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Design of Flexible Pavement by IRC Method Based on Cumulative Standard Axle

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A B S T R A C T

The design of flexible pavements using the Indian Roads Congress (IRC) method. This method centres on the concept of Cumulative Standard Axles (CSA), which represents the total number of standard axle loads. A pavement is expected to endure over its design life.

The design process involves determining factors like initial traffic volume, traffic growth rate, design life, and vehicle damage factor. Using this information and the subgrade's California Bearing Ratio (CBR) value, pavement thickness charts from IRC:37 are employed to determine the total pavement thickness. These charts account for granular sub-base, base course, and bituminous surfacing thicknesses.

This IRC method offers a practical approach to designing flexible pavements that can withstand anticipated traffic loads for their intended lifespan.

Keywords: CBR, pavement, soil, properties, GI

1. Introduction

1.1. Overview

Flexible pavements, the most common type of road structure, consist of layered materials that distribute traffic loads over the subgrade. Their design is crucial for ensuring safe, durable, and cost-effective transportation infrastructure. The Indian Roads Congress (IRC) method provides a well-established approach for designing flexible pavements in India, catering to various traffic volumes and subgrade strengths.

1.2. Necessity of Study

Traffic patterns are constantly evolving, with increasing vehicle weight and volume placing greater demands on pavements. Improper design can lead to premature pavement failure, resulting in increased maintenance costs, traffic disruptions, and safety hazards. This necessitates a systematic method like IRC to ensure pavements can withstand anticipated traffic loads throughout their design life.

1.3. Objectives of Study

This study delves into the design of flexible pavements using the IRC method. The primary objective is to understand how the concept of Cumulative Standard Axles (CSA) is employed to determine the optimal pavement thickness required to accommodate the expected traffic over the design life.

1.4. Advantages

The IRC method offers several advantages:

- **Traffic-based Design:** It considers the actual traffic volume and growth rate, leading to a more realistic design compared to static load approaches.
- **CBR-based Design:** By incorporating the subgrade's strength (CBR value), it ensures pavements are tailored to the specific site conditions.
- **Standardized Charts:** The use of pre-defined design charts simplifies the design process and promotes consistency.

1.5. Significance of Study

Understanding the IRC method empowers engineers to design flexible pavements that are:

- **Durable:** They can withstand the anticipated traffic loads for their design life, minimizing maintenance needs and replacement costs.
- **Safe:** Properly designed pavements provide a stable and smooth riding surface, contributing to road safety.
- **Cost-effective:** By optimizing pavement thickness based on traffic and subgrade conditions, the IRC method promotes resource efficiency and reduces life-cycle costs.

2. Literature Review

The IRC method for flexible pavement design has undergone significant evolution as reflected in IRC:37 publications. IRC:37-2001 introduced the concept of Cumulative Standard Axles (CSA) as a key design parameter. It provided traffic charts linking CSA, subgrade California Bearing Ratio (CBR), and total pavement thickness. This method offered a practical approach based on empirical correlations.

IRC:37-2018 acknowledges the limitations of the 2001 method, particularly its lack of consideration for climatic factors and axle load spectrum. It incorporates Mechanistic-Empirical (M-E) principles for a more robust design approach. However, the concept of CSA remains relevant. The guidelines still provide charts for quick design estimations, with appropriate adjustments made for factors like vehicle damage factors (VDF) that account for different axle types

2.2 Research Articles:

- **"Designing of Flexible Pavement for IET Lucknow, Using Group Index Method" (International Journal of Research Publication & Reviews):** This article might present a case study of flexible pavement design using the Group Index method. While the Group Index method offers a quicker approach, it's important to compare its accuracy and limitations with the CBR method as per current IRC recommendations.

3. Cumulative Standard Axle

The IRC method for flexible pavement design employs the concept of CSA to determine the optimal pavement thickness based on anticipated traffic loads over the design life. Here's a breakdown of the methodology:

1. Design Traffic:

- **Initial Traffic:** Estimate the initial daily traffic volume (in terms of Commercial Vehicles Per Day - CVPD) for the year of completion. Traffic data from government agencies or previous studies can be used.
- **Traffic Growth Rate:** Account for the expected increase in traffic volume over the design life. This can be based on historical data or regional growth projections.
- **Design Life:** Specify the desired lifespan of the pavement in years (typically 10 to 15 years for major roads).

2. Vehicle Damage Factor (VDF):

- Conduct an axle load survey to determine the distribution of different axle types within the commercial vehicle traffic.
- Assign VDF values to each axle type based on their damaging effect compared to a standard single axle with an 8160 kg load. Standard VDF tables are available in IRC guidelines.
- Calculate the total VDF by multiplying the VDF of each axle type by its corresponding percentage within the traffic stream and summing the products.

