

IRC method of design of flexible pavements

Lecture Notes in Transportation Systems Engineering

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1 Overview

Indian roads congress has specified the design procedures for flexible pavements based on CBR values. The Pavement designs given in the previous edition IRC:37-1984 were applicable to design traffic upto only 30 million standard axles (msa). The earlier code is empirical in nature which has limitations regarding applicability and extrapolation. This guidelines follows analytical designs and developed new set of designs up to 150 msa in IRC:37-2001.

2 Scope

These guidelines will apply to design of flexible pavements for Expressway, National Highways, State Highways, Major District Roads, and other categories of roads. Flexible pavements are considered to include the pavements which have bituminous surfacing and granular base and sub-base courses conforming to IRC/ MOST standards. These guidelines apply to new pavements.

3 Design criteria

The flexible pavements has been modeled as a three layer structure and stresses and strains at critical locations have been computed using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered:

1. vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
2. horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
3. pavement deformation within the bituminous layer.

While the permanent deformation within the bituminous layer can be controlled by meeting the mix design requirements, thickness of granular and bituminous layers are selected using the analytical design approach so that strains at the critical points are within

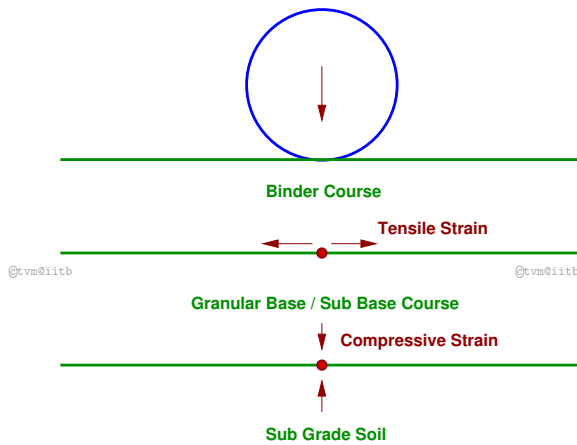


Figure 1: Critical Locations in Pavement

the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the stiffness of dense bituminous macadam (DBM) layer with 60/70 bitumen has been used in the analysis.

4 Failure Criteria

A and B are the critical locations for tensile strains (ϵ_t). Maximum value of the strain is adopted for design. C is the critical location for the vertical subgrade strain (ϵ_z) since the maximum value of the (ϵ_z) occurs mostly at C.

Fatigue Criteria:

Bituminous surfacings of pavements display flexural fatigue cracking if the tensile strain at the bottom of the bituminous layer is beyond certain limit. The relation between the fatigue life of the pavement and the tensile strain in the bottom of the bituminous layer was obtained as

$$N_f = 2.21 \times 10^{-4} \times \left(\frac{1}{\epsilon_t} \right)^{3.89} \times \left(\frac{1}{E} \right)^{0.854} \quad (1)$$

in which, N_f is the allowable number of load repetitions to control fatigue cracking and E is the Elastic modulus of bituminous layer. The use of equation 1 would result in fatigue cracking of 20% of the total area.

Rutting Criteria

The allowable number of load repetitions to control permanent deformation can be expressed as

$$N_r = 4.1656 \times 10^{-8} \times \left(\frac{1}{\epsilon_z} \right)^{4.5337} \quad (2)$$

N_r is the number of cumulative standard axles to produce rutting of 20 mm.

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5 Design procedure

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

- Design traffic in terms of cumulative number of standard axles; and
- CBR value of subgrade.

6 Design traffic

The method considers traffic in terms of the cumulative number of standard axles (8160 kg) to be carried by the pavement during the design life. This requires the following information:

1. Initial traffic in terms of CVPD
2. Traffic growth rate during the design life
3. Design life in number of years
4. Vehicle damage factor (VDF)
5. Distribution of commercial traffic over the carriage way.

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Initial traffic

Initial traffic is determined in terms of commercial vehicles per day (CVPD). For the structural design of the pavement only commercial vehicles are considered assuming laden weight of three tonnes or more and their axle loading will be considered. Estimate of the initial daily average traffic flow for any road should normally be based on 7-day 24-hour classified traffic counts (ADT). In case of new roads, traffic estimates can be made on the basis of potential land use and traffic on existing routes in the area.

Traffic growth rate

Traffic growth rates can be estimated (i) by studying the past trends of traffic growth, and (ii) by establishing econometric models. If adequate data is not available, it is recommended that an average annual growth rate of 7.5 percent may be adopted.

Design life

For the purpose of the pavement design, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary. It is recommended that pavements for arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for 20 years and other categories of roads for 10 to 15 years.

Vehicle Damage Factor

The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles per commercial vehicle. The VDF varies with the axle configuration, axle loading, terrain, type of road, and from region to region. The axle load equivalency factors are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC:37 2001. The exact VDF values are arrived after extensive field surveys.

6.1 Vehicle distribution

A realistic assessment of distribution of commercial traffic by direction and by lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until reliable data is available, the following distribution may be assumed.

