International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 13 Special Issue 02 | 2026

Sustainable Subgrade Stabilization using Plastic Waste and Rice Husk Ash

Mrs. Anjali Vishnu Surushe[1], Mr. Akshay Ramesh Lad[2], Mr. Vaibhav Devidas Wankar[3], Prof. Atul Baliram Adhao[4]

[1,2,3] Student of, Department of Civil Engineering, Siddhivinayak Technical Campus, Shegaon, Maharashtra, India

[4] Assistant Professor, Department of Civil Engineering, Siddhivinayak Technical Campus, Shegaon, Maharashtra, India

DOI: 10.5281/zenodo.19538396

ABSTRACT

Rapid infrastructure development demands sustainable engineering solutions that minimize environmental impact while enhancing soil performance. This research investigates the use of plastic waste and rice husk ash (RHA) as eco-friendly stabilizers for subgrade soil. Laboratory experiments were conducted by mixing varying proportions of shredded plastic and RHA with clayey soil. Results reveal significant improvement in bearing capacity, compaction characteristics, and CBR strength, demonstrating that the blended use of plastic waste and RHA can be a viable alternative to traditional stabilizers like lime and cement. The approach diverts agricultural and municipal waste from landfills, aligning with circular economy principles.

Keywords:- Subgrade stabilization, plastic waste, rice husk ash, soil improvement, CBR, sustainable materials

1. INTRODUCTION

The increasing demand for road infrastructure has intensified the need to enhance subgrade soil performance, particularly in regions characterized by weak or problematic soils. Conventional soil stabilization techniques using cement and lime are widely adopted due to their effectiveness; however, they are associated with high costs and considerable environmental impacts. To address these concerns, sustainable alternatives incorporating waste materials have gained significant attention in geotechnical engineering.

Plastic waste and rice husk ash (RHA) are abundantly available solid wastes that present serious disposal and environmental challenges. The incorporation of plastic waste into soil has been shown to improve ductility and resistance to deformation, while RHA, which is rich in silica, exhibits pozzolanic properties that contribute to enhanced soil strength. This study investigates the combined utilization of plastic waste and rice husk ash as eco-friendly stabilizing agents to improve the engineering properties of subgrade soil for sustainable road construction.

In addition, coconut shell ash (CSA) has demonstrated potential in enhancing certain strength and durability characteristics of cement-based materials. Therefore, this study also evaluates the mechanical and durability performance of cement bricks incorporating coconut shell ash and compares them with conventional cement bricks to assess their suitability for sustainable construction applications

1.1 Problem Statement

The rapid expansion of road infrastructure has increased the demand for strong and durable subgrade soils; however, many construction sites are characterized by weak or problematic soils with low bearing capacity and high susceptibility to deformation. Conventional stabilization methods using cement and lime, although effective, are costly and contribute significantly to environmental degradation through high energy consumption and carbon emissions. At the same time, the accumulation of solid wastes such as plastic waste, rice husk ash (RHA), and coconut shell ash (CSA) presents serious environmental and disposal challenges. While previous studies indicate that plastic waste can enhance soil ductility, RHA possesses pozzolanic properties that improve soil strength, and CSA may enhance the mechanical and durability performance of cement-based materials, their integrated and systematic application in subgrade stabilization and brick production remains insufficiently explored. Therefore, there is a need to investigate sustainable, cost-effective alternatives that utilize these waste materials to improve engineering performance while simultaneously addressing environmental concerns.

1.2 Objectives

- To improve subgrade soil strength using plastic waste and Rice Husk Ash.
- To study the effect of plastic waste and RHA on CBR and bearing capacity
- To identify the optimum mix proportion for soil stabilization.

- To promote sustainable and eco-friendly road construction practices.

2. LITERATURE REVIEW

Subgrade Stabilization has significant environmental impacts, prompting research into sustainable alternatives.Plastic Waste and RHA, improving strength, durability, and sustainability. This review summarizes previous studies on its use and identifies areas for further research.

