Flexible Pavement Design as per IRC: 37-2012

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Abstract— This paper focuses at proposing a design pavement with the use of IIT PAVE and IRC: 37 - 2012 for a stretch of Balasinor to Dev Junction in Mahisagar District of Gujarat state, the existing traffic on the particular stretch of SH-2 was 1386 CVPD. The pavement is designed for calculated MSA and with the obtained values of horizontal and a vertical strain was calculated according. The actual design of MSA would be calculated and checked for the fatigue and rutting type of failure for a design life of 15 years. Resilience modulus is calculated and the proposed designed of pavement thickness provided. Existing CBR value was taken from soil investigation. According to the IRC 37-2012 guideline if the CBR value varies at every KM than 90th Percentile CBR value was taken for a design that criteria also are taken into consideration in this research paper. From the outcome of analysis shows that the Tensile strain on the bottom of BC (ε_t), a compressive strain on the top of Subgrade (ε_v) for new pavement was within the permissible limit.

Key words: Pavement Design, Fatigue Criteria, Rutting Criteria, IITPAVE

I. INTRODUCTION

A road network system is one of the most important necessities for the economic development of any country, particularly developing countries. Many of developing countries, therefore, invest a huge amount in road construction, while many developing countries appreciate the necessity for huge investment in the capital development of roads. In India large road networks built at great expense, have been inadequately maintained and used more heavily than the design values. The main deficiencies affecting our highway system apart from inadequate capacity and insufficient pavement thickness include poor riding quality, week and distresses, congested sections, excessive axle loading. Many ongoing research works already published about the defects in the flexible pavement and the maintenance of flexible pavements. In the past, lots of researchers have already studied the defects and problems of maintaining the flexible pavements all over the world.

II. PRINCIPLES OF FLEXIBLE PAVEMENT DESIGN

A flexible pavement is modeled as an elastic multilayer structure. Stresses and strains at critical locations shown in figure 1 are computed using a linear layered elastic model. The stress analysis software IITPAVE has been used for the computation of stresses and strains in flexible pavements. Tensile strain (ε_t) at the bottom of the bituminous layer and the vertical subgrade strain (ε_v) on the top of the subgrade is conventionally considered as critical parameters for pavement design to limit cracking and rutting in the bituminous layers and non-bituminous layers respectively. The computation also indicates that tensile strain, near the surface close to the edge of a wheel, can be sufficiently large to initiate longitudinal surface cracking followed by transverse cracking much before the flexural cracking of the bottom layer if the mix tensile strength is not adequate at higher temperatures.

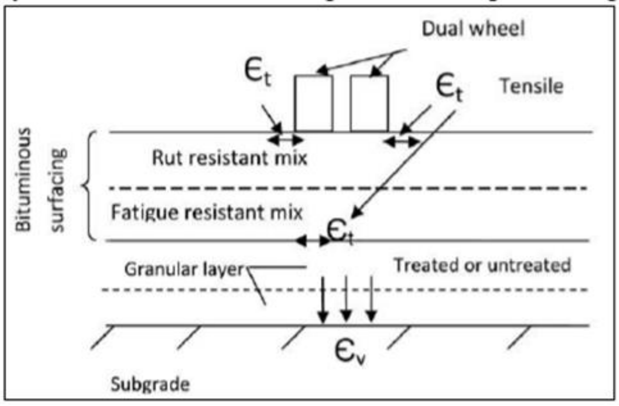


Fig. 1: Different Layers of the Flexible Pavement

III. DATA COLLECTION & ANALYSIS

A. *Classified volume count survey*

Classified volume count survey was carried out to obtained PCU value for selected stretch. The classified traffic volume count survey was carried out at Gadhavada village (Ch. 05/720 km). From 12 hours survey the CVPD value obtained was 1386 and traffic composition from graph shows that the maximum contribution of 26% by 4-wheeler and 25% 2-wheeler. PCU values are taken according to the IRC: 64-1990.

