Analysis and Design of Bituminous Pavements

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Lecture – 46

Overview of Mechanistic-Empirical Pavement Design Methods - IRC

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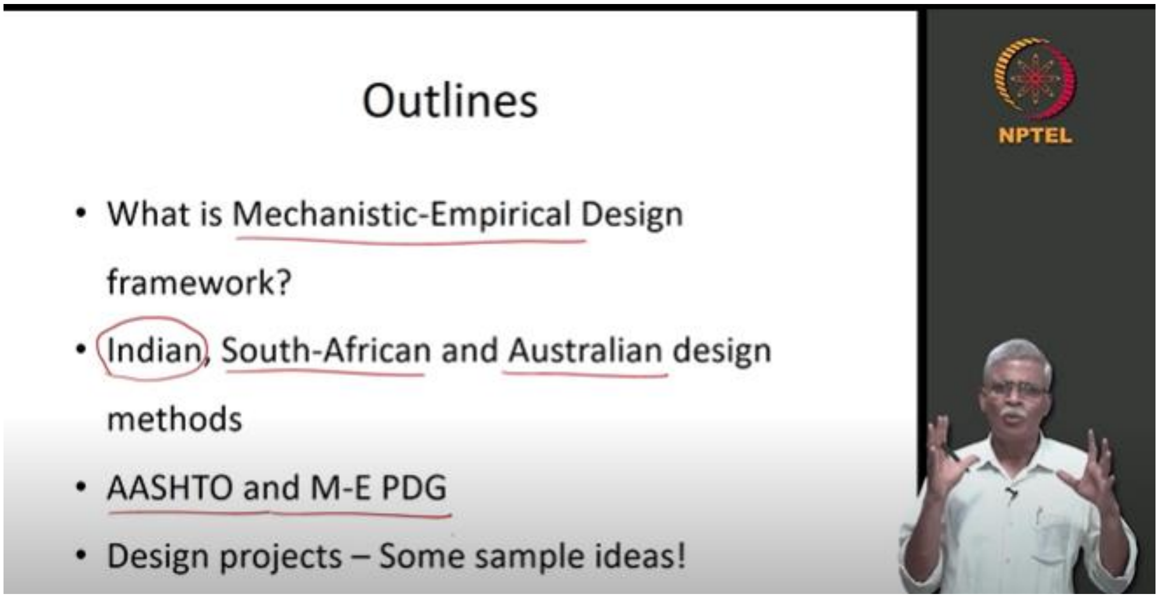

So, hello everyone, we are in the final stages of this particular course. So, what we are now going to do is to discuss about the overall framework for the analysis and design of bituminous pavement. So, what exactly I mean by this? Now, we need to understand few things, you probably would have heard this word mechanistic empirical many times during this course. So, we will try to look at it little more in detail. Then we will look at three different design codes. I will emphasize on Indian, South African and Australian design methods, they are slightly similar to what we do for IRC 37. And then I will get on to one of the most comprehensive and detailed design code which is the AASHTO. What Dr. Nivitha would have taught you is about the old AASHTO which is based on reliability based method with PCA and all those things. But right now what we are going to talk about is the AASHTOWARE or the mechanistic empirical pavement design guidelines. It is lot more comprehensive as you will realize.

So, the manner in which I am going to approach is not to make you work out problems which is what Dr. Padmarekha has already done for IRC37. But to tell you about the fundamental philosophy of this design guidelines. And at the end of it I am going to spend some half an hour that will be the last lecture to give you lot of ideas, suggestions related to the design projects. I assume that many of you here who are taking this course will be doing your graduate studies at different universities across the country. And you might be expected to do design project. You may also want to do your B.Tech or your M.Tech, M.E, B.E project work. So, it will be nice to have a design project. And in fact at IIT Madras where I have been teaching this course for close to 18 years or so, one compulsory component that I insist is the students should submit a design report. What I am going to do is I am going to share with you one PDF file of the design report submitted by one of my students which I think is a fairly comprehensive design report. So, let us get on with life.

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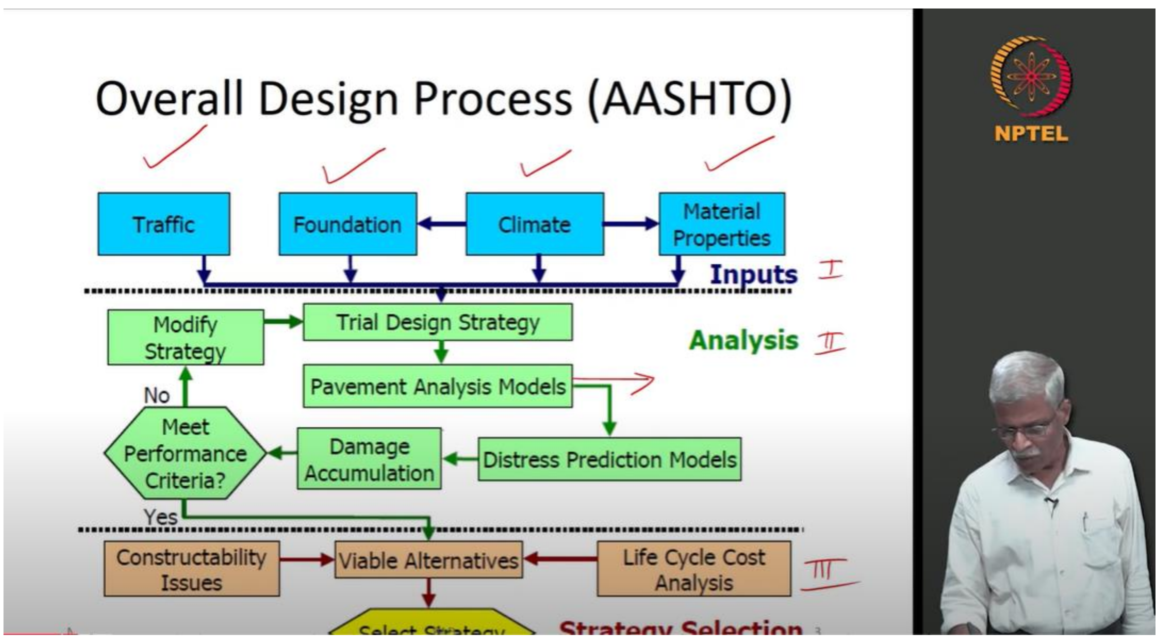

This is the first slide that I showed. In fact, when the very first time when we introduced the course, we talked about the overall design process. What exactly is the overall design process? The same thing. This is your input, this is your analysis, this is the strategy selection. So, now you have already heard about the material properties, the climate, the bearing capacity of the soil, how to analyze for traffic. Then you talked about one layer, two layer, three layer theories. Then we talked about rutting, fatigue and the various distress prediction models and something about the performance criteria, modify strategy and so on and so forth. So, this is quite familiar to all of you. So, now we want to relook at some of these things in a little more detailed way and that is why I wanted to show this particular slide to you.

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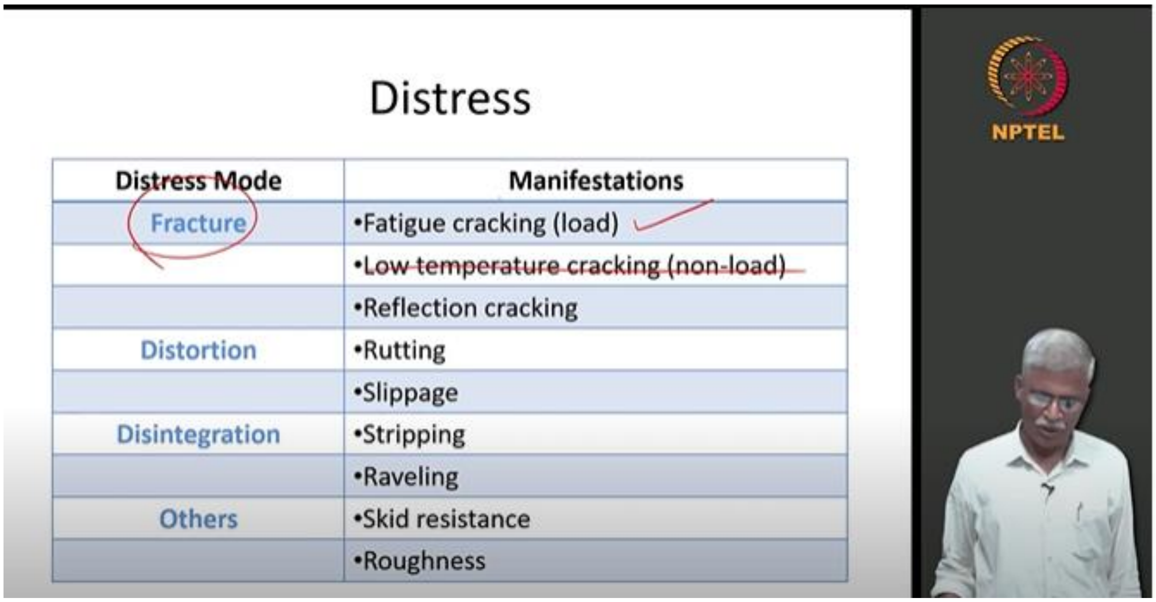

So, first let us start talking about the distress. I think you must be thinking when you are designing any structure, why do you really want to talk about the distress and in fact, most of the design strategies that you see will address the issue in a completely different way. But as far as the pavements are concerned, what we normally do is to start the design process from the point of view of how the pavement will fail. So, you first want to understand how the pavement will fail and then you try to see how you have to integrate such a failure in your design process. So, we go in a completely different fashion. Now, you must be thinking why we should do that. The reason why we should do it is your pavements are built for 5 years or maybe maximum 10 years and even before the end of 5 years, you start doing the maintenance. Is this something only specific for Indian condition? No. Throughout the world depending on the quality control that you see or the local conditions or the traffic intensities, the period may vary from 4 years, 5 years or 6 years. Since ours is a growing country, there is substantial amount of traffic that is coming there, that means truck. When I am talking about traffic, I am not talking about bicycle, two-wheeler, car or auto and by this time, you must know which traffic that I am talking about the trucks. There is a considerable increase in the growth of this truck traffic because this is what fuels our economy, right. And when there is so much of increase in the truck traffic, there is also going to be substantial amount of damage that will happen to the pavement. So, what we really need to do is to ensure that we understand this distress process related to the expected traffic repetitions and then inbuilt this in the design. And as I said before, it is a trial design strategy, right.

