Flexible Pavement Design

1. Computation of Design Traffic

The design traffic, in terms of the cumulative number of standard axles to be carried during the design period of the road, should be estimated using equation 4.5.
This can be computed using the following equation:

$$\mathbf{N} = \frac{\mathbf{365\ x\ [(1+r)^{n}-1]}}{r} \mathbf{\ x\ A \ X\ D\ x\ F}$$

Where,

N **=** The cumulative number of standard axles to be catered for in the design in terms of Msa.
D = Lateral distribution factor (as explained in para 4.5)
F = Vehicle damage factor (VDF) (5.00 as per Table 4.2 Indicative VDF values. Page-16 (for More than 1500))

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). Variation of the rate of growth over different periods of the design period, if available, may be considered for estimating the design traffic.

P = The traffic in the year of completion of construction may be estimated using equation 4.6.

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

Where,

P = Number of commercial vehicles per day as per last count.
x = Number of years between the last count and the year of completion of construction.

Category of Road: Expressway

Two-lane two-way roads – Clause 4.5.1.3
Standard Width of Road: 7.50m

Traffic Calculation (in msa)

Description	**P (cv/day)**	**x (in year)**	**r**	**A (cv/day)**	**F**	**n (in year)**	**D**	**N_{des} (msa)**	Remarks
For Granular Layer	1529	2	5%	1686	5.00	25	0.50	**73.43**	
For Bituminous Layer	1529	2	5%	1686	5.00	25	0.50	**73.43**	

Since the road belongs to Expressway category with **73.43** msa, VG40 binder mix for BC as well as DBM should be used as per recommended of IRC 37-2018 Vide Para 12.3 Page-36 For 90% Reliability

2. Determination of Sub-Grade Effective CBR **IRC: 37-2018**

6.3 **Resilient modulus of the sub-grade:**

a) CBR of Sub-grade Soil

$$M_{RS} = 10.0 \times CBR \qquad \text{for CBR} \leq 5.00\ \% \text{ -- (6.1)}$$

$$M_{RS} = 17.6 \times (CBR)^{0.64} \qquad \text{for CBR} > 5.00\ \% \text{ -- (6.2)}$$

Where:
M_{RS} = Resilient modulus of subgrade soil (in MPa).
CBR = California bearing ratio of subgrade soil (%).

Note: Poisson's ratio value or subgrade soil may be taken as 0.35.

a) CBR of the borrow soil used for preparing the 500 mm thick compacted subgrade = 20%
b) CBR of Sub-grade Soil = 4.78%

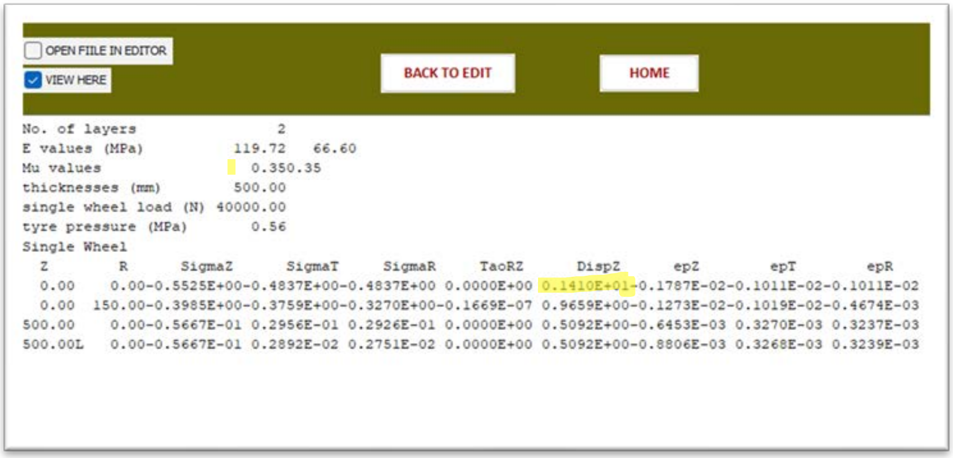
M_{RS} for borrow soil = 119.72 Mpa (500mm Provided thickness)
M_{RS} for Sub-grade Soil. = 47.80 Mpa

6.4 Effective modulus/CBR for design:

Step-1 Using IITPAVE software, determine the **maximum surface deflection (δ)** due to a single wheel load.

