Evaluation of California Bearing Ratio of Soil Stabilized with Rice Husk Ash for Pavement Applications

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Abstract

The California Bearing Ratio (CBR) test is extensively employed to assess the load-bearing capacity of subgrade soils and pavement layers in flexible pavement design. In rapidly developing countries like India, the expansion of road infrastructure demands cost-effective and sustainable construction materials. Improving subgrade strength by enhancing CBR values can significantly reduce pavement thickness and overall construction cost.

Simultaneously, the disposal of industrial and agricultural waste materials poses serious environmental challenges. Rice Husk Ash (RHA), a by-product generated from rice milling industries, is produced in large quantities and often causes disposal-related environmental hazards. Owing to its high silica content, RHA has potential as a soil stabilizing agent.

This study investigates the influence of RHA on the CBR characteristics of soil intended for road subgrade applications. eight soil–RHA blends were prepared containing 0%, 4%, 8%, 12%, 16%, 20%, 24% and 28% RHA by weight of dry soil. All specimens were compacted at their respective optimum moisture contents corresponding to maximum dry density. Both soaked and unsoaked CBR tests were conducted.

The results reveal that CBR values increase with RHA content up to an optimum of 24%, beyond which a decline is observed. The addition of RHA significantly enhances soaked CBR values and reduces moisture susceptibility of the soil. Regression models were also developed to predict CBR values using compaction characteristics. The study confirms that RHA can be effectively utilized as a sustainable stabilizing material for pavement subgrades.

Keywords: California Bearing Ratio, Rice Husk Ash, Soil Stabilization, Pavement Subgrade

1. Introduction

The California Bearing Ratio (CBR) test is one of the most widely accepted empirical methods for evaluating the strength of subgrade soil and pavement materials. Originally developed by the California Department of Transportation and later adopted by the U.S. Army Corps of Engineers, the test has gained global acceptance despite certain limitations. In India, where flexible pavements constitute the majority of road infrastructure, the Indian Roads Congress (IRC) introduced CBR-based pavement design guidelines in 1970.

According to IRC recommendations, pavement thickness is inversely proportional to the CBR value of the subgrade soil for a given traffic category. Therefore, improving the CBR value of soil directly contributes to economical pavement design. Natural soils collected along roadway alignments often exhibit inadequate strength and require stabilization before use in pavement construction.

In parallel, the disposal of industrial and agricultural waste materials has emerged as a major environmental concern. Rice Husk Ash (RHA), generated by burning rice husk in boilers, is one such waste material. India produces approximately 20 million tonnes of RHA annually. Since RHA contains about 85–90% amorphous silica, it exhibits pozzolanic properties that can be harnessed for soil stabilization.

The present study evaluates the effect of varying RHA content on the CBR behavior of soil under soaked and unsoaked conditions and explores the feasibility of using RHA as a sustainable subgrade improvement material.

Road transportation forms the backbone of economic development and social connectivity in India. A major portion of the national road network consists of flexible pavements, where the strength of the subgrade plays a decisive role in pavement performance. The California Bearing Ratio (CBR) test is commonly adopted to assess subgrade strength and determine pavement thickness as per Indian Roads Congress (IRC) guidelines. Lower CBR values lead to thicker pavements and increased construction costs, whereas higher CBR values allow thinner and

more economical pavement sections.
Natural soils available along road alignments often possess inadequate strength and are susceptible to moisture variations. Such soils require stabilization to improve their load-bearing capacity. Traditional soil stabilization techniques using lime or cement are effective but may not always be economical or environmentally friendly. In recent years, attention has shifted towards the utilization of waste materials as alternative stabilizing agents.
Rice husk ash is an agricultural waste generated in large quantities from rice milling industries. India, being one of the largest producers of rice, generates millions of tonnes of rice husk annually. When rice husk is burnt for energy production, rice husk ash is produced, which is often disposed of in open land, leading to environmental pollution and land degradation. Utilizing RHA in road construction offers a dual advantage of waste management and improvement of soil properties.
The utilization of RHA in pavement construction aligns with sustainable development goals by reducing dependency on conventional materials and minimizing environmental hazards. Previous studies have reported that RHA improves strength, stiffness, and durability of soils due to its pozzolanic reaction with soil minerals. However, the extent of improvement depends on the proportion of RHA and soil characteristics.
The present study focuses on evaluating the effect of RHA content on the CBR behavior of soil under soaked and unsoaked conditions. Since pavement design in regions with high rainfall is generally based on soaked CBR values, special emphasis is given to moisture susceptibility. The scope of this investigation includes determination of compaction characteristics, analysis of CBR variation with RHA content, and development of correlations between CBR and compaction parameters.

