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Design of flexible pavement using manual and software approach

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ABSTRACT -Indian road transportation infrastructure is rapidly expanding with the ambitious development of road networks under National Highways Development Programme (NHDP), State Highways Improvement Programmes (SHIPs), Bharat Nirman, PradhanMantri Gram SadakYojana (PMGSY) etc. Also, other category roads and airports are largely expanded. The fast growing Indian economy will further demand for road transport network with a high quality pavement structure as the main corridors are required to cater to very heavy traffic-both in terms of number and axle loading. Road-laying under the Golden Quadrilateral project and the North-South and East-West corridors project of National Highways Authority of India (NHAI) has been quantitatively significant.

Currently, majority of the Indian roads are flexible pavements, the ones having bituminous layers. earlier, there used to be scarcity of cement and India went for flexible pavements with bituminous toppings. Now, flexible pavement are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic. Another major advantage of these roads is that their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance

Here, this paper discusses about how to design a flexible pavement using **CBR** method and further analyze the result using IIT PAVE software

I. INTRODUCTION

Transportation Infrastructure shows the economic growth and status of country's development. The designs and structures of Road Transport Infrastructure reduces the Road accidents and traffic Jams. The growths of four wheelers are increasing day by day, to face the present situations and estimation of feature, the solution is the Road Widening, for the improvement of traffic performance

A typical flexible pavement consists of a bituminous surface course over base course and sub-base course. The surface course may consist of one or more bituminous or Hot Mix Asphalt (HMA) layers. These pavements have negligible flexure strength and hence undergo deformation under the action of loads. The rate of structural deterioration of flexible pavement depends on several factors such as

• The stability of the entity provident structure and the component layers.

• Efficiency functions of the pavement drainage system and sensitivity of the climate

The load from trucks is directly applied on the wearing course, and it gets dispersed (in the form of a truncated cone) with depth in the base, sub base, and subgrade courses, and then ultimately to the ground. Since the stress induced by traffic loading is highest at the top, the surface layer has maximum stiffness (measured by resilient modulus) and contributes the most to pavement strength. The layers below have lesser stiffness but are equally important in the pavement composition.

The maintenance engineering should therefore carryout structural evaluation studies periodically, based on the design period time, under given static and dynamic loads once the pavement is evaluated

There are various methods for the design of flexible pavement, but CBR method is the most acceptable one and also suggested by our IRC:37.

By using IRC :37 and CBR value as well as traffic data we can select a flexible pavement thickness from IRC catalogue , but this thickness may not be economical sometimes and needs to be revised hence we check this economy through IIT PAVE software. This software computes actual value of strains coming on pavement due to wheel load.

Figure 1: showing layers of flexible pavement

In today`s scenario the economic growth of a community is dependent upon highway development to enhance mobility. But due to ineffectiveness of road engineers in designing of pavement, has led to costly failures / wastages & expensive in some cases. Improperly planned, designed, constructed & maintained roads can disrupt the social & economic characteristic of any size community. Therefore, for conservative & proficient construction of roads, correct design of thickness of pavement is crucial. A Flexible pavement is one that is made up of one or more layer of materials of highest quality material forming the top layer. The load carrying capacity of the flexible pavement is derived from the load distribution property & not from its flexural strength.

II. LITERATURE REVIEW

2.1.Tests on subgrade/soil

2.1.1California Bearing Ratio (CBR) Test

CBR(California bearing ratio) method (IRC 37 1984) The CBR method was developed originally by the California state highway department. The California bearing ratio is a measure of the strength of the subgrade of the road or other paved area and of the materials used in its construction. CBR is the ratio expressed in % of force per unit area required to penetrate a soil mass with standard circular plunger of 50mm diameter at the rate of 1.25mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 mm and 5.0 mm.

The CBR test is a penetration test in which a standard piston, with a diameter of 50 mm is used to penetrate the soil at a standard rate of 1.25 mm/minute. Although the force rises with the depth of penetration, in many cases, it does not increase as quickly as it does for the standard crushed rock, so the ratio falls. The CBR is a measure of resistance of a material to penetration of a standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered to if a high degree of reproducibility is desired. The CBR test may be conducted on a remoulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement

$$\text{CBR} = \frac{\text{Total load}}{\text{Standard load}} \times 100$$

Figure2: CBR testing

2.1.2Plastic limit test

This test is conducted to find the plastic limit of soil sample.

