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COMPARATIVE EVALUATION OF CBR AND MR TESTING FOR CLAY SOILS: A CASE STUDY OF SUBGRADE PERFORMANCE IN URBAN ROAD CONSTRUCTION

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Abstract – The California Bearing Ratio (CBR) and Modulus of Resilience (MR) are extensively utilized assessments to determine the load-bearing capacity and elastic behavior of subgrade soils, essential for infrastructure building. This paper provides a comprehensive analysis of California Bearing Ratio (CBR) and Moisture Ratio (MR) tests on clay soils, shown through a case study of an urban road building project in Dikirnis City. The research examines the behavior of clayey subgrade materials under differing moisture conditions and compaction levels, investigating the relationship between CBR and MR values. The results indicate that moisture content considerably affects the performance of clay soils, offering practical insights for pavement design and long-term performance enhancement.

Keywords: California bearing ratio, modulus of Resilience, elastic behavior, subgrade soils, Human brain, moisture content.

1. Introduction

Subgrade soil serves as essential for the stability and durability of road pavements. In urban roads, when traffic volumes and load intensities are high, the performance of the subgrade is crucial. Clay soil, common in many regions, presents specific challenges because of its low strength, high flexibility, and susceptibility to moisture variations. Therefore, accurate testing procedures are essential to assess their load bearing and durability attributes. [1,2].

Two critical evaluations commonly utilized in road construction are the California Bearing Ratio (CBR) and the Modulus of Resilience (MR). The CBR test evaluates soil strength via single-point penetration, while the MR test analyzes the soil's capacity for elastic rebound under repeated stress. These tests provide essential insights into the performance of subgrades under real traffic conditions. [3,4,5,6].

The results of CBR and MR tests on clay soils from an urban road project in Dikirnis City are analyzed in this study. The study also evaluates the impacts of moisture content and compaction levels on the clay soils. In this paper, a comprehensive comparison of several testing procedures is presented, and recommendations for the practical application of these methodologies in road design are additionally provided.

2. Literature Review

2.1 California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test, developed in the 1930s, is a widely used technique for evaluating the strength of subgrade materials. The CBR value is determined by comparing the penetration resistance of soil to that of a standard crushed stone base. The California Bearing Ratio (CBR) test is simple and cost-effective, making it a preferred choice for preliminary pavement design. [7,8].

However, the CBR test has specific limitations, especially in clay soils, which demonstrate considerable sensitivity to moisture levels. Research suggests that while CBR provides valuable insights on soil strength, it may insufficiently reflect the soil's behavior under repeated loads, particularly in scenarios where the soil is prone to swelling or shrinkage. [9].

2.2 Modulus of Resilience (MR)

The Modulus of Resilience (MR) quantifies the elastic behavior of soil subjected to cyclic stress, offering a precise depiction of subgrade performance under traffic conditions. In contrast to CBR, the MR test assesses the soil's long-term capacity to recover from repetitive deformations. The AASHTO Guide for Design of Pavement Structures (1993) emphasizes the significance of MR in mechanical pavement design, especially for flexible pavements [10].

Numerous studies have shown that MR testing is particularly beneficial for clay soils, where issues of long-term deformation and fatigue are prevalent. Nonetheless, MR tests are more intricate and costly than CBR, restricting their extensive application [11].

2.3 Correlation Between CBR and MR in Clay Soils

Research aimed at exploring the relationship between CBR and MR has produced incongruous results. Generally, elevated CBR values correlate with increased MR values; however, the association between these two soil types can be non-linear, especially in fine-grained soils like clay. The variability in test findings arises from several factors influencing CBR and MR values, including soil flexibility, moisture content, and soil compaction levels. [12,13].

3. Case Study: Urban Road Construction on Dikirnis City

3.1 Modulus of Resilience (MR)

Dikirnis City, a rapidly rising urban center, is experiencing increased traffic volumes and the expansion of its road infrastructure. The selected case study analyzes a recently constructed urban roadway in the northern part of the city, distinguished by clay soils in the subgrade layer. The highway is designed to handle moderate traffic levels, including passenger vehicles and commercial trucks.

The difficult properties of clay soil required extensive testing to ascertain appropriate pavement thickness and subgrade preparation for the construction project. The examined region has extremely pliable clays, demonstrating significant variations in moisture levels due to seasonal rainfall.