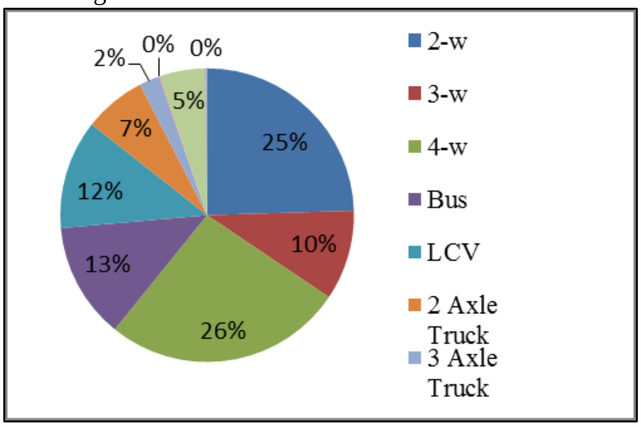


Fig. 2: Traffic volume count

CVPD = 405+572+217+70+3+105+14 = 1386 cv/day

The design traffic is considered regarding of the cumulative number of standard axles to be carried during the design life of the road. Its computation involves the estimates of the initial volume of commercial vehicles per day, lateral distribution of traffic, the growth rate and the design life in years and the vehicle damage factor to convert commercial vehicle in standard axle the following equation is used to make the required calculation:

$$N_S = \frac{365*A[(1+r)^X-1]*D*F}{r} \qquad (1.1)$$

Where,

Ns = Cumulative number of standard axles

A = Initial traffic in the year of finishing of construction regarding CVPD

= 〖P(1+r)〗^x =1489.95

r = Yearly growth rate of commercial vehicles = 7.5%

x = Design life = 15 years

D = Lane distribution factor = 0.75

F = Vehicle damage factor =3.5

From the equation (1.1), N_s = 37.29msa

For reliability of design, we take 40msa traffic instead of 37.29msa.

B. Trial pit investigation for existing subgrade characteristics and pavement crust thickness

For subgrade soil investigation every 1 km interval in an alternative direction, the pits of 1m x1m x1.5m was dug with the help of back-hoe and the soil sampling was carried out. The stretch of upto 1 to 6 km, the soil is SM and from 6 to 12 km the soil having CL classification. From soil testing, we can get CBR values which are ranges 6.8% to 19.87%. From the observed CBR value, the 90th percentile value is taken as per IRC: 37-2012. For section-1 (1km to 6km), the 90th percentile CBR value is 14.2% and for Section-2 (6km to 12km), it is 8.9%.

C. Evaluation of Allowable strain:

Allowable strain at the critical location,

(Grade of Bitumen = VG-40 & Traffic = 40 MSA)

1) Fatigue Strain Calculation:

The strain due to fatigue is calculated for 90 percent reliability and input required is the modulus of resilient of bituminous mix that is considered for VG40 at 35°C for the bituminous mix as per IRC: 37-2012 is 3000 MPa.

$$\mathbf{N_f = 0.5161 * C * 10^{-4} * \left[\frac{1}{\varepsilon_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}} \qquad (1.2)$$

Where,

C = $\mathbf{10^M}$,$\mathbf{M = 4.84 * \left(\frac{V_b}{V_a+V_b} - 0.69\right)}$,N_f = 40*$\mathbf{10^6}$,

V_a= 3%, V_b= 13%, $\mathbf{M_R}$= 3000 MPa

From equation (1.2), $\boldsymbol{\varepsilon_t}$= 215.1*$\mathbf{10^{-6}}$ (developed due to traffic)

Rutting strain calculation:

The strain due to rutting is calculated for 90 percent reliability,

$$\mathbf{N = 1.41 * 10^{-8} * \left[\frac{1}{\varepsilon_v}\right]^{4.5337}} \qquad (1.3)$$

From equation (1.3), $\boldsymbol{\varepsilon_v}$= 390.4*$\mathbf{10^{-6}}$ (developed due to traffic)

IV. DESIGN OF FLEXIBLE PAVEMENT

The proposed flexible pavement design is according to IRC: 37-2012 and checked its performance criteria by IIT-PAVE software.

