Analysis and Design of Bituminous Pavements

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Lecture - 42

Design Input and IITPAVE software

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We have seen different steps involved in the design of pavements. Now we will see different inputs for the pavement design and first, we will focus on traffic factors. Professor Neethu Roy has already explained in detail about various traffic factors that are considered for pavement design. Here we will focus only on specifications related to IRC 37: 2018 design.
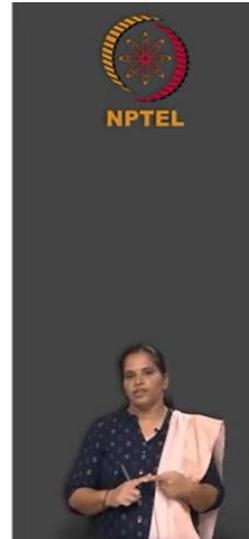
Traffic Volume

- Weight > 3000 kg

- Present volume and projected volume

- Number of vehicles in terms of commercial vehicle per day

- MoRTH – 16 different class of vehicle with 4 different axle configuration
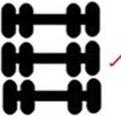
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One of the main factors that are used for the design is traffic volume. So we consider vehicles that have a weight greater than 3000 kg in the design of pavement. It means that any vehicle that has a weight of less than 3000 kg does not induce any damage to the pavement. So we need a present number of vehicles and a projected number of vehicles to compute the number of repetitions that are used throughout its pavement life. So we represent the number of vehicles in terms of commercial vehicles per day. MoRTH has suggested 16 different classes of vehicles using pavement and with 4 different axle configurations.
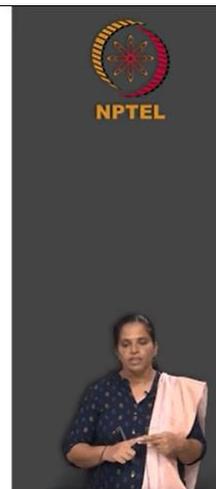
Traffic Volume

- Axle configuration
  - Single axle, single wheel
  - Single axle, dual wheel
  - Tandem axle
  - Tridem axle

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So these are the axle configurations that the Indian highway has. We can see 4 different axle configurations that include single axle single wheel, single axle dual wheel, tandem axle and tridem axle. So these axle configurations are important for the determination of a vehicle damage factor and for the determination of stresses and strain in the pavement. So you know that the stress and strain in the pavement depend on the type of axle configuration. IRC 37 uses tandem axle as 2 repetitions of a single axle dual wheel and considers tridem axle as 3 repetitions of a single axle dual wheel.

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Sr No	Type of Vehicle	Axle Combination on Tractor	Axle Combination on Trailer	No of Axles
1	Two Axle Rigid Truck	Two tyres on front axle and four tyres on rear axle	-	2
2	Three Axle Rigid Truck	Two tyres on front axle and eight tyres on rear tandem (two) axle	-	3
3	Four Axle Rigid Truck	Two tyres each on two axles and eight tyres on one tandem (two) axle	-	4
4	Five Axle Rigid Truck	Two tyres each on three axles and eight tyres on one tandem (two) axle	-	5
5	Five Axle Rigid Truck	Two tyres each on two axles, four tyres on one axle and eight tyres on one tandem (two) axle	-	5
6	Six Axle Rigid Truck	Two tyres each on four axles and eight tyres on one tandem (two) axle	-	6
7	Tractor - semi articulated trailers	Two tyres on front axle and four tyres on rear axle	Four tyres on single axle	3
8	Tractor - semi articulated trailers	Two tyres on front axle and four tyres on rear axle	Eight tyres on tandem (two) axle	4

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So these are 16 different classifications of a vehicle that use Indian highways. You can see that these classifications are grouped under 3 major groups. One is a rigid truck and second one is a semi-rigid truck and the third one is a tractor-trailer unit. So each truck has a different number of axles varying from 2 to 6 and different axle configurations. For example, 2 axle truck has a single axle single wheel as a front axle, a single axle dual wheel as a rear axle. Now if you consider 6 axle truck, you can see 2 numbers of single axle single wheel and 2 number of tandem axles here. But IRC considers 1 tandem axle as a 2 repetition of a single axle dual wheel. So you have a total of 6 axles here in this truck category.

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So you can have 16 different classifications or arrangements of an axle and the number of axles varies from 2 to 6.

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We measure traffic volume following IRC 9 guidelines. IRC 9 states that you count the traffic volume continuously for 7 days and 24 hours and take the daily average and we get the average daily truck traffic. And this average daily truck traffic is used in the computation of the number of repetitions of a standard axle load. We also need a vehicle growth rate. If the number is not

available, IRC suggests using 5 % as a vehicle growth rate. So now the number of vehicles that are acting on a pavement throughout its design life or n year is given by the following formula.

$$\text{Number of vehicle} = \frac{365[(1 + r)^n - 1]A}{r}$$

Here r is the growth rate, n is design life and A is the average daily truck. If the number of lanes is more than 1, this total number of vehicles will be laterally distributed. So the lateral distribution factor is the next factor to be considered and it governs the number of vehicles per lane.

