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Review of Sustainable Soil Stabilization Using Rice Husk Ash, Coir Fibre, Lime and Recycled Gypsum

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Abstract

Expansive soils can create substantial difficulties for roads and foundations because their volume changes with moisture. They may swell during wet periods, shrink as they dry, and lose bearing capacity when saturated. Research has therefore explored agricultural and industrial by-products as alternatives or supplements to conventional soil binders. This review considers published work on rice husk ash (RHA), lime, coir fibre and recycled gypsum, with attention to plasticity, compaction, California Bearing Ratio (CBR), unconfined compressive strength (UCS), swelling and durability. The studies reviewed indicate that appropriately proportioned RHA may reduce plasticity and expansion while improving strength; lime can modify clay behaviour and promote strength development; coir fibre can restrain crack propagation and improve deformation response; and a recycled gypsum–RHA blend has reduced expansion in a particular expansive soil. Outcomes vary with soil composition, additive quality, mix proportions, compaction and curing. Evidence on long-term performance, environmental compatibility, field behaviour and consistent reporting remains limited. Accordingly, proposed mixtures should be assessed through replicated testing of several engineering properties and durability before they are adopted in practice.

1. Introduction

Expansive soils undergo changes in volume as their water content changes. Repeated swelling and shrinkage can damage pavements, produce cracks and cause uneven movement in lightly loaded structures. Soil stabilization aims to limit these effects by changing the soil structure, reducing plasticity, increasing strength or making the material less responsive to moisture. Performance depends not only on the stabilizer but also on the untreated soil, additive chemistry, dosage, water content, compaction effort and curing conditions [1,2].

Lime and cement are established stabilizing agents, but waste-derived materials are receiving attention because they may make use of discarded resources and reduce the quantity of conventional binder required. Rice husk ash is an agricultural residue containing silica; its reactivity varies with burning and processing conditions. Coir fibre provides reinforcement rather than acting as a mineral binder: it can bridge cracks and resist tensile movement. Recycled gypsum has also been investigated in combination with RHA for controlling expansion [1–3]. Since these materials operate through different mechanisms, their effects should be evaluated individually and in combinations rather than assumed to be interchangeable.

2. Review methodology

This paper presents a narrative review based on the literature-survey material supplied for the review and publication records available through journal and publisher sources. Greater weight was given to studies with identifiable publication informatio n, including a DOI or publisher metadata. The papers differed in soil type, additive content, curing duration and testing procedure; therefore, their findings were compared descriptively rather than combined statistically. No universal optimum dosage is proposed. Some entries in the initial survey did not contain enough bibliographic information for independent verification and have not been included in the reference list. For a fully reproducible journal review, the databases, search terms, date limits and screening criteria should also be documented.

3. Literature review

3.1 Rice husk ash stabilization

Rice husk ash can influence particle arrangement and the water required to compact a soil mixture. Where suitable calcium is available, reactive silica in the ash may participate in cementitious reactions. Its effectiveness is affected by ash fineness, silica content, residual unburnt carbon and the characteristics of the soil being treated. Onyechere et al. examined the effect of RHA on properties including compaction, specific gravity, CBR and Atterberg limits [4]. Measuring several properties is important because a higher bearing capacity alone does not establish that plasticity, swelling and compaction behaviour have also improved.

Sharma et al. (2026) investigated RHA-treated expansive subgrade soil using laboratory testing and explainable machine-learning methods. In their soil, the treatment reduced differential free swell and plasticity while increasing UCS and soaked CBR. The strongest overall response was reported at approximately 10–15% RHA. Under the pavement-design assumptions used in that study, the analysis also indicated a 26% reduction in flexible pavement thickness [1]. These results relate to the specific soil and design conditions investigated and should not be treated as a universal dosage or pavement-design rule.

Predictive models and response-surface approaches can help describe the relationship between RHA content and soil performance. However, their reliability should be checked using soils that were not part of the original model-development dataset. The most effective RHA proportion may change with soil mineralogy, ash properties and curing conditions [1].

3.2 Lime and RHA combinations

Lime initially changes clay behaviour through cation exchange and particle flocculation. Longer-term strength development can occur when lime reacts with available silica and alumina. In a lime–RHA blend, lime supplies calcium while the ash may contribute reactive silica. Faluyi et al. evaluated lime–RHA-treated soils using CBR, compaction, UCS and triaxial tests and reported improved geotechnical performance for the soils considered [5]. This supports examining RHA as a supplementary stabilizer, but the proportions should be selected for the specific soil. Laboratory curing and moisture conditions should also be chosen to represent the intended field application as closely as possible.

3.3 Coir fibre reinforcement

Coir fibre reinforces soil by carrying tensile forces and connecting developing cracks; it does not function in the same way as a mineral binder. The outcome depends on fibre length, aspect ratio, quantity, treatment and distribution throughout the mixtur e. Poor dispersion or excessive fibre can make the mix non-uniform and interfere with compaction.

Sridhar et al. studied treated coir fibre in black cotton soil, including its durability under demanding exposure conditions [2]. Durability is important because natural fibres may deteriorate during wetting–drying cycles or exposure to contaminated water and other harsh environments. Initial strength improvement should therefore be considered alongside the performance retained after exposure.