A. For section-1 (1 km to 6 km) the crust thickness was taken as per IRC: 37-2012 which is shown below:

Considering CBR of Existing subgrade is 14.2% & Traffic 40msa

Layer	Layer	Particulars	Thickness (mm)
Layer-1	BC	Wearing course	40
	DBM	Binder course	95
Layer-2	WMM	Base	250
Layer-3	GSB	Sub-base	200

Table 1: Pavement thickness as per Plate-7

For Subgrade,	For Granular Layers,
$\mathbf{M_{R\ subgrade}}$=17.6* $\mathbf{CBR^{0.64}}$	$\mathbf{M_R}$ =0.2*$\mathbf{h^{0.45}}$*$\mathbf{M_{R\ subgrade}}$
$\mathbf{M_{R\ subgrade}}$=17.6* $\mathbf{14.2^{0.64}}$	$\mathbf{M_R}$ =0.2*$\mathbf{450^{0.45}}$*96.16
$\mathbf{M_{R\ subgrade}}$=96.16 MPa	$\mathbf{M_R}$ =300.57 MPa

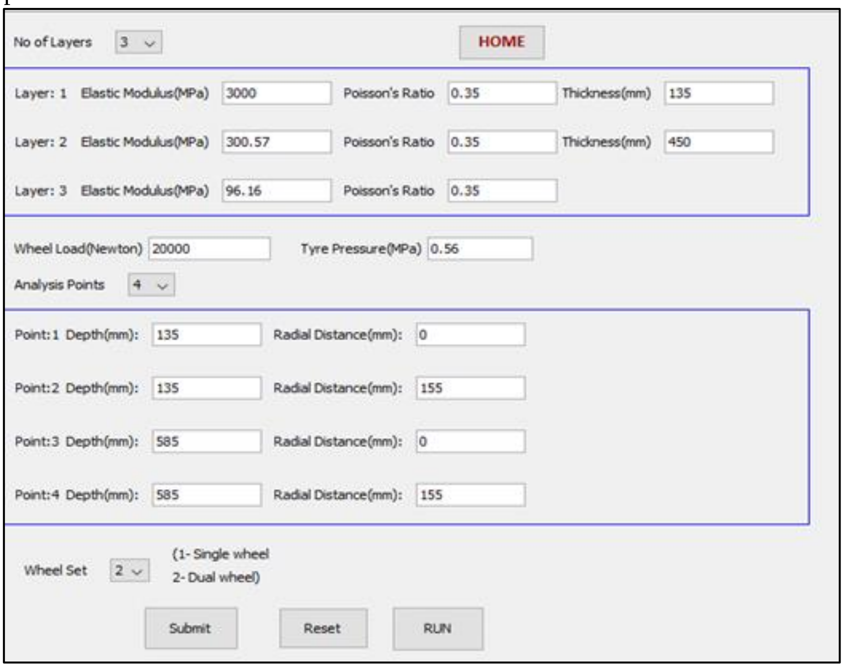
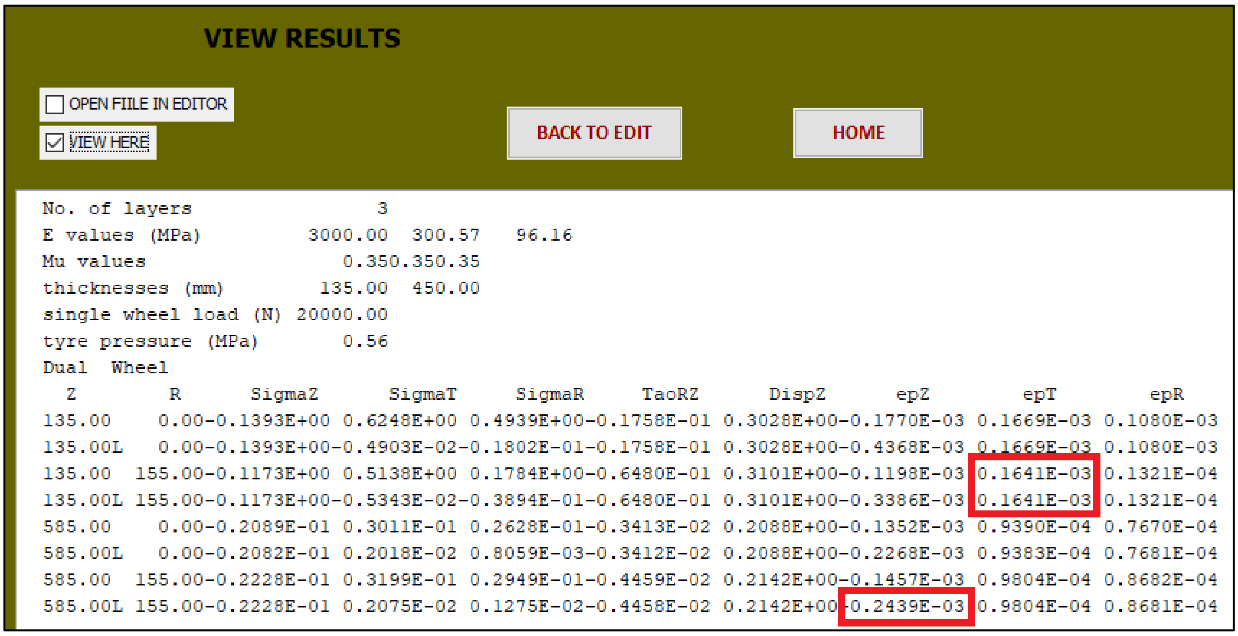