➢The soil sample is mixed with sufficient amount of distilled water on marble/glass plate to make it plastic enough to be shaped in to a ball.

➢Some sample is taken and taken and made into a ball. That ball is rolled on a glass plate with hand by applying sufficient pressure. It is rolled into a thread of uniform diameter throughout its length

Figure 3: Plastic limit testing

2.1.3. Liquid limit test

Liquid limit of soil is the minimum water content at which a pat of soil cut by a groove of standard dimension will flow together for a distance of 12 mm under an impact of 25 blows in the apparatus(either Casagrande or Cone Penetrometer.

Figure 4: Liquid limit testing

2.1.4.Sieve analysis test

The grain size analysis test is performed to determine the percentage of each size of grain that is contained within a soil sample, and the results of the test can be used to produce the grain size distribution curve. This information is used to classify the soil and to predict its behavior. The two methods generally used to find the grain size distribution are:

- Sieve analysis which is used for particle sizes larger than 0.075 mm in diameter and
- Hydrometer analysis which is used for particle sizes smaller than 0.075 mm in diameter

Figure 5: sieve analysis testing

2.2IIT-PAVE

Pavement design has always been a complex and critical process in roadway engineering. With the ever-growing demand for optimized infrastructure, meeting safety, environmental and budgetary requirements has become even more challenging. As such, flexible pavement design has taken on greater importance in recent years.

IIT Pave is a software package that facilitates rapid, accurate and reliable flexible pavement design. It has been developed by researchers at the Illinois Institute of Technology (IIT) and is now being made available to the public

IITPAVE software has been developed for the analysis 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. The single vertical load applied at the surface is described in terms of (any one)

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

For IITPAVE, wheel load and contact pressure are the load inputs. The pavement inputsrequired 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 analyze 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 similarnature (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 in the 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 center of the circular contact area of one wheel load).

2.2.1 Failure criteria of flexible pavement

(determination of strain using IIT pave software**)**

I. Rutting failure

The vertical compressive strain on top of the subgrade is considered to be the critical mechanistic parameter for controlling subgrade rutting.

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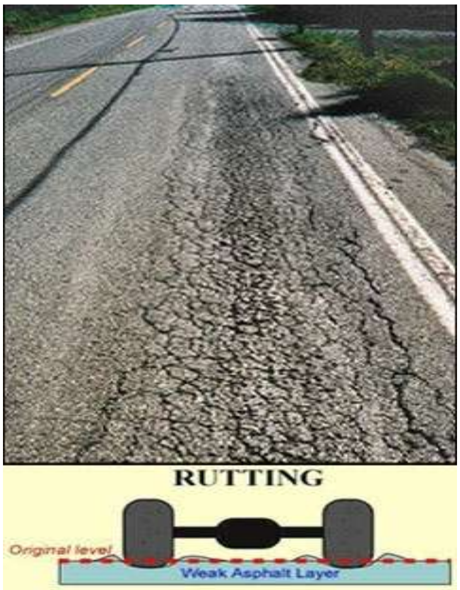

Figure 6: Rutting failure in flexible pavement

II. Fatigue failure

Horizontal tensile strain at the bottom of the bituminous layer is taken as a mechanistic parameter which has to be limited to control bottom-up cracking in bituminous layer.

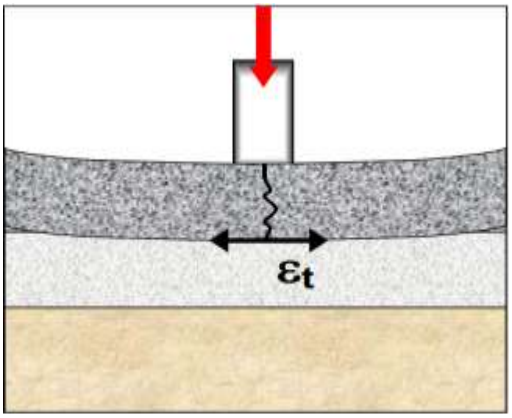

Figure 7: Fatigue failure in pavement

For the satisfactory performance of bituminous pavements and to ensure that the magnitudes of distresses are within acceptable levels during the service life period, the guidelines recommend that the pavement sections be selected in such a way that they satisfy the limiting stresses and strains prescribed by the performance models adopted in the guidelines for subgrade rutting, bottom-up cracking of bituminous layer and fatigue cracking of cement treated base

III. DESIGN PROCEDURE

3.1 Computation of CBR value

CBR test performed on the soil sample collected from site. The value of CBR comes out to be 5.3 %.

