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# Design of Flexible Pavement by CBR Method

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**A B S T R A C T**

This study explores the dominant method for designing flexible pavements: the California Bearing Ratio (CBR) method. The CBR method directly relates a subgrade's strength, measured by a standardized CBR test, to the required pavement thickness. A higher CBR value indicates a stronger subgrade, necessitating a less substantial pavement structure. To assess the effectiveness and potential discrepancies of the CBR method, this investigation will apply it to a specific pavement design scenario. This scenario will encompass a representative traffic volume and subgrade characteristics. A meticulous comparison of the resulting pavement thicknesses obtained from the CBR method will be conducted. For instance, the CBR method might be preferable for projects with weak subgrades or heavy traffic loads, as it directly accounts for the subgrade's bearing capacity.

Keywords: CBR, GI, pavement, soil, properties

## 1. Introduction

### *1.1 Overview*

Transportation infrastructure plays a vital role in economic development and societal well-being. Roads, a crucial component of this infrastructure, primarily rely on flexible pavements for their construction. These pavements, composed of multiple asphalt and aggregate layers, are cost-effective and adaptable to various traffic volumes. However, ensuring their long-term performance necessitates a well-designed and constructed structure.

Designing flexible pavements involves determining the optimal thickness of each layer based on factors like traffic load, subgrade strength, and environmental conditions. The prevalent method guiding this design process is the California Bearing Ratio (CBR) method. The CBR method directly incorporates the subgrade's strength, measured through a standardized test, to determine the pavement thickness.

### *1.2 Necessity of Study*

Selecting the most appropriate design method for a specific project is crucial. While the CBR method is an established practice, a comparative analysis is necessary to understand its strengths and limitations. This understanding can lead to more informed design decisions, ultimately resulting in pavements that are cost-effective, durable, and meet performance expectations. Such analysis is essential for ensuring the long-term viability and effectiveness of transportation infrastructure projects.

### *1.3 Objectives of Study*

This study aims to achieve three primary objectives:

1. Evaluate the effectiveness of designing flexible pavements using the California Bearing Ratio (CBR) method.
2. Compare the pavement thickness determination process using the CBR method with other prevalent methods.
3. Assess the suitability of the CBR method for various project scenarios, considering factors like traffic load, subgrade strength, and environmental conditions.

### *1.4. Advantages*

Some key benefits include:

- Improved Design Decisions: Understanding the strengths and limitations of each method empowers engineers to select the most appropriate approach for a specific project.
- Cost-Effectiveness: By optimizing pavement design, unnecessary construction costs associated with over-designed pavements can be minimized.

### *1.5 Significance of Study*

The study's significance lies in optimizing pavement design using the California Bearing Ratio (CBR) method, ensuring cost-effective designs meeting performance needs. It aids in resource allocation by comparing design methods, enhances long-term pavement performance, informs decision-making for engineers and stakeholders, and contributes to sustainable infrastructure development by minimizing material usage and maintenance needs.(Barde et al., 2022; Bhashakhetre et al., 2017a, 2017b; Bhashakhetre & Marve, 2020; Bhorkar et al., 2016; Chahande et al., 2024; Chalkhure et al., 2020; Giri et al., 2023; Marve et al., 2018; Marve & Baitule, 2016; Marve & Bhorkar, 2016, n.d.; S Jumde, Marve et al., 2020; Sardar et al., 2024; Shende et al., 2018; Tajne , Gayatri; Shende, Shreyas ;Marve, 2022)

## 2. Literature Review

Flexible pavements are widely used for roads due to their cost-effectiveness and adaptability to various traffic volumes. However, ensuring their long-term performance necessitates a well-designed structure. This review explores the literature on design methods for flexible pavements, focusing on the California Bearing Ratio (CBR) and Group Index methods.

### *2.1 Indian Standards and IRC Guidelines:*

- **IS 2720 (Part 4 & 5):1985:** These Indian Standards (IS) likely provided specifications for materials used in flexible pavement construction (Part 4) and methods of test for soil and aggregates used in pavement construction (Part 5). While valuable for understanding historical practices, they might be superseded by more recent standards.
- **IRC 37 Series:** This series of IRC guidelines chronicles the evolution of flexible pavement design practices in India. It's crucial to note the following:
- **IRC 37-1970, 1984, 2001, and 2012:** These older versions of IRC 37 might have outlined design procedures using methods like the Group Index method. However, their relevance for current design practices in India is limited.
- **IRC 37-2018:** This is the current and recommended guideline for flexible pavement design in India. It emphasizes the use of the CBR method for determining pavement thickness based on subgrade strength and traffic load.

