Analysis and Design of Bituminous Pavements

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Lecture – 54

Summary of the Course and Design Projects

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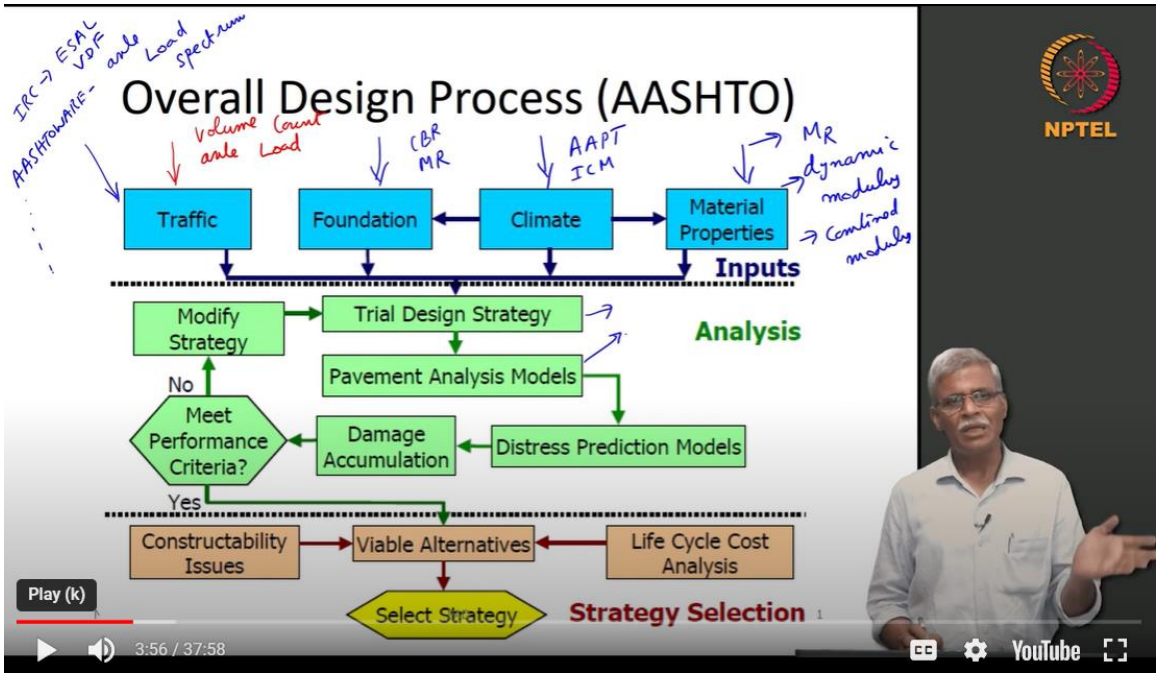

So, welcome back to the last lecture. So this is the last week and this is going to be the last lecture for this course. So what I am going to do is the following, I am just going to give you a brief summary of what we covered till now and I am also going to talk to you some interesting ideas related to the design projects. In fact, my take off for this course is very simple. I have been teaching this at IIT Madras from 2004 almost continuously for 18 years and I always find out that whenever you teach any design course only when the students actually solve a practical problem. So what I do is more or less the same content is covered except that we will also add lot more the mathematical aspect related to reliability and give them an axial load data, tell them that this is some location in the country, go do the design. So they have to hunt and find the weather information, material characterization, do the analysis of the traffic, then do the design as per AASHTO, IRC, South African, Australian and so on and so forth and then they submit a final design report in which they list the

various thickness that they are going to get. And most of the students are able to make the connections and that is the most important thing as far as the teaching a design course is concerned.

So let us go back to the starting point, this is where we started and this is where we are also going to end. So the overall design process is the following. So now you know what this means. So this is traffic you know very well. So you are talking about volume count, you are talking about axial load. Now depending on the country where you live, you can analyze this in different ways. So if it is IRC, you are going to talk in terms of ESAL, VDF and so on and so forth. If it is going to be AASHTO where you are going to talk in terms of the full axial load spectrum. So there are many different ways of handling this. So this is as far as the traffic is concerned. Now let us talk in terms of the foundation. So again should we use CBR, should we use resilient modulus, what we need to do? So that comes here and then if you are talking about climate, are you talking in terms of AAPT or are you talking in terms of integrated climate model, what is that we need to do? That also is clear. Now all these are related to the material properties. So for bituminous, so you want to measure resilient modulus or do you want to measure dynamic modulus or you want to measure the combined modulus, all these things come here. So these are the inputs, there is no problem in the inputs and these inputs are handled in different ways by different countries. There is no problem there. Now as I said this is always proof checking and again you come to the pavement analysis.