- **Alhassan, M. (2008).** Potentials of rice husk ash for soil stabilization. Assumption University Journal of Technology, 11(4), 246–250..
- **Basha, E.A., Hashim, R., Mahmud, H.B. & Muntohar, A.S. (2005).** Stabilization of residual soil with rice husk ash and cement. Construction and Building Materials, 19(6), 448–453..
- **Choudhary, A.K., Jha, J.N. & Gill, K.S. (2010).** A study on CBR behavior of waste plastic strip reinforced soil. Emirates Journal for Engineering Research, 15(1), 51–57.
- **Ganesan, K., Rajagopal, K. & Thangavel, K. (2008).** Rice husk ash blended cement: Assessment of optimal level of replacement. Construction and Building Materials, 22(8), 1675–1683.
- **Kumar, A. & Sharma, R. (2021).** Sustainable stabilization of clay soil using rice husk ash and plastic waste. International Journal of Pavement Engineering, 22(5), 612–623.
- **Muntohar, A.S. & Hantoro, G. (2000).** Influence of rice husk ash and lime on engineering properties of expansive soils. Electronic Journal of Geotechnical Engineering, 5.
- **Patel, V., Desai, M. & Mehta, P. (2022).** Performance evaluation of hybrid waste stabilized subgrade soils. Materials Today: Proceedings, 56, 2450–2456.

2.1 Conclusion Based on Reviewed Literature

The literature reviewed indicates that rice husk ash (RHA) and plastic waste are effective materials for sustainable subgrade stabilization when used within optimal percentage ranges. Most studies report that the addition of 5–20% RHA by dry weight of soil significantly reduces plasticity index and swelling potential while increasing unconfined compressive strength (UCS) and California Bearing Ratio (CBR). Strength improvement is generally observed up to an optimum range of 10–15% RHA, beyond which performance may decline due to dilution effects and insufficient calcium availability for pozzolanic reactions**.**

2.2 Identified Research Gaps

Although numerous studies report strength improvement of subgrade soils using 5–20% rice husk ash (RHA) and 0.5–2% plastic waste, existing research remains largely laboratory-based and empirical. There is limited understanding of the coupled chemo-mechanical interaction between pozzolanic bonding (RHA) and tensile reinforcement (plastic waste).

The combined chemo-mechanical behavior, long-term durability under cyclic loading, standardized mix design procedures, and quantitative sustainability assessment—aligned with frameworks of the United Nations Environment Programme—remain insufficiently investigated**.**

3. METHODOLOGY

3.1 Materials

3.1.1 Rice Husk Ash

Rice Husk Ash (RHA) is an agricultural by-product obtained from the controlled combustion of rice husk, which constitutes about 20–22% of the weight of harvested rice. India, being one of the largest rice-producing countries, generates significant quantities of rice husk annually, making RHA an abundantly available waste material. When rice husk is burned under controlled temperatures between 500°C and 700°C, the resulting ash contains a high percentage of amorphous silica, which is highly reactive and suitable for engineering applications. The effective utilization of RHA supports sustainable waste management strategies promoted by the United Nations Environment Programme.In geotechnical applications, RHA significantly improves the engineering properties of clayey and expansive soils. The addition of 5–15% RHA generally reduces plasticity index and swell potential while increasing California Bearing Ratio (CBR) and unconfined compressive strength (UCS). Although the inclusion of RHA may increase optimum moisture content and slightly reduce maximum dry density due to its low density, the overall strength enhancement outweighs these effects. Optimum performance is typically observed around 10–15% RHA content, beyond which strength may decline due to dilution of soil particles.RHA serves as an eco-friendly, cost-effective, and technically viable material for sustainable subgrade stabilization.

3.1.2 Plastic Waste

Plastic waste was sourced from local collection centres and informal waste segregation units rather than from commercial suppliers. This deliberate choice was made to ensure that the study reflects real-world conditions road construction agencies working with waste-based stabilizers will inevitably use post-consumer plastic rather than laboratory-grade polymer. By using actual waste material, the study ensures its findings are applicable in practice.

Three types of commonly discarded plastics were selected for this study, chosen because they represent the largest volume categories of plastic waste generated in Indian cities and towns.

Low-Density Polyethylene (LDPE) includes thin carry bags, food packaging films, cling wraps, and shrink films. LDPE is flexible, has a relatively low melting point (around 105–115 °C), and a specific gravity of approximately 0.92. Its flexibility is a useful property — when shredded into strips, LDPE pieces act as pliable fibres within the soil matrix that can deform slightly under stress without breaking, absorbing and redistributing tensile stresses within the soil

High-Density Polyethylene (HDPE) is found in thicker products such as milk cans, water containers, and heavy-duty bags. HDPE is stiffer and tougher than LDPE, with a specific gravity of around 0.96. When shredded into strips, HDPE pieces provide a more rigid inclusion within the soil, beneficial in resisting deformation under load.