3. Traffic Distribution:

- Consider the distribution of commercial vehicle traffic across traffic lanes. Typically, a distribution factor of 0.75 is used for two-lane undivided roads, accounting for heavier traffic concentration on the nearside lane.

4. Cumulative Standard Axles (CSA):

- Using the above data, calculate the CSA using the following formula:

CSA = (Initial CVPD x VDF x Traffic Growth Factor^n) x 365 x n / (2 x Distribution Factor)

Where:

n = Design life in years

Traffic Growth Factor = 1 + (Growth Rate in %) / 100

5. Subgrade Strength:

- Determine the California Bearing Ratio (CBR) of the subgrade soil through laboratory testing. CBR represents the subgrade's ability to support traffic loads.

6. Design Charts:

- Refer to IRC:37 guidelines (2001 or 2018). The specific code edition might influence the chart format, but the underlying principles remain similar.
- Locate the appropriate design chart based on the calculated CSA. These charts typically have traffic (CSA) on the x-axis and total pavement thickness on the y-axis.
- Select the design curve corresponding to the subgrade CBR value obtained from testing.

7. Pavement Thickness Determination:

- The intersection point of the chosen CSA value and the corresponding CBR curve on the design chart provides the total recommended pavement thickness.

8. Individual Layer Thicknesses:

- IRC:37 may not directly provide individual layer thicknesses (sub-base, base, surfacing). However, empirical relationships or specific design procedures from other codes or project specifications can be used to distribute the total thickness among different pavement layers

4. Test Procedure

The IRC method for flexible pavement design relies on input data obtained through various investigations and tests. Here's a breakdown of the key test procedures involved:

1. Traffic Data Collection:

- This doesn't involve a specific test but rather data acquisition. Traffic volume data (CVPD) for different vehicle categories is often obtained from government agencies responsible for traffic surveys and road networks. Alternatively, manual traffic counts can be conducted for the specific project location.

2. Axle Load Survey:

- This on-site survey involves recording the axle configuration and weight of commercial vehicles using the proposed roadway. Weighbridges or portable axle weight scales are used to measure the individual axle loads of passing vehicles.
- The survey should capture a representative sample of traffic over a specified period to account for seasonal variations and peak traffic hours.
- The data is then analyzed to determine the distribution of different axle types (single, tandem, tridem) and their corresponding axle loads.

3. California Bearing Ratio (CBR) Test (IS: 2720 - Part 13):

- This laboratory test measures the CBR value of the subgrade soil, a crucial parameter for pavement design using the IRC method.
- The test involves preparing undisturbed or remolded soil samples in a mold and subjecting them to a standardized penetration test using a plunger.

- The load-penetration data is used to determine the CBR, which is the ratio of the unit force required to penetrate the soil sample at a specific depth to the unit force required to penetrate a standard crushed California rock sample at the same depth.
- This test is typically conducted on multiple soil samples obtained from representative boreholes at the pavement site.

4. Other Tests (Optional):

- Depending on project requirements or specific concerns, additional tests might be recommended:
  - **Gradation Analysis (IS: 2720 - Part 4):** This test determines the particle size distribution of granular materials used in pavement layers (sub-base, base) to ensure proper drainage and structural integrity.
  - **Los Angeles Abrasion Test (IS: 2386):** This test measures the resistance of coarse aggregate to wear and abrasion, which is important for the durability of pavement layers.
  - **Soil Classification Tests (IS: 2720):** These tests identify the soil type and its engineering properties, which can influence decisions related to drainage and subgrade stabilization.

5. Data Analysis and Interpretation:

- The collected data from traffic counts, axle load surveys, and laboratory tests needs to be carefully analyzed and interpreted.
- Traffic data is used to calculate the initial CVPD and project the future traffic volume using the chosen growth rate.
- Axle load survey data helps determine the VDF by assigning appropriate values to different axle configurations based on their damaging potential compared to the standard single axle.
- The CBR test results provide the subgrade strength, which is a critical factor for selecting the appropriate design chart in the IRC guidelines.

This is the revised method suggested by IRC and is most commonly used nowadays for flexible pavement design. Instead of the number of vehicles per day, cumulative standard axle load is found. The revised design charts now contain seven curves categorized based on CBR value with the cumulative standard axle on the x-axis and total pavement thickness on the y-axis.

