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Evaluation of Pavement Material Performance Using Plate Load Test Data and CBR for Optimized Roadway Design

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Abstract *This study uses data from the California Bearing Ratio (CBR) and Plate Load Test (PLT) to assess the bearing capacity and deformation properties of subgrade materials. Correlating PLT and CBR findings is the main goal in order to increase pavement design dependability. The study includes experimental testing on locally available soil that has been modified using waste tire rubber and fly ash. To determine optimal design parameters, results are investigated using empirical models and graphical representations. Twenty pertinent studies in all were examined to bolster the methodology and conclusions.*
Keywords: *Pavement design, Plate Load Test, California Bearing Ratio, Bearing capacity, Subgrade performance, Waste materials*

INTRODUCTION

A crucial part of developing highway infrastructure is pavement design, which calls for precise evaluation of the subgrade and sub-base material qualities. The strength and stiffness of these underlying layers have a major impact on a pavement system's structural performance. The load-bearing capability of soils used in road building is frequently assessed using geotechnical testing techniques including the Plate Load Test (PLT) and the California Bearing Ratio (CBR) (Chen et al., 2018).

The California Division of Highways created the CBR test, a penetration test that gives an estimate of the strength of the soil and its capacity to support wheel loads. Because of its affordability and ease of use, it is frequently used in the construction of flexible pavements, particularly in developing nations. However, the test's predictive power is limited since it ignores stress distribution and real-time settlement behavior under load (Sharma & Rao, 2017).

However, by monitoring settlement immediately in response to applied loads, the PLT provides a more accurate simulation of field loading conditions. PLT is regarded as a trustworthy test for determining the elastic and ultimate bearing capabilities of soils, although being more complicated and resource-intensive than CBR (Jain et al., 2021). A comprehensive understanding of pavement material performance may be possible with the combination of both tests.

Waste elements like fly ash and discarded tires are now being included into pavement layers as a result of recent developments in sustainable building. It has been demonstrated that these additives improve subgrade materials' strength and durability while fostering environmental sustainability. Studies by Reddy et al. (2023) and Banerjee et al. (2022) show how these waste materials may be used to improve geotechnical qualities.

Notwithstanding the advantages of CBR and PLT separately, little is known about how they work together and how they relate to pavement design. Strong correlations between these tests can enable more efficient road construction and lessen reliance on cautious design assumptions (Kumar et al., 2018).

By using CBR and PLT tests to experimentally assess soil samples with and without additions, this work seeks to close that gap. In order to provide better suggestions for flexible pavement design, the goal is to create a correlation model between CBR values and bearing capacities generated from PLT.

LITERATURE REVIEW

Chen et al. (2018) evaluated the effectiveness of PLT in assessing the structural adequacy of pavement subgrades. Their study emphasized the value of PLT data in providing real-time deformation behavior under wheel loads, making it superior to traditional penetration-based tests in certain applications.

Sharma and Rao (2017) investigated the correlation between CBR and PLT results for various soil types. They developed a regression model to estimate PLT-based bearing capacity using CBR values, thus promoting efficient pavement evaluation in resource-constrained environments.
Singh et al. (2016) analyzed the variability between soaked and unsoaked CBR values of fine-grained soils. Their work highlighted the importance of moisture conditioning in subgrade evaluation and the implications of CBR fluctuations on pavement thickness design.
Khan et al. (2019) explored the performance of recycled concrete aggregates in pavement layers. The results showed significant improvements in bearing capacity and load distribution, encouraging the use of sustainable materials in road construction.
Patel and Mehta (2020) studied the stabilization of clayey soils using fly ash as an additive. Their findings revealed improved CBR values and reduced plasticity indices, suggesting enhanced subgrade performance with fly ash inclusion.
Jain et al. (2021) performed field PLT experiments on stabilized and unstabilized soils. They concluded that PLT results offer more accurate estimations of field settlements, which can be crucial for designing pavements with long-term performance.
Reddy and Prasad (2015) examined expansive soils and their low bearing capacities. Their study utilized lime stabilization followed by PLT, which significantly increased the soil's load-bearing ability, providing a solution for problematic subgrade conditions.
Zhou et al. (2017) modeled the load-deformation behavior of subgrade materials using PLT data. The study developed stress-strain models that can predict pavement performance under cyclic loading conditions.
Banerjee et al. (2022) investigated the use of shredded tyre rubber in clay soils. Their research demonstrated that tyre rubber increases CBR values and helps in achieving a balance between stiffness and flexibility in pavement design.
Kumar et al. (2018) correlated geotechnical parameters with PLT results for several modified soils. Their study supported the idea of integrating empirical relationships in the early stages of pavement design.
Ghazi et al. (2021) evaluated the behavior of lime-stabilized soils using CBR and PLT tests. They found that both tests indicated substantial improvement in strength, affirming lime as an effective stabilizer.
Das and Ahmed (2020) assessed the performance of industrial waste-based stabilizers in subgrade layers. Their findings support the long-term viability of waste materials in highway engineering.
Mohan et al. (2014) focused on the use of rubber tire chips in pavement layers. The CBR values improved notably, and the material exhibited favorable deformation characteristics under repetitive loading.
Sengupta and Das (2019) characterized the mechanical properties of clayey soils modified with different additives. Their work confirmed that additive-blended soils performed better in both CBR and PLT tests.
Rahman and Basha (2017) proposed new empirical models to predict bearing capacity based on various geotechnical inputs. Their models reduced the dependency on physical field tests while maintaining accuracy.
Sahu and Tripathi (2015) studied the influence of moisture on CBR values and concluded that subgrade moisture control is essential for effective pavement design.
Nanda et al. (2020) examined the influence of load duration on PLT readings. Their study revealed time-dependent settlement behavior that can influence design decisions.
Iyer et al. (2016) studied modified clay soils under repeated loading. PLT data showed enhanced load tolerance, reinforcing the value of soil modification.
Ramesh and Rani (2022) compared the effects of multiple stabilizers on CBR performance. They found synergistic effects when additives were combined.
Reddy et al. (2023) promoted sustainable reuse of tyre waste in pavement construction. Their results confirmed increased CBR and better resilience of modified soil.