Polyethylene Terephthalate (PET) is the plastic used in water bottles and soft drink bottles. PET has the highest specific gravity of the three (approximately 1.38) and the highest tensile strength. When shredded into strips, PET fibres offer excellent tensile resistance, making them the most effective reinforcing fibre of the three types. For this study, the three types were mixed together in roughly equal proportions by weight before processing, to simulate real-world collection where perfect type-specific segregation is rarely feasible.

3.1.3 Soil

The subgrade soil, which forms the foundation of the pavement structure, was collected from a depth of 0.5 to 1.5 m below ground level while carefully excluding the topsoil to avoid organic contamination. Sampling was carried out as per IS 2720 (Part 1): 1983 to ensure representative and minimally disturbed samples. The soil appeared dark brown, fine-grained, sticky when wet, and showed surface cracks when dry, indicating clayey characteristics. Laboratory classification was performed according to IS 1498: 1970 using grain size analysis, Atterberg limits, and specific gravity tests. Grain size results showed that about 68% of the soil particles were finer than 75 microns, confirming it as predominantly fine-grained soil. The liquid limit was found to be 48% and the plastic limit 22%, resulting in a plasticity index of 26%. Since the liquid limit exceeded 35% and the values plotted above the A-line, the soil was classified as CH — inorganic clay of high plasticity. The specific gravity of 2.67 indicated the absence of significant organic matter. The natural moisture content ranged from 18% to 22%. The shrinkage limit was 14%, showing considerable volume change potential. The free swell index was 55%, indicating medium to high swelling behavior. The standard Proctor test yielded a maximum dry density of 1.62 g/cc at an optimum moisture content of 22.5%. These properties reveal that the soil is highly compressible and moisture sensitive. It is likely to lose strength when wet and crack upon drying. Such behavior makes it unsuitable as a pavement subgrade without treatment. Therefore, stabilization is necessary to improve its engineering performance and ensure long-term pavement durability**.**

3.1.4 Water

Ordinary potable tap water from the laboratory supply was used for all tests requiring moisture — including Atterberg limits determination, Standard Proctor compaction tests, and specimen preparation for CBR and UCS testing. The water was tested and found to be free from dissolved organic matter, excessive salts, and other impurities that could interfere with pozzolanic reactions. The pH of the tap water was measured at approximately 7.2, which is essentially neutral and well within the acceptable range for geotechnical testing. Distilled water was used specifically for the specific gravity test, where even minor dissolved substances can affect accuracy.

3.2 Design, Mixing, and of Materials

The design mix for sustainable subgrade stabilization using Rice Husk Ash (RHA) and plastic waste is developed based on optimum percentage ranges identified in previous studies and preliminary laboratory trials. In general, RHA is added in proportions of 5%, 10%, 15%, and 20% by dry weight of soil to determine the optimum pozzolanic contribution, while shredded plastic waste (PET/HDPE) is incorporated in smaller amounts of 0.5%, 1%, 1.5%, and 2% to provide mechanical reinforcement.Experimental evidence indicates that a hybrid mix of approximately 10–15% RHA combined with 1–1.5% plastic waste often yields maximum improvement in California Bearing Ratio (CBR), unconfined compressive strength (UCS), and reduction in plasticity index. The soil, RHA, and plastic are first mixed in dry condition to ensure uniform distribution, followed by the addition of water corresponding to the Optimum Moisture Content (OMC) determined from Standard Proctor tests. Compaction is carried out at Maximum Dry Density (MDD), and specimens are cured for 7–28 days to allow pozzolanic reactions to develop strength. This mix design approach integrates chemical stabilization from RHA with tensile reinforcement from plastic waste, providing an optimized and sustainable subgrade material.

