Analysis and Design of Bituminous Pavements

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Lecture - 41

IRC design steps

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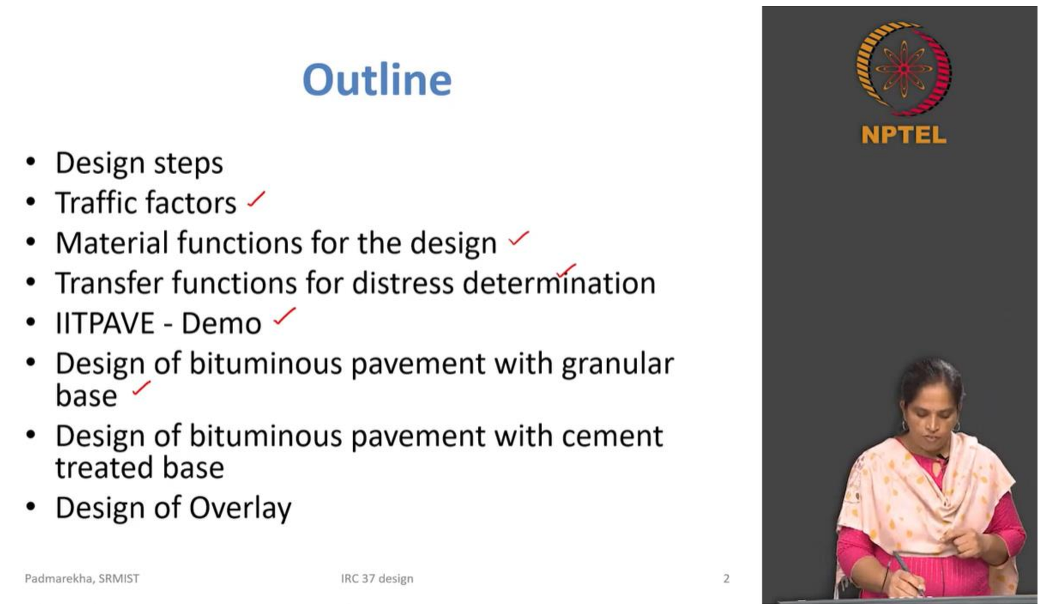

In this lecture, I will introduce IRC 37 design guidelines for the design of bituminous pavement. This is the outline of our presentation. First, I will explain the design steps involved in the design of bituminous pavement followed by different inputs that are required for the design. The input here is grouped into two, one is related to traffic factors. We know that the traffic for the design is considered in terms of the number of repetitions of standard axle loads. So, for the computation of the number of repetitions of a standard axle load, we need traffic volume, vehicle damage factor, lane distribution factor, and traffic growth.

We will see IRC specifications related to these traffic parameters under this head. The second group of input here is material functions that are used for the design. The two main material functions used for the computation of stress and strains are a modulus parameter and a poisson's ratio value. There are some other important indirect inputs that go into the design of pavement.

So, we will see IRC specifications related to material functions under this head. So, once we determine critical stresses and strain, so this stress and strain have to be transferred to a distress function. So, we do this using transfer functions. So, IRC recommended transfer functions are listed in this head. IRC uses software called IITPAVE for the computation of critical stresses and strain.

So, we will also have a demo of the IITPAVE software. Once we are familiar with the usage of IITPAVE software, we will see a critical example for the design of bituminous pavement with a granular layer and for the design of bituminous pavement with a cement treated layer and finally, we will also do one overlay design after estimating the existing life of the pavement.

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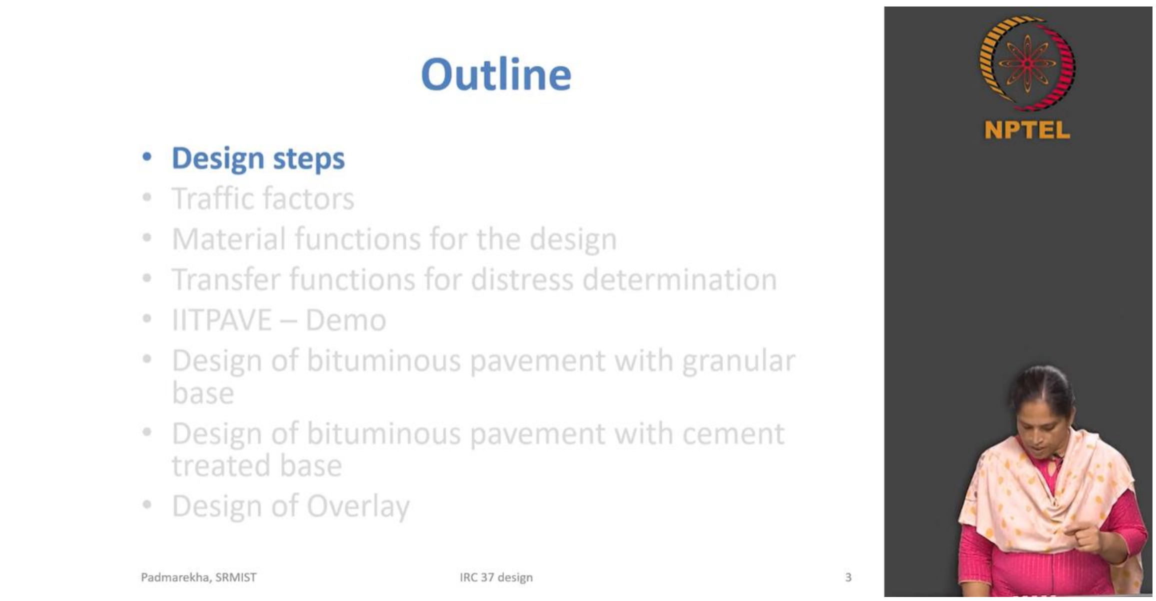

First, we will start with the design step here.