Initial (Two-Way) Traffic Volume in Terms of Commercial Vehicles Per Day	Rolling Terrain	Plain Hilly Terrain
0-150	1.7	0.6
150-1500	3.9	1.7
More than 1500	5.0	2.8

Table 1 – Indicative VDF values

Traffic Category (Daily Traffic)	Bitumen Surfacing Thickness (mm) – Typical Range
Low Traffic (Up to 150 vehicles)	20 - 30 (Surface treatment only)
Medium Traffic (150 - 450 vehicles	40 - 50 (BC wearing course)
High Traffic (450 - 3000 vehicles)	50 - 70 (DBM wearing course)
Very High Traffic (Over 3000 vehicles)	70 - 100 (DBM or Asphalt Concrete wearing course)

Table 2 – Bitumen Surfacing recommendations as per IRC 37

5. Calculations

Tridem axle with dual wheel on either side

$$MSA = \frac{365 \times ((1+r)^n - 1) \times A \times D \times F}{r}$$

where,

r = 6% = 0.06

A = P(1 + r)^x = 500 (1+0.06)^1.5 = 545.66 = ~550 veh/day ………(x = 1.5 years)

D = 3.9

F = 1

$$MSA = \frac{365 \times ((1+0.06)^{1.5} - 1) \times 550 \times 1 \times 3.9}{0.06}$$

MSA = 18.22 = ~20msa

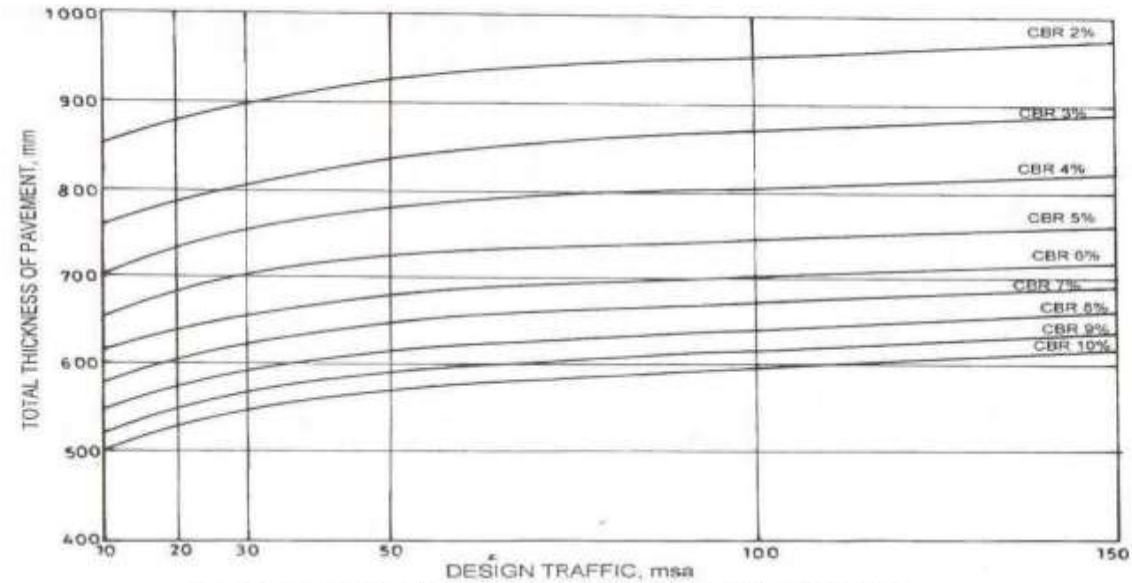

Fig. 2. Pavement Thickness Design Chart for Traffic 10-150 msa

Fig 1– Pavement thickness design chart for traffic 10-150msa

using above chart from IRC 37 pg no.9 We obtain,

Total thickness of pavement = 540mm = 21.25 inches.

Total pavement thickness for CBR 9% and traffic 20 msa

[This value of CBR is derived in the pervious paper i.e. Design of Flexible Pavement by using CBR method]

Total thickness of pavement = 540mm = 21.25 inches … (from IRC:37 2001)

Pavement composition can be obtained by interpolation from Pavement Design Catalogue

(IRC:37 2001).

(a) Bituminous surfacing = 60 mm DBM

(b) Road-base = 90 mm WBM

(c) Sub-base = 130 mm GSB

The design procedure given by IRC makes use of the CBR value, million standard axle concept, and vehicle damage factor. Traffic distributions along the lanes are taken into account. The design is meant for design traffic which is arrived at using a growth rate.

6. Result & Conclusion

The IRC method, employing the concept of Cumulative Standard Axles (CSA), offers a practical and efficient approach to design flexible pavements in India. This method considers anticipated traffic loads throughout the design life and subgrade strength (CBR) to determine the optimal pavement thickness.

In this example, based on the calculated CSA and a subgrade CBR value (assumed for illustration), the IRC design charts indicated a total pavement thickness of 540 mm (21.25 inches). Further details regarding individual layer thicknesses can be obtained through interpolation from pavement design catalogs like IRC:37 2001. Here, the possible composition is:

- Bituminous surfacing: 60 mm DBM
- Road-base: 90 mm WBM
- Sub-base: 130 mm GSB

The IRC method provides a standardized framework for designing pavements that are cost-effective, durable, and can accommodate the expected traffic volume for their intended lifespan.

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