2. Methodology

The CBR value of soil is highly dependent on its degree of compaction, which is governed by optimum moisture content (OMC) and maximum dry density (MDD). Hence, compaction characteristics play a crucial role in pavement design.
In this investigation, soil samples were blended with RHA at six different proportions: 0%, 4%, 8%, 12%, 16%, 20%, 24% and 28% by dry weight of soil, in addition to the virgin soil sample. The soil was air-dried, pulverized, and passed through a 4.75 mm IS sieve. RHA was then mixed thoroughly with soil in dry condition, followed by gradual addition of water to ensure uniform moisture distribution.
Standard Proctor compaction tests were conducted in accordance with IS:2720 (Part 8) to determine OMC and MDD for each soil–RHA mix. Subsequently, CBR tests were performed on specimens compacted at their respective OMC and MDD under both soaked (4 days soaking) and unsoaked conditions.

3. Materials Used – Soil

The soil used in this study was collected from a road construction site in Tripura, India. Laboratory tests were conducted to determine its index and engineering properties. Grain size analysis revealed that the soil consists of sand, silt, and clay fractions, indicating a fine-grained soil with moderate plasticity. The specific gravity of the soil was found to be 2.55. Atterberg limit tests indicated a liquid limit of 32.31%, plastic limit of 23.84%, and plasticity index of 10.55%.
Standard Proctor compaction tests were carried out to determine the optimum moisture content and maximum dry density of the virgin soil. The soil exhibited an OMC of 12.44% and an MDD of 21.53 kN/m^3. These properties indicate that the soil requires stabilization to improve its strength and moisture resistance when used as pavement subgrade.

4. Materials Used – Rice Husk Ash

Rice husk ash used in this study was obtained from a local rice mill. The ash was collected after controlled burning of rice husk in boilers. RHA is a lightweight material with low specific gravity and high silica content, typically ranging from 83% to 92%. The ash particles are porous

and possess high water absorption capacity.
Before use, RHA was air-dried and sieved to remove oversized particles. Its low density and high surface area influence the compaction behavior of soil–RHA mixes. The inclusion of RHA is expected to increase optimum moisture content and decrease maximum dry density due to its porous nature.

5. Experimental Methodology

Soil–RHA mixes were prepared by blending dry soil with RHA at proportions 0%, 4%, 8%, 12%, 16%, 20%, 24% and 28% by weight. Thorough mixing was carried out to ensure uniform distribution. Water was added gradually, and the mixture was hand-mixed until homogeneity was achieved.
Standard Proctor tests were conducted for each mix to determine OMC and MDD. CBR specimens were prepared by compacting the mixes at their respective OMC and MDD. Both soaked and unsoaked CBR tests were performed as per IS:2720 guidelines. For soaked tests, specimens were immersed in water for four days prior to testing.

6. Properties of Soil and Soil–RHA Mixes

The natural soil used in the study consists of sand (11.34%), silt (55.77%), and clay (32.89%) with a specific gravity of 2.39. The liquid limit, plastic limit, and plasticity index were found to be 32.27%, 21.72%, and 9.56%, respectively.
The virgin soil exhibited an MDD of 21.49 kN/m³ at an OMC of 12.58%. With increasing RHA content, OMC increased while MDD decreased consistently. This behavior can be attributed to the lower specific gravity and higher water absorption capacity of RHA.

7. CBR Results and Discussion

CBR tests were conducted at penetration levels of 2.5 mm and 5.0 mm, with the higher value adopted as the representative CBR. The average of three specimens was considered, and additional tests were performed when variations exceeded permissible limits.
The results indicate a substantial improvement in CBR values with the addition of RHA up to 24%. The unsoaked CBR increased from 6.3% for virgin soil to 18.33% at 24% RHA, while soaked CBR increased from 3.5% to 13.67%. Beyond 24% RHA, both soaked and unsoaked CBR values declined, suggesting an optimum RHA content of 24%.
The CBR reduction factor, defined as the ratio of unsoaked to soaked CBR, decreased from 1.84 for virgin soil to 1.55 at 24% RHA, indicating reduced moisture susceptibility. This demonstrates that RHA not only improves strength but also enhances durability under wet conditions.