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Traffic Volume

- Volume per lane – Lane distribution factor (D)

Lane Type		Factor
Single lane	Vehicle from both direction	1 ✓
Intermediate lane		0.75 ✓
Two lane, two way (single carriageway)		0.50 ✓
Four lane, two way (single carriageway)		0.40 ✓
Two lane (dual carriageway)	Vehicle from one direction	0.75
Three lane (Dual carriageway)		0.60
Four lane (Dual carriageway)		0.45

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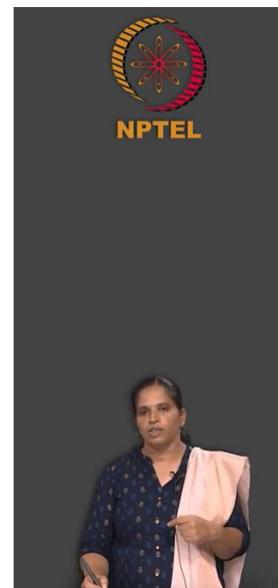
So this is the IRC suggested lane distribution factor or lateral distribution factor. We can see that depending on whether the highway is a divided highway or an undivided highway, we use vehicles computed from both directions or from one direction. In case it is an undivided highway, use the sum of vehicles from both directions and use the lane distribution factor as a factor from this volume considered in both directions. So in case it is a single lane, the lane distribution factor is considered as 1. If it is an intermediate lane, 0.75 times the sum of vehicles moving in both directions. If it is two lane two way, it is a single carriageway, so it is 0.5 and if

it is a four lane two-way single carriageway, it is 0.4. So all these factors are considered as the sum of total vehicles flowing from both the directions. In case it is a dual carriageway or a divided carriageway, these factors are based on the vehicle from one direction. You can consider both directions to have an equal volume in case you do not have data to segregate. So, 0.75 into the number of vehicles flowing in one direction gives you the total number of vehicle in one lane if you have a two lane carriageway. If it is a three lane, lane distribution factor is 0.6 and if it is a four lane, lane distribution factor is 0.45.
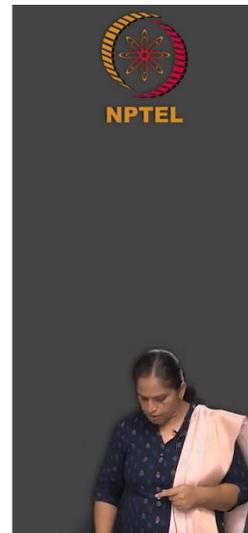
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Traffic Volume

$$No. of\ vehicle = \frac{365\ [(1+r)^n - 1]A}{r}$$

$$No. of\ vehicle/lane = \frac{365\ [(1+r)^n - 1]A}{r}\ D$$

So when you multiply the number of vehicles by a lane distribution factor D, it gives you the number of vehicles per lane.

$$\text{Number of vehicle per lane} = \frac{365[(1+r)^n - 1]A}{r}\ D$$

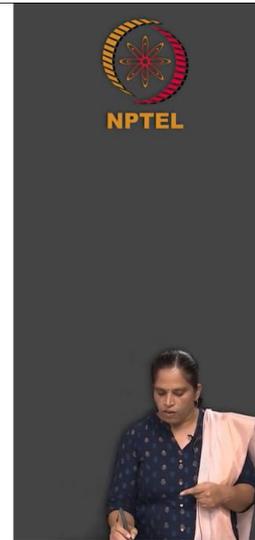Now we also need to convert this number of vehicles in terms of standard axle load repetitions. For this, we use a conversion factor called vehicle damage factor or VDF. VDF is a multiplier to convert any commercial vehicle having different axle configurations and different axle weights into an equivalent number of standard axle loads. So one standard axle is considered as 80 kN single axle with a dual wheel.

On multiplying the number of vehicles with VDF, we get the number of repetitions of a standard axle load. So we need an equivalency factor here. This equivalency factor computation

depends on the axle configurations. The equivalency factor equation for different axle types can be computed using the following equations.

$$\text{Single axle with single wheel on either side} = \left(\frac{\text{Axle load in kN}}{65}\right)^4$$

$$\text{Single axle with dual wheel on either side} = \left(\frac{\text{Axle load in kN}}{80}\right)^4$$

$$\text{Tandem axle with dual wheel on either side} = \left(\frac{\text{Axle load in kN}}{148}\right)^4$$

$$\text{Tridem axle with dual wheel on either side} = \left(\frac{\text{Axle load in kN}}{224}\right)^4$$

So this gives us the equivalency factor for any axle load. VDF is the sum of all equivalency factors corresponding to the number of axles in a vehicle.

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For example, if a front axle of a vehicle is a single axle single wheel type and it weighs 6.5 tonnes and the rear axle is a single axle dual wheel type and it weighs 8 tonnes, now what will be

its vehicle damage factor? It is only one vehicle here. Now front axle is a single axle single wheel.

$$\text{Single axle with single wheel on either side} = \left(\frac{\text{Axle load in kN}}{65}\right)^4 = \left(\frac{6.5}{6.5}\right)^4$$

$$\text{Single axle with dual wheel on either side} = \left(\frac{\text{Axle load in kN}}{80}\right)^4 = \left(\frac{8}{8}\right)^4$$

$$F = 1+1 = 2$$

Its equivalency number will be axle load in kN divided by 65 raised to the power 4. So it is 6.5 tons. You have 6.5 divided by 6.5 raised to power 4 as the equivalency factor for the front axle and equivalency factor for the rear axle is 8 tonnes divided by 80 kN, if you convert into tonnes you will have 8 again raised to power 4. So this vehicle with a front axle of 6.5 tons and rear axle of 8 tons is equal to 2 (1+1) repetitions of a standard axle load. When you multiply the number of vehicles per lane by the vehicle damage factor (F), it gives you the number of repetitions of a standard axle load. So N_{des} here is a number of repetitions of standard axle load.