So, now when we talk about the failure mode, what you are going to see is fracture. So, fracture is your fatigue cracking load induced. We would not worry too much about the low temperature cracking in our country, but this is something to do with the fatigue cracking. And then there is also something called reflection cracking that can happen. That is basically because you have this old distressed pavement which is fairly cracked and then you try to lay a new layer on top of it without any preventive maintenance, let us say provision of geogrids or glass grids. So, what can happen? All the cracks can actually reflect and come to the surface. Then you are talking about distortion which is rutting, slippage, disintegration, stripping, raveling, skid resistance and all. And in these things, the one that is structurally connected is your fatigue cracking as well as rutting. There are many that could be called as non-load induced, something related to the choice of wrong materials for the wrong environmental conditions and so on. But right now these are the two things that is related to the structural performance of the pavement.

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So, we have seen this picture many number of time, but you need to understand this happens because you are going to have repeated load at one specific place and I have also mentioned something about vehicle wander. So, you are going to have your lane 3.75, 3.5 meters and there is going to be specific locations in this lane width in which it is going to be subjected to repeated loading. And these are the fatigue cracking that you are going to see.

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The second thing that you are going to see is your rutting. This is your longitudinal depression in the wheel path that you are seeing. So, these are some of the most important structural deficiencies that we need to understand.

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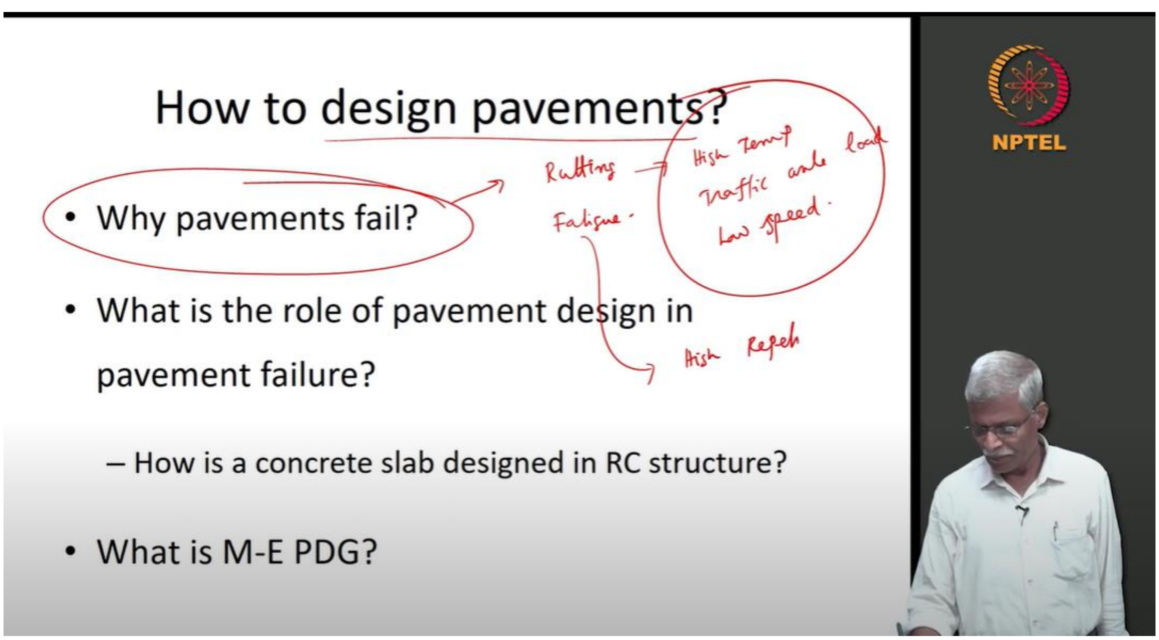

So, now let us ask some basic questions. How do you design a pavement? And as I mentioned before I start talking about how do I design a pavement, what I really want to ask is why do the pavements fail? Basically, before that again you want to say how do the pavement fail? So, you are going to say then the pavements can fail due to rutting or fatigue. Now, why do the pavement fail like this? So, then you can talk in terms of you know high temperature, then traffic axle load and low speed you can say. So, you can categorize these are some of the reasons. So, you are going to have high temperature, heavy traffic axle load and low speed and these are these three dangerous combinations as far as the rutting is concerned.

What about fatigue, high repetitions? Then the temperature is so when I say low you need to understand I am not really talking about temperatures below 0 ^{o}C, but slightly in the 10, 20 ^{o}C. Then you are talking about I would not really worry too much about the low speed here because the material is going to become very stiff and there is going to be the failure mode is going to be completely different. It is going to be the accumulation of strain leading to fracture of the material fatigue of the material. So, these two things are going to be there and I can even write in terms of the modulus value.

So, if your material is aged and if it has become stiffer and there is going to be a likely reason that it is going to be fracture fatigue. So, this is the manner in which the failure is going to take place. So, why do the pavements fails in terms of structural design you can talk in terms of inadequate pavement thickness, inadequate pavement materials etc. I mean using a material that is inappropriate see for instance just to give an example there are two binders VG30 and VG10 there are two locations let us say Srinagar and Chennai. Now, what will happen if you use this think about it will it work it will not work. Why it will not work because if you are using a softer binder at a location such as Chennai where the air temperature can go up to 40-42 ^{o}C that means the pavement temperature can go up to 60 ^{o}C it can fail due to rutting. What will happen in a place like Srinagar where the air temperature is low and the binder is stiff then it can fail due to cracking. So, this is how the pavements fail. Now, what exactly is the role of the pavement design in the pavement failure? So, in fact that is why I am saying the pavement design process is always a trial design process. And that is why I also ask this question how is a concrete slab designed in a RC structure it is designed in a completely different way. So, if it can withstand so many years and in fact that is what I keep repeating ours is a country in which you have temples religious structures built and they last for 1000 years or more. So, why is that a road structure fails so soon. The reason is all the following at least at the end of this course you should be able to understand why now why now why building a pavement structure is lot more complicated than building a high rise building or an industrial structure. So, how is a concrete slab designed in a RC structure? The design is fairly straight forward we know what is the load that is going to come every possibility is taken into account. Here that is the problem the reliability or what exactly we can expect always comes with some kind of a statistical probability right.

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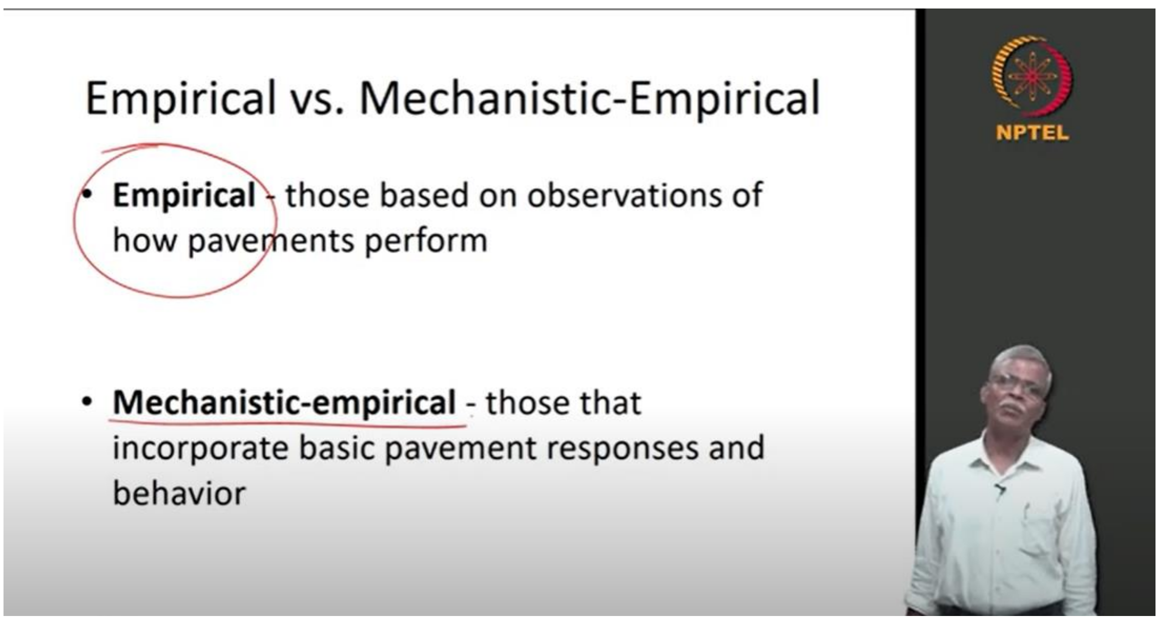

So, here is where MEPDG plays a critical role. So, let us understand what is this mechanistic and empirical. In the olden days and in fact most of you who are familiar with reading from few undergraduate textbooks they are fairly outdated and they will be showing you some simple CBR graphs with some traffic loading and with some design thickness. These are what are called the empirical methods of doing it basically based on empirical observations on how the pavements perform. Life is fairly simple and straight forward you can basically say you know 40 mm BC, 100 mm DBM, 250 mm granular base, 250 mm another granular sub base and it should last for 5 years. So, if it was so simple and straight forward we do not need to have this comprehensive course, but that is not how it is.

So, what is mechanistic empirical is those that incorporate basic pavement responses and behavior. And in fact what we do in the layer theory we do we found out what is the component of horizontal strain, what is the component of vertical strain and then we will try to relate it with what one can expect related to the expected life related to rutting or fatigue. And that is what actually has already been discussed by different teachers here like Dr. Nivitha, Dr. Neethu Roy or Dr. Padma.