Fig. 3: Input Sheet of IITPAVE for Section-1

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No. of layers               3
E values (MPa)        3000.00  300.57   96.16
Mu values                 0.350.350.35
thicknesses (mm)        135.00  450.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
135.00    0.00-0.1393E+00 0.6248E+00 0.4939E+00-0.1758E-01 0.3028E+00-0.1770E-03 0.1669E-03 0.1080E-03
135.00L   0.00-0.1393E+00-0.4903E-02-0.1802E-01-0.1758E-01 0.3028E+00-0.4368E-03 0.1669E-03 0.1080E-03
135.00  155.00-0.1173E+00 0.5138E+00 0.1784E+00-0.6480E-01 0.3101E+00-0.1198E-03 0.1641E-03 0.1321E-04
135.00L 155.00-0.1173E+00-0.5343E-02-0.3894E-01-0.6480E-01 0.3101E+00-0.3386E-03 0.1641E-03 0.1321E-04
585.00    0.00-0.2089E-01 0.3011E-01 0.2628E-01-0.3413E-02 0.2088E+00-0.1352E-03 0.9390E-04 0.7670E-04
585.00L   0.00-0.2082E-01 0.2018E-02 0.8059E-03-0.3412E-02 0.2088E+00-0.2268E-03 0.9383E-04 0.7681E-04
585.00  155.00-0.2228E-01 0.3199E-01 0.2949E-01-0.4459E-02 0.2142E+00-0.1457E-03 0.9804E-04 0.8682E-04
585.00L 155.00-0.2228E-01 0.2075E-02 0.1275E-02-0.4458E-02 0.2142E+00-0.2439E-03 0.9804E-04 0.8681E-04
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Fig. 4: Result Sheet of IITPAVE for Section-1

For the above thickness, the strains at critical locations calculated by IITPAVE software are:

Tensile strain on bottom of BC ($\boldsymbol{\varepsilon_t}$) = 164.1*$\mathbf{10^{-6}}$ < 215*$\mathbf{10^{-6}}$

Compressive strain on the top of Subgrade ($\boldsymbol{\varepsilon_v}$) = 243.9*$\mathbf{10^{-6}}$ <390.4*$\mathbf{10^{-6}}$

Hence, proposed crust composition is safe for 40 msa.

B. For section-2 (6 km to 12 km) the crust thickness was taken as per IRC: 37-2012 which is shown below:

Considering CBR of Existing subgrade is 8.9% & Traffic 40 msa

Layer	Layer	Particulars	Thickness (mm)
Layer-1	BC	Wearing course	40
	DBM	Binder course	100
Layer-2	WMM	Base	250
Layer-3	GSB	Sub-base	200

Table 1: Pavement thickness as per Plate-6

For Subgrade,	For Granular Layers,
$\mathbf{M_{R\ subgrade}}$=17.6*$\mathbf{CBR^{0.64}}$	$\mathbf{M_R}$ =0.2*$\mathbf{h^{0.45}}$*$\mathbf{M_{R\ subgrade}}$
$\mathbf{M_{R\ subgrade}}$=17.6*$\mathbf{8.9^{0.64}}$	$\mathbf{M_R}$ =0.2*$\mathbf{450^{0.45}}$*71.31
$\mathbf{M_{R\ subgrade}}$=71.31 MPa	$\mathbf{M_R}$ =222.89 MPa

