Design of flexible pavement using experimental and software approach

Ayush Pandey[1], Kumar Vanshaj[2], Gaurav Singh[3], Saurabh Yadav[4], J.B. Srivastav[5]

[1,3,4] B.tech Final Year Civil Engineering Department, Institute of Engineering & Technology, Lucknow.
[2] Assistant Professor, Civil Engineering Department, Institute of Engineering & Technology, Lucknow
[5] Professor, Civil Engineering Department, Institute of Engineering & Technology, Lucknow

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Abstract India's transport sector is large and diverse; it caters to the needs of 1.1 billion people. Roads are the dominant mode of transportation in India today. They carry almost 85 percent of the country's passenger traffic and more than 60 percent of its freight.

Flexile pavements are by far consists most of the portion of Indian roads owing to the fact that they are less expensive, easy for maintenance and repair, less technicality involve etc.

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus, the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade. In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive)on the top and the lowest load bearing capacity material (andleast expensive) on the bottom.

INTRODUCTION

The type of highway pavement that transmits the imposed wheel load to the underlying layers by a grain-to-grain transfer mechanism and is commonly constructed utilizing bitumen & aggregates is known asflexible pavement.

Figure1. Flexible Pavement at IET Lucknow

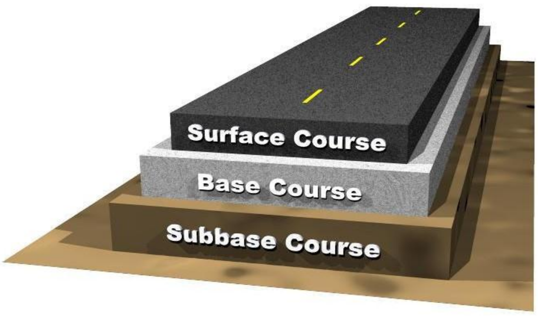

Figure2. Different Layers of Flexible Pavement

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements.

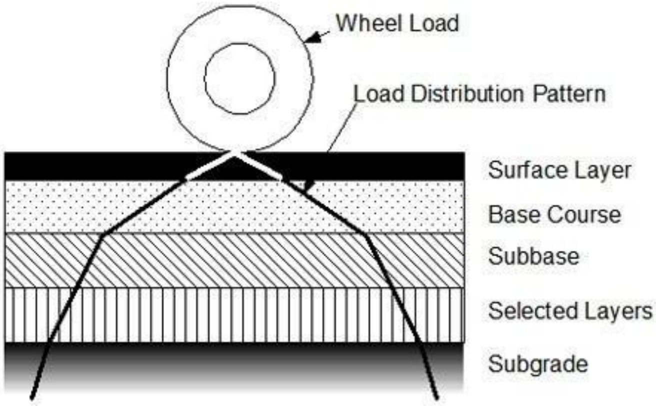

Figure3. Load distribution pattern

These pavements have negligible flexural strength therefore undergoes deformation under the action ofloads.

Load from standard vehicles acts on the wearing coarse and it gets dispersed with depth in the base, sub base, and subgrade coarse. As the load is applied on top surface hence traffic loading is highest on top surface asa result stiffness of different layers decreases from top to bottom. But these layers also are equally important inpavement composition.

From the past there are various methods for the designof flexible pavement, but the most adoptable method isCBR method because it is also suggested by our IRC:37.

With the help of CBR value and traffic data, we canselect a depth from catalogue given by IRC:37.

The depth suggested by IRC sometimes comes out tobe over safe and uneconomical, therefore revision in depth may be needed. This revision can be done through IIT PAVE software. This software computes actual strain that acts on the pavement at required sections due to superimposed load.

LITERATURE REVIEW

IITPAVE software has been developed for theanalysis of linear elastic layered pavement system. The stresses, strains and defections caused at different locations in a pavement by a uniformly distributed single load applied over a circular contact area at the surface of pavement can be computed using this software. The effect of additional loads (which should also be uniformly distributed loads over circular contact areas) was considered using superposition principle.

Punmia et. al (2005) have reported stresses in homogeneous mass; elastic deformation under circular load and Burmister analysis for flexible pavement. Charts for vertical deflections have been developed. The design curves by Group Index Method and CaliforniaBearing Ratio Method have been developed. In Group Index Method, the curves are plotted between Group Index and thickness. In California Bearing Ratio Method curves are plotted between thickness of construction and California Bearing Ratio.