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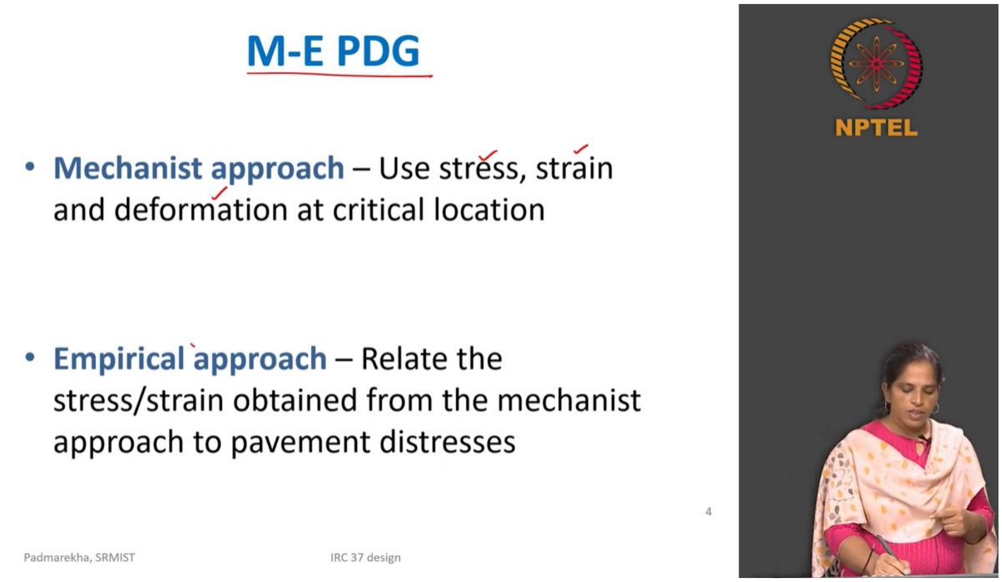

This IRC guideline is called a Mechanistic-Empirical Pavement Design Guideline or MEPDG. This is mechanistic because it uses linear elastic theory in computing stress, strain and deformation at critical locations. The computed stress-strain values are further used in determining distress at different locations using empirical equations which is why it is combined called a mechanistic empirical approach.

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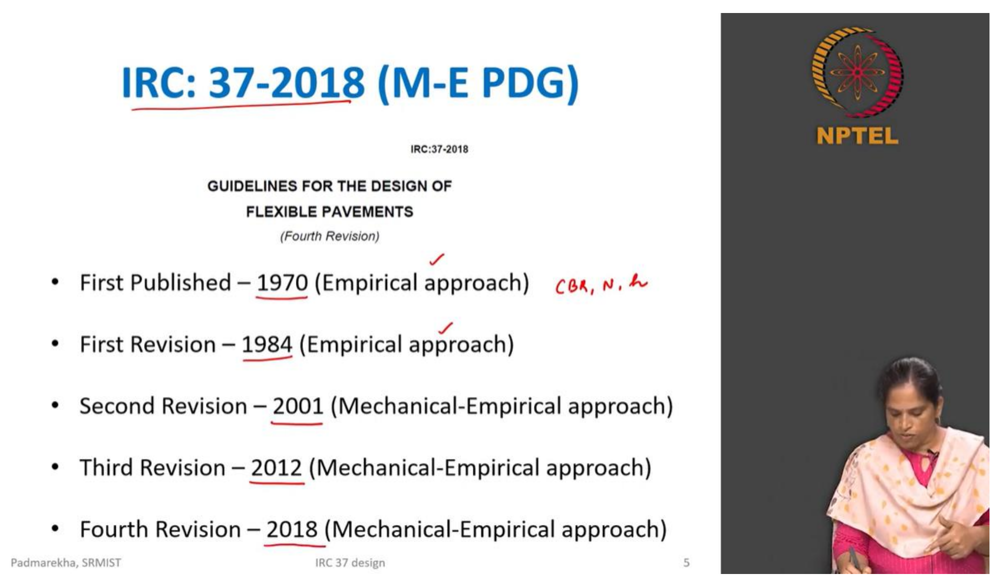

The current guideline is IRC 37: 2018, but this IRC 37 was first introduced in 1970 and the first revision was made in 1984. In both versions, the designs are based on the empirical approach. This is an empirical approach because we have design charts relating CBR value, the number of repetitions of a standard axle load to the total thickness of the pavement, and this design charts were made based on the empirical relations. The mechanistic approach was first introduced in the second revision made in 2001.

The layers of bituminous pavements are assumed as linear elastic, and the stress and strain at critical locations are computed using FPAVE software. And these critical stresses and strains are related to distress in the pavement. The distress initially considered was rutting in the subgrade layer and fatigue damage in the HMA layer. In the third revision made in 2012, the reliability functions were introduced in the computation of distress and the use of new materials such as RAP binder and emulsion mixes are introduced. In the fourth revision, the feedback received from the academic experts and industrial experts were introduced and the current version is the fourth revision of IRC 37.

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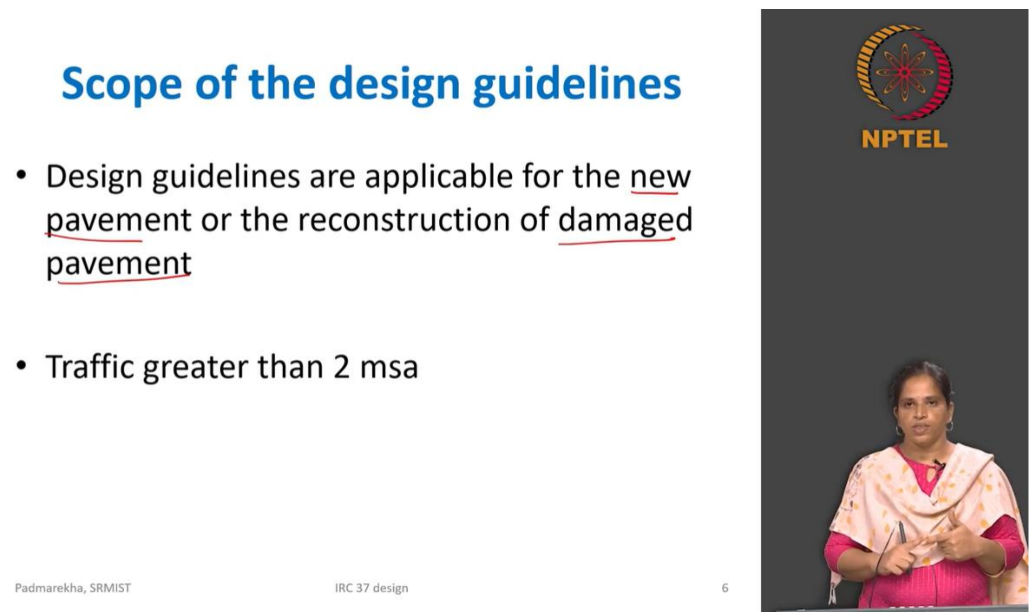