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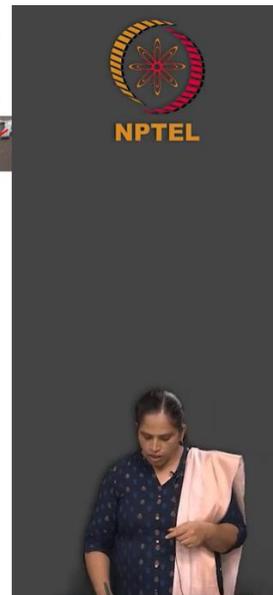
For the computation of a vehicle damage factor, we need an axle load. The axle loads are measured by using static measurements. You have a weighing pad here and the vehicle stands

over the weighing pad and we measure the wheel load. When the wheel load is multiplied by 2, we get an axle load. See again we cannot consider all 100% volume here for the computation of an axle load. So IRC suggests the minimum sample size for conducting an axle load survey. It all depends on what is the traffic volume there. If the number of commercial vehicles per day is less than 3000 vehicles, you can consider the sample size to be 20% of the total volume. When it is between 3000 to 6000, it is 15% of the total volume and if it is greater than 6000, 10% of the total volume with the minimum numbers to be 600 and 900 commercial vehicles per day.

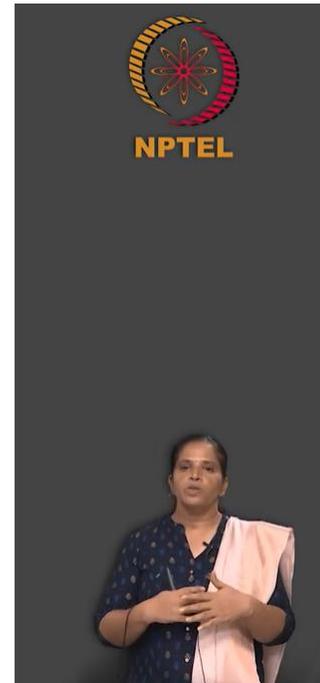When you have the number of axle loads now, these axle load data can be grouped at different intervals depending upon the axle configurations. If you have a single axle configuration, you can group at an interval of 10 kN, tandem axle configuration at 20 kN and the tridem axle configurations to be 30 kN.

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Single Axle Loads		Tandem Axle Loads		Tridem Axle Loads	
Axle Load Class (kN)	Expected Repetitions	Axle Load Class (kN)	Expected Repetitions	Axle Load Class (kN)	Expected Repetitions
185-195	70000 ✓	390-410	200000	585-615	35000
175-185	90000	370-390	230000	555-585	40000
165-175	92000	350-370	240000	525-555	40000
155-165	300000	330-350	235000	495-525	45000
145-155	280000	310-330	225000	465-495	43000
135-145	650000	290-310	475000	435-465	110000
125-135	600000	270-290	450000	405-435	100000
115-125	1340000	250-270	1435000	375-405	330000
105-115	1300000	230-250	1250000	345-375	300000
95-105	1500000	210-230	1185000	315-345	275000
85-95	1350000	190-210	1000000	285-315	260000
<85	3700000	170-190	800000	255-285	180000
		<170	3200000	<255	720000

This is a typical example after grouping data. You can see that single axles from different classes of vehicles are combined and grouped here. So you can see the group interval here is 10 kN. You have the number of repetitions of axle load that has a weight between 185 kN to 195 kN

as 70000. So you can see the grouping interval for a single axle single wheel or dual wheel to be at the interval of 10 kN, for a tandem axle it is at the interval of 20 kN and for a tridem axle at the interval of 30 kN. So this grouping will help us to reduce the data size and it will be easy for further computations.

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So the next input that we give for the design is a material function.

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The main material function that we need for the design is the modulus. We know that the layers are assumed as elastic and we compute the stresses and strain. Instead of an elastic modulus, we consider here a resilient modulus for the design purpose. So we use resilient modulus for the hot mix asphalt layer, granular layer, and soil layer. In case we use a cement treated base layer, we use an elastic modulus there. We will see in detail about this modulus for different layers.

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IRC suggests to measure the resilient modulus of subgrade soil following AASHTO T307. In case you cannot measure a resilient modulus value, there is also empirical equations available relating resilient modulus to a CBR of soil.

$$M_{RS} = 10.0 \times CBR \text{ for } CBR \leq 5\%$$

$$M_{RS} = 17.6 \times (CBR)^{0.64} \text{ for } CBR \leq 5\%$$

We can relate resilient modulus to CBR value. Suppose you have a 1 km stretch of a road and we have 1 CBR for every 100 meters and totally we have 10 CBR values, all 10 CBR values may not be the same. In such a case what CBR value we will use for the design here? So it all

depends on what is the traffic volume here. If the traffic at the corridor is more than 20 MSA we go for 90th percentile CBR. If the traffic at the corridor is less than 20 MSA we go for the 80th percentile CBR value. So you compute the percentile CBR here and use it for the design.

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If we have a subgrade divided into sub-layers, we may have different CBR for different sub-layers, but for design purposes, we consider the subgrade as a single layer. Now again the next question is which CBR to use here? It all depends on the equivalent CBR value or equivalent modulus value. So suppose you have 2 sub-layers, each layer has a modulus, 2 different moduli E1 and E2. You perform a stress-strain analysis and compute the vertical deflection at the surface due to a wheel load and equate the surface deflection to a single-layer structure with a modulus E. So the surface deflection computed here will be the same as the deflection here.