Considering available data for design.

a) Poisson's ratio value of both the layers (μ) = 0.35
b) Single Wheel Load = 40000N (For estimating the effective subgrade strength as per para 6.4 of the guidelines, select a single wheel load of 40,000 (N))



Step-2 Using the maximum surface deflection (δ) computed in step-1 above, **estimate the resilient modulus M_{RS}** of the equivalent single layer using equation 6.3.

$$M_{RS} = \frac{2\,(1-\mu^2)\rho\alpha]}{\delta} \quad \text{--(6.3)}$$

Where,

M_{RS} = Resilient modulus shall be limited to a maximum value of 100 Mpa. Para 6
μ = Poisson's ratio
P = Contact pressure for the above specified load (p)
a = Radius of circular contact area for this load and contact pressure.
δ = Obtained maximum surface deflection computed in step-1 above

Now,

μ = 0.35, p = 0.56 MPa a = 150.80 mm , δ = 1.549 mm

Then,

M_{RS} = 95.17 <100.00 MPa # Ok Value is accepted

Effective CBR value for above accepted estimated resilient modulus M_{RS}

$$\text{CBR} = \sqrt[0.64]{\frac{M_{RS}}{17.6}} = 13.97\%$$ **Since the value is > 5% . Hence Ok.**

3. Determination and Checking for Resilient Modulus of Granular Materials

Trial Granular Pavement Components					
Description	1st Layer	2nd Layer	3rd Layer	4th Layer	5th Layer
Materials to be used	GSB	WMM			
Thickness of materials (mm)	230	250			

Resilient Modulus of GSB layer:

$$\boldsymbol{M_{GRAN} = 0.2(h)^{0.45} \text{ x } M_{RSUPPORT}}$$

Where,

M_{GRAN} = Resilient modulus of the granular layer (MPa).
h = Thickness of granular layer in mm [GSB + WMM].
$M_{RSUPPORT}$ = (Effective) Resilient modulus of the supporting layer (MPa).

Now if h = 480 mm , $M_{RSUPPORT}$ = 95.17 MPa
Then M_{GRAN} = 306.35 says **305 MPa.**

4. Determination of Sub-Grade Rutting Criteria **IRC: 37 2018**

3.6.1 **Sub-grade rutting criteria**

$N_R = 1.41656 \text{ x } 10^{-08} [1/\varepsilon_v]^{4.5337}$ for 80% Reliability

$\mathbf{N_R} = 1.4100 \text{ x } 10^{-08} [1/\varepsilon_v]^{4.5337}$ for 90% Reliability

N_R = Subgrade rutting life (cumulative equivalent number of 80 kN standard axle loads that can be served by the pavement before the critical rut depth of 20 mm or more occurs).

$\boldsymbol{\varepsilon}_V$ = Vertical compressive strain at the top of the subgrade calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system.

For 90% Reliability here N_R =73430000 (As per traffic calculation)

Allowable Vertical Sub-grade Strain (ε_v) = 341.48

5. Determination of Fatigue Cracking Criteria for Bituminous Layer

3.6.2 Fatigue cracking criteria for bituminous layer

$\mathbf{N_f} = 1.6064 \text{ x C x } 10^{-04} \text{ x } [1/\varepsilon_t]^{3.89} \text{ x } [1/M_{Rm}]^{0.854}$

$\mathbf{N_f} = 0.5161 \times C \times 10^{-04} \times [1/\varepsilon_t]^{3.89} \times [1/M_{Rm}]^{0.854}$

Where,

$C = 10^M$ and $M = 4.84\left(\frac{V_{be}}{V_a+V_{be}} - 0.69\right)$

V_a = per cent volume of air void in the mix used in the bottom bituminous layer.

V_{be} = per cent volume of effective bitumen in the mix used in the bottom bituminous layer.