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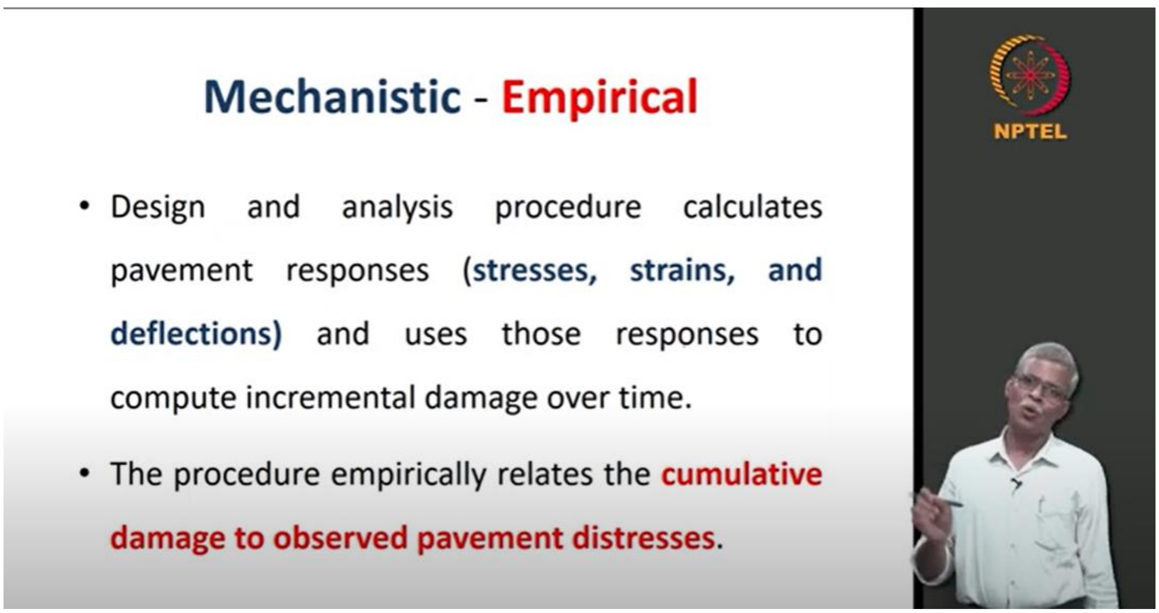

So, what I want to now make is I want to make a very clear statement here and in fact if you are listening to this video you may want to pause here and write this statement. Design and analysis procedure calculates pavement responses. Now what are the pavement responses? Stresses, strains and deflection and use these responses to compute incremental damage over time. So, the procedure empirically relates the damage to observed pavement distresses. So, this portion is mechanistic and this portion is empirical. I will explain this in detail here.

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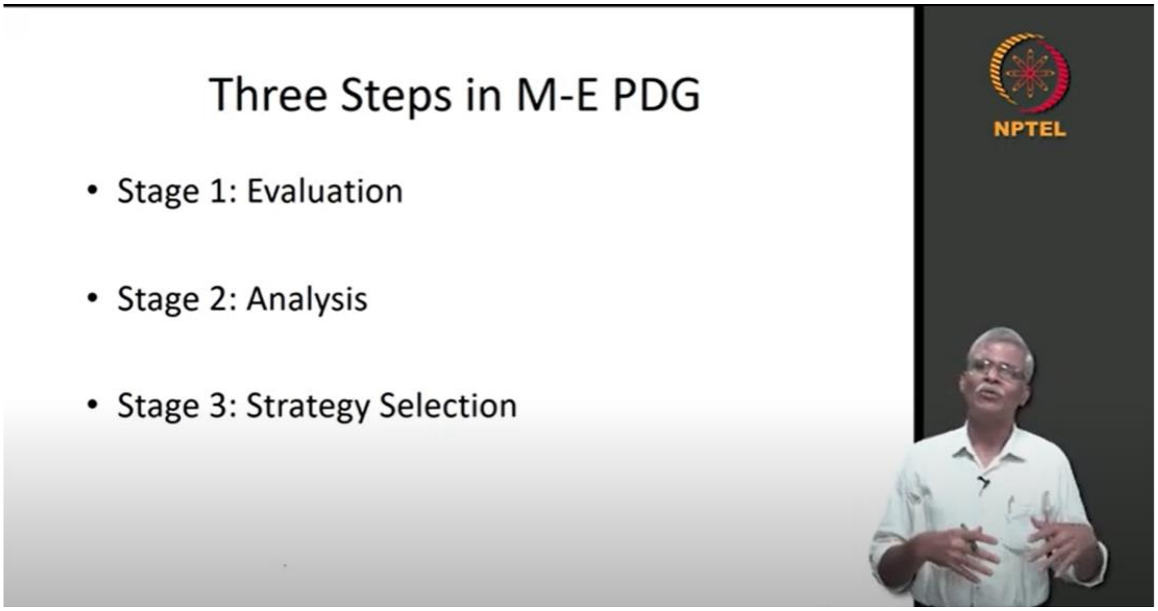

So, what are all the three steps in the mechanistic empirical pavement design method? Please understand all I am trying to do now is to give you a bird's eye view of the whole design process in a very broad spectrum. And so when we first set up this framework for looking at the pavement design, we can now look at IRC37, we can look at the South African court, we can look at the Australian court and then finally we can look at the AASHTOWARE MEPDG and after looking at all these things then you will get fairly good idea about what kind of design projects one can work out. First and foremost thing is evaluation, second is analysis, third is strategy selection.

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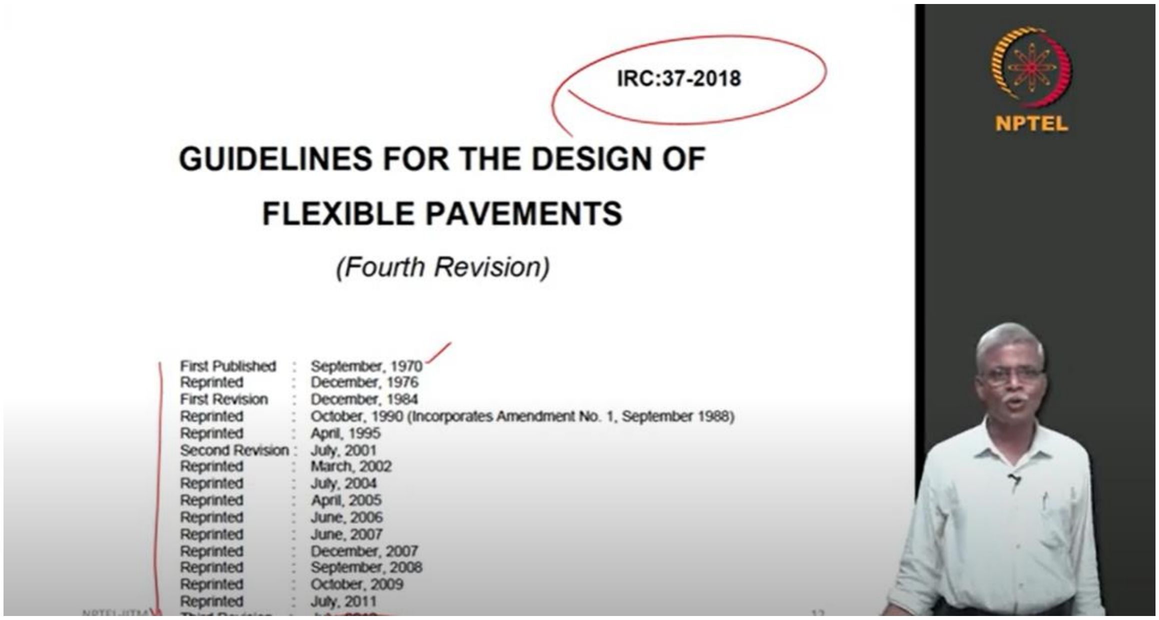

So, let us now take a look at India. What do we do here in India? So, this is what we follow IRC37 2018 and in fact the reason why I gave is you can actually see the rich history here. So, from 1972 it has come all the way up to November 2018. Hopefully it will it should go for another revision around 2023. I am not sure whether they are doing it, but they should do it because it is long overdue and these codes have to be revised very often. Only then they will become relevant to what is really happening here. So, in fact if you look at it, the first published 1970, first revision was made 14 years after that, second revision was made another 15-16 years, 17 years after that. The third revision was made again after 10 years and slowly in 6 years they did the fourth revision. So, probably in 2023 or 2024 the fifth revision should come.

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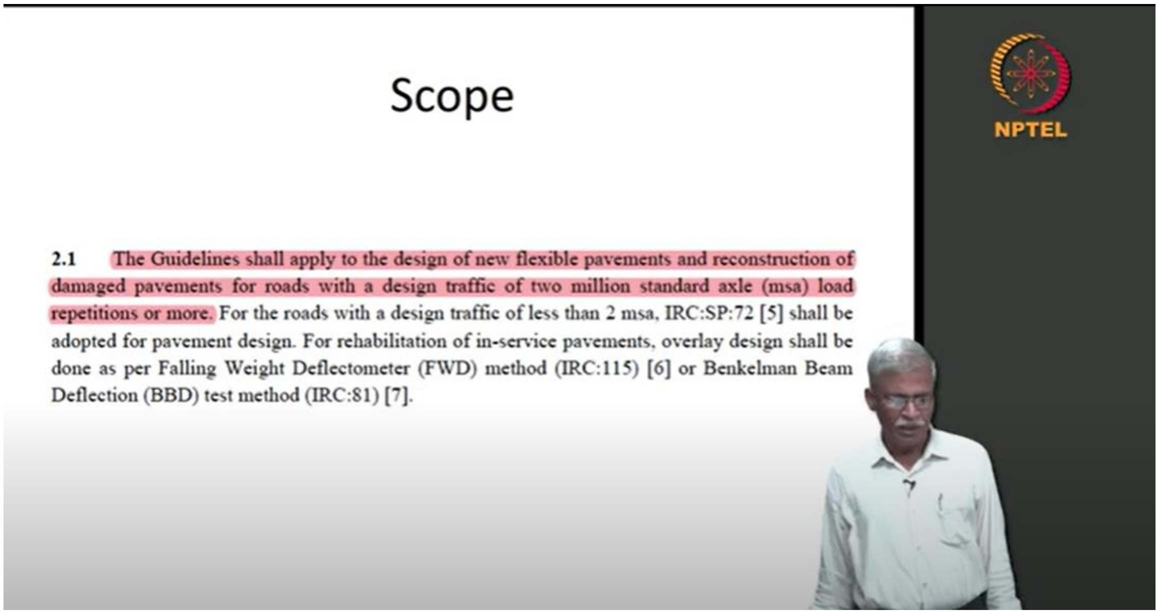

Now what exactly is the scope of this design guide? I have highlighted this and you may want to read it. The design guide shall apply to the design of new bituminous pavement. They write it as flexible pavement, new bituminous pavement and reconstruction of damaged pavements for roads with a design traffic of 2 million standard axle load or more. That is what it is. Rest of the things we will ignore.