Combining coir fibre with RHA or lime may offer complementary effects: the mineral additive can alter the soil matrix, while the fibres may improve deformation behaviour and limit crack growth. Further experiments should separate the effects of each material from the interaction between them. Fibre treatment, dimensions, dosage, distribution and curing duration need to be reported so that results can be reproduced.

3.4 Recycled gypsum and RHA

Tan and Adajar examined recycled gypsum and RHA as additives for expansive soil. In the soil they tested, gypsum on its own increased plasticity, whereas the addition of RHA reduced it. Their blend containing 15% recycled gypsum and 10% RHA met the non-expansive criterion adopted in that study and also affected maximum dry density and optimum moisture content [3]. This illustrates that a combined treatment may behave differently from either component used separately. The same proportions should not be transferred directly to other soils without checking soil chemistry, the relevant expansion criteria, leaching potential and durability.

4. Discussion and key findings

Across the reviewed work, soil stabilization influences several connected engineering properties. Plasticity, compaction, swelling, CBR, UCS and durability should be evaluated together; a single strength measurement is not sufficient to establish that a treatment is suitable. Reported optimum contents vary and apply to the materials and procedures used in each study. Meaningful comparison requires details of the untreated soil and its classification, complete mix proportions, specimen preparation, compaction energy, curing period and whether CBR results were obtained under soaked or unsoaked conditions.

5. Research gaps and future scope

Long-term durability: Further work should examine wet–dry cycling, repeated loading, erosion and the strength retained by ash- and fibre-treated soils over time.

Consistent reporting: Studies should document soil classification and, where available, mineralogy; additive composition; the basis used to calculate dosage; compaction procedures; curing conditions; and the test standards followed.

Combined-additive effects: Replicated factorial or response-surface experiments could distinguish the individual contributions of RHA, lime, coir fibre and recycled gypsum, as well as interactions between them.

Environmental compatibility: Leaching behaviour and possible sulphate-related risks from recycled gypsum mixtures need evaluation. The source and processing history of each waste-derived material should also be recorded.

Field verification: Laboratory findings should be compared with monitored pavement sections and assessed against the design standards applicable to the intended location.

Predictive modelling: Models should be tested on independent soils, with uncertainty, input variables and dataset limitations clearly described.

6. Conclusions

The studies considered suggest that RHA, lime, coir fibre and recycled gypsum can improve selected properties of expansive or otherwise problematic soils. RHA has been associated with changes in plasticity and swelling and improvements in CBR and UCS. Lime modifies clay behaviour and can support strength gain, while coir fibre reinforces the soil by bridging cracks. A recycled gypsum–RHA mixture reduced expansion in one of the soils reviewed. In all cases, performance depends on the soil, the properties and dosage of the additive, the mixture design and the curing conditions.

The reviewed evidence does not establish one mixture that is optimal for every soil. Before practical use, a proposed treatment should be tested across multiple engineering properties, assessed for durability and environmental compatibility, and validat ed under field conditions. Future studies would be strengthened by repeatable experiments, transparent reporting and field monitoring, allowing waste-derived stabilizers to be evaluated more reliably for sustainable geotechnical and pavement applications.

Table 1. Summary of reviewed stabilization approaches

Stabilization method	Reported trend in the reviewed studies	Main point to verify
RHA	Reduced plasticity and swelling and increased UCS or CBR at suitable contents in selected studies [1,4].	Soil mineralogy, ash quality and curing conditions.
Lime + RHA	Lime modifies clay behaviour and RHA may contribute reactive silica; improved properties were reported in tested soils [5].	Dosage and curing must be appropriate for the soil.
Coir fibre	Can bridge cracks and improve deformation response; durability was examined in black cotton soil [2].	Fibre size, distribution, dosage and exposure conditions.
Recycled gypsum + RHA	A particular blend reduced expansion and changed compaction characteristics [3].	Sulphate compatibility, leaching and long-term durability.

References

[1] A. Sharma, K. Singh, A. Senagah, N. Sidhu, A. K. Tiwary, G. Juneja, S. K. Verma, R. Gupta, and P. S. Joia, “Performance-based evaluation and UCS prediction of rice husk ash-stabilized expansive subgrade soil using experiments and explainable machine learning,” Multiscale and Multidisciplinary Modeling, Experiments and Design, vol. 9, art. 150, 2026. doi: 10.1007/s41939-026-01233-7.

[2] R. Sridhar, H. C. Guruprasad, D. T. Naveenkumar, and D. M. Sangeetha, “Influence of treated coir fiber on durability properties of black cotton soil,” Materials Today: Proceedings, vol. 80, Part 2, pp. 1611–1616, 2023. doi: 10.1016/j.matpr.2023.02.127.

[3] J. F. Tan and M. A. Q. Adajar, “Recycled gypsum and rice husk ash as additives in the stabilization of expansive soil,” International Journal of GEOMATE, vol. 18, no. 70, pp. 197–202, 2020. doi: 10.21660/2020.70.9201.

[4] I. C. Onyechere et al., “Influence of rice husk ash on the engineering properties of soil,” NIPES Journal of Science and Technology Research, 2025.

[5] S. O. Faluyi, O. O. Amu, and J. S. Adekanmi, “Geotechnical characteristics of soils stabilized with lime–rice husk ash for road construction in Nigeria Southwestern States,” 2025.