Design of Flexible Pavement as per IRC:37-2018 and using IIT - Pave

Aditya Mehta[1] Amit Mishra[2] Kalpesh Nikumbh[3] Tanmay Ponkshe[4] SnehlataYadav[5]
[1,2,3,4]Under Graduate Student [5]Assistant Professor
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,4,5]A.P. Shah Institute of Technology, Thane, Maharashtra, India

Abstract— Transportation plays a crucial role in the overall development of a country. Roads are the primary means of transportation. Flexible pavement is chosen over cement concrete roads as they have the great dominance that these can be strengthened and improved in stages with the growth in traffic. The failure of bitumen pavement is because of the fatigue cracking and rutting deformation. the project aims to design flexible pavement with the help of IRC:37-2018 guidelines and using IIT - PAVE software to determine the stress and strains values at a critical location at different layers of pavement. The design of flexible pavement mainly depends on the strength of the sub-grade soil and the traffic load. The design follows various procedures like the acquisition of data related to the traffic and sub-grade soil CBR values, traffic is examined on the basis of Equivalent Standard Axle Load (ESAL) and here the standard axle is defined as a single axle dual wheel with a load of 80 KN. Then selecting the various layer combinations while keeping the top surface of bituminous concrete the same for all the trials and changing the composition of base and sub-base layer suggested by IRC:37-2018. The different base and sub-base compositions like Granular Base, Granular Sub-base, cementitious Sub-base, and bitumen emulsion treated RAP layers are selected along with their design thickness and resilient modulus. The pavement is designed for rutting and fatigue life and examined by IIT - Pave later on. Also, perpetual pavement designs are opted out for some of the chosen layer combinations.

Keywords: Aluminium Matrix, Manufacturing, Sand Casting, Hardness, Toughness

I. Introduction

Various factors like wheel load, sub-grade strength, climatic factors, stress distribution, characteristics of materials used, and environmental factors affect the pavement design. In India, the designing of pavement is done as per IRC guidelines. For a flexible pavement, an elastic multi-layer structure is of use. A linear layered elastic model is of help for computation for stresses and strains at critical locations. The compilation of stress and tension in the flexible pavement can be gained by the use of Stress analysis software IIT - PAVE.

IIT - Pave software is an advanced version of FPAVE. A multi-layer analysis programmer is used for designing and analysis of flexible pavement by IRC: 37-2012 guidelines. In this software, the input data required is the thickness of a pavement layer, the elastic modulus of each layer, loads applied over the surface of the pavement, critical locations depth, tire pressure, spacing between the wheels, and Poisson´s ratio as input. The mechanical parameters updated in the output page are vertical stress (Sigma Z), tangential stress (Sigma T), radial stress (Sigma R), shear stress (Tao RZ), vertical deflection (Disp Z), vertical strain (ep z), horizontal tangential strain (ep T), and horizontal radial strain (ep R). 96+

A pavement with a life of fifty years or more is generally considered a long-life pavement or perpetual pavement. In the Indian context, pavements with design traffic of 300 million standard axle or more are contrived as long-life pavements. If the tensile strain caused by the traffic in the bituminous layer is less than 70 micro strain the bituminous surface will never crack. Similarly, if the vertical sub-grade tension is less than 200 micro strains, there will be practically minute rutting in the sub-grade.

II. Methodology

The method used in data analysis is a mechanistic-empirical method that is considered for the design life of the pavement is done in such a manner that it resists the fatigue cracking in the bitumen surface which is extended to 20 percent of the pavement surface area or the terminal rutting of 20 mm of the pavement which happens earlier. The mechanistic-empirical software called IIT - PAVE is applied to analyze the pavement responses. The structural analysis of flexible pavement for IIT - PAVE is done based on multi-layer theory.

The design of flexible pavement is done as an elastic multi-layer structure. A linear layered elastic model is used to derive the stresses and strains at critical locations. The stresses and strains in the flexible pavements are calculated with the help of a stress analysis software, IIT - Pave. The tensile strain, Єt, which is at the bottom of the layer of bitumen, and the vertical sub-grade strain, Єv, at the top of the sub-grade are considered conventionally as critical parameters for pavement design to restrict cracking and rutting in the non-bituminous layers and bituminous layers respectively. The calculation also shows that, to initiate the longitudinal surface cracking, the tensile stress near the surface close to the edge of a wheel. Which is followed by a transverse cracking much before the flexural cracking of the bottom layer if the mixed tensile strength is not enough at higher temperatures.

III. Design and Analysis

The pavement was totally designed based on the IRC:37-2018 guidelines and later it is analysed by using IIT - PAVE software.

A. *Design Traffic*

A traffic volume survey was carried out at Kasarvadavli bus stop Ghodbundar road, Thane starting from 7 am to 7 pm. From 12 hours survey, the CVPD value was obtained and in the analysis part of the traffic volume count survey, the commercial vehicle having a laden weight of 3 tonnes or more was perceived.