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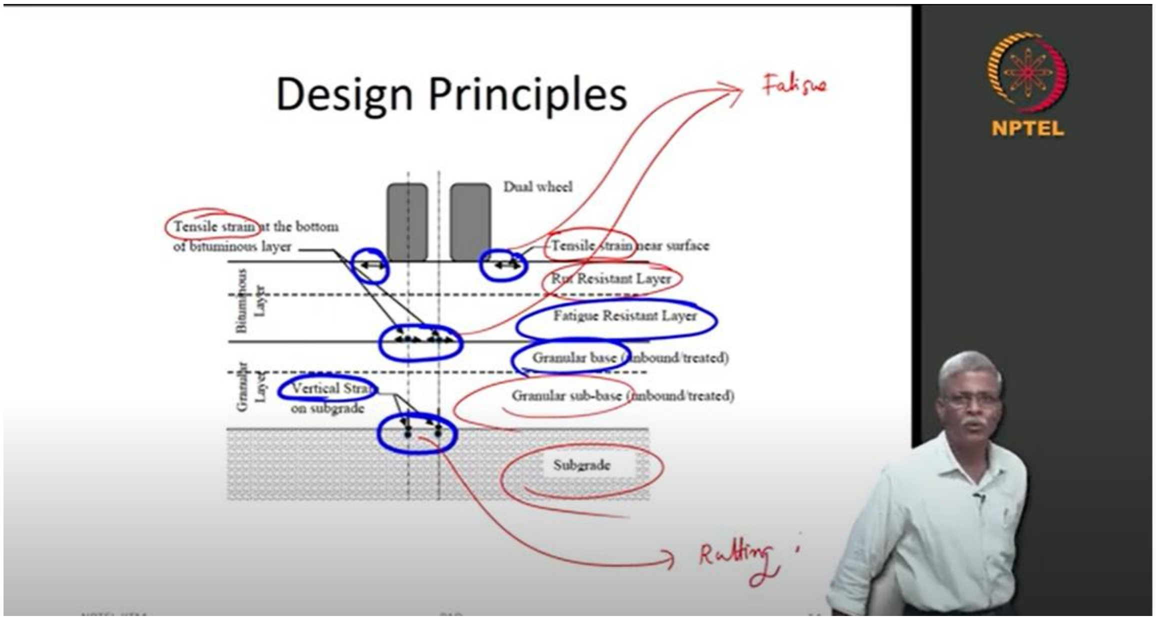

So now this is the design principle. Let us understand this very carefully. You have seen this cross section many times. I have been discussing this from the starting. Professor Padma also would have discussed this little earlier. So, this is your pavement cross section. So there is a rut resistance layer, there is a fatigue resistance layer. So there is a granular base, there is a granular subbase and then there is a subgrade. Now if you take a look at it, the critical strains, tensile strain; tensile strain and the compressive strain, they are measured at some specific point. So they are measured here, here, here as well as here. So what is the idea here? So this has something to do with the fatigue and this has something to do with the rutting. So this is the assumption that is followed in IRC37. Now is this assumption a correct assumption? It may not be true, but this is a design guideline. Design guidelines keeps revising itself. So probably in the next revision you might see a better refinement of the design procedure.

But now first let us take a look at it. Why are the strains measured near the surface? Because there is something called top-down cracking that can happen. How does a top-down cracking happens? What can happen is at the surface where the tire is in contact with the pavement, considerable amount of stresses is induced between the tire and the pavement. Number one - strains. Number two, because of the aging that happens, because it is the surface that is exposed to the environmental condition, there is aging that happens, the material becomes stiff, right, and then I have also substantial strain. So the third is what can happen? I have mentioned this in the earlier classes. What is really called as horizontal traction can happen. So what is this horizontal traction? You are driving along the highway. You see that there is an intersection and there is a vehicle coming in this side. So what do you do? You press the brake. So when you do that what will happen? Momentarily there is going to be a load transfer from the rear to the front and it goes back. So if you try to resolve the forces, there are going to be forces in the vertical direction, there are also forces in the horizontal direction, okay. And when such things are happening, you are going to have tensile strains at the surface and repeated load applications, you are going to see that the cracks are going to propagate from the surface. And you will see those things near intersections, near unsignalized intersection in rural highway. You will be seeing this. And in fact, if you take a core of such material, you will actually see that the crack propagates from the surface and goes down, but normally we expect that the cracks will propagate from the bottom and go to the top. So in this case, the cracks will propagate from the surface and go to the bottom. So these are what are called as top down cracking. So you need to estimate what is the tensile strain at the surface.

Then obviously you are looking at the fatigue resistance of the material. Similarly, you are going to see that at the bottom, you are going to measure for rutting. Now the important question that will come to your mind is, no, you are asking me to measure the vertical compressive strain on top of the subgrade and then you say that it is related to rutting. Then why is that I see a rut resistance layer at the top? The idea is very simple. What IRC says or what we follow in India, which is a very simple assumption that we make related to the design is, each and every layer is going to be subjected to rutting, ok, permanent deformation they are going to show. But our assumption is which is the weakest layer in this whole thing; subgrade. So let us find out the vertical compressive strain on top of the subgrade and let us limit that value. If you limit that value, it is assumed that the individual layer rutting, see because our assumption when we did the layer theory is the modulus values keeps increasing. So if I could limit the strain here, the strains that are going to see on the higher layers may not be that much substantial.

Fair enough, but why do I still see a rut resistance layer? Because we know for a fact that a bituminous mixture is laid with around 6 to 8 % air voids. I am not really sure how many of you have actually taken a course on mix design or pavement materials or anything like that because we have another course called the mechanical characterization of bituminous material in which I mentioned little bit in passing about the mix design, but I do not really get into the details. So the idea is in mix design, you will be actually adding around 4 to 8 %, laying a mix which is having 6 to 8 % air voids and this will be subjected to repeated loading. There will be a densification that will happen and because of basically with which you might see some rutting. So what IRC would want us to do is, since this is the topmost layer and since this is the layer that is in contact with the load that is being transferred from the tire to the pavement, make the layer rut resistance, but do not check for its rut resistance because you are going to check it only based on the weakest layer. I hope it is clear.

Fatigue can happen in every layer, but we will be checking for the fatigue only at the surface as well as at the bottom of the bituminous layer, but the distress equations that we are going to see are not going to be related to the fatigue that you are going to see at the surface, not for top down cracking, but that is a different issue.

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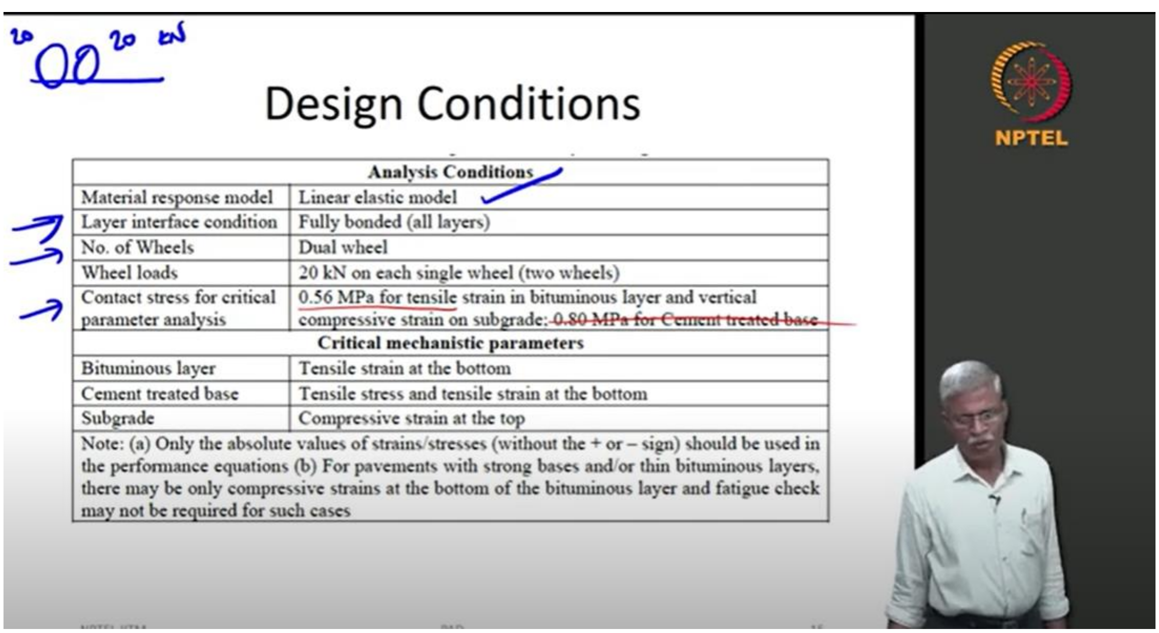

Now here is the design conditions that are followed. This is a linear elastic model. I am repeating the same what Professor Padma must have told you, but I am basically doing it because I just want this process to kind of get you there. So the material response model is going to be linear elastic model and now you must remember the assumptions that we made in the three-layer theory. What is that? It is a fully bonded one. Number of wheels is dual wheels, so that means you have 20 kN and contact stress that you are going to see here is 0.56 MPa. We will not be worried too much about the cement treated base. Now what are all the critical mechanic parameter? Now see this. It says for bituminous layer you are going to check only for the tensile strain at the bottom and for subgrade you are going to check at the compressive strain at the top and there are some statements that are made you can read it.