These design guidelines are applicable for a new pavement design as well as for the design of damaged pavement. We use these guidelines for the design of pavements where the traffic is greater than 2 million standard axle load. These are detailed steps involved in the design. We call this IRC method of design a proof-checking method of design. This is because we select the trial section and check the design criteria for the specific trial section. If the design criteria are met, we say that the design is viable. Otherwise, we go modify the trial section, redo all the computations, and check the design criteria to check whether the design criteria are met or not. So, this process is iterated many times till we meet the design criteria.

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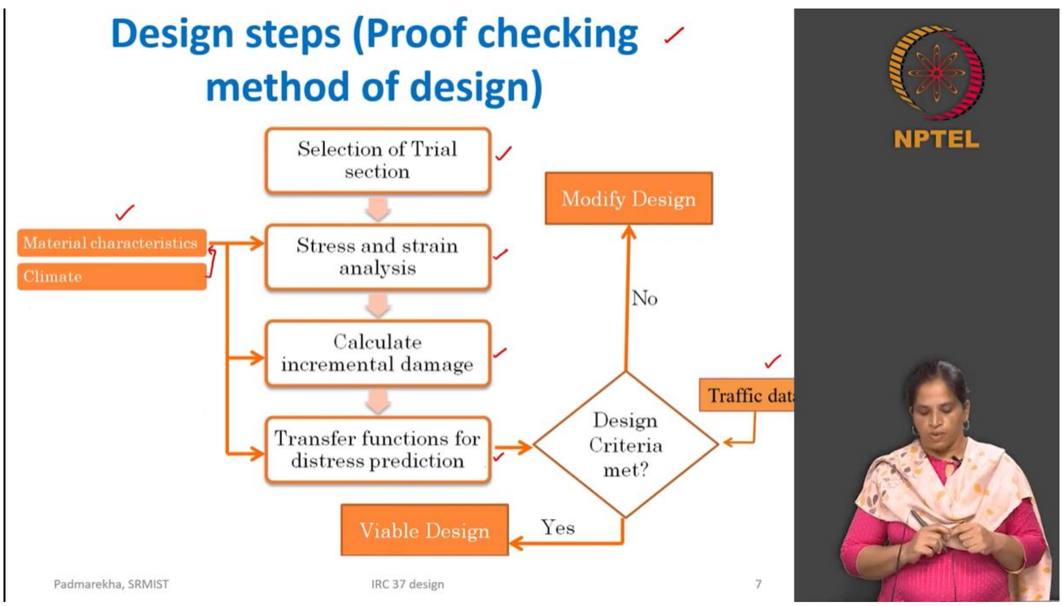

In the assumption of trial sections, we need data such as what should be the number of layers here, what should be the thickness of each layer and what is the material property for each layer here. So, once we get the trial section, we compute stress-strain at critical locations assuming each layer to be linearly elastic. For this purpose, we need a material characteristic function. For the selection of material characteristic functions, you also have to keep in mind this material functions depends on the climatic conditions. The selection of material greatly depends on the geographical locations of the pavement here. Once we calculate stresses and strain, these stress strains are transferred to distress in the pavement and we check whether the distress that we predicted is meeting our design criteria. So, for this purpose, we also need traffic data in terms of number of repetitions of a standard axle load. If the design criteria are met, we say that the design is viable. If it is not met, we go modify the trial section and repeat this process till we get the viable design here. IRC 37 recommends a five layer structure for this purpose. The top two layers are bituminous material.

For the surface layer we expect to be a rut-resistant layer, and second layer we expect it to be a fatigue damage resistant layer. For the use of the surface layer, IRC recommends using bituminous concrete, stone mastic asphalt or a semi-dense bituminous concrete, and these layers are expected to be a rut resistant layer. For the binder course, IRC recommends using a dense bituminous macadam layer and a bituminous macadam layer as these layers are more fatigue resistant. So, the base layer and subbase layer can be a granular layer or it can be a bonded layer. In case it is a granular layer, the typical example is a wet mix macadam layer and water bound macadam layer.

In case we use a cement treated layer, any cementitious materials like cement, lime, fly ash or soil, or a combination of these materials can be used for the preparation of cement treated layers. So, the both base course and subbase course can be a cement treated layer or it can be a granular layer. The bottommost layer is a compacted layer of at least 500 mm thickness and we call this a compacted subgrade layer. So, we need layer properties corresponding to these 5 layers for the design of pavements. In case you see the layer properties such as modulus value and poisson's ratio values are similar to the bituminous concrete, you can combine and consider both the bituminous layer to be a 1 layer, and if base course and sub base course are granular layers and it layers properties are nearly similar, you can combine both these layers as a base and subbase course to be as a 1 layer for the design purpose. In such case, you will have a 3 layered structure for the design alone.