Subagio et.al (2005) discusses a case study for multilayer pavement structural analysis using methods of equivalent thickness. An approximate method has been developed to calculate stresses and strains in multilayer pavement systems by transforming this structure into an equivalent one-layer system with equivalent thicknesses of one elastic modulus. This concept is known as the method of equivalent thickness which assumes that the stresses and strains below a layer depend on the stiffness of that layer.

Khan (1998) elaborates the Group Index Method and California Bearing Ratio Method for design of flexible pavements. In Group Index Method the thickness is obtained by first determining the Group Index of soil. Thecurves are plotted between Group Index of subgrade and thickness for various traffic conditions.

Structural Analysis of the selected pavementstructure:

This is to be done by running the IITPAVE software or any other linear elastic layer programme using as inputs the layer thicknesses, the layer moduli, the layer

Poisson's ratio values, the standard axle load of 80 kN distributed on four wheels (20 kN on each wheel), and a tyre pressure as 0.56 MPa. For carrying out fatigue damage analysis of cement treated bases, the axle load under consideration and a contact pressure of 0.80 MPa will be considered. The program will output the stresses, strains and deflections at selected critical locations in the pavement from which the values of critical mechanistic parameters can be identified for design. A soft copy of the IITPAVE software isattached as part of this document. Details about IITPAVE and instructions for its installation and use are given in Annex-I.

The single vertical load applied at the surfaceis described in terms of (any one)

- contact pressure and radius of contactarea
- Wheel load and contact pressure
- Wheel load and radius of contact area.

For IITPAVE, wheel load and contact pressure are the load inputs. The pavementinputs required are the elastic properties (elastic/resilient moduli and Poisson's ratio values of all the pavement layers) and the thicknesses of all the layers (excluding subgrade). IITPAVE software, in its current version, can be used to analyse pavements with a maximum of ten layers including the subgrade. If the number of layers in the pavement is more than ten, different layers of similar nature (e.g., granular, bituminous) can be combined and considered as one layer. Cylindrical coordinate system is followed in the program. Thus, the location of any element inthe pavement is defined by (a) depth of the location of the element from the surface of the pavement and the radial distance of the element measured from the vertical axis of symmetry (along the centre of the circular contact area of one wheel load).

OBJECTIVE

- To design the flexible pavement by CBR methodusing IRC 37-2018.
- To analyze the depth using IIT pave software.
- To determine strains at critical points using IIT pavesoftware.
- To find the optimal design of flexible pavementusing various method.

DESIGN PROCEDURE

1. **Computation of CBR value**

   Cbr test performed on the soil samplecollected fromsite. The value of CBR comes out to be 5.3 %.

2. **Computation of traffic data**

   Traffic data is computed from the formula given byIRC 37 $N_{des} = 365*[(1+r)^n - 1]*A*D*F/r$
   Traffic for the road comes out to be 4.3MSA

3. **Selection of trial depth from IRC:37 2012**

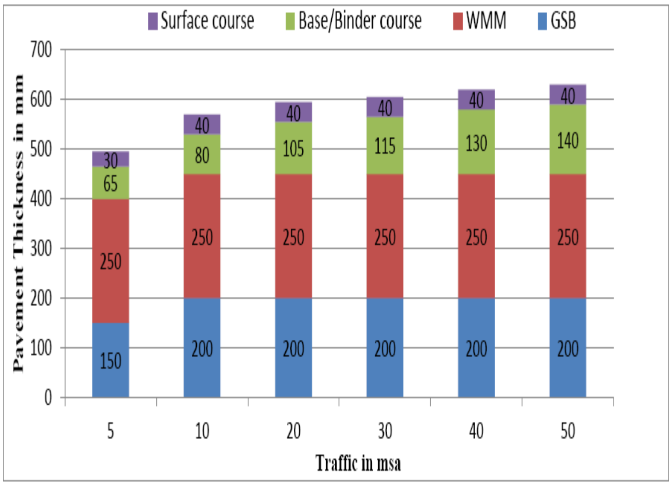

Figure4. Thickness of Different layer corresponding 5% CBRWe have selected 1st depth as trial on software

4. Calculation of Resilient Modulus (M):

Mbitumen = 700MPa (for VG30 @ 30^oC) [IRC:37-2018table7.1]