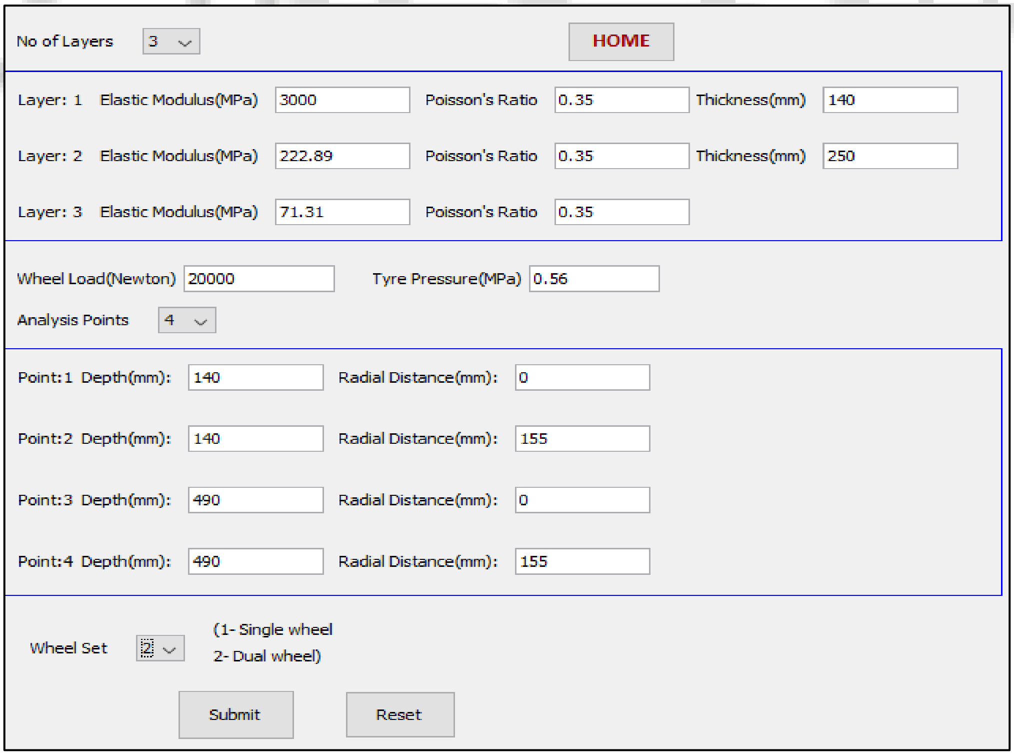
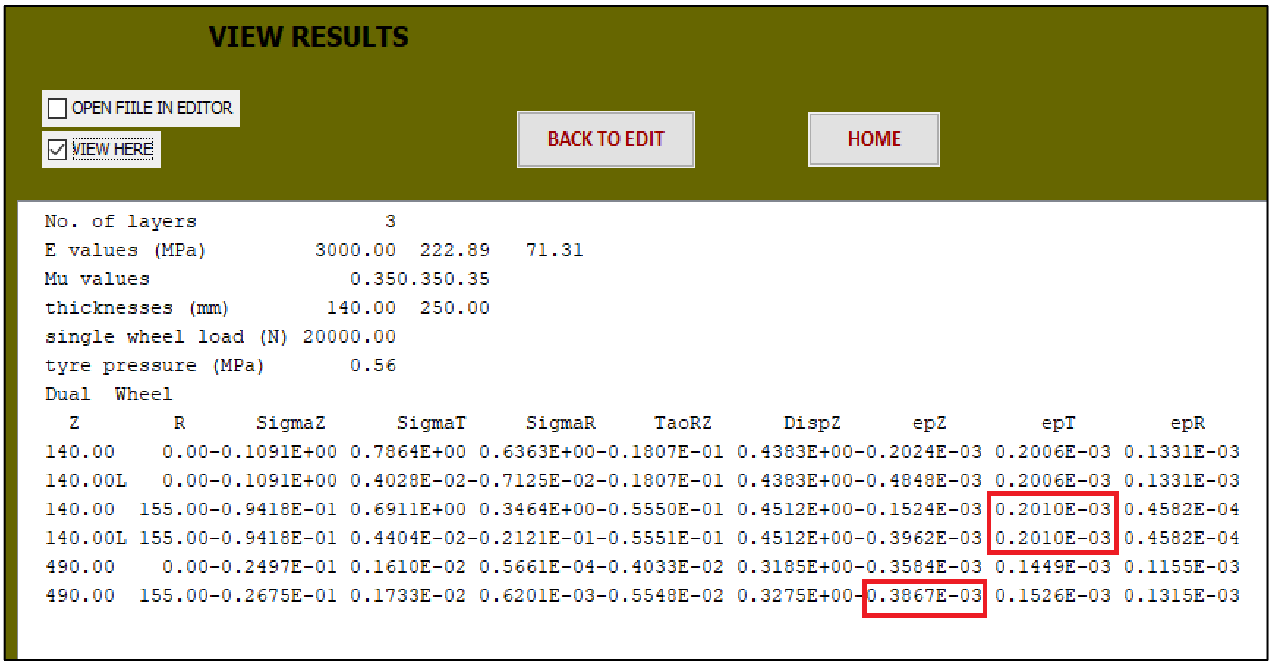