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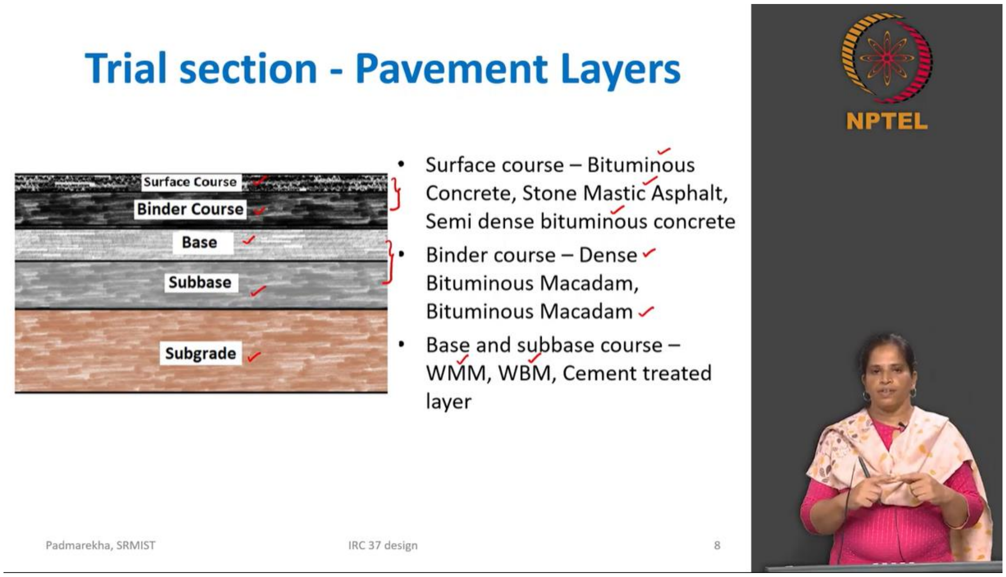

With this 5 layered structure, IRC recommends 6 different combinations for each layer, one typical combination of the cross section is shown here. In this cross-section, it includes rut resistant layer as a top layer and fatigue resistant layer as a second layer, both these layers are HMA layers. So, this HMA layer rests on a granular base and granular subbase, and the bottommost layer is a compacted subgrade soil. You have a 5 layered structure in case if you provide a granular base and granular subbase, you have 2 critical analyses to be conducted, one is a fatigue damage analysis and this fatigue damage is assumed to occur.

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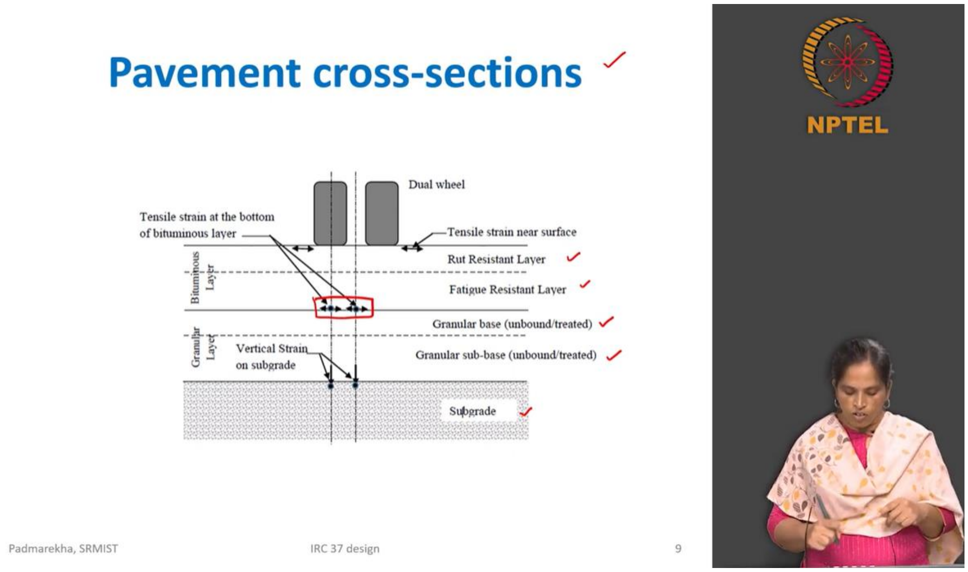

We know that the pavement is a 5 layered structure and IRC recommends 6 different combinations for 5 layers, one typical cross section is shown here. In this cross-section, the pavement consists of 2 layers, one top layer is a rut-resistant layer and the bottom layer is a fatigue resistant layer. This asphalt layer rests on a granular base and granular subbase and compacted subgrade layer. If you provide this kind of a combination, we need to perform 2 analyses here, one corresponds to the fatigue damage of the asphalt layer and that is induced by tensile strain at the bottom of an asphalt layer. In addition we also need to check with the rutting of a subgrade layer and that is induced due to vertical strain at the top of a subgrade layer.

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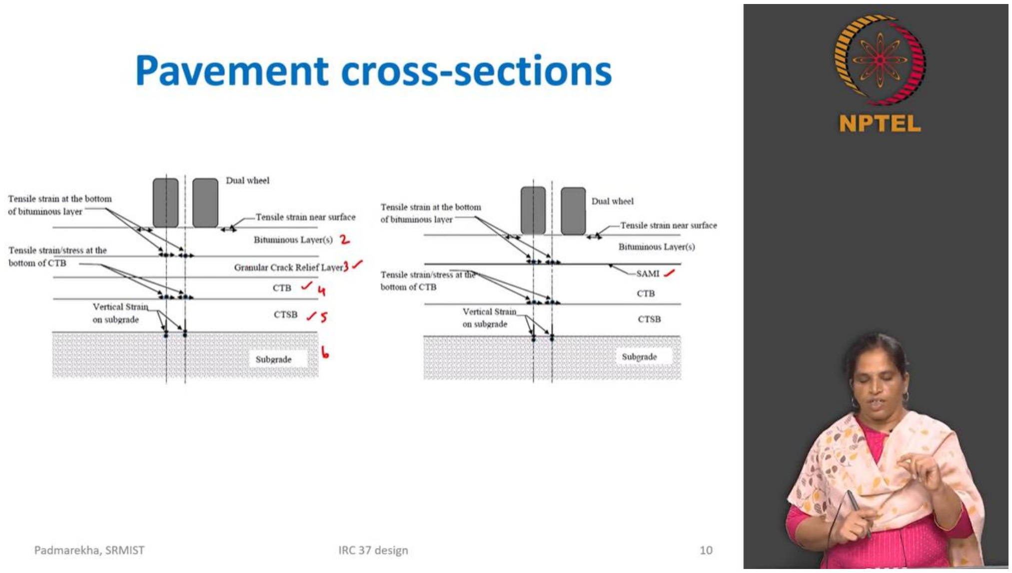