So what will be the modulus that causes the surface deflection of δ here? So δ can be computed using software here and modulus can be estimated using this expression.

$$M_{RS} = \frac{2(1 - \mu^2)pa}{\delta}$$

So, the resilient modulus relating to the surface deflection value here is given here. Here μ is a poisson's ratio, p is a contact pressure, we use 560 kPa as a contact pressure, and a is a contact radius. So if the load is 40 kN and if the contact pressure is 560 kPa, you can compute the contact radius from the load and pressure and you will find it out to be 150.8 mm. This is the equivalence modulus we use for the design purpose and there is also a limitation considered in the IRC 37. So IRC recommends limiting the use of modulus value to 100 MPa.

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Modulus of Granular sub-base and base

$$M_{RGRAN} = 0.2(h)^{0.45*}M_{RSUPPORT} \qquad (7.1)$$

Where,

h	= thickness of granular layer in mm
M_{RGRAN}	= resilient modulus of the granular layer (MPa)
$M_{RSUPPORT}$	= (effective) resilient modulus of the supporting layer (MPa)

- Thickness of the sub-base should be sufficient to take construction traffic and not cause rutting in the subgrade layer
- Thickness of sub-base to take minimum of 10000 repetition of 40kN load with 560 kPa pressure

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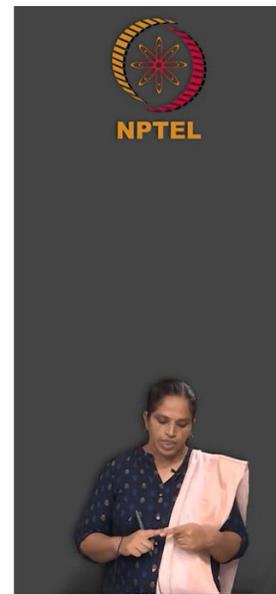
Next is the modulus of a granular layer that can be a base layer and a subbase layer. We know that the modulus that is a resilient modulus of a granular layer is pressure dependent. So, if the depth of the granular or a subbase layer is going to change, the modulus value is going to change. IRC uses only one single modulus here for the entire depth and that modulus can be computed using an empirical equation given here.

$$M_{RGRAN} = 0.2(h)^{0.45}M_{RSUPPORT}$$

This modulus is a function of the height or depth of the granular layer and the modulus of the subgrade layer here. So, $M_{RSUPPORT}$ represents the modulus of a subgrade layer that is an effective modulus to be considered here. If both base course and subbase courses are made out of a granular layer, you can consider both to be the same layer and compute the modulus

here. But one thing we have to ensure is that the subbase that we are providing above the subgrade layer should be sufficient enough to take the load and prevent the rutting of a subgrade layer during the construction process. So, typically we consider 10,000 repetitions of 40 kN load to be acting on a subbase layer during construction. This 10,000 repetitions of load may induce rutting on the subgrade layer. So, the thickness of a base course should be adequate to prevent rutting on the subgrade layer.

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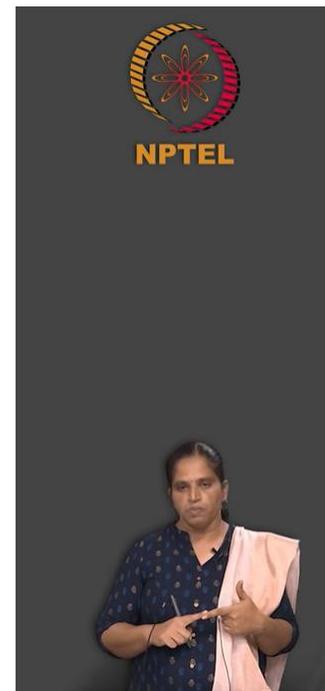
Modulus of Cement treated base and sub-base

$$E_{CTSB} = 1000 * UCS \qquad (7.2)$$

Where

UCS = 28-day unconfined compressive strength (MPa) of the cementitious granular material. It should be ensured that the average laboratory strength value should be more than 1.5 times the required (design) field strength.

E_{CTSB} = Elastic modulus (MPa) of 28-day cured CTSB material

- Modulus of CTSB – 600 Mpa
- Flexural strength or Modulus of Rupture of CTB

If the base course or a subbase course is cement treated, the elastic modulus of a cement treated base and subbase can be computed using this empirical equation where UCS is unconfined compressive strength of a cementitious material.

$$E_{CTSB} = 1000 \times UCS$$

So, when you compute using this equation, you may get the modulus in the range of 2000 to 6000 MPa, but IRC restricts the modulus usage of cement treated subbase to the value of 600 MPa. And we also need a flexural strength or modulus of rupture of cement treated base for the computation of cumulative damage in the cement treated base course.