3.2 Computation of traffic data

Traffic data is computed from the formula given by IRC 37

$Ndes = 365*[(1+r)^n – 1]*A*D*F/r$

Traffic for the road comes out to be 4.3MSA

3.3 Selection of trial depth from IRC:37 2012

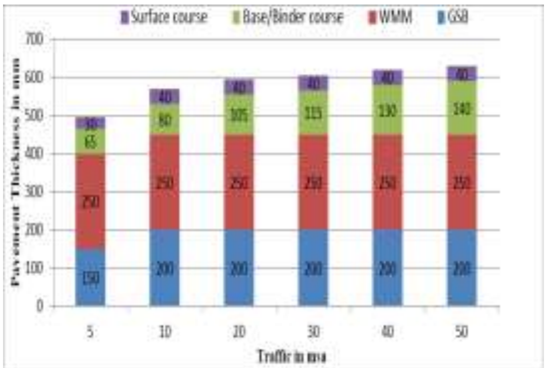

Figure 8: Catalogue trial depth by IRC :37 2018

We have selected 1st depth as trial on software

3.4.Calculation of Resilient Modulus (M):

$M_{bitumen}$= 700MPa (for VG30 @ 30°C) [IRC:37-2018 table7.1]

$M_{subgrade}$= 17.6 * $(CBR)^{0.64}$ for CBR > 5 % ($M_{subgrade} = M_{RSUPPORT}$)

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

$M_{RGRAN} = 0.2(h)^{0.45}* M_{RSUPPORT} = 0.2*(400)^{0.45}*51.17 = 151.7$MPa

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

$N_R = N_f$=Ndes $=4.34*10^6$

For Rutting,

$N_R = 4.1656 \times 10^{-08} [1/\varepsilon_v]^{4.5337}$ (for 80 % reliability)

$= 4.34*10^6$

Implies, $\varepsilon_{vmax} = 809.25*10^{-6}$

For Fatigue,

$N_f = 1.6064*C*10^{-04} [1/\varepsilon_t]^{3.89}* [1/M_{Rm}]^{0.854}$ (for 80 % reliability)

$=4.34*10^6$

Implies, $\varepsilon_{t\ max} = 536*10^{-6}$

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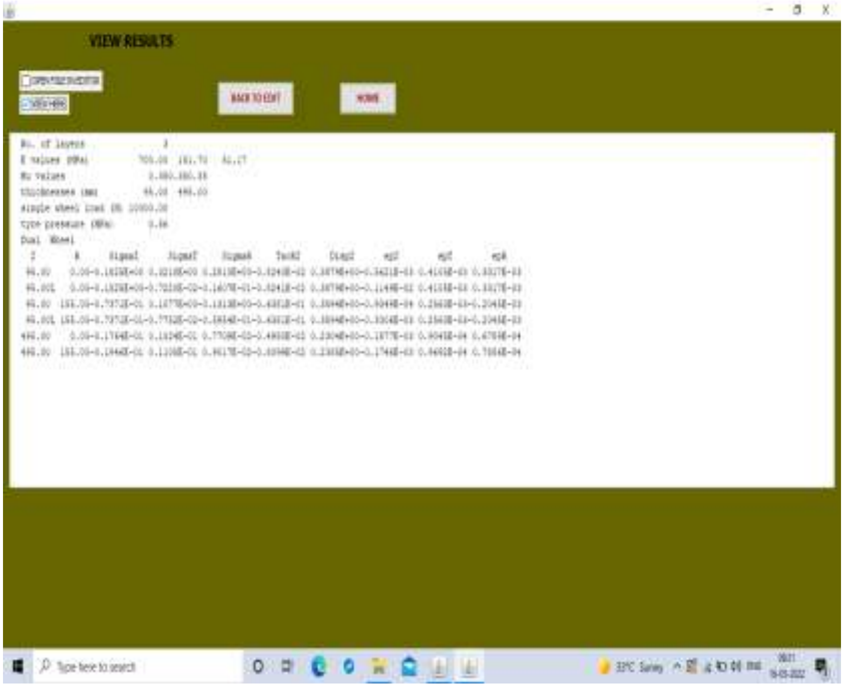
3.6. Now, substituted the above values i.e., (a) Thickness of Layers; (b) Resilient Modulus; (c) Poisson's Ratio (0.35 for every layer); (d) Wheel load (standard load of 20kN); (e) Tyre pressure (standard pressure for GSB i.e., 0.56) and (f) Analysis point details (respective depths and radial distance) in the software (IITPAVE) and obtained the values of ε_v and ε_t as following:

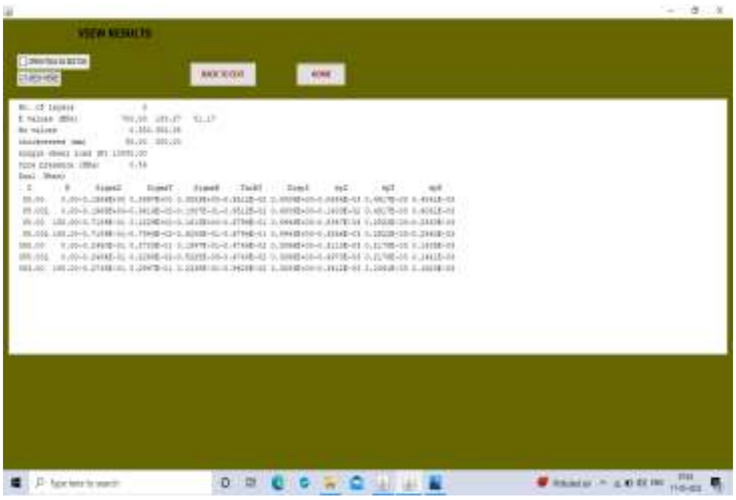
$\varepsilon_{t\ @95mm} = 410.05*10^{-6} < \varepsilon_{t\ max}$
$\varepsilon_{v@495mm} = 157.77*10^{-6} < \varepsilon_{v\ max}$



Further changing the thickness of the layers and calculating values of ε_v and ε_t again.
Thickness of Layer1 = 85mm
Thickness of Layer2 = 300mm

$M_{RGRAN} = 0.2(h)^{0.45} * M_{RSUPPORT} = 0.2*(300)^{0.45}*51.17 = 133.27MPa$

Substituted this value of M_{RGRAN} with the previous value and obtained the values of ε_v and ε_t as following:
$\varepsilon_{t\ @85mm} = 394.16*10^{-6} < \varepsilon_{t\ max}$ $\varepsilon_{v@385mm} = 479.3*10^{-6} < \varepsilon_{v\ max}$.



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Hence our Final Pavement will be:

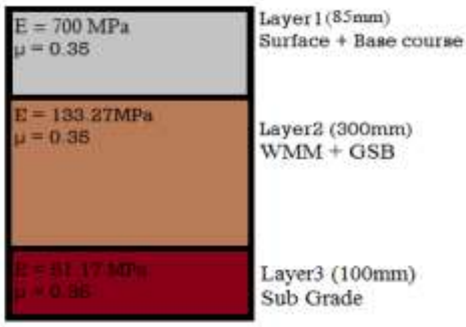

Figure 9 : final economical depth

CONCLUSION

Sr. 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.	**Sub grade**	**51.17**	**0.35**	**100**

For the above input the output available in strain value at different locations have been found throgh IIT-PAVE

1. Allowable Horizontal Tensile Strain in bituminous layer $\varepsilon_{t\ max}$ = $536*10^{-6}$ based on fatigue model
2. Allowable vertical compressive strain on subgrade layer $\varepsilon_{v\ max}$ = $809.25*10^{-6}$ from the rutting model

From the IIT-PAVE output screen result

1. Horizontal Tensile Strain in bituminous layer is $\varepsilon_{t\ @95mm}$= $410.05*10^{-6}$
2. Allowable vertical compressive strain on subgrade layer is $157.77*10^{-6}$

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