The total number of LCV, Buses, 2A, and 3A Trucks were summed up and analyzed to find the commercial

vehicles of different axles and the vehicle damage factor as 5238 CVPD and 4.5.
Assuming 50% traffic in each direction = 2619 CVPD
Cumulative number of standard axles to be catered for in the design

$$NDes = 365 \times \left(\frac{[(1+r)n-1]}{r}\right) \times A \times D \times F \;\ldots\ldots\ldots(1)$$

NDes = cumulative number of standard axles to be catered for during the design period of 'n' years
A = initial traffic
D = lateral distribution factor
F = vehicle damage factor (VDF)
n = design period, in years
r = annual growth rate of commercial vehicles in decimal (e.g., for 6 per cent annual growth rate, r = 0.06).
Design Traffic is 112 million standard axles

B. Sub-grade Resilience Modulus

The behaviour of the sub grade is essentially elastic under the transient traffic loading with negligible permanent deformation in a single pass. Resilient modulus is the measure of its elastic behaviour determined from recoverable deformation in the laboratory tests. The modulus is an important parameter for design and the performance of a pavement. The relation between resilient modulus and the effective CBR is given as

$$MR\,(MPa) = 10 * CBR \; for \; CBR < 5 \qquad (2)$$

$$MR\,(MPa) = 17.6 * (CBR)^{0.64} \quad for \; CBR > 5 \qquad (3)$$

The resilient modulus of a natural sub-grade having the CBR value 4.6% is 46 Mpa and a borrowed sub-grade of thickness 500 mm with CBR 9% is 71.82 Mpa

Effective sub-grade resilience modulus is estimated using IIT - PAVE software from which the deflection value is obtained which is in this case 2.27 mm and later using equation 4 the effective sub-grade resilient modulus is calculated.

$$[2b\,(1-\mu^{\wedge}2)\,pa]/\delta \qquad \ldots\ldots\ldots(4)$$

p = contact pressure = 0.56 MPa
a = radius of circular contact area
μ = Poisson's ratio
Effective Modulus of Sub-grade is 65.29 Mpa

C. Layer Combinations Selection

Various layer combinations have been tried out in this project and their thickness; strains are shown in the tabular format.
Trial 1: Bituminous Pavement with Granular Base and Sub-base
Trial 2: Bituminous Pavement, Granular Base (WMM) and CTSB
Trial 3: Bituminous Pavement with RAP Material Treated with Foamed Bitumen and CTSB
Trial 4: Perpetual Pavement: Bituminous Pavement with Granular Base and Sub-base
Trial 5: Perpetual Pavement: Bituminous Pavement, Granular Base (WMM) and CTSB

The design thickness for different composition of materials has been found out using design catalogue given in code. The different compositions are mentioned below,

Composition	Total thickness inmm
Trial 1	670
Trial 2	730
Trial 3	470
Trial 4	800
Trial 5	710

Table 1: Pavement thickness for different composition

D. Sub-grade Resilience Modulus

Two fatigue equations were fitted, one in which the computed strains in 80 per cent of the actual data in the scatter plot were higher than the limiting strains predicted by the model (and termed as 80 per cent reliability level in these guidelines) and the other corresponding to 90 per cent reliability level.

Allowable Horizontal tensile strain (εt) was determined for all the pavement compositions by adopting 90% reliability using equation 6 and also by analyzing in IIT - PAVE and the corresponding values are given in table.2 as given below

$$Nf = 2.21 * 10^{-04} * \left[\frac{1}{\varepsilon t}\right]^{3.89} * \left[\frac{1}{MR}\right]^{0.854} \qquad \ldots\ldots\ldots(5)$$

$$Nf = 0.5161 * C * 10^{-04} * \left[\frac{1}{\varepsilon t}\right]^{3.89} * \left[\frac{1}{MR}\right]^{0.854} \qquad (6)$$

Nf = fatigue life of bituminous layer
Et = maximum horizontal tensile strain at the bottom of the bottom bituminous layer
Mr = resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer.

Composition	IRC equation	IITPAVE
Trial 1	$156x10^{-6}$	$143x10^{-6}$
Trial 2	$156x10^{-6}$	$105x10^{-6}$
Trial 3	$156x10^{-6}$	$102x10^{-6}$
Trial 4	$80x10^{-6}$	$75x10^{-6.}$
Trial 5	$80x10^{-6}$	$79x10^{-6.}$

Table 2: Horizontal tensile strength

E. Rutting Criteria

The reliability levels of 90 percent and 80 percent which have been collected during the studies which are used in pavement performance data also have been calibrated in the rutting model.

Allowable vertical compressive strain (εv) was determined for all the pavement compositions by adopting 90% reliability using equation 8 and also by analyzing in IIT - PAVE and the corresponding values are given in table.3 as given below

$$Nr = 4.1656 * 10^{-08} * \left[\frac{1}{\varepsilon v}\right]^{4.5337} \qquad \ldots\ldots\ldots(7)$$

$$Nr = 1.41 * 10^{-08} * \left[\frac{1}{\varepsilon v}\right]^{4.5337} \qquad \ldots\ldots\ldots(8)$$

Nr = sub-grade rutting life
Ev = vertical compressive strain at the top of the sub-grade calculated using linear elastic layered theory

Composition	IRC equation	IITPAVE
Trial 1	$312x10^{-6}$	$235x10^{-6}$
Trial 2	$312x10^{-6}$	$158x10^{-6}$
Trial 3	$312x10^{-6}$	$307x10^{-6}$
Trial 4	$200x10^{-6}$	$136x10^{-6}$
Trial 5	$200x10^{-6}$	$141x10^{-6}$

Table 3: Vertical compressive strain

IV. Conclusion

From the various trial result, it can be concluded that the trial 1 of bituminous concrete, Granular base and sub base is the most common layer combination used for the highway design. If the granular sub-base material is weak or lack of availability of natural material is there then the CTSB layer can replace the granular sub-base, the use of RAP layer is uncommon in India, the old flexible layer is disposed of or used in land filling instead of recycling and reusing it in pavement. For highly important road perpetual pavement are the best solution but for its high amount of initial cost is required for the project and therefore it can't be used in every highway design.

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