Modulus of Bituminous mix

S.No	Traffic Level	Surface course		Base/Binder Course	
		Mix type	Bitumen type	Mix type	Bitumen type
1	>50 msa	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen		
2	20-50 msa	SMA	Modified bitumen or VG40	DBM	VG40
		GGRB	Crumb rubber modified bitumen		
		BC	With modified bitumen or VG40		
3	<20 msa[1]	BC/SDBC/PMC/MSS/ Surface Dressing	VG40 or VG30	DBM/ BM	VG40 or VG30

- Resilient modulus computed following ASTM:4123 /ASTM: D7369
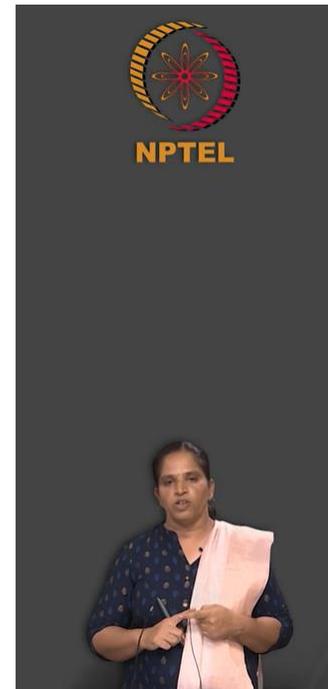
We characterize a bituminous mixture also by resilient modulus value and IRC suggests measuring a resilient modulus of different bituminous mixtures in the laboratory following ASTM: 4123 standard. This ASTM 4123 is a withdrawn standard where the resilient modulus in the laboratory is computed for an assumed poisson's ratio value. The revised standard is ASTM D7369 where both poisson's ratio as well as resilient modulus is computed from the laboratory test. Different types of layers used for two different bituminous courses are given here one is for a surface course, and another is for the binder course.

We can see that the binder course commonly used is a DBM or bituminous macadam in which VG40 binders are used here. Depending on the type of binder, the modulus value is going to vary here. The surface course is a rut-resistant layer, for which stone mastic asphalt or bituminous concrete are commonly used. Depending upon the traffic intensity, either we use a modified binder or an unmodified binder, or again depending on the binder here the modulus value is going to change.

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Modulus of Bituminous mix

Table 9.2 Indicative values of resilient modulus (MPa) of bituminous mixes

| Mix type	Average Annual Pavement Temperature °C				
	20	25	30	35	40
BC and DBM for VG10 bitumen ✓	2300	2000	1450	1000	800
BC and DBM for VG30 bitumen ✓	3500	3000	2500	2000	1250
BC and DBM for VG40 bitumen	6000	5000	4000	3000	2000
BC with Modified Bitumen (IRC: SP: 53)	5700	3800	2400	1600	1300
BM with VG10 bitumen	500 MPa at 35°C				
BM with VG30 bitumen	700 MPa at 35°C				
RAP treated with 4 per cent bitumen emulsion/ foamed bitumen with 2-2.5 per cent residual bitumen and 1.0 per cent cementitious material.	800 MPa at 35°C				
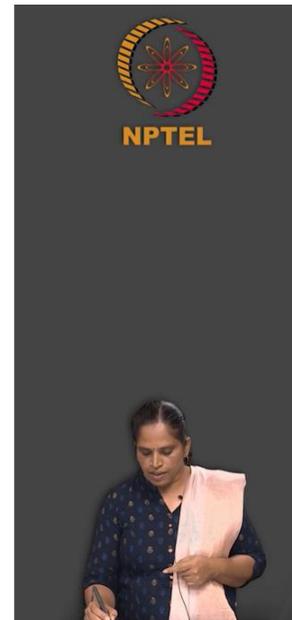
This is an indicative value of resilient modulus value for different bituminous mixtures. You can see that for any given mixture (BC or DBM), depending on the type of bitumen we use, the modulus value varies and the modulus is also sensitive to temperature. IRC suggests measuring resilient modulus value at 35°C and using it in the design. In case you are designing pavement for a snowbound area, you can prefer measuring a resilient modulus value at 20°C.

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Poisson's ratio

Table 11.1 Recommended material properties for structural layers

Material Type	Elastic/Resilient modulus (MPa)	Poisson's ratio
Bituminous layer with VG40 or Modified Bitumen ✓	3000 or tested value (whichever is less) ✓	0.35
Bituminous layer with VG30 ✓	2000 or tested value (whichever is less) ✓	0.35
Cement treated base ✓	5000 ✓	0.25
Cold recycled base	800 ✓	0.35
Granular interlayer	450 ✓	0.35
Cement treated sub-base	600 ✓	0.25
Unbound granular layers ✓	Use Eq. 7.1 ✓	0.35
Unbound granular base over CTSB sub-base ✓	300 for natural gravel ✓ 350 for crushed aggregates	0.35 0.35
Subgrade	Use Eq. 6.1 or 6.2 ✓	0.35
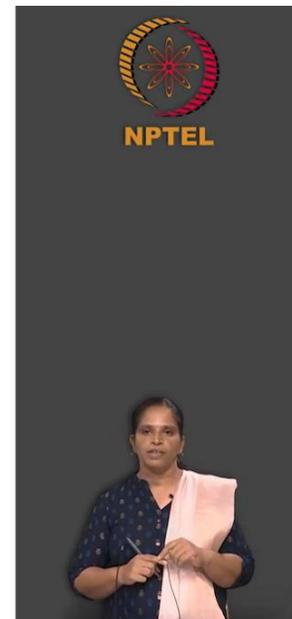
These are the list of material properties that are used for the design purpose. For a bituminous mixture with VG40 or modified bitumen, the resilient modulus used is 3000 MPa or a laboratory tested value, whichever is lower. Now for a bituminous layer with the VG30, 2000 MPa or laboratory tested value, whichever is lower is preferred here.

For a cement treated base, we use 5000 MPa and for a cold recycled base course, we use 800 MPa. For a granular layer or a crack relief granular layer, we use 450 MPa. If it is a cement treated material but used in the subbase it is a 600 MPa and if it is any unbound granular layer, the resilient modulus value is computed based on the equations that are the thickness of a granular layer and the modulus of the supporting layer. If it is an unbound granular base course resting over an exclusive cement treated subbase, then we consider either 300 or 350 MPa. For a subgrade, again we have empirical equations relating resilient modulus to CBR value. You can use it in case you do not have a laboratory determined value here.