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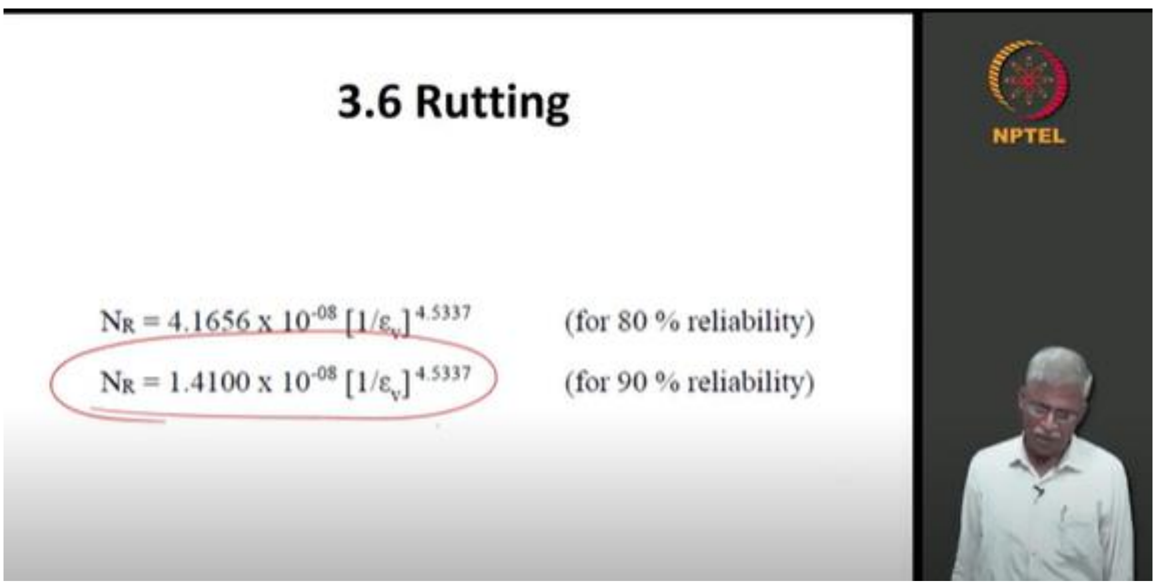

$$N_R = 4.1656 \times 10^{-08} \left[\frac{1}{\varepsilon_v}\right]^{4.5337} \qquad \text{(for 80\% reliability)}$$

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

So let us go to the first distress equation and this is where I want you to take a very careful look at it and this is what I am trying to tell you through this final lecture series. Now let us take a look at this particular expression. How do you interpret this equation? It says number of repetitions N_R is equal to some number 1.41×10^{-08} multiplied by $\frac{1}{\varepsilon_v}$ to the power 4.5337 and this is for 90 % reliability. Now by this time you should know what is 90 percent reliability, what is 80 % reliability. Now let us understand this carefully. Let us take a look at the left side of the equation. So this left side of the equation says number of repetitions.

Now the first few things that you need to ask. Number of repetitions means what? Number of what repetitions? So they are going to say 80 kN standard power. Because now you know how to use vehicle damage factor, lane distribution factor, directional distribution factor, annual average daily truck traffic and so on and so forth and bring out the broad spectrum in terms of the standard axial load; 80 kN load. Number of repetitions in and in fact you want this to be in millions and the number of repetitions to what? So you will say that will cause 20 mm rutting or 10 mm rutting. If you want you can take 10 mm also and I suggest that you go take a look at IRC37 find out what IRC37 says. Does it say 20 mm rutting or does it say 10 mm rutting? Take it as a homework.

So now I look at it. So this equation looks very interesting. So number of repetitions to failure in terms of an 80 kN standard load which will lead to 20 mm rutting. So your definition of failure is 20 mm rutting. What causes that 20 mm rutting, 80 kN standard load? How many repetitions that is what this equation will give you? Excellent. Let us come to this side. Now what are these factors? These are what are called as calibration factors. So this is where your mechanistic empirical will play a critical role. So what is this ε_v? Oh you will know what is ε_v. All I really need to do is use KENPAVE or IITPAVE or whatever you want, layer 1, layer 2, layer 3 and let us say this is my subgrade. I can put the material properties here and I can compute ε_v. So this is ε_v. Now tell me what is the mechanistic portion here? What is the empirical portion here? The mechanistic portion is assuming a layered linear elastic theory and computing the vertical compressive strain on top of the subgrade.

Straight forward procedure, if I give you the cross-section and the thickness and the modulus value and the load that is applied and the tire contact area, whichever software you use, either you use exact solution, there are no exact solutions, whatever you do, you are going to get only one value ε_v. There is no problem there. So that is mechanistic straight forward stress strain analysis.

What about the empirical formula? Then when you look at it you realize, ok, so now I understand what you mean. This 4.5337, 1.41×10^{-08} seems to be coming from some empirical data collection, right? So now how do you justify it? You say on the left hand side I see that number of repetitions to failure to cause 20 mm rut depth is related to one vertical compressive strain. So on one side you are talking about failure. So this side is failure, right? This side is, let me reduce the thickness, this side is strain. The strain is related to the failure and this relationship is established based on large amount of field data, calibration and validation of local and global calibration factors. And these factors change when the reliability level changes. So that means if you use 80 % reliability, roughly you will say that same pavement structure can take four times more, right? Roughly four times, 3.8 times more. That is what you are trying to say here.

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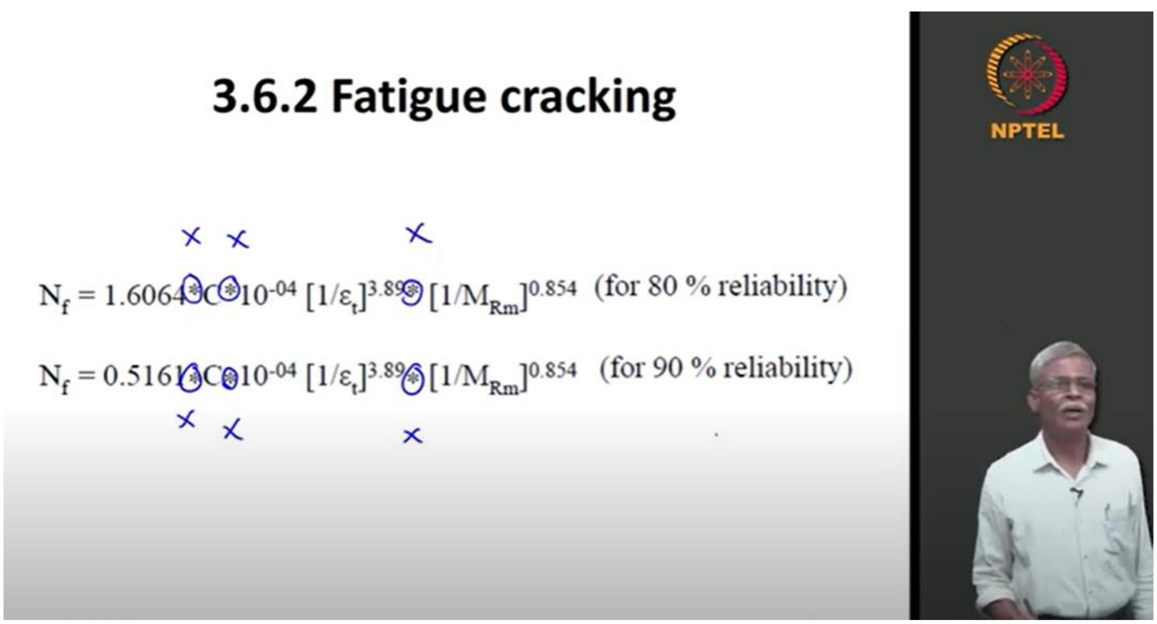

$$N_f = 1.6064 \times C \times 10^{-04} \left[\frac{1}{\varepsilon_t}\right]^{3.89} \left[\frac{1}{M_{Rm}}\right]^{0.854} \quad \text{(for 80\% reliability)}$$

$$N_f = 0.5161 \times C \times 10^{-04} \left[\frac{1}{\varepsilon_t}\right]^{3.89} \left[\frac{1}{M_{Rm}}\right]^{0.854} \quad \text{(for 90\% reliability)}$$

Now when you take a look at the fatigue the story is the same. See somehow I do not like these kind of symbols. Ideally it should be multiplication symbol. So my request to the young students here is not to use asterisk when you are typesetting your documents but to use the multiplication symbol. And asterisk has a different meaning in mechanics. It is called as convolution, okay? So please do not use that, right? Now let us take a look at it.

So this is the material property, resilient modulus. This is ε_t tensile strain and what is this N_f? This N_f is again 80 kN fatigue, some proportion of percentage of crack. Same story. So here it is strain, here it is damage and this is the process. Now you must be wondering as to why this modulus is also here. I think I have already discussed this. You may want to go back and recollect why the modulus is there. See because if you know the modulus you can compute the strain. So if that is the case why this is here? Take a look at it and these factors such as C are all explained in IRC37, okay? So this is as far as the bituminous mixtures are concerned. So that is the distress part, okay? So now let us go through this stage by stage.

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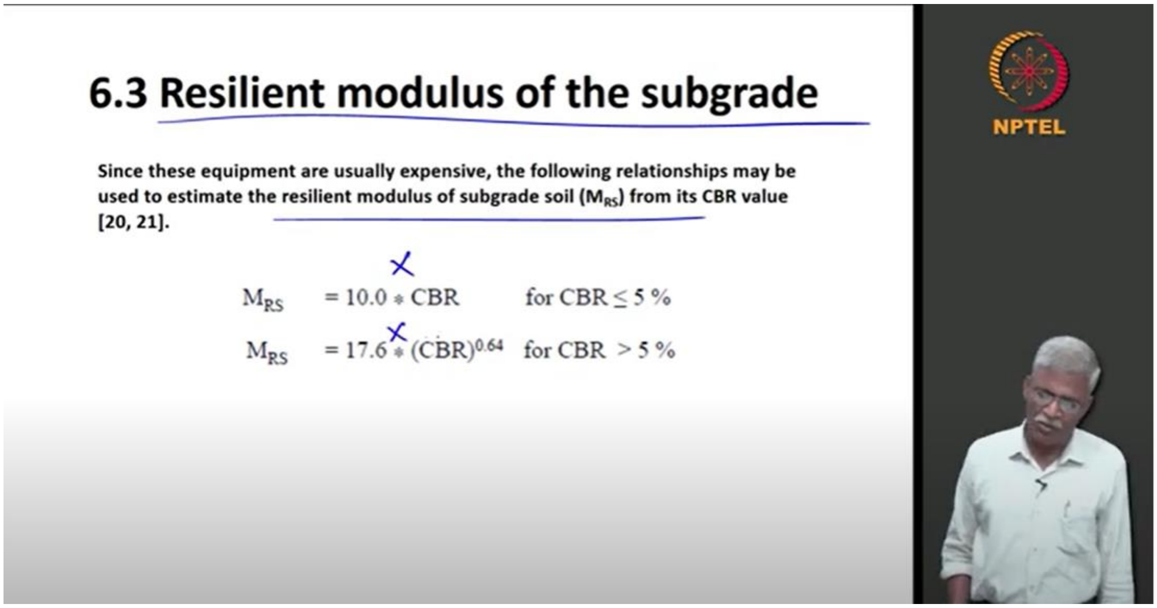

$$M_{RS} = 10 \times CBR \qquad \text{(for CBR} \leq 5\%)$$

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

What did you see? That was the distress part, distress equation. Now let us start putting the material properties. So this is the resilient modulus of the subgrade. Now what exactly is resilient modulus of granular material? You need to basically test it using AASHTO T307 procedure. If you do not know how to measure it just send me a mail and then I will explain to you, okay? So this is the resilient modulus and here IRC gives you a simple short cut. It says if you know the CBR value you can find out the resilient modulus. My suggestion is if you are a practitioner please go to your nearest lab and measure the resilient modulus. But if you are a student who is working out some simple problem, assume in that the resilient the CBR value is 10% and compute the modulus and keep on moving here, okay? Right.

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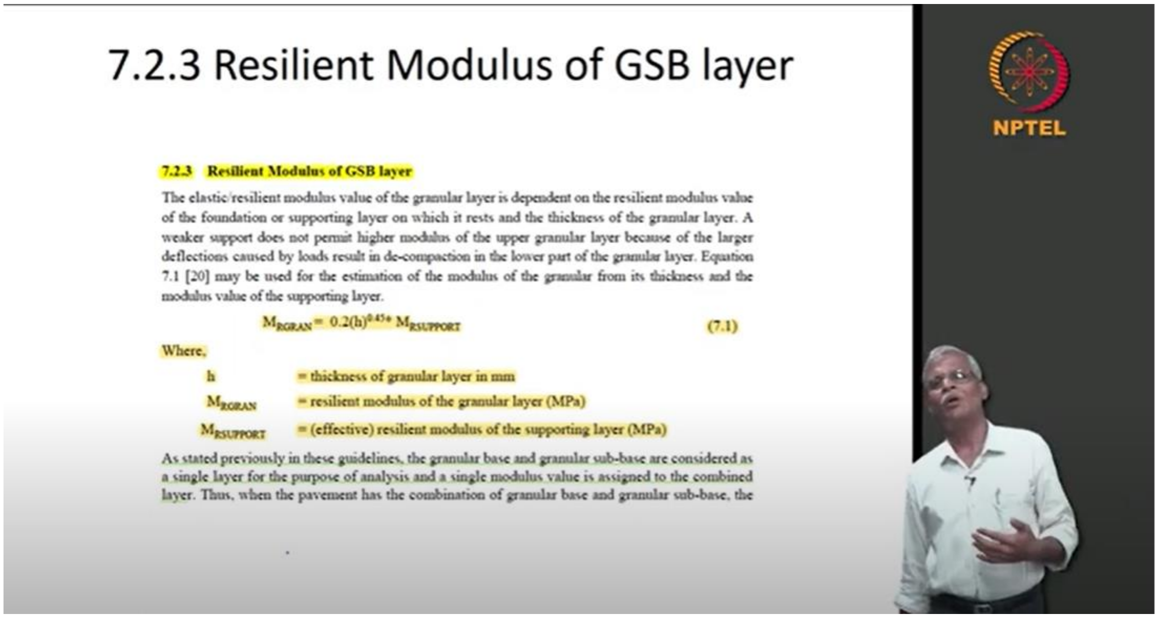

Now we talked about the distress equations. We first talked about the pavement cross section, the design idea. What is the design idea? Where is rutting? Where is fatigue? Then we said okay so these are the equations relating the rutting to the expected design traffic, fatigue to the design traffic. Now how will we compute this ε_t and ε_v? We need to provide the material properties. What are the material properties? Modulus of values for subgrade modulus values for subbase and base and so on and so forth. So there is a resilient modulus of the GSB layer. The expressions are given here. This would have been discussed in detail. They are also available as part of IRC37. You can take a look at it.

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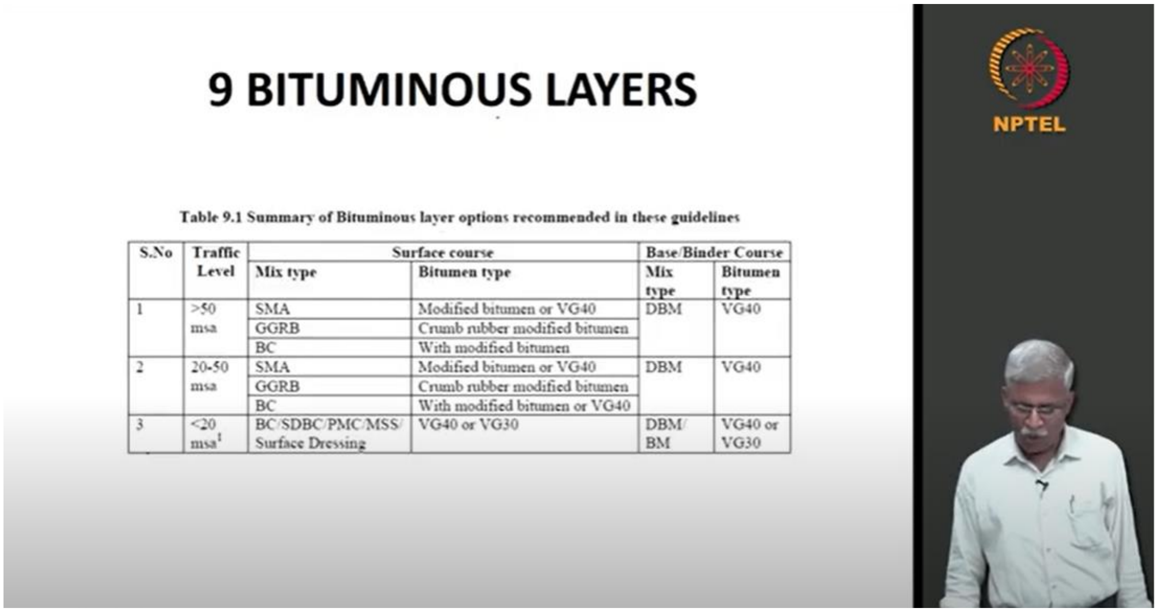

Table 9.1 Summary of Bituminous layer options recommended in these guidelines

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

So you can do that and then now come to the bituminous layer. Now IRC basically says if it is above 50 msa, they say you should use modified bitumen or VG40 and these are the some of the mixes that you are expected to use here. So this is more about layer combinations and so on what they really want you to do.

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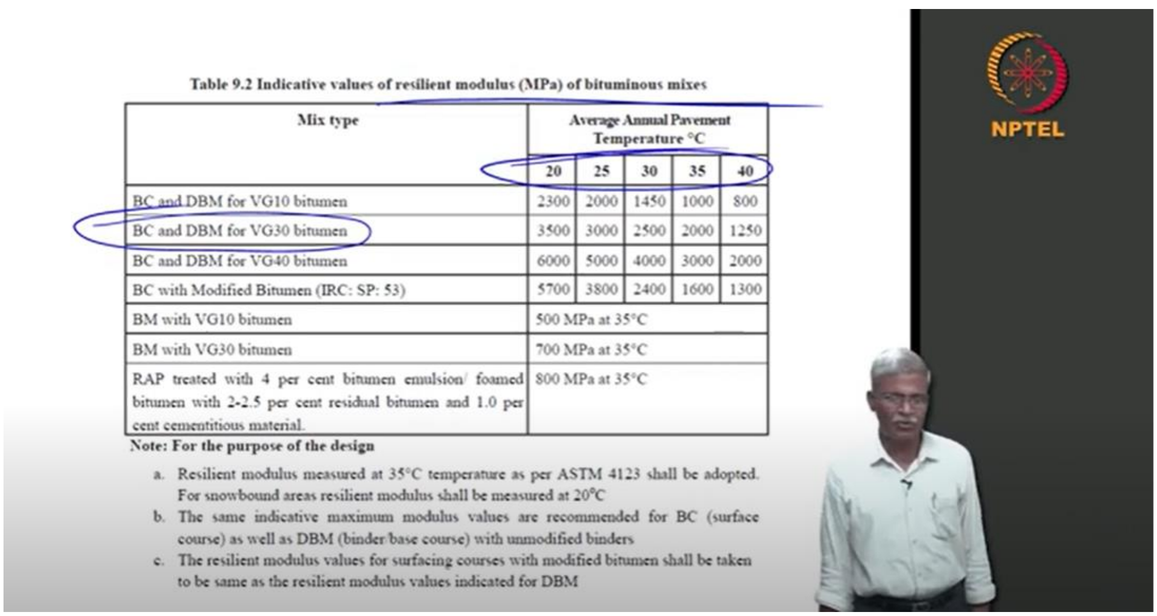

Table 9.2 Indicative values of resilient modulus (MPa) of bituminous mixes

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				

Note: For the purpose of the design

a. Resilient modulus measured at 35°C temperature as per ASTM 4123 shall be adopted. For snowbound areas resilient modulus shall be measured at 20°C
b. The same indicative maximum modulus values are recommended for BC (surface course) as well as DBM (binder/base course) with unmodified binders
c. The resilient modulus values for surfacing courses with modified bitumen shall be taken to be same as the resilient modulus values indicated for DBM

And for all of this they give you some indicative values of resilient modulus of bituminous mixtures. Now one needs to be careful about it. The resilient modulus of granular material is completely different from the resilient modulus of bituminous material. They are measured in a completely different way. The fundamental idea is also completely different. So you need to understand it very carefully. So for instance let us take a look at VG30 bitumen. There are three, four temperatures that are given here 20, 25, 30, 35 and 40 and they also tell you that this is average annual pavement temperature. Now this is a very important assumption that they make that it is the average annual pavement temperature. Again I am talking more from the general perspective of pavement design. So I will not get into the detail about how is this average annual pavement temperature computed. But what they are telling you is to take an average value and they also give you tentative guide lines here.

Now read this carefully. Resilient modulus measured at 35 ^{o}C as per ASTM D4123 shall be adopted. Now there is a small problem here because it is IRC is aware of it. This ASTM D4123 is withdrawn. In lieu of ASTM D4123, ASTM D7369 is has been introduced and that is a kind of tedious complex method. So what a IRC says look there is only one difference. What is the gauge length that you use? In ASTM D4123 you assume a Poisson's ratio of 0.45. You measure the horizontal deformation and then you use a simple formula to compute what is the modulus. In ASTM D7369 you do not assume a Poisson's ratio. You actually compute the Poisson's ratio because you measure not only the horizontal deformation you also measure what is called as the vertical deformation. So but there are also philosophically there are big differences between these two code. I am not going to get into that but what I really want to emphasize is the following. That there are 3, 4 temperatures that are given. There are indicative bituminous mixtures values are given. So what as a pavement designer what will bother me is so you are telling me that I should use a modulus value for a temperature corresponding to an average value. So that means you are not going to ask me to use high temperature separate equation, low temperature separate equation, separate modulus value. But you want me to use the modulus value that is an average of high and low temperature. So that is where the crux is.

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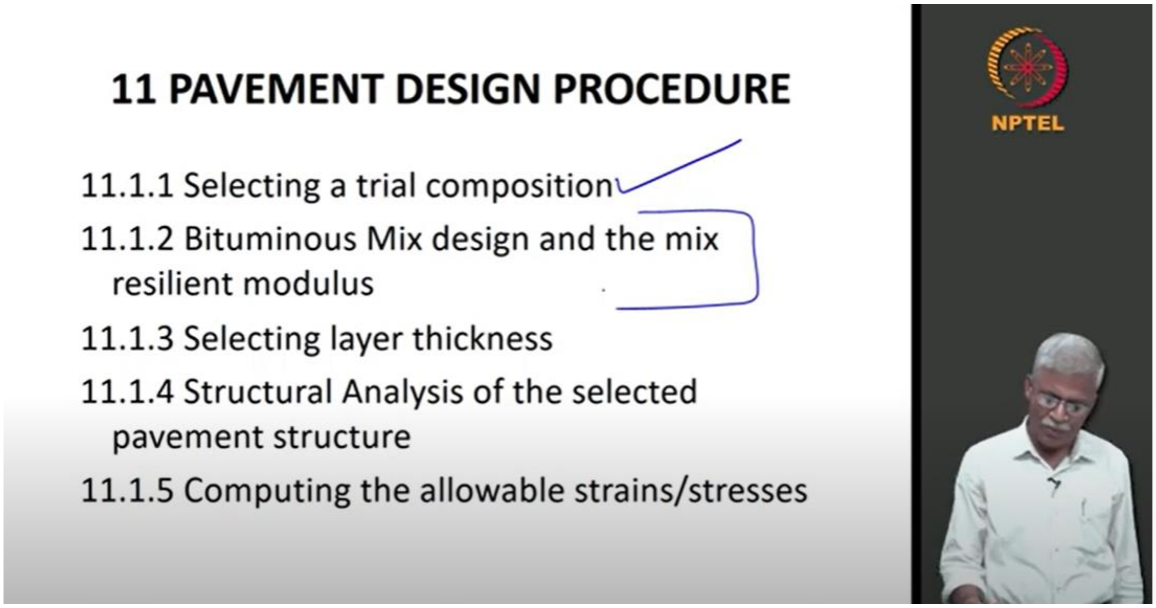

So what is the procedure that they ask you to do? They ask you to take a trial composition. Remember this very carefully this is a proof of the design. You are not doing a new design. So you will pick one trial combination. Then typically what you should do as a pavement engineer you should do the mix design immediately and then find out the material property. Now this needs to be emphasized here very carefully. If you are doing a concrete slab design or concrete beam design is you assume a M20 or M30 concrete. The construction site knows very clearly how to make that M20, M30 concrete. There are procedures systematically followed. IS 456 will tell you if you know the grade of the concrete what is the modulus value, flexural stress to properties that you need to use. They are also given very clearly. So that means the mix design and the structural design, the modulus value used in the structural design are intricately connected. That is not the case here. So that means you might pick a 3000 MPa VG40 bitumen at 35 ^{o}C. But it is no guarantee that you will use a mix that you have designed in the lab which will have 3000 MPa.

So you need to understand this very carefully. So that is the mix design and then measure the mix resilient modulus, select the trial thickness, layer thickness and do the structural analysis. Use either KENPAVE or IITPAVE. They are the same and compute the allowable strains and stresses here.

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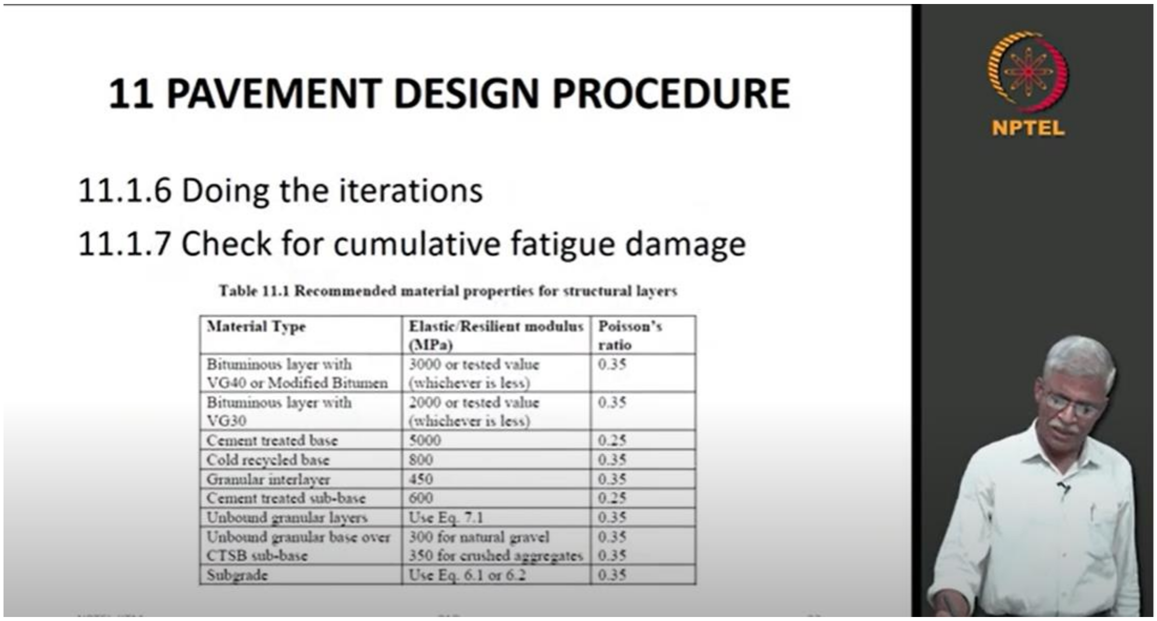

Do the iterations, check for cumulative fatigue damage and it keeps going like this. Now when they worked out some sample guidelines, they have used some of the following properties. And in fact you can actually take a look at these things. So you can actually see 3000 MPa with VG40 bitumen, 3000 MPa with VG40 bitumen corresponds to 35 ^{o}C. So 35 ^{o}C for annual average pavement temperature, there are and for the various subgrade values, modulus values, there are designs that have been worked out.

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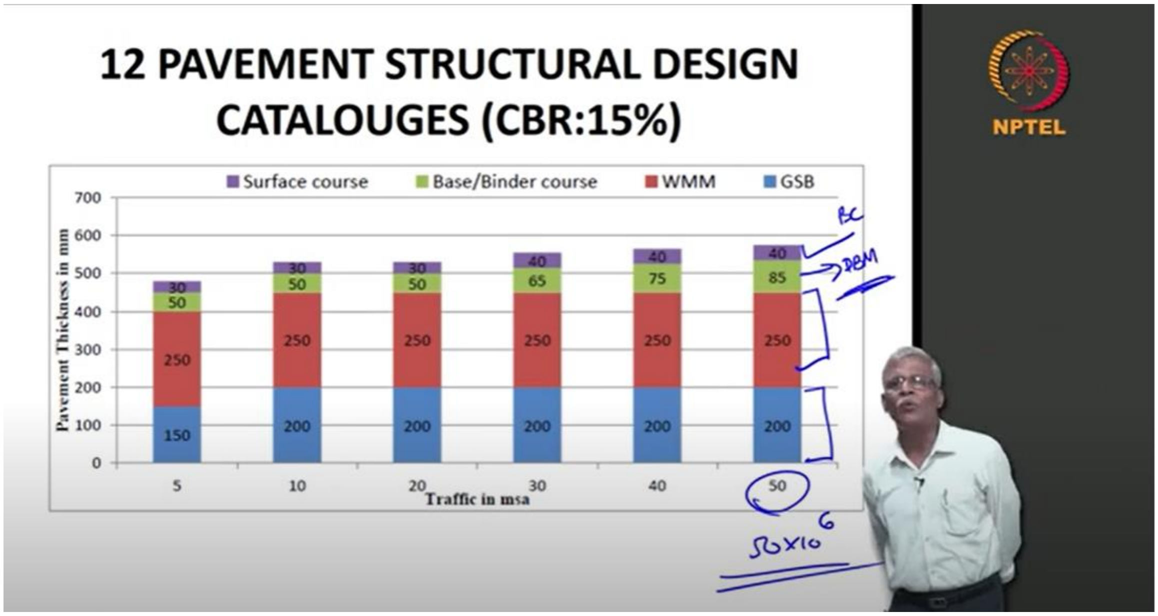

Now you see this design. So this is where the main issue is. So there is a surface course 40 mm, I am talking about 50×10^6. So 200 mm is granular subbase. This is your wet mix macadam. This is your DBM and this is your BC. Now how will you proof check this design? What you will do? You will use all the modulus properties corresponding to it. Find out what is the ε_t here. Find out what is the ε_v here and go back substitute this in this equation or in this equation and check whether the cross section that you have provided can handle more than 50×10^6. If it can handle more than 50×10^6, then you basically say that okay so I have done a good design here. Now the catch. What is the catch? What if you are able to meet horizontal tensile strain and not vertical compressive strain or vice versa? What should you do? So you need to keep iterating this process.

Now this is all worked out for 35 ^oC. What if you have to work it out for 30 ^oC? So let us say you come from a location where the AAPT that particular temperature, this temperature, average annual pavement temperature is 25 ^oC. Now you will be using 5000 MPa. So what will happen when you use the 5000 MPa? You do not need this much thickness. You need a different thickness. How do you work it out? Which cross-section you should change? And in fact if you look at it very carefully, you will see that from 10 msa to 50 msa, the thickness of the granular layer sub base as well as the wet mix mechanism remains the same. So that means you can actually do whatever you want here. I think it is a nice strategy because you know when you really want to scale up your, so if the traffic repetitions are more and you are doing a rehabilitation and all those things, you need to add, keep adding different layer thickness and so on. And at the time you do not want to start digging all the way up to the granular layers. You do not need to do that. So that is the whole idea that is given here. So when we talk about the design project, we will do it. So this is for CBR 15%, this is for CBR 5% and the thickness values are completely different.

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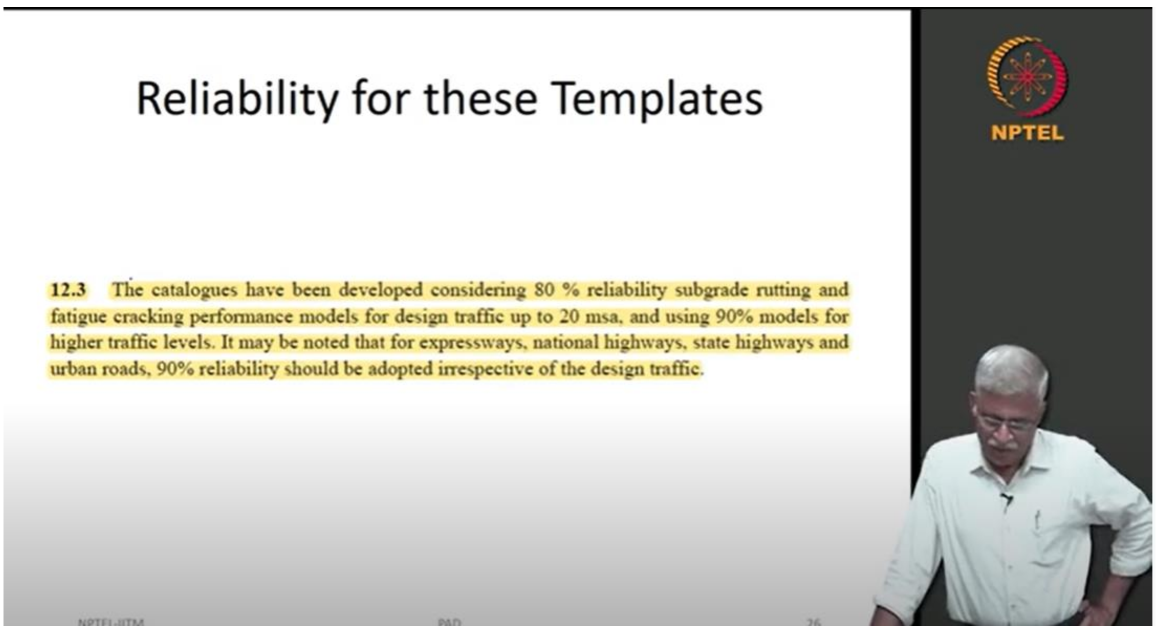

Now the catalogs have been developed considering 80% reliability subgrade rutting and fatigue performance models for design traffic up to 20 MSA and using 90% models for higher traffic level. In fact, they tell you clearly that for national highway, state highways and expressways, you should always be doing 90% reliability and so on and so forth.

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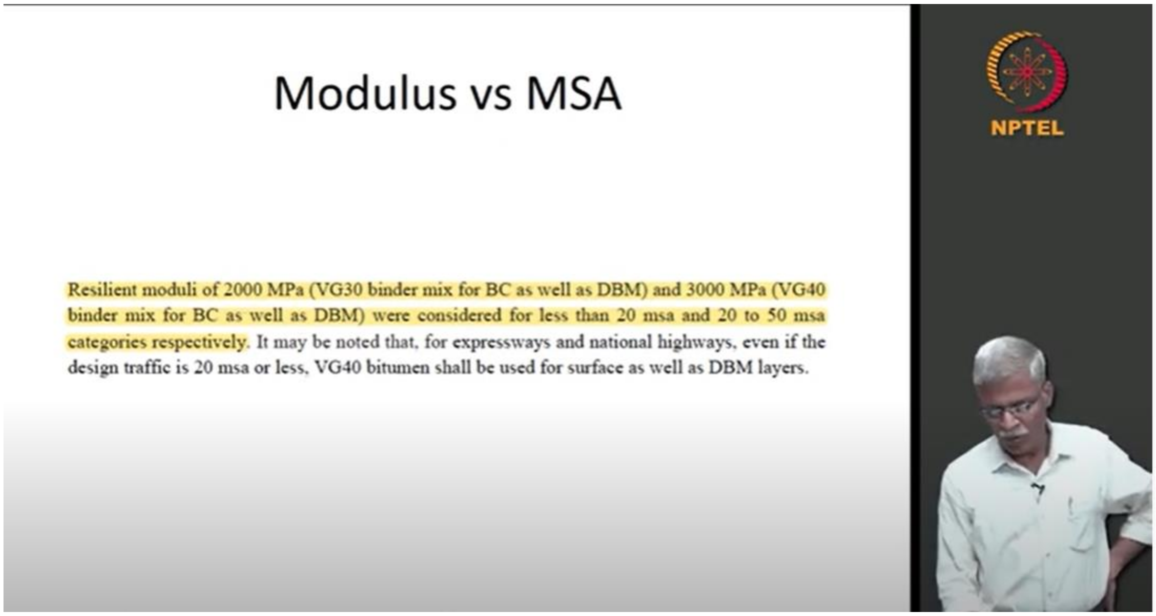

And it will also be noted that resilient modulus of 2000 MPa and 3000 MPa were considered for less than 20 msa and 20 to 50 msa categories respectively. So now for your location, if this is 4000 MPa, what should you do? Because this is a design guideline, they would like to give you worst case scenario, but you do not want to really work on that, you want to do something more.

So how do we really do that? So what I am going to do is, I have given you now a general overview of IRC37 from a broader perspective. So to reiterate, these are all the following steps. Take a cross section, look at assumptions related to the critical strain locations, number one. Then number two, how do you relate your traffic, bring it down to one common denominator, 80 kN standard axle load, that is what you did. Now is it necessary that I have to do it? No, we will see later that it is not necessary to do that, except that the calculations become tricky, that is number two. Then number three, what is this mechanistic part here in IRC37 and the empirical part there, the mechanistic part is computing this stress and strain for any given modulus using a layer theory program. What is the empirical part? How do you relate the strains to failure? Failure in terms of rutting, failure in terms of fatigue, that is the empirical part here. What are the, so there is a mechanistic empirical distress transfer functions are given for different reliability for rutting, different reliability for fatigue, they are given there. Now what is the next thing that you need to do? Material properties are given, sample material properties are given, it is suggested that you measure, but if you are not able to measure, they give you some idea about these are the modulus values that you should use, you use those modulus values. Then after that what you really want to do? You do the computation, find out the stresses and strains, substitute it in this equation, check whether it meets your traffic, expected traffic, right, for different reliabilities.

Now what is the main crux here? The crux is what is the average annual pavement temperature, that is the main crux. What, how do we really take all the traffic spectrum and put it in terms of 80 kN standard axial load. Now what about the distresses? Different layers will have different distress, is it taken into account? No, there is only one distress that is taken into account for the entire bituminous layer in terms of fatigue. One rutting parameter is measured only at one particular point. What if we measure it at all the particular points, so that means you will have different distress functions for different layers. These are the things that we are going to talk in the subsequent lectures. Thank you so much.