Depending on the country you look for, you can either use the integral transform techniques or you can use the layered linear elastic theory and this is what it is. So if it is going to be IRC 37, there are going to be only 2 distress equations and 2 strains that you are going to compute and use them for computing the damage. But if it is some other country, you are going to measure the rutting or fatigue damage for different layers at different locations. You might even go to the extent of variation as per the axial type, yearly, monthly and then the quintiles and so on and so forth. So that is what it is. Now the damage accumulation models can be either very simple or it can be very complicated. So this is the whole thing. Then modify the, meet the performance criteria, otherwise modify the strategy. So the life cycle cost analysis excepting one or two design methods for instance South Africa or

AASHTO where, not many of them integrated. South Africa has an interesting way of trying to find out how the system will behave before doing the actual construction. So these are, this is the overall design process that one needs to keep in mind. And what we really wanted to do in this course is to give you a brief overview of it.

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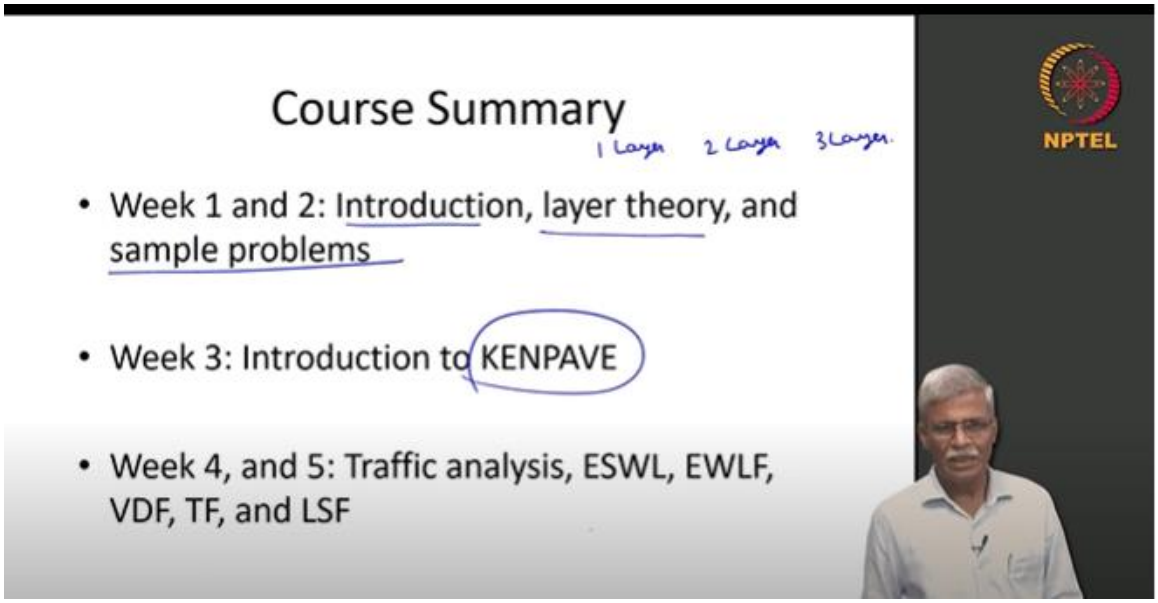

So what did we do in this course? We started with the introduction, then we started with the layer theory, one layer, two layer, three layers and then we solved some simple sample problems. Then after that to do the subsequent calculations we introduced a software tool. We used KENPAVE and then after that we went into traffic analysis, equivalent single wheel load, equivalent wheel load factor, vehicle damage factor, truck factor, load spectra factor, all those things were introduced. So this is about stress strain analysis and this is the

software that was used to do the stress strain analysis. This whole thing about is how to handle traffic. So if you try to sink it here, so this was finished. Then after that this pavement analysis method was done. Then we came to modulus for pavement design.

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