4. RESULTS & DISCUSSION

4.1 PLASTICITY TEST

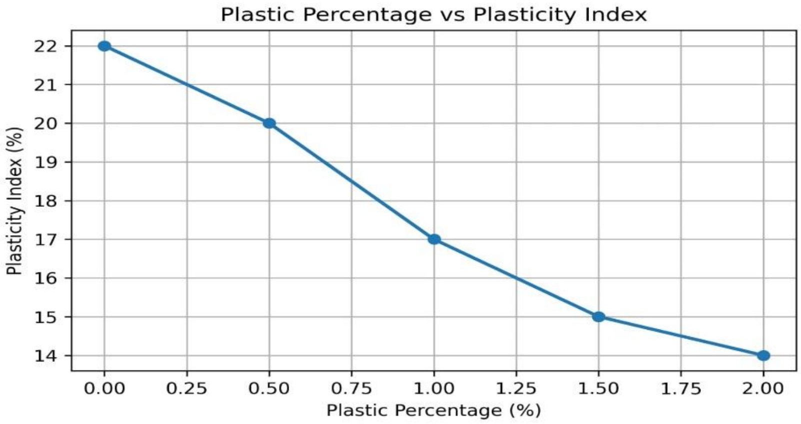
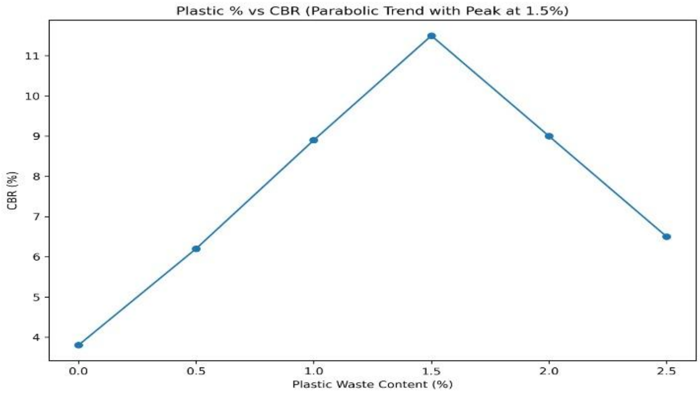


Chart -1 Plastic % vs Plasticity Index

The graph shows a decreasing linear relationship between plastic waste content and Plasticity Index (PI). As the plastic percentage increases, the PI gradually decreases because plastic particles reduce clay activity and limit water absorption. This lowers the soil's plastic behavior and shrink–swell potential. The linear downward trend indicates consistent improvement in soil workability with increasing plastic content.

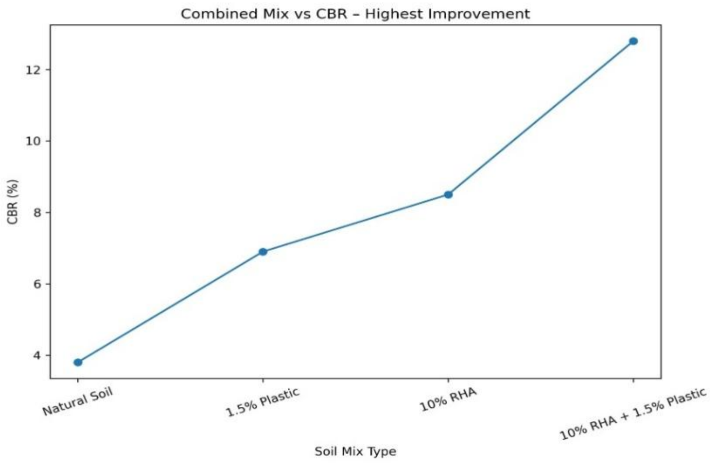
4.2 CBR TEST



Chat -2 Plastic % vs CBR

The graph shows a parabolic relationship between plastic waste content and CBR value. As plastic percentage increases from 0% to 1.5%, the CBR rises significantly due to improved tensile reinforcement and better load distribution. The maximum CBR is achieved at 1.5% plastic, indicating the optimum dosage. Beyond 1.5%, the CBR decreases because excess plastic reduces soil–particle bonding and creates voids. Thus, 1.5% plastic is the optimum content for maximum strength improvement.

4.3 CBR TEST



Chat -2 Plastic % vs CBR

The graph above clearly shows that the combined mix (10% RHA + 1.5% Plastic) provides the highest improvement in CBR compared to individual stabilization methods and natural soil.