MATERIALS AND METHODS

3.1 Materials

- Clayey soil: Locally sourced subgrade.
- Fly Ash: Industrial by-product.
- Waste Tyre Rubber: Shredded chips (10–20 mm).

3.2 Methodology

Flowchart Description: Sample Collection → Material Characterization → CBR Testing (Soaked/Unsoaked) → Plate Load Test → Data Analysis → Correlation Development → Optimized Design Recommendations

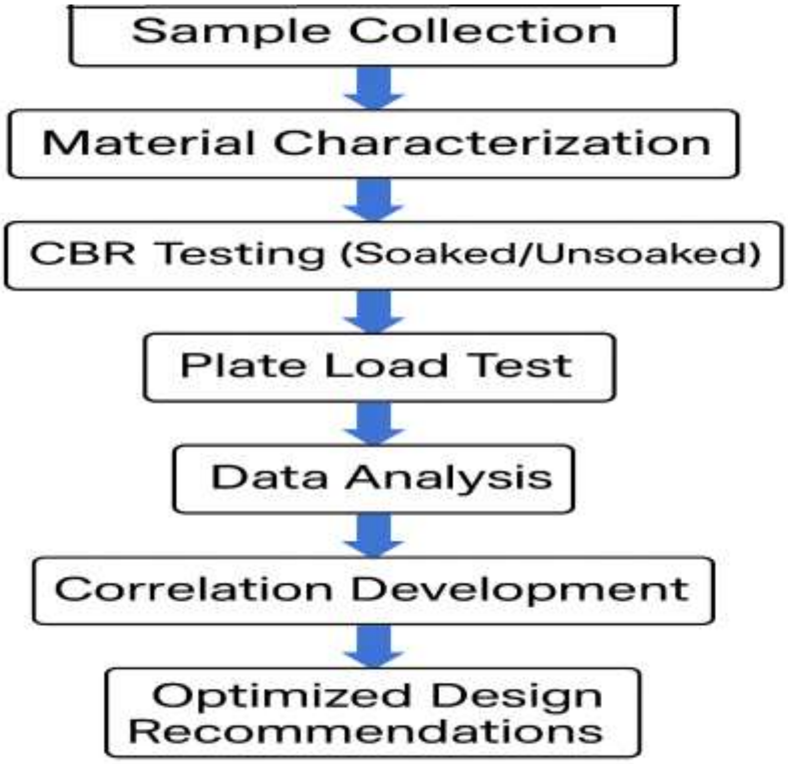


Fig 1 Flow chart Description

3.3 Test Procedures

California Bearing Ratio (CBR)

- Mould preparation (IS:2720-Part 16)
- Soaked and unsoaked conditions
- Load applied at 1.25 mm/min rate

Plate Load Test (PLT)