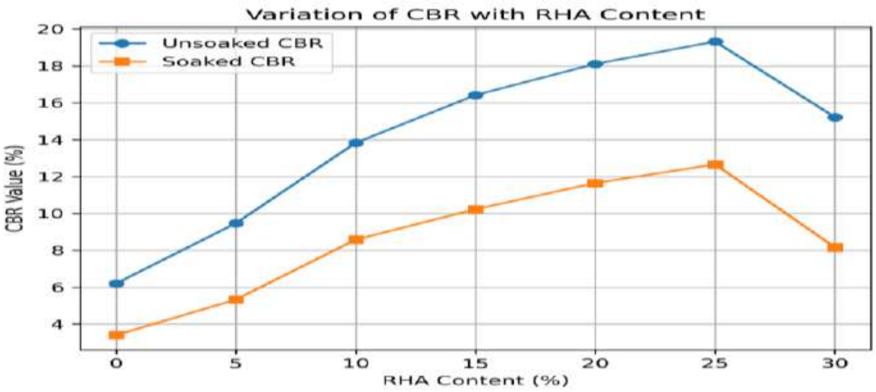

Figure 1: Variation of CBR with RHA content

Figure 1 represents Variation of CBR with RHA Content
- X-axis: RHA Content (%)
- Y-axis: CBR Value (%)
- Two curves:
  - Unsoaked CBR
  - SoakedCBR

leearly shows increase in CBR up to 24% RHA and reduction at 28% RHA,

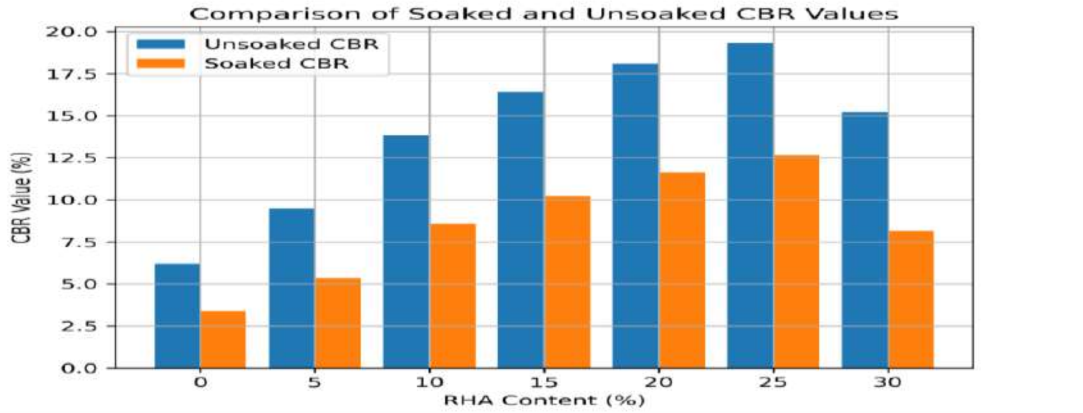

Figure 2: Bar chart of soaked and unsoaked CBR values

Bar Chart represents Comparison of Soaked and Unsoaked CBR Values

- Side-by-side bars for each RHA percentage.
- Figure 1: Variation of CBR with RHA Content
- Figure 2: Comparison of Soaked and Unsoaked CBR Values

8. Conclusions

Based on the experimental investigation, the following conclusions are drawn:

- CBR values increase with RHA content up to an optimum of 24%, beyond which strength decreases.
- The addition of RHA significantly enhances both soaked and unsoaked CBR values of soil.
- Moisture susceptibility of soil is reduced with increasing RHA content up to 24%.
- Soaked CBR improved from 3.5% to 13.67%, enabling reduction in pavement thickness.
- RHA can be effectively utilized as a sustainable and eco-friendly stabilizing material for pavement subgrades.
- Regression equations developed in this study can assist in estimating CBR values from compaction characteristics.

The use of rice husk ash in road construction not only improves pavement performance but also addresses environmental concerns related to waste disposal.

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