- **Single lane roads:** Traffic tends to be more channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions.
- **Two-lane single carriageway roads:** The design should be based on 75 % of the commercial vehicles in both directions.
- **Four-lane single carriageway roads:** The design should be based on 40 % of the total number of commercial vehicles in both directions.
- **Dual carriageway roads:** For the design of dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles in each direction. For dual three-lane carriageway and dual four-lane carriageway the distribution factor will be 60.% and 45 % respectively.

6.2 Design traffic

The design traffic is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic during the design life of the road. This can be computed using the following equation:

$$N = \frac{365 \times [(1 + r)^n - 1]}{r} \times A \times D \times F \tag{3}$$

where N is the cumulative number of standard axles to be catered for the design in terms of million standards axle (msa), A is the initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day, D is the lane distribution factors, F is the vehicle damage factor, n is the design life in years, and r is the annual growth rate of commercial vehicles ($r=-0.075$ if growth rate is 7.5 percent per annum). The traffic in the year of completion is estimated using the following formula:

$$A = P (1 + r)^x \tag{4}$$

where p is the number of commercial vehicles as per last count, and x is the number of years between the last count and the year of completion between the last count and the year of completion of the project.

7 Pavement thickness design charts

For the design of pavements to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10 %. The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing. The individual layers are designed based on the the recommendations given below and the subsequent tables.

8 Pavement composition

Sub-base

Sub-base materials comprise natural sand, gravel, laterite, brick metal, crushed stone or combinations thereof meeting the prescribed grading and physical requirements. The sub-base material should have a minimum CBR of 20 % and 30 % for traffic upto 2 msa and traffic exceeding 2 msa respectively. Sub-base usually consist of granular or WBM and the thickness should not be less than 150 mm for design traffic less than 10 msa and 200 mm for design traffic of 1:0 msa and above.

Base

The recommended designs are for unbounded granular bases which comprise conventional water bound macadam (WBM) or wet mix macadam (WMM) or equivalent conforming to MOST specifications. The materials should be of good quality with minimum thickness of 225 mm for traffic up to 2 msa an 150 mm for traffic exceeding 2 msa.

Bituminous surfacing

The surfacing consists of a wearing course or a binder course plus wearing course. The most commonly used wearing courses are surface dressing, open graded premix

carpet, mix seal surfacing, semi-dense bituminous concrete and bituminous concrete. For binder course, MOST specifies, it is desirable to use bituminous macadam (BM) for traffic upto 5 msa and dense bituminous macadam (DBM) for traffic more than 5 msa.

9 Numerical example

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Design the pavement for construction of a new bypass with the following data:

1. Two lane carriage way
2. Initial traffic in the year of completion of construction = 400 CVPD (sum of both directions)
3. Traffic growth rate = 7.5 %
4. Design life = 15 years
5. Vehicle damage factor based on axle load survey = 2.5 standard axle per commercial vehicle
6. Design CBR of subgrade soil = 4%.

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9.0.1 Solution

1. Distribution factor = 0.75

2.

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$$\begin{aligned}
 N &= \frac{365 \times [(1 + 0.075)^{15} - 1]}{0.075} \times 400 \times 0.75 \times 2.5 \\
 &= 7200000 \\
 &= 7.2 \text{ msa}
 \end{aligned}$$

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3. Total pavement thickness for CBR 4% and traffic 7.2 msa from IRC:37 2001 chart1 = 660 mm
4. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC:37 2001).

- (a) Bituminous surfacing = 25 mm SDBC + 70 mm DBM
- (b) Road-base = 250 mm WBM
- (c) sub-base = 315 mm granular material of CBR not less than 30 %

10 Summary

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

11 Problems

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1. Design the pavement for construction of a new two lane carriageway for design life 15 years using IRC method. The initial traffic in the year of completion in each direction is 150 CVPD and growth rate is 5%. Vehicle damage factor based on axle load survey = 2.5 std axle per commercial vehicle. Design CBR of subgrade soil=4%.

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12 Solutions

1. Distribution factor = 0.75

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- 2.

$$\begin{aligned}
 N &= \frac{365 \times [(1 + 0.05)^{15} - 1]}{0.05} \times 300 \times 0.75 \times 2.5 \\
 &= 4430348.837 \\
 &= 4.4 \text{ msa}
 \end{aligned}$$

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3. Total pavement thickness for CBR 4% and traffic 4.4 msa from IRC:37 2001 chart1 = 580 mm
4. Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC:37 2001).

- (a) Bituminous surfacing = 20 mm PC + 50 mm BM
- (b) Road-base = 250 mm Granular base
- (c) sub-base = 280 mm granular material.

Exercises

1. Not Available

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References

1. IRC. *Guidelines for the design of flexible pavements*. Number 37. New Delhi, 2002.

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Acknowledgments

I wish to thank several of my students and staff of NPTEL for their contribution in this lecture. I also appreciate your constructive feedback which may be sent to **tvm@civil.iitb.ac.in**

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