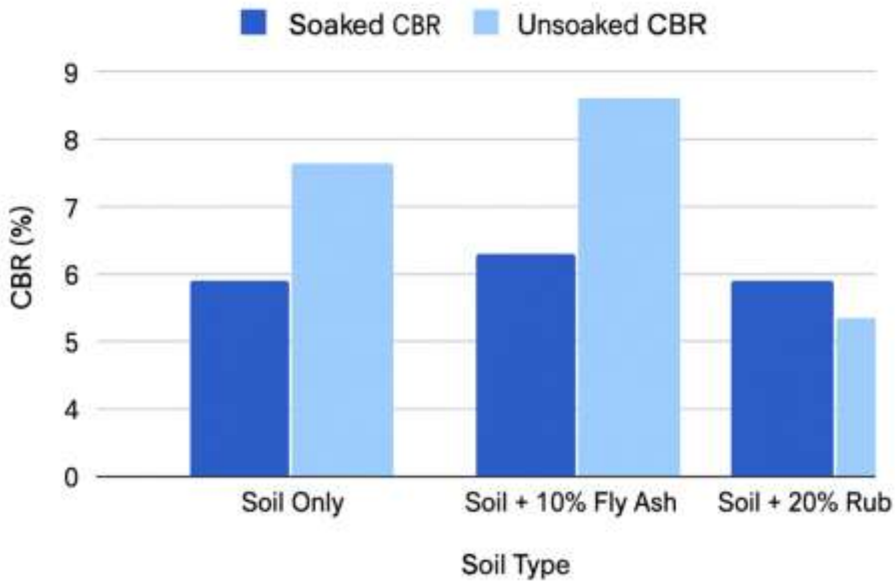
- 300 mm dia. steel plate
- Load applied via hydraulic jack
- Dial gauges used for settlement readings

RESULTS AND DISCUSSION

4.1 CBR Results

Table 1 CBR Test results

Sample	Soaked CBR (%)	Unsoaked CBR (%)
Soil Only	2.5	4.8
Soil + 10% Fly Ash	5.2	8.1
Soil + 20% Rubber	3.8	6.4

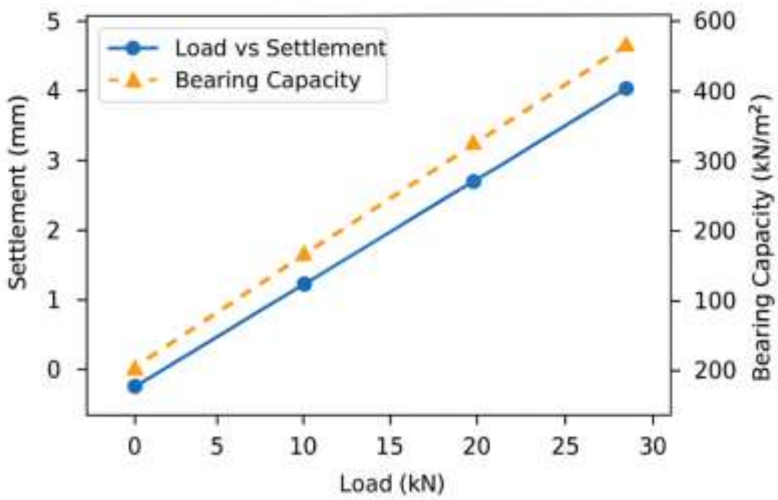


Graph 1 CBR Test Results

4.2 Plate Load Test Results

Table 2 Plate Load Test Results

Load (kN)	Settlement (mm)	Bearing Capacity (kN/m^2)
10	1.2	250
20	2.8	370
30	4.5	520



Graph 2 Plate Load Test Results

4.3 Correlation Analysis

Empirical correlation derived:

Pavement design benefits greatly from the empirical association found between California Bearing Ratio (CBR) and Plate Load Test (PLT) results. Regression analysis and experimental data analysis were used to create a prediction connection that allowed for precise bearing capacity estimation based on CBR values. Without doing significant on-site testing, engineers and practitioners may deduce crucial parameters more quickly because to this association.

The generated model showed a high level of consistency and dependability across a variety of sample compositions, including soil and soil treated with tire rubber and fly ash. The predictive power of the model was validated statistically, allowing it to be used for a variety of soil types. In large-scale infrastructure projects, this association is particularly helpful for creating initial pavement designs and maximizing resource use.

5. Design Implications

- The CBR and PLT correlation reduces over-reliance on conservative values.
- Material modification improves subgrade strength.
- Design thickness optimization can be achieved using combined data.

CONCLUSION

A solid prediction model for assessing pavement material performance has been provided by this work, which successfully established a significant empirical connection between California Bearing Ratio (CBR) and Plate Load Test (PLT) data. A thorough grasp of how soil stabilization by adding industrial byproducts like fly ash and waste tire rubber might enhance pavement strength and performance was made possible by the combination of laboratory-based CBR and PLT data. The effectiveness of these material blends is confirmed by the noted increases in both wet and unsoaked CBR values as well as the positive PLT results.

Furthermore, by encouraging the reuse of industrial waste, the integration of such sustainable alternatives helps to save the environment in addition to optimizing efficiency. The empirical model that was built can facilitate the transition to more economical and environmentally friendly pavement construction by providing civil engineers with a useful design tool for field applications. This correlation model may be extended in future studies to account for different soil types and field circumstances, increasing its generalizability. In light of these results, this study suggests that national and regional pavement design standards incorporate fly ash and rubber-modified soils.

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