$\mathbf{N_f}$ = fatigue life of bituminous layer (cumulative equivalent number of 80 kN standard axle loads that can be served by the pavement before the critical cracked area of 20% or more of paved surface area occurs).

ε_t = maximum horizontal tensile strain at the bottom of the bottom bituminous layer (DBM) calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system.

$\mathbf{M_{RM}}$ = resilient modulus (MPa) of the bituminous mix used in the bottom bituminous layer, selected as per the recommendations made in these guidelines.

Here ,

design Traffic($\mathbf{N_f}$) = 73430000

As per Clause 9.2 Page-32 => Recommended % volume of air void in the mix used in the bottom bituminous layer (DBM)

Double layers construction V_a = 3.0%

As per Clause 12.3 Page-37 => Recommended % volume of effective bitumen in mix used in bottom bituminous layer (DBM).

For design traffic = 130.91 MPa V_{be} = 11.5%

Hence value of C = 3.16

For 90% Reliability:

Allowable Horizontal Tensile Strain (ε_t) = 150.088

6. Determination and Checking for Resilient Modulus of Bituminous Mix

	Pavement Design Trial

Assumed layers thickness from Ref. 12 Pavement Structural Design Catalogues	**Description**	**1st Layer**	**2nd Layer**	**3rd Layer**	**4th Layer**	**5th Layer**	**Top Layer**
	Materials to be used	GSB	WMM	0	0	DBM	BC
	Thickness of materials (mm)	**230**	**250**	**0**	**0**	**100**	**40**

Resilient Modulus of Bituminous layer:
Since the road belongs to Expressway category with 130.91msa, VG40 binder mix for BC as well as DBM should be used as per recommended of IRC 37-2018 Vide Para 12.3 Page-36.

Hence Resilient Modulus of VG40 binder mix for BC as well as DBM = 3000MPa

h (Consider thickness of bituminous layer in mm [DBM + BC]) = 140 mm

Step 1.) Using IITPAVE software, determine the **maximum surface deflection (δ)** due to a single wheel load.

Considering available data for design.

c) Poisson's ratio value of both the layers (μ) = 0.35
d) Single Wheel Load = 40000

Step 2.) Using the maximum surface deflection (δ) computed in step-1 above, **estimate the resilient modulus M_{RS}** of the equivalent single layer using equation 6.3.

$$\mathbf{M_{RS}} = \frac{2\,(1-\mu^2)\rho\alpha]}{\delta} \quad \text{--(6.3)}$$

Where,

$\mathbf{M_{RS}}$ = Resilient modulus shall be limited to a **maximum value of 100 Mpa**. Para 6
μ = Poisson's ratio
P = Contact pressure for the above specified load (p)
a = Radius of circular contact area for this load and contact pressure.
δ = Obtained maximum surface deflection computed in step-1 above

Now,

μ = 0.35 , p = 0.56 MPa a = 150.80 mm , δ = 1.482 mm

Then,

$\mathbf{M_{RS}}$ = 100.00 MPa # Ok Value is accepted

Effective CBR value for above accepted estimated resilient modulus M_{RS}

$$CBR = \sqrt[0.64]{\frac{M_{RS}}{17.6}} = 15.10\%$$ **Since the value is > 5% . Hence Ok**

COMPUTATION OF ACTUAL FAILURE CRITERIA			
Calculated Result (as per clause 3.6.1 & 3.6.2)		IIT-Pave Output Result (Screen shot attached)	
Strain	Allowable Strain	Actual Strain	Remark
Allowable Vertical Sub-grade Strain (ε_v)	300.598		
Allowable Horizontal Tensile Strain (ε_t)	150.088		

So, It is not Safe for Subgrade Rutting Criteria as Allowable < Actual
So, It is not Safe for bituminous fatigue Criteria as Allowable < Actual

Final pavement design components	Pavement Design Accepted Trial					
	Description	Existing Layers				Provided Layers
		1st Layer	2nd Layer	3rd Layer	3rd Layer	4th Layer	Top Layer
	Pavement Components	GSB	WMM	0	0	DBM	BC
	Thickness of materials (mm)	230	250	0	0	100	40