The second combination recommended by IRC is the use of cement treated base course and cement treated subbase course. We go for a cement treated base course, if the stress in the bituminous layer is excessive or if the granular base course thickness is too high to provide. In such case we go for a cement treated base. So, this cement treated base is a stiff layer, it will reduce the tensile strain at the bottom of an asphalt layer. In case if you provide a cement treated base and cement treated subbase course, we know that cement treated base layers are more prone to cracking. So, there are chances that the crack from the base layer propagates to the top surface. To prevent the crack from propagating to the bituminous layer, we need an additional crack relief layer here between the cement treated base course and a bituminous layer. This crack relief layer can be a granular layer or stress-absorbent member interface layer. If it is a granular layer, you can imagine a compacted granular layer of 100 mm thickness. This granular layer is considered as one of the structural layers for the design purpose. So, if you provide this granular layer, the number of layers used here includes, if bituminous layer if it is a 2 layer, and this is a third layer and this is the fourth, fifth and sixth layer structure.

In case you use a stress-absorbent member interface layer, you can imagine an asphalt mastic layer of 25 mm thickness as a stress-absorbent member interface layer. In such case, we do not consider this stress-absorbent member interface layer as a structural member and we consider it as a 5 layered structure for the analysis.

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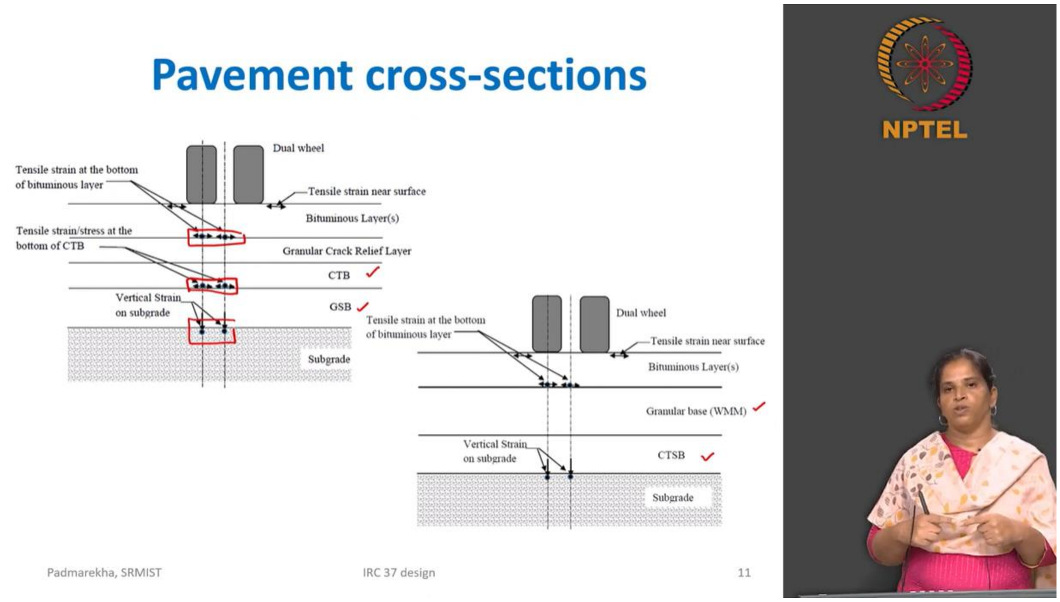

The next combination recommended by IRC 37 as either a base course or subbase course is considered a cement treated layer. We have here the base course as a cement treated layer, subbase course as a granular layer. In the next cross-section, you have subbase course as a cement treated layer and a base course as a granular layer. So, if you provide a cement treated base course, you need a crack relief layer here. If the cement treated subbase course is provided, the above base course itself will serve as a crack relief layer and you do not need an additional layer in this case. So, in case you provide a cement treated base course, you need an additional analysis in addition to HMA layer fatigue and subgrade rutting. We need to check for the cracking in the base course. So, we know that the tensile strain at the bottom of a layer will be critical for cracking.

So, we determine tensile strain at the bottom of a cement-treated layer and we check for damage in the cement treated layer. If the damage exceeds the allowable value, you can just go for increasing the thickness of the cement treated layer and redo the design process till we get this tensile strain at the bottom of a cement treated layer within the allowable limit.

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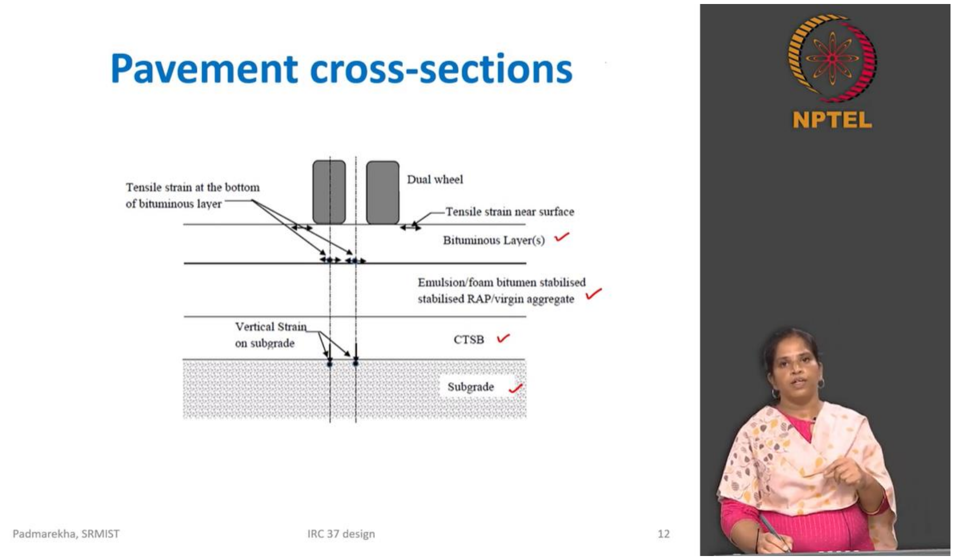

The final cross-section recommended by IRC 37 uses emulsified bitumen or RAP bitumen in the base course. So, this cross-section again is a typical 5 layered structure with 1 or 2 layers as a bituminous layer. The base course is considered here as a RAP material or emulsified bitumen. This base course rests on a cement treated base, subbase and on the compacted subgrade soil. So, when you use emulsified bitumen or RAP bitumen on the base course, we consider this as a granular material and use a modulus value corresponding to that specific granular material and we do the design here.