You can see that the poisson's ratio of all the materials except cement treated base is considered 0.35. If you have a cement treated material, the poisson's ratio is considered 0.25. So these are the material functions we use for the design.

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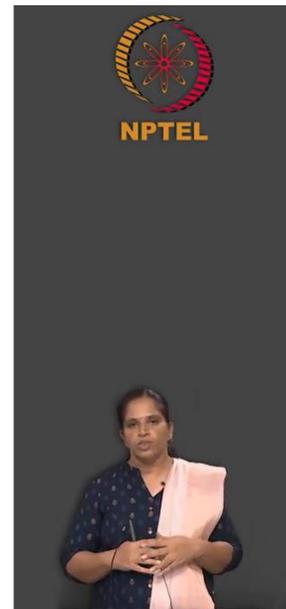
Now, we will talk about the transfer function that we use to convert the strain to the distress in the material.

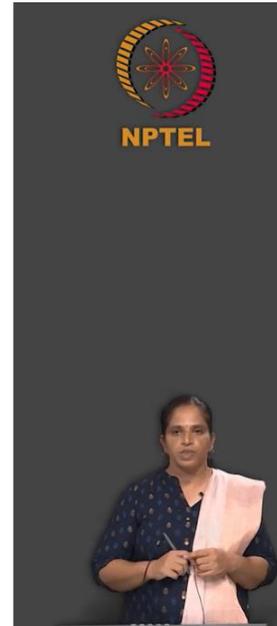(Refer Slide Time: 20:50)

Distresses

- Rutting of subgrade ✓

- Fatigue damage of HMA layer ✓

- Fatigue damage of CTB ✓

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So we consider three different distresses one is rutting for subgrade and other is fatigue damage of an HMA layer and the third one is a fatigue damage of a cement-treated base.

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Subgrade rutting

$$N_R = 4.1656 \times 10^{-08} \, [1/\varepsilon_v]^{4.5337} \qquad \text{(for 80 \% reliability)} \qquad (3.1)$$

$$N_R = 1.4100 \times 10^{-08} \, [1/\varepsilon_v]^{4.5337} \qquad \text{(for 90 \% reliability)} \qquad (3.2)$$

Where

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)

ε_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|

- Consider 90% reliability for traffic more than 20 msa ✓

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These are the distress equations that are used to compute the rutting life of a pavement. You can see that number of repetitions of a standard axle load that pavement can withstand before the

subgrade fails in rutting is related to a compressive strain at the top of a subgrade layer. So you have two different equations, one corresponding to 80% reliability and the other corresponding to 90% reliability.

$$N_f = 4.1656 \times 10^{-8} \left[\frac{1}{\varepsilon_v}\right]^{4.5337} \quad \text{(for 80\% reliability)}$$

$$N_f = 1.4100 \times 10^{-8} \left[\frac{1}{\varepsilon_v}\right]^{4.5337} \quad \text{(for 90\% reliability)}$$

We consider 90% reliability equations for the computation if the traffic is more than 20 MSA, otherwise, you can go for 80% reliability here. For either 80% or 90% reliability, the structure of the equation remains the same and only the constants which are used for computation of the number of repetitions of a standard axle load vary here for 80 and 90% reliability.

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HMA Fatigue damage

$N_f = 1.6064 * C * 10^{-04} [1/\varepsilon_t]^{3.89} * [1/M_{Rm}]^{0.854}$ (for 80 % reliability) ✔ (3.3)

$N_f = 0.5161 * C * 10^{-04} [1/\varepsilon_t]^{3.89} * [1/M_{Rm}]^{0.854}$ (for 90 % reliability) ✔ (3.4)

Where

$C = 10^M$, and $M = 4.84 \left(\frac{Vbe}{Va+Vbe} - 0.69\right)$

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

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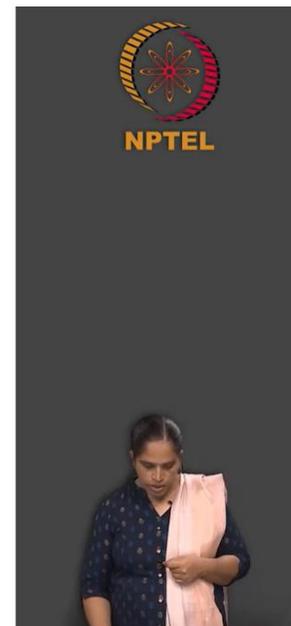
For the computation of an HMA fatigue damage, the number of repetitions of standard axle load that induces damage of 20% of the area for 80% and 90% reliability is given here.

$$N_f = 1.6064 \times C \times 10^{-4} \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_{Rm}}\right]^{0.854} \text{(for 80\% reliability)}$$

$$N_f = 0.5161 \times C \times 10^{-4} \left[\frac{1}{\varepsilon_t}\right]^{3.89} \times \left[\frac{1}{M_{Rm}}\right]^{0.854} \text{(for 90\% reliability)}$$

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

You can see that this N_f also depends on the modulus value and the volumetric properties of the bituminous mixture here. So ε_t is the maximum tensile strain at the bottom of an asphalt layer. We compute this based on the stress-strain analysis.