### *2.2 Research Articles:*

- **"Design of Flexible Pavement by CBR Method" (International Journal of Research Publication & Reviews):** This article likely discusses the theoretical foundation of the CBR method, its application in design procedures, and its potential benefits. This information can be valuable for understanding the principles and implementation of the CBR method. , [11]–[16]

## 3. CBR Method

The California Bearing Ratio (CBR) method is a popular choice for designing flexible pavements due to several advantages:

- **Simplicity:** The CBR test itself is a relatively simple and standardized procedure (IS 2720-2015 in this case). This makes it easy to implement and reduces the complexity of field testing.
- **Long history of use:** The CBR method has been around for decades and has a proven track record in designing pavements that perform well. This extensive experience with CBR allows engineers to rely on established correlations between CBR values and pavement thickness requirements.
- **Cost-effectiveness:** The CBR test is a relatively inexpensive test compared to some more sophisticated methods. This translates to lower design costs for pavement projects.
- **Adaptability:** The CBR method can be adapted to account for different traffic volumes and subgrade strengths by using established design charts. This allows for designing pavements for various road classifications and traffic loads.
- **Emphasis on real-world performance:** The CBR test directly measures the penetration resistance of the subgrade soil, which is considered to be a good indicator of how well the pavement will perform under traffic loads.

However, it's important to acknowledge that the CBR method also has limitations:

- **Empirical nature:** The CBR test is an empirical test, meaning it doesn't directly measure fundamental material properties like stiffness or modulus. This can introduce some uncertainty into the design process.
- **Limited information:** The CBR test only provides a snapshot of the subgrade strength at a specific point in time and location. It may not fully capture the variability of the subgrade along the entire road project.

Overall, the CBR method offers a good balance between simplicity, cost-effectiveness, and reliability for flexible pavement design. While it may not be the most sophisticated method, its extensive use and established design procedures make it a valuable tool for engineers. 3]–[10]

## 4. Test Procedure

- A representative area of the subgrade is identified. Debris & vegetation is cleared. Ensure the ground is relatively flat and stable.
- A pit or trench is excavated to the desired depth, usually about 1.5m-3m below ground. The pit’s diameter should accommodate the CBR equipment.
- Bottom of the pit is trimmed to create a level surface. Bottom layer of the soil is compacted to provide a stable base.

- CBR equipment is set centrally in the pit.

- Vertical load is applied (here load was applied via truck) and readings are noted through dial gauges. Two dial gauge are installed to note loading applied and penetration.

- The load applied and the corresponding penetration depth is recorded at regular intervals until desired penetration value is reached.

**Table 1 – Standard Load Values for CBR Test**

| **Penetration (mm)** | **Standard Load (Kg)** | **Unit Standard Load (Kg)** |
|---|---|---|
| **2.5** | 1370 | 70 |
| **5.** | 2055 | 105 |
| **7.5** | 2630 | 134 |
| **10.0** | 3180 | 162 |
| **12.5** | 3600 | 183 |

The CBR values are usually calculated for penetration of 2.5 mm and 5mm. Generally, CBR value at 2.5mm will be greater than at 5mm and this value is taken as CBR for design purpose.

$$\text{CBR, \%} = \frac{\left[\begin{array}{l}\text{Load (or pressure) sustained by the}\\ \text{specimen at 2.5 or 5.0 mm penetration}\end{array}\right]}{\left[\begin{array}{l}\text{Load (or pressure) sustained by standard aggregates}\\ \text{at the corresponding penetration level}\end{array}\right]} \times 100$$

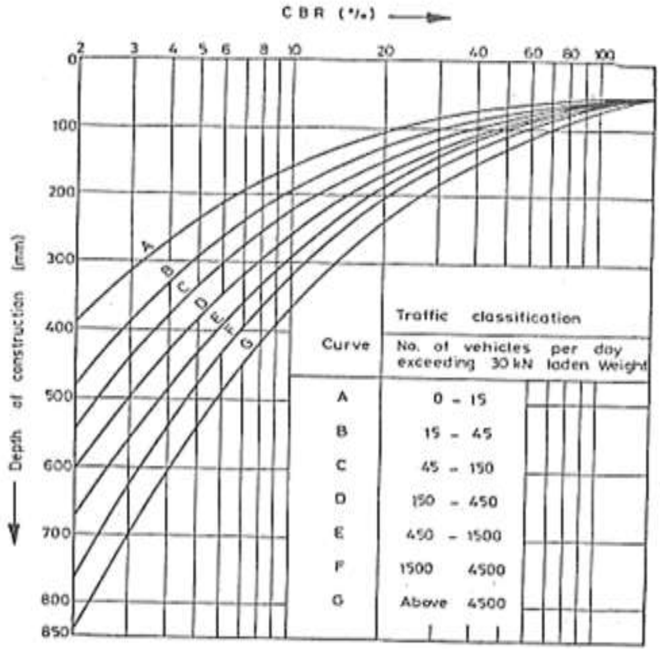


**Fig 1 - Design Chart IRC 37 for CBR Method**

## 5. Calculations

**Table 2 – CBR observations**

| **Penetration (mm)** | **Load Division test-1** | **Load (kg)** | **Corrected Load** | **Load Division test-1** | **Load (kg)** | **Corrected Load (kg)** |
|---|---|---|---|---|---|---|
| 0.00 | 0 | 0.00 | | 0.00 | 0.00 | |
| 0.50 | 22 | 67.98 | | 0.00 | 0.00 | |
| 1.00 | 28 | 86.52 | | 0.00 | 0.00 | |
| 1.50 | 33 | 101.97 | | 0.00 | 0.00 | |
| 2.00 | 38 | 117.42 | | 0.00 | 0.00 | |
| 2.50 | 42 | 129.78 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3.00 | 45 | 139.05 | | 0.00 | 0.00 | |
| 4.00 | 48 | 148.32 | | 0.00 | 0.00 | |
| 5.00 | 51 | 157.59 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7.50 | 55 | 169.95 | | 0.00 | 0.00 | |