Fig. 5: Input Sheet of IITPAVE for Section-2

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No. of layers                3
E values (MPa)         3000.00  222.89   71.31
Mu values                 0.350.350.35
thicknesses (mm)        140.00  250.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z         R       SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
140.00     0.00-0.1091E+00 0.7864E+00 0.6363E+00-0.1807E-01 0.4383E+00-0.2024E-03 0.2006E-03 0.1331E-03
140.00L    0.00-0.1091E+00 0.4028E-02-0.7125E-02-0.1807E-01 0.4383E+00-0.4848E-03 0.2006E-03 0.1331E-03
140.00   155.00-0.9418E-01 0.6911E+00 0.3464E+00-0.5550E-01 0.4512E+00-0.1524E-03 0.2010E-03 0.4582E-04
140.00L  155.00-0.9418E-01 0.4404E-02-0.2121E-01-0.5551E-01 0.4512E+00-0.3962E-03 0.2010E-03 0.4582E-04
490.00     0.00-0.2497E-01 0.1610E-02 0.5661E-04-0.4033E-02 0.3185E+00-0.3584E-03 0.1449E-03 0.1155E-03
490.00   155.00-0.2675E-01 0.1733E-02 0.6201E-03-0.5548E-02 0.3275E+00-0.3867E-03 0.1526E-03 0.1315E-03
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Fig. 6: Result Sheet of IITPAVE for Section-2

For the above thickness, the strains at critical locations calculated by IITPAVE software are: Tensile strain on the bottom of BC ($\boldsymbol{\varepsilon_t}$) = 201.0*$\mathbf{10^{-6}}$ < 215*$\mathbf{10^{-6}}$

Compressive strain on the top of Subgrade ($\boldsymbol{\varepsilon_v}$) = 386.7*$\mathbf{10^{-6}}$ <390.4*$\mathbf{10^{-6}}$

Hence, proposed crust composition is safe for 40 msa.