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CTB Fatigue damage

$$N = RF \left[\frac{\left(\frac{113000}{E^{0.804}} + 191\right)}{\varepsilon_t}\right]^{12} \quad (3.5)$$

Where,

RF = reliability factor for cementitious materials for failure against fatigue

= 1 for Expressways, National Highways, Sate Highways and Urban Roads and for other categories of roads if the design traffic is more than 10 msa

= 2 for all other cases

N = No of standard axle load repetitions which the CTB can sustain

E = elastic modulus of CTB material (MPa)

ε_t = tensile strain at the bottom of the CTB layer (micro strain).

For cement-treated material fatigue damage, IRC 37 has given two equations. One is based on Australian practice and the other is based on AASHTO practice.

$$N = RF \left[\frac{\left(\frac{113000}{E^{0.804}} + 191\right)}{\varepsilon_t}\right]^{12}$$

The above equation is based on the Australian standard. RF is the reliability factor which is taken as either 1 or 2 depending on the importance of a road. So if we design an expressway, national highway, state highway, or any important road that has a traffic of more than 10 MSA, we consider RF to be 1 otherwise you can make it 2 that is, you are increasing the life by twice.

N is nothing but the number of repetitions that cement treated base can withstand before it fails in fatigue damage. Here E is the modulus of a cement-treated base and ε_t is a strain at the bottom of a cement-treated base. So this is an Australian practice.

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Now MEPDG practice of computing the number of repetitions of a standard axle load that cement-treated base can withstand is given here. So it is classified based on the class or axle load group of a vehicle i.

$$\log_{10}N_{fi} = \frac{0.972 - (\frac{\sigma_t}{M_{Rup}})}{0.0825}$$

So we have σ_t which is a critical stress at the bottom of a cement-treated layer, M_{Rup} is modulus of rupture or it is the flexural strength of a concrete computed after 28 days of curing and we call σ_t/M_{Rup} to be the stress ratio. Once you compute N_{fi} for different classes of vehicles, you can sum it up and compute a cumulative damage factor (CDF) to be the ratio of traffic load repetitions by N_{fi} computed using this expression.

$$\text{CFD} = \sum \frac{n_i}{N_{fi}}$$

If you have traffic load grouped in this way for a single axle, tandem axle, and tridem axle, you can compute N_{fi} for each class of axle and for each load group and you can sum it up and compute a cumulative fatigue damage using the above expression. And we make sure that this cumulative fatigue damage value is always less than 1. So we design or determine the thickness based on this cumulative damage factor.

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Once we understand what are the inputs that we give into a pavement design and how these strains computed are transferred to the distress in the pavement, we will see software that is used in the computation of stresses and strain. So IRC 37 comes with a software called IITPAVE. IITPAVE considers pavement layers as linearly elastic layers and computes stresses and strain at different locations.

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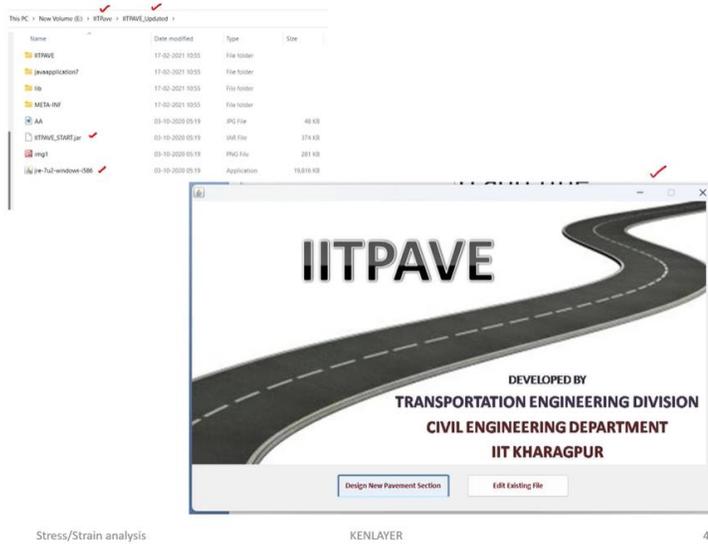
When you purchase IRC 37, you will get a CD and when you open a folder in that with IITPAVE and IITPAVE updated, you will have a Java file here. First, install this Java application file and after installation, open IITPAVE_START.jar. When you open it, you will get a window something like this and this is the software which we are going to use. In this, you have 2 options. To design a new pavement section, click on the new pavement section.