Msubgrade = 17.6 * $(CBR)^{0.64}$ for CBR > 5 % (Msubgrade =MRSUPPORT)

= 17.6* $(5.3)^{0.64}$ = 51.17MPa

MRGRAN = $0.2(h)^{0.45}$* MRSUPPORT = 0.2*$(400)^{0.45}$*51.17 =151.7MPa

5. Calculation of Maximum allowable Strain for Rutting& Fatigue:

NR = Nf = Ndes =4.34*10^6

For Rutting,

NR = 4.1656 x 10^{-08} $[1/\varepsilon v]^{4.5337}$ (for 80 % reliability)

= 4.34*10^6

Implies, εv max = 809.25*10^{-6}

For Fatigue,

Nf = 1.6064*C*10^{-04} $[1/\varepsilon t]^{3.89}$* $[1/MRm]^{0.854}$ (for 80 % reliability)

=4.34*10^6

Implies, εt max = 536*10^{-6}

6. Now, substituted the above values i.e.,

(a) Thickness of Layers;
(b) Resilient Modulus;
(c) Poisson's Ratio (0.35 forevery layer);
(d) Wheel load (standard load of 20kN);
(e) Tyre pressure (standard pressure for GSB i.e., 0.56) and

(f) Analysis point details (respective depths and radial distance) in the software (IITPAVE) and obtained the values of εv and εt as following:

εt @95mm= $410.05*10^{-6}$ < εt max

εv@495mm = $157.77*10^{-6}$ < εv max

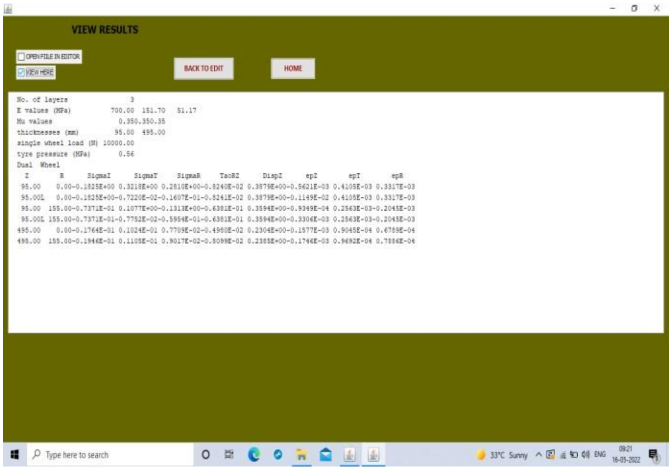

Figure5. Strains from trial 1

Further changing the thickness of the layers andcalculating values of εv and εt again.

Thickness of Layer1 = 85mm Thickness of Layer2 = 300mm

MRGRAN = $0.2(h)^{0.45}$* MRSUPPORT = $0.2*(300)^{0.45}*51.17$ =133.27MPa

Substituted this value of MRGRAN with the previous valueand obtained the values of εv and εt as following:

εt @85mm= $394.16*10^{-6}$ < εt max

εv@385mm = $479.3*10^{-6}$ < εv max

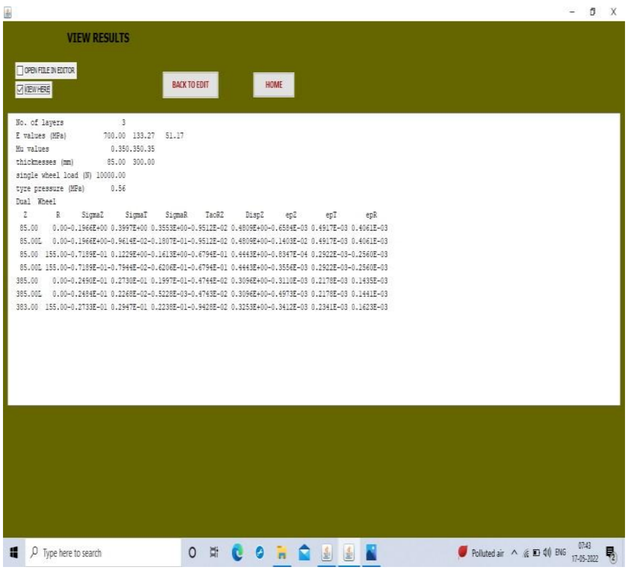

Figure6. Strains from Trial 2

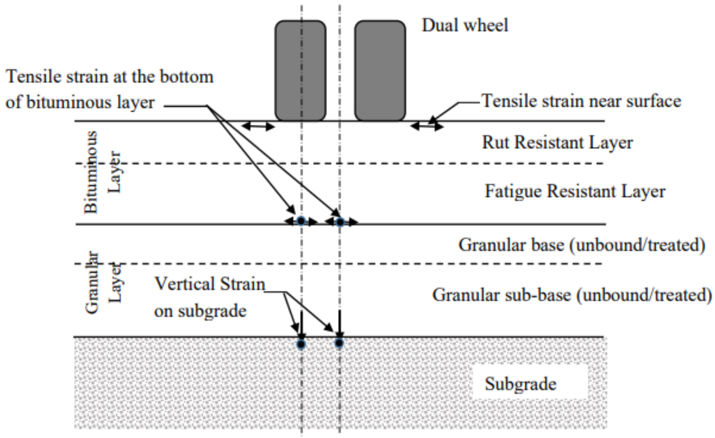

Figure7. Compressive and tensile strains at different layers

Hence our Final Pavement will

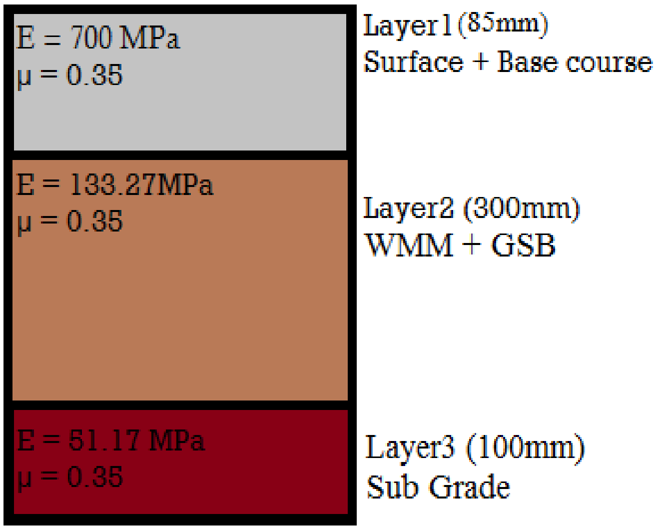

Figure8. Final Thickness of Different Layers

RESULTS:

1. Considering the fatigue criteria mentioned in IRC:37-2018, we have obtained certain value oftensile strain. This value of tensile strain is the maximum value of tensile strain that can be allowed on the pavement.

2. Considering the rutting criteria mentioned in IRC;37-2018, we have obtained certain value ofcompressive strain. This value of compressive strain is the maximum value of compressive strain that can be allowed on the pavement.

3. The tensile and compressive strains obtained from the software is much lesser then the tensileand compressive strain obtained by using the formulas mentioned in the IRC:37-2018.

4. So, we can reduce the thickness of the different layers by some amount so that the difference between the strains obtained by bothe the method is reduced.

The values of strains are mentioned below:

1. εt max = $536*10^{-6}$
2. εv max = $809.25*10^{-6}$
3. εt @95mm= $410.05*10^{-6} < \varepsilon t$ max

4. $\varepsilon v@495mm = 157.77*10^{-6} < \varepsilon v\ max$

The values of the thickness of different layers arementioned below:

S. No	Layers	Modulus (in MPa)	Poisson's Ratio	Thickness (in mm)
1.	Bituminous Layer	700	0.35	85
2.	WMM +GSB	133.27	0.35	300
3.	Subgrade	51.17	0.35	100

CONCLUSION:

1. From the values of the maximum tensile strain and maximum compressive strain obtained from the formuls mentioned in the IRC:37-2018 (the manual method) and the values of the tensile and compressive straims obtained by putting the values of thickness of different lyers, we can conclude that we can further reduce the thickness of each layer by some amount so that the strain differences obtained by both method isreduced.

2. This difference suggests us that even after the reduction of the thickness of each layers we can still construct safe pavement with the strainwithin the safe limits.

3. Now, the reduction of different layer concludesthat we can still make the safe and proper functionable pavement with reduced amount ofthe Material used.

Thus the reduction of the material can bring us to theconstruction of more economic pavement.

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