C. Cross-section of flexible pavement:

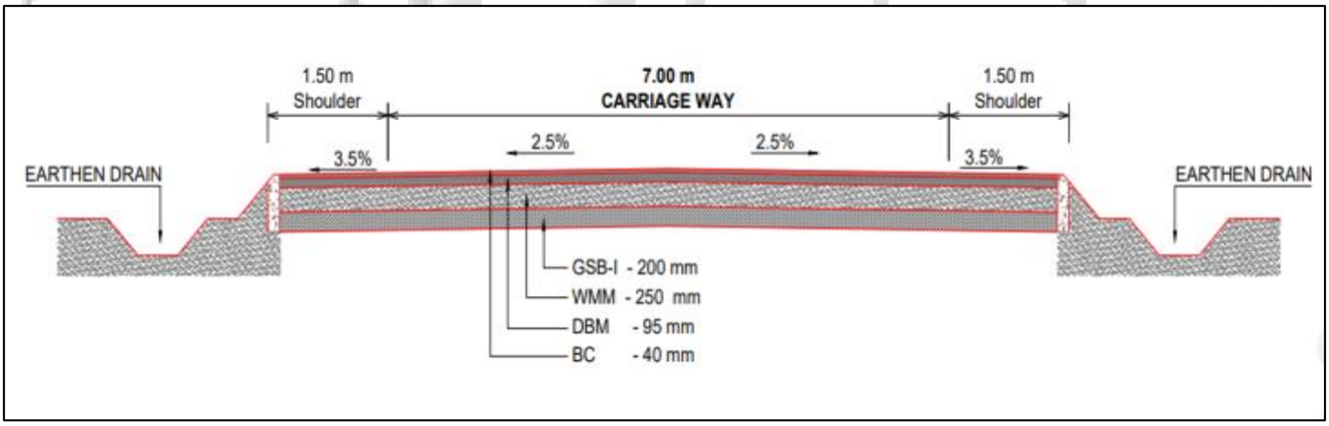

Fig. 7: Cross-section of flexible pavement for section-1(Chainage: 01+000 to 06+000)

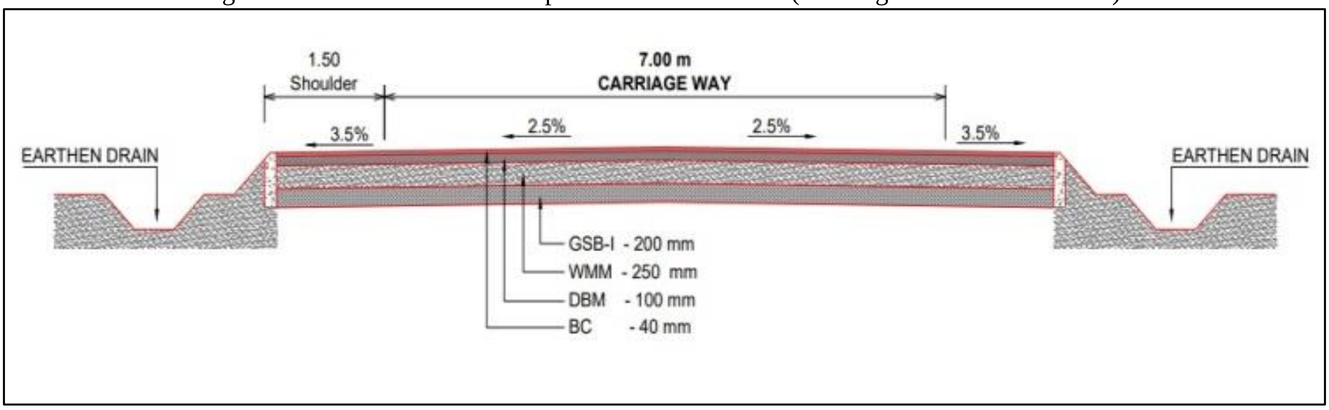

Fig. 8: Cross-section of flexible pavement for section-2 (Chainage: 06+000 to 12+000)

V. CONCLUSION

For section-1, the fatigue strain calculated IIT-PAVE software is 164.1 micron at the bottom of the bituminous layer, which is quite lower than 215 microns calculated as per performance model for 90 % reliability and the rutting strain calculated as per multi layered elastic theory using software IIT-PAVE is 243.9 micron at the top of subgrade layer which is lower than 390.4 microns calculated as per performance model for 90 % reliability. Therefore, the pavement is safe in fatigue and rutting failure in its service life.

For section-2, the fatigue strain calculated software IIT-PAVE is 201 micron at the bottom of the bituminous layer which is quite lower than 215 microns calculated as per performance model for 90 % reliability and the rutting strain calculated as per multi layered elastic theory using software IIT-PAVE is 386.7 micron at the top of subgrade layer which is lower than 390.4 microns calculated as per performance model for 90 % reliability. Therefore, the pavement is safe in fatigue and rutting failure in its service life.

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