The graph shows that natural soil has a low CBR (~3.8%), indicating weak subgrade strength. Adding 1.5% plastic increases CBR (~6.9%) due to tensile reinforcement. With 10% RHA, CBR further improves (~8.5%) because of pozzolanic bonding. The highest CBR (~12.8%) is achieved with the combined mix (10% RHA + 1.5% plastic), showing a strong synergistic effect. This confirms that hybrid stabilization gives maximum strength improvement for subgrade soil.

5. CONCLUSION

The experimental investigation on sustainable subgrade stabilization using plastic waste and rice husk ash (RHA) demonstrates that the incorporation of these waste materials significantly enhances the geotechnical performance of weak subgrade soils. The inclusion of RHA improves the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) due to pozzolanic reactions that generate cementitious compounds within the soil matrix. A reduction in plasticity index and swelling characteristics was observed, indicating improved volumetric stability.

The addition of plastic waste fibers further contributes to mechanical reinforcement by increasing ductility, tensile resistance, and resistance to crack propagation. Although a gradual decrease in Maximum Dry Density (MDD) and an increase in Optimum Moisture Content (OMC) were noted with higher RHA content, the overall strength enhancement outweighs these variations. An optimum mix proportion of approximately 8–12% RHA combined with 0.5–1% plastic waste yielded the most favorable results in terms of strength and durability.

From a sustainability perspective, the proposed stabilization technique promotes effective utilization of agricultural and polymer waste, reduces environmental pollution, and minimizes reliance on conventional stabilizers such as cement and lime. Therefore, the combined use of plastic waste and RHA presents a technically feasible, economically viable, and environmentally sustainable solution for subgrade improvement in flexible pavement construction.

6. REFERENCES

[1] A. B. Muntohar and G. Hantoro, "Influence of rice husk ash and lime on engineering properties of a clayey subgrade," Electronic Journal of Geotechnical Engineering, vol. 15, pp. 1395–1408, 2010. Available: https://journal.umy.ac.id/index.php/st/article/view/841

[2] G. Sipiq, "Soil stabilization with a mixture of rice husk ash and lime: A literature review," IRCEE, vol. 2, no. 1, 2025. Available: https://sihojurnal.com/index.php/ircee/article/view/327

[3] B. H. J. Pushpakumara and W. S. W. Mendis, "Suitability of rice husk ash (RHA) with lime as a soil stabilizer in geotechnical applications," International Journal of Geo Engineering, vol. 13, 2022. Available: https://link.springer.com/article/10.1186/s40703-021-00169-w

[4] B. Jayo and G. Durán, "Mechanical behavior of low plasticity clay soil stabilized with rice husk ash," Materials Science Forum, vol. 1060, pp. 195–199, 2022.

[5] N. Soni et al., "Soil stabilization using rice husk ash and sugarcane bagasse ash," IJRASET, 2024. Available: https://www.ijraset.com/research-paper/soil-stabilization-using-rice-husk-ash-andsugarcane-bagasse-ash

[6] P. Pavan Kumar et al., "An experimental study on soil stabilization by using cement, fly ash and natural waste," International Journal of Construction Engineering, vol. 7, no. 1, 2025. Available: https://iaeme.com/Home/article_id/IJCE_07_01_001

[7] S. Syahril et al., "Sustainable soft clay stabilization using rice husk ash," Geomate Journal, vol. 29, no. 131,

2025. Available: https://geomatejournal.com/geomate/article/view/4842
[8] "Subgrade stabilization using rice husk ash based geopolymer (GRHA)," Case Studies in Construction Materials, vol. 13, 2020. Available: https://www.sciencedirect.com/science/article/pii/S2214509520300607
[9] "Stabilization of alluvial soil for subgrade using agricultural waste ashes," International Journal of Pavement Research and Technology, vol. 10, no. 2, 2017.
[10] A. G. Abarajithan et al., "Feasibility of soil stabilization using rice husk ash and coir fibre," IJERT, vol. 6, no. 4, 2017. Available: https://www.ijert.org/feasibility-of-soil-stabilization-using-rice-husk-ash-and-coir-fibre
[11] D. Dalal and P. Berwal, "Utilization of rice husk ash in soil subgrade stabilization," IJRP Seminar, vol. 7, no. 4, 2016. Available: https://jrps.shodhsagar.com/index.php/j/article/view/850
[12] R. K. Gupta et al., "Performance evaluation of soil stabilized with plastic waste and rice husk ash," Proc. ICACE, 2021. Available: https://ieeexplore.ieee.org/document/9486732