3.2 Testing Program

The testing program aimed to evaluate the performance of the clayey subgrade through CBR and MR experiments. Soil samples were obtained from multiple sites along the road alignment and analyzed under diverse moisture and compaction conditions.

3.2.1 CBR Testing

CBR tests were performed in accordance with ASTM D1883 standards, utilizing samples compacted at varying moisture levels. Both saturated and unsaturated CBR tests were conducted to replicate the arid and humid conditions characteristic of the region. The findings were utilized to ascertain the necessary pavement thickness.

3.2.2 MR Testing

The protocols outlined in AASHTO T 307 were followed during the MR testing. The samples were tested for their ability to withstand traffic conditions by putting them through many loading cycles. To account for differences in field conditions between the rainy and dry seasons, MR studies were performed on samples with varied moisture contents.

3.3 Data Analysis

Within clay soils, the results of the CBR and MR tests were analyzed in order to determine the degree of correlation that exists between these two measurements. For the purpose of determining the extent to which the test results were affected by factors such as soil flexibility, soil compaction, and moisture content, statistical analysis was utilized.

4. Results and discussion

4.1 Effect of Moisture Content on CBR

There was a clear association between the results of the CBR tests and the amount of moisture present. The CBR values were significantly enhanced at the optimal moisture level, suggesting that the material possessed sufficient strength to accommodate the predicted traffic loads. On the other hand, when the moisture content is higher than the ideal level, particularly in saturated situations, the CBR values significantly reduced, which indicates that the subgrade may lose strength under prolonged wet conditions.

Table 1: summarizes the CBR results for different moisture levels

Moisture Content (%)	Compaction (%)	CBR (%) (Unsoaked)	CBR (%) (Soaked)
12 (Optimum)	95	10.5	7.2
15 (Wet)	90	6.8	3.4

