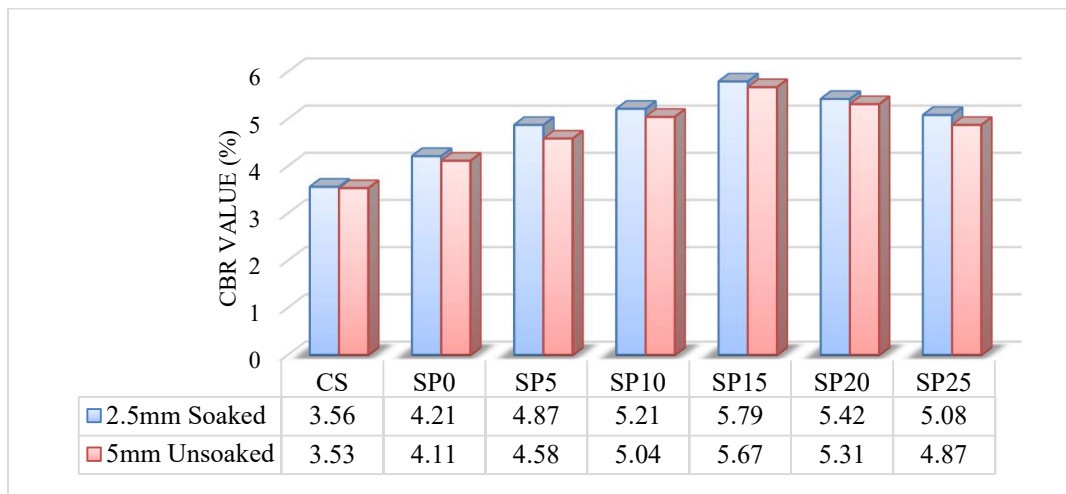


Figure 3: Comparison of soaked CBR Values of different Soil Samples (Soaked & Unsoaked). (Source: author)

RESULTS AND DISCUSSION

The study found that the Plasticity Index decreased from 10.46% to 2.49% with the addition of RHA and lime content, indicating a transition towards a non-plastic state. Dry density improved with RHA and lime content up to a specific limit, then exhibited a downward trend. The peak value of MDD (1.912g/cc) was obtained at S.P. 15 (RHA-15% and Lime-3%), and the corresponding OMC was reported. The addition of more than 15% RHA had an adverse effect on the bonding behavior of soil particles, as reflected in the CBR test. The CBR value improved with RHA content ranging from 0-15% with 3% lime due to the presence of silica oxide in RHA. The combination of RHA with lime made the soil more plastic, reducing the soil particle bond. The CBR followed a downward trend with increased RHA and lime, indicating reduced plasticity. In the future work, simulations like parametric optimizations could further optimize these processes by predicting optimal RHA and lime content for various soil types, reducing testing times and costs [19-23]. AI-powered material science simulations could further optimize these processes by predicting optimal RHA and lime content for various soil types, reducing testing times and costs [24-26].

CONCLUSIONS

The study found that using residual husk (RHA) and lime stabilized soil subgrade, resulting in a 61.48% increase in strength. This method not only improved subgrade properties but also addressed environmental concerns related to RHA disposal. Experiments were conducted to evaluate geotechnical properties, including liquid limit, plastic limit, moisture content, maximum dry density, and California Bearing Ratio. The optimal RHA quantity was found to be 15% with a constant 3% lime percentage, resulting in a significant increase in soil strength. Key findings included a decrease in plasticity index, improved dry density, and a peak MDD value. However, over 15% RHA negatively affected soil particle bonding behavior. The combination of RHA and lime made soil more plastic, reducing particle bond, and decreased CBR, indicating reduced plasticity.

REFERENCES

1. S. M. Arif, *J. Adv. Res. Civ. Environ. Eng.* **4**, 19-24 (2017).
2. S. Y. Amakye, S. J. Abbey, C. A. Booth, and A. M. Mahamadu, *Geotechnics* **1**, 307-329 (2021).
3. C. O. Okagbue, *J. Mater. Civ. Eng.* **19**, 14-18 (2007).

4. A. Ali, S. A. Khan, and E. F. Karim, *Proc. Eng.* (2019).
5. A. B. Alabi, A. O. Olutaiwo, and A. O. Adeboje, *J. Eng. Res. Appl.***5**, 32-40 (2015).
6. A. A. Firoozi, C. Guney Olgun, A. A. Firoozi, and M. S. Baghini, *Int. J. Geo-Eng* **8**, 1-16 (2017).
7. M. Ornek, M. Laman, A. Demir, and A. Yildiz, *Soils Found.***52**, 69-80 (2012).
8. B. H. J. Pushpakumara and W. S. W. Mendis, *Int. J. Geo-Eng.***13**, 4 (2022).
9. E. M. Kwofie and M. Ngadi, *Renew. Sustain. Energy Rev.***72**, 465-472 (2017).
10. G. Athira, A. Bahurudeen, and S. Appari, *J. Clean. Prod.***236**, 117598 (2019).
11. S. K. Singh and S. M. Arif, *Int. J. Res. Eng. Technol.***3**, 209-213 (2014).
12. M. Varsha, P. S. Kumar, and B. S. Rathi, *Chemosphere***287**, 132270 (2022).
13. B. A. Tayeh, R. Alyousef, H. Alabduljabbar, and A. Alaskar, *J. Clean. Prod.***312**, 127734 (2021).
14. M. C. Mishra, K. Sateesh Babu, N. G. Reddy, P. P. Dey, and B. Hanumantha Rao, *J. Hazard. Toxic Radioact. Waste***23**, 04019012 (2019).
15. T. R. Karatai, *Doctoral dissertation, JKUAT* (2018).
16. Bureau of Indian Standards, *2720 Methods of Test for Soils: Part 5 Determination of Liquid and Plastic Limit* (Bureau of Indian Standards, New Delhi, 1985).
17. Bureau of Indian Standards, *2720 Methods of Test for Soils: Part 8 Determination of OMC & MDD* (Bureau of Indian Standards, New Delhi, 1985).
18. Bureau of Indian Standards, IS: 2720- Part 16 Code of Practice for Method of testing of California Bearing Ratio of soil (Bureau of Indian Standards, New Delhi, 1987).
19. H. Kumar, A. S. Wadhwa, S. Akhai, and A. Kaushik, *Eng. Res. Express***6**, 025542 (2024).
20. H. Kumar, A. S. Wadhwa, S. Akhai, and A. Kaushik, *Eng. Res. Express***6**, 025505 (2024).
21. S. M. Arif, Strength Development in Silty Sandy Soil Stabilized with Rbi Grade 81 (2018).
22. M. Rana and S. Akhai, *Mater. Today: Proc.***65**, 3205-3210 (2022).
23. S. Akhai and M. Rana, *Mater. Today: Proc.***65**, 3165-3169 (2022).
24. A. Khursheed and E. S. Pathak, *Int. Res. J. Eng. Technol.***10**, 56-59 (2023).
25. S. Akhai, *Explainable Artif. Intell. Healthcare***1**, 119-129 (2024).
26. S. Akhai and V. Kumar, *Sustain. Secur. Pract. Blockchain Quantum Post-Quantum Technol. Real Time Appl.***125-153** (2024).