CBR corresponding to 2.5mm penetration = 9.5%

CBR corresponding to 5.0 mm = (98/2055)*100 = 7.7%

Average Daily Traffic (ADT) = 500 vehicles/day

Annual rate of growth of traffic (r) = 6%

Time taken for pavement construction (n) = 1.5 year

No. of vehicles for design (A) = P $(1 + r)^{(n)}$

= $500(1+0.06)^{1.5}$ = 545.66 = ~550 vehicles/day

Therefore, Design Curve E is to be used for design as the design traffic volume is in the range 450 to 1500 vehicles/day.

Using the design chart, the total pavement thickness over subgrade having CBR of 9.5% is obtained as 30cm for curve E. Thus, 30cm of pavement materials is required to cover the natural soil subgrade having 9.5% CBR value.

Therefore, the thickness of base and sub base courses are 9cm and 13cm having CBR value 55% and 30% using the design chart. The CBR values for the gravel and road metal are assumed as follows:

**Table 3 – CBR values for gravel & road metal**

| Type of Material | Suggested CBR Value (%) |
|---|---|
| **Gravel** | 30 |
| **Road Metal** | 55 |

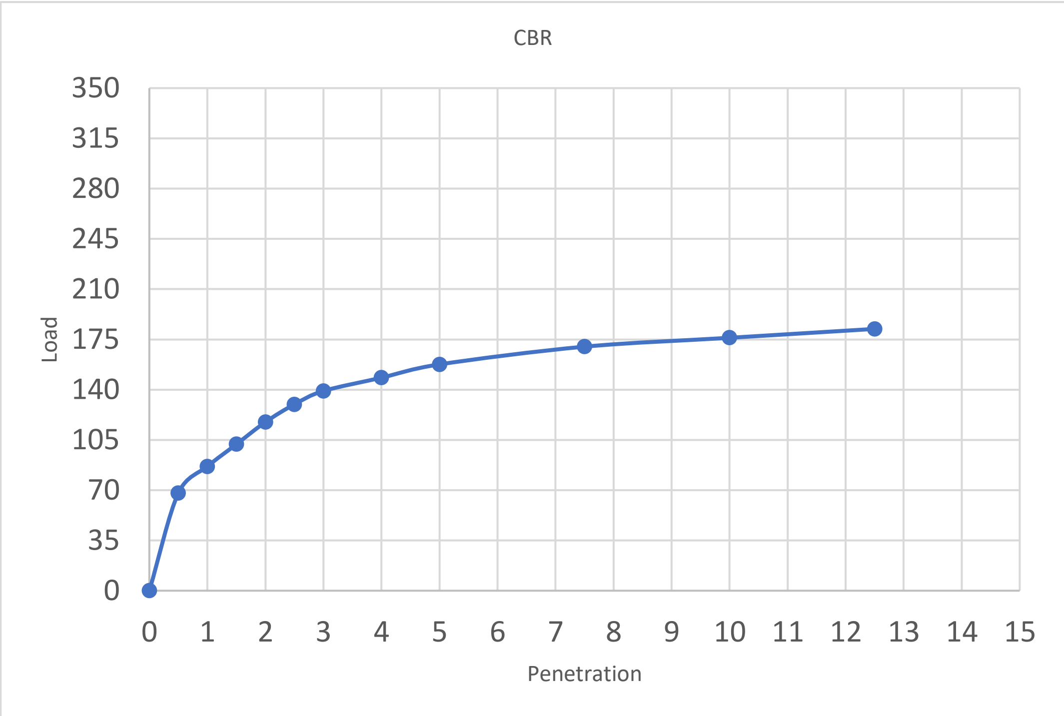


**Fig. 2 – CBR Graph**

## 6. Result & Conclusion

The analysis conducted using the CBR method has provided valuable insights into the pavement design process. With an Average Daily Traffic (ADT) of 500 vehicles/day and an Annual Rate of Growth of Traffic of 6%, the design has been tailored to withstand the anticipated traffic loading over time. The predicted time taken for pavement construction, spanning 1.5 years, has been factored into the design considerations.

Based on the CBR values of 30% for gravel and 55% for road metal, a pavement thickness of 30 cm has been determined. This thickness reflects the structural requirements necessary to support the specified traffic loadings while adhering to the guidelines outlined by the Indian Road Congress (IRC) in 2018 & 2019.

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