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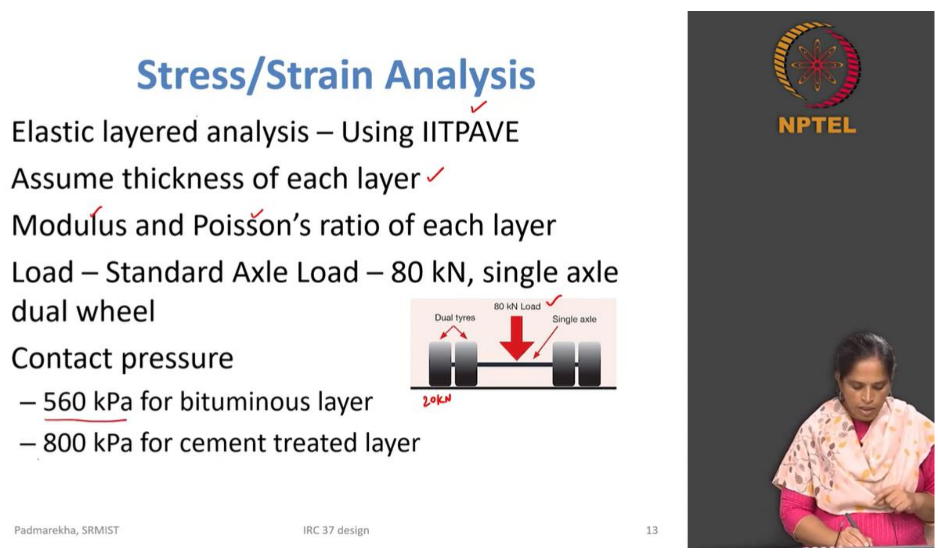

Once we decide upon the layer combinations, we need to determine critical stresses and strain. For this purpose, we use IITPave software here. IITPave software assumes each layer to be a linearly elastic layer and determines stresses and strains.

For this purpose, we need to assume the thickness of each layer, give the modulus and poisson's ratio of each layer as an input. The layer structure is subjected to a traffic load that is a standard axle load here. We consider 80 kN single axle dual wheel as a standard axle load. If you have a total of 80 kN with a 4 wheel on it, so each wheel will carry 20 kN load. So, this 20 kN load, will give a pressure of 560 kPa on a bituminous concrete layer and 800 kPa on the cement treated layer. So, we use these contact pressure for the design.

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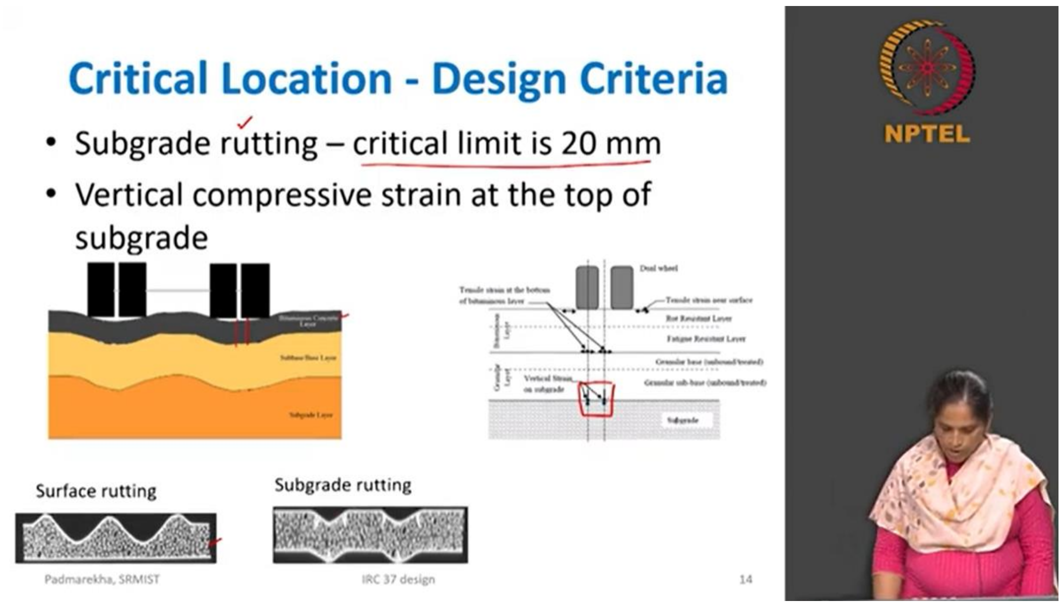

Once we determine critical stresses and strain, we need to relate this to the distress. We have seen that we have typically two different distress, one is a subgrade rutting and the other is fatigue damage distress. So the rutting can happen on any of the individual layers or it can happen on the subgrade layer. If the rutting happens on the top surface, when you core the sample, you will typically see that the bottom of the surface will be straight and the top surface will have a permanent deformation.

So, this rutting is considered by taking care of a rut resistant material used in the top layer. When the subgrade ruts, you can see that the subsequent layer above the subgrade ruts and the top surface when you core it, you can see the rutting in both the bottom and the top of the layer here. So, the design includes only the subgrade rutting and not the rutting related to the subgrade here. So, we determine the critical strain that induces the subgrade rutting which is a vertical compressive strain at the top of a subgrade and we convert this to a rut depth. So, the critical limit of a rut depth is considered as 20 millimeter rut depth. So, we say that the pavement fails in subgrade rutting if the rut depth exceeds 20 mm.