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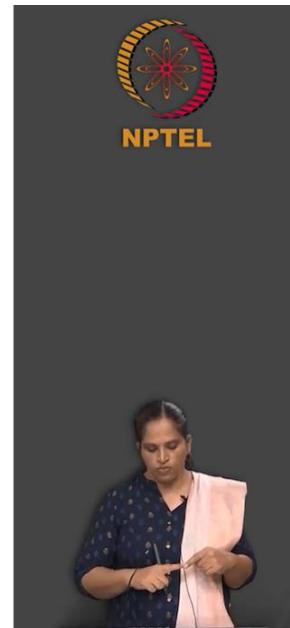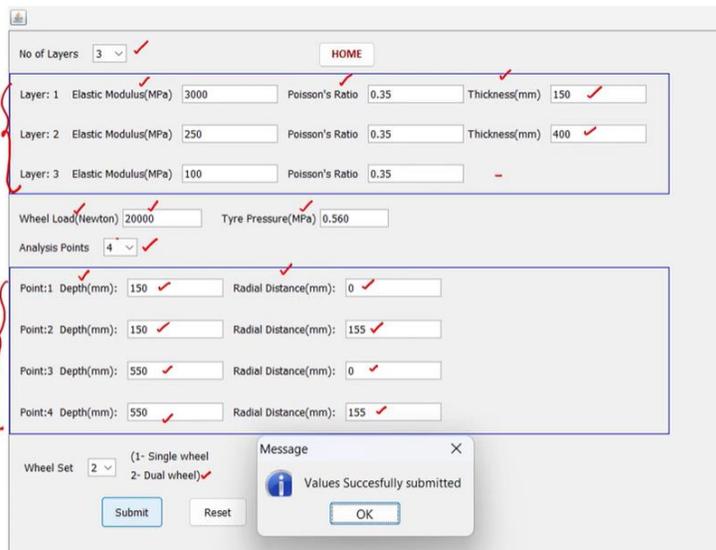
When you open a new design, this is the window you will get and you will have first input as the number of layers. Once you define the number of layers, you will have the layer numbers listed here depending on the number you give. I have given 3 layers here, so you have 3 lists here. You have an elastic modulus value, poisson's ratio value and thickness value defined for each layer.

You do not have a thickness for the final layer because the subgrade layer is considered to have an infinite thickness. So you give the elastic modulus value in terms of MPa and you give the poisson's ratio value, thickness in terms of millimeters. So the next input is a wheel load given in terms of Newton. If it is a standard axle load, each wheel load is 20 kN or 20×10^3 Newton. The tire pressure used for the granular layer design is 560 kPa or 0.56 MPa. This is related to the load input.

Now what are the number of locations at which you need to find stresses and strain? I have defined the number of points to be 4. You will see 4 different points to be listed after you define 4 here. So you need to give the depth and the radial distance at which you need the stress. Now if I need the stress value at the interface of the first and second layers, it is 150 mm because the thickness of the first layer is 150.

Now if I give a radial distance of 0, it indicates exactly at the center of loading. Now if I give a radial distance of 155, it is between the two loading systems. If you define wheel load to be dual, it is exactly at the center of 2 wheel loads. Now the second interface is at a depth of 400 plus 150, which is 550. So at the depth of 550 mm and at the radial distance of 0 and 155 mm, we will get the stress value.

You can define any number of points as given here. You can only consider a single wheel or dual wheel here for the analysis in case you have a tandem axle or a tridem axle. One tandem axle is considered as 2 repetitions of one single axle and one tridem axle is considered as 3 repetitions of a single axle. So you convert it into a single axle and use one wheel or a dual wheel here. Once you give all input and click the submit button, you will get this message value as successfully submitted.

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So once you submit there will be an option to run the program after you compile it you will get the message done and once you give this, the final view results will be like this.

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If your view result is empty, you click view here so that you will get all the values displayed. Now in the result, you will see a number of layers. We have given the modulus of

each layer, poisson's ratio value, thickness of each layer, wheel load, tire pressure, and contact radius will be automatically computed, and whether we are using dual wheel or a single wheel. So these are the depth at which we are computing strains and stress and these are the radial distance at which we are computing stress and strain. You have 3 normal stress σ_z, σ_t and σ_r and 1 shear stress and 3 normal strains ε_z, ε_t and ε_r is also given.

You also have a displacement measured at that particular depth and radial distance. So these are the inputs you will get it. Now from this input, you need to identify what does the critical strain that induces rutting or that induces fatigue damage and you have to select and use it in the distress transfer functions.
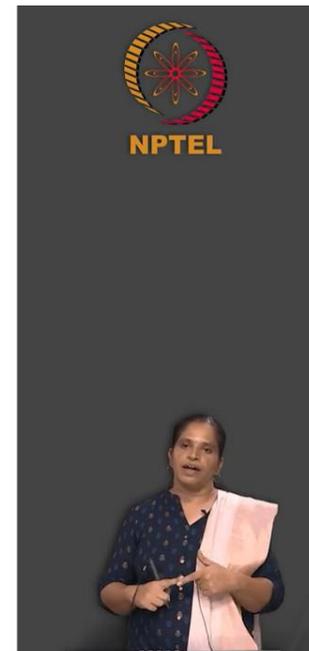
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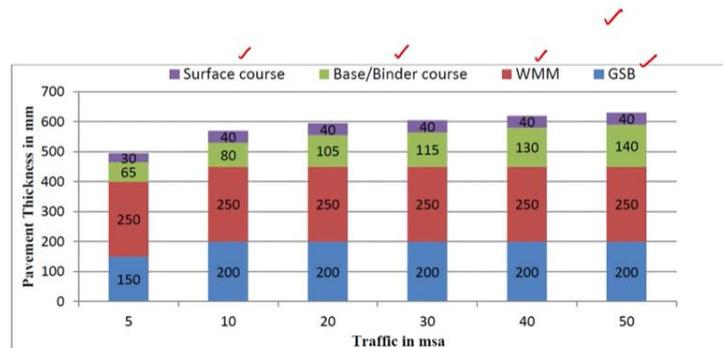
So we also have a design catalogue chart given in IRC for 6 different categories of cross sections that we have discussed already. This is one typical cross-section for a granular base course and a granular subbase course. So granular base course is considered as WMM and you have GSB granular subbase course with 2 asphalt layers, one with the surface layer and the other is a binder layer resting on the base course.

These design charts are developed for specific input data. Most of the time these design charts may not match with our input data. So you need to do a detailed analysis and compute or verify the thickness of the pavement.