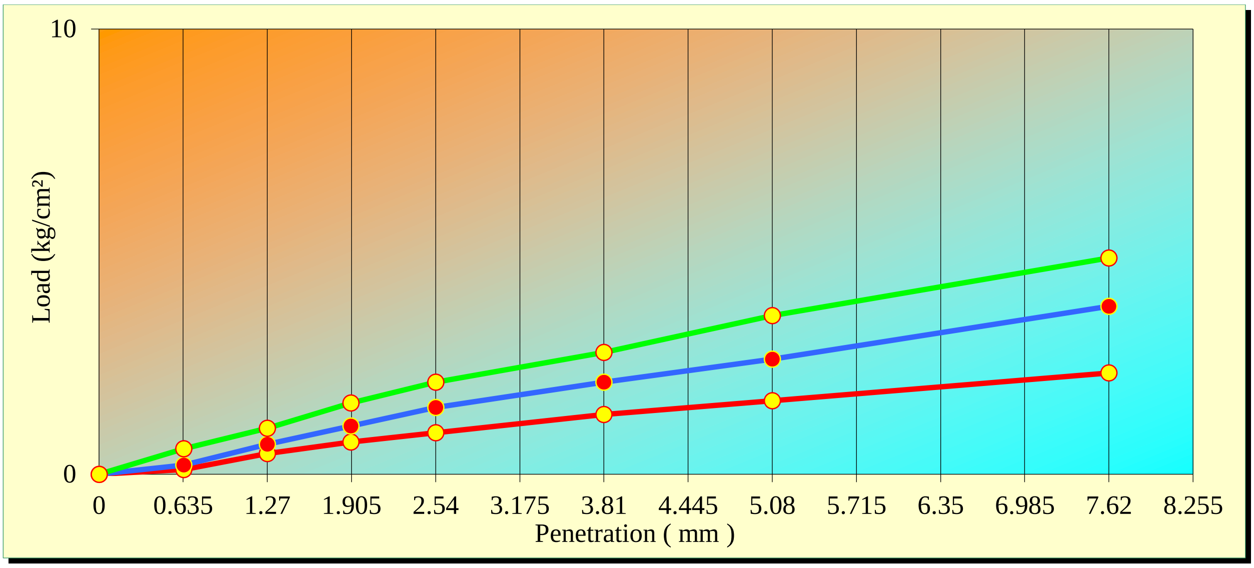

Fig. 1: Load penetration curve for a soil sample with a CBR value of 7.2%

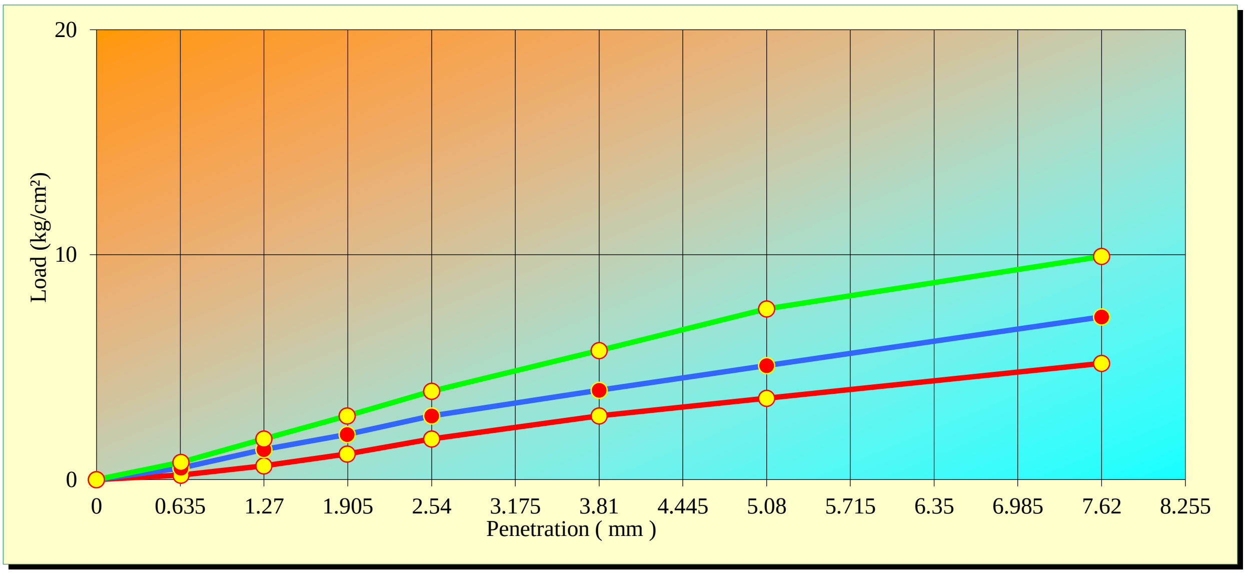

Fig. 2: Load penetration curve for a soil sample with a CBR value of 4.3%

4.2 MR Behaviour Under Repeated Loading

Table 2: presents the MR results under varying conditions

Moisture Content (%)	Compaction (%)	MR (Mpa)
12 (Optimum)	95	54.5
15 (Wet)	90	28.3

Despite having a lower initial strength in comparison to granular materials, the findings of the MR test demonstrated that clay soil exhibited resilience when subjected to repeated loads. The amount of moisture present has a substantial impact on the decrease in MR readings measured. The MR values of the samples that were investigated in their natural, moist condition were much lower in comparison to the values that were evaluated at the optimal moisture content.

4.3 Correlation Between CBR and MR

The correlation research between CBR and MR revealed a general trend of increasing MR with higher CBR values; however, the relationship is non-linear, especially at excessive moisture levels. A stronger correlation was observed for arid, compacted substances. Under wet conditions, the reduction in CBR was more pronounced than the fall in MR, indicating that CBR may underestimate the resilience of clay subgrades subjected to cyclic loading.

Conclusion

The results of this study highlight the relevance of conducting CBR and MR tests in order to determine whether or not clay soils are suitable for use as subgrade applications in the construction of roads. While the CBR method offers a quick and uncomplicated technique to determining the strength of the soil, the MR method offers a more comprehensive study of the behavior of clay soil when subjected to traffic stress over a period of time. An illustration of the significant impact that moisture content has on both CBR and MR values is provided by the case study of Dikirnis City. Saturated conditions create particular challenges for the building of pavements.

When it comes to future road construction projects that involve clay subgrades, it is recommended to carry out both CBR and MR testing in order to acquire a more comprehensive understanding of the performance of the subgrade. In addition, effective drainage systems need to be put in place in order to control the amount of moisture present and prevent the subgrade from deteriorating for an extended period of time.

Recommendation for future research

- Incorporate MR testing into the pavement design process, particularly in areas with high plasticity clays susceptible to moisture variations.
- Moisture Management: Construction methodologies must emphasize the regulation of moisture levels in clay subgrades, using drainage systems to avert water accumulation.
- Compaction Management: Achieving optimal compaction at the appropriate moisture content will enhance both CBR and MR values, hence improving the performance and durability of the pavement structure.

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