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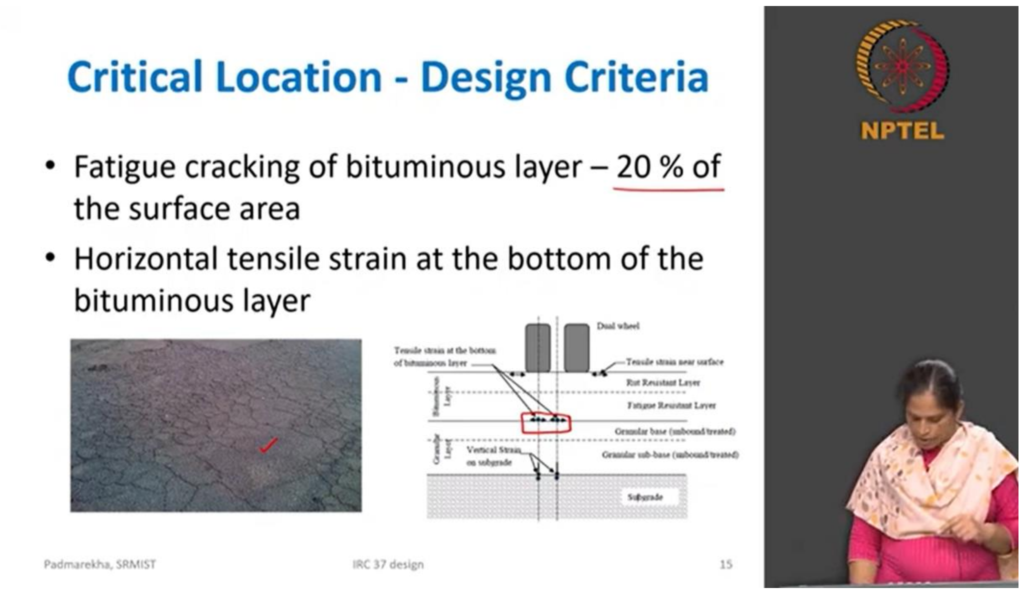

The next distress is fatigue damage distress. We know that tensile strain at the bottom of an asphalt layer induces fatigue damage. When the tensile strain exceeds you can see the crack from the bottom propagates to the top surface and the typical cracks look like this. We measure crack in terms of a percentage area and the critical limit is considered as 20 percent of the area to be a cracked area. So, when the cracked area exceeds 20 percent surface area, we say that the pavement failed in fatigue damage.

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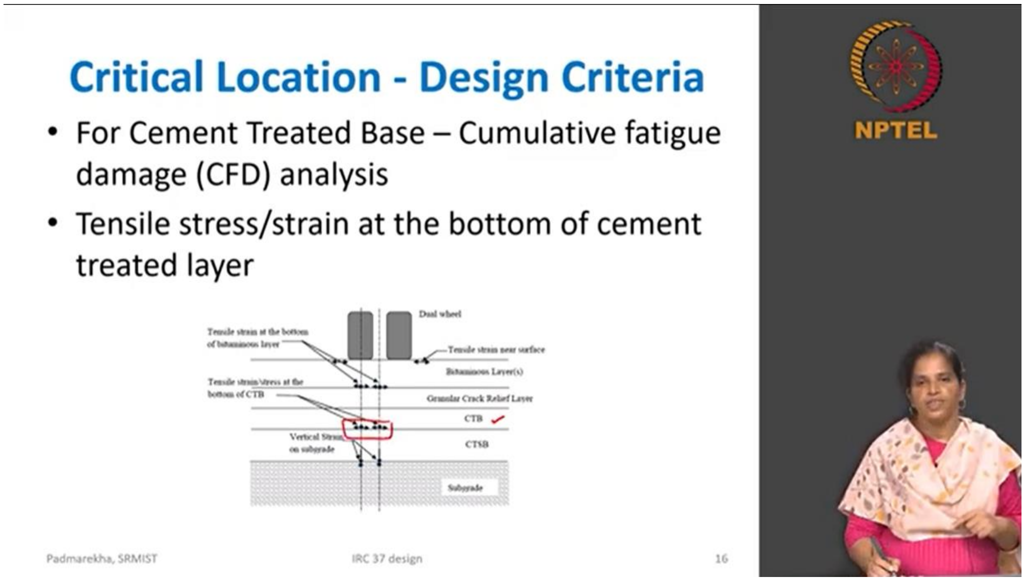

In case you provide a cement treated base course, we need to do an additional analysis here to confirm whether the cement treated base is without any cracks. You assume a thickness of a cement treated base course and determine tensile strain at the bottom of a cement treated base, compute the damage ratio, and check whether the damage ratio is within the allowable limit. If the design damage ratio exceeds the allowable limit go for the increase in thickness.

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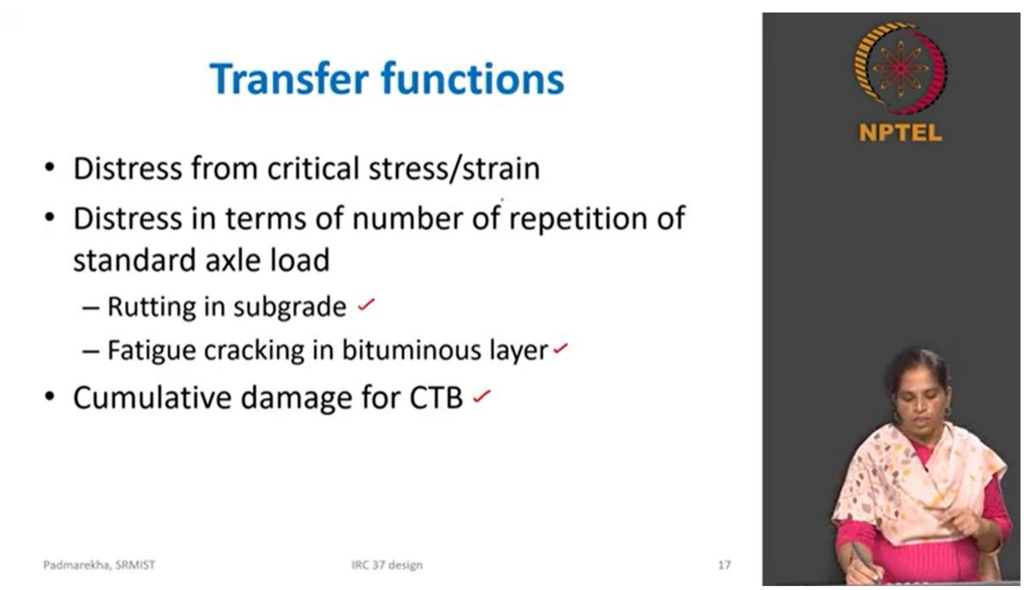

So, these are the 3 typical analyses we need to compute and for this analysis purpose, we need a distress function. So, one distress function corresponds to rutting, another distress function corresponding to fatigue damage, and a cumulative distress function related to cement treated base course. These distress functions are in terms of the number of repetitions of a standard axle load. So, we can relate the traffic conditions and the results obtained from these distress functions.

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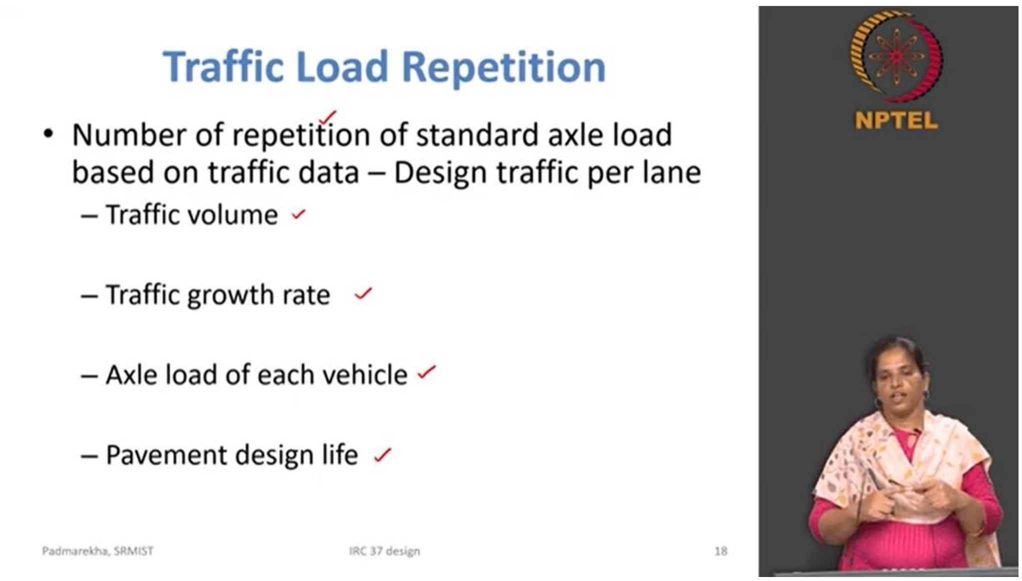

We need traffic data for checking with design criteria here. So, we consider traffic in terms of the number of repetitions of a standard axle load. For this computation of the number of repetitions of a standard axle load, we need traffic volume, traffic growth rate, axle load of each vehicle, and the pavement design life.

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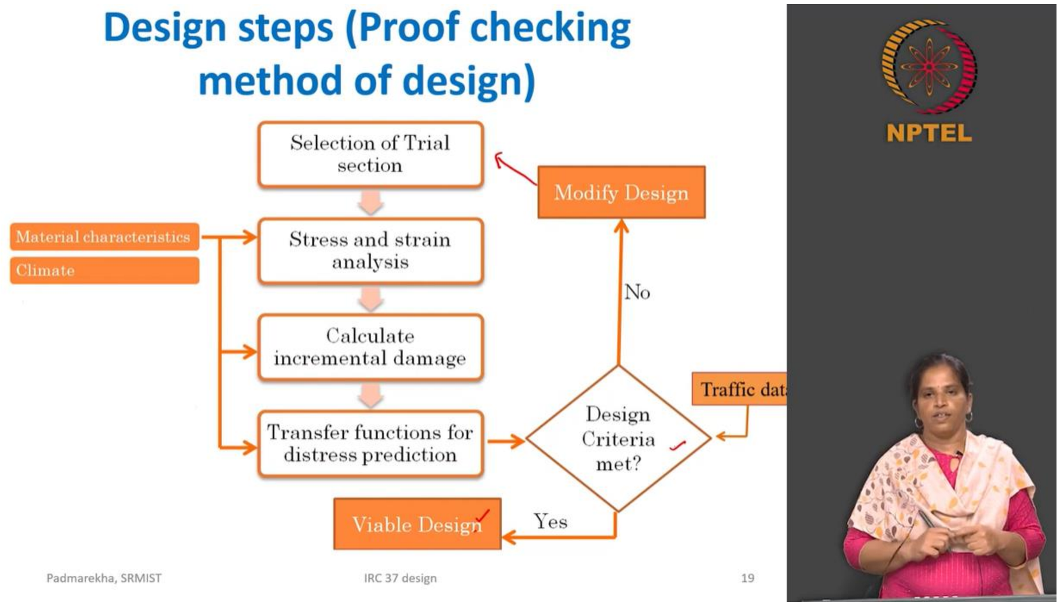

So, now with all these data you can compute the number of repetitions of a standard axle load and check whether the design criteria are met here. If the design criteria are met, we say that the design is viable, otherwise, if the rut depth exceeds 20 millimeters or if the fatigue damage exceeds 20% of a cracked surface in terms of the number of repetitions of a standard axle load, you go modify the design. The qualifying design includes different trial sections, it can be different thickness or the use of different layer combinations, so as to get the viable design here. In the next lecture, we will see what are the traffic factors to be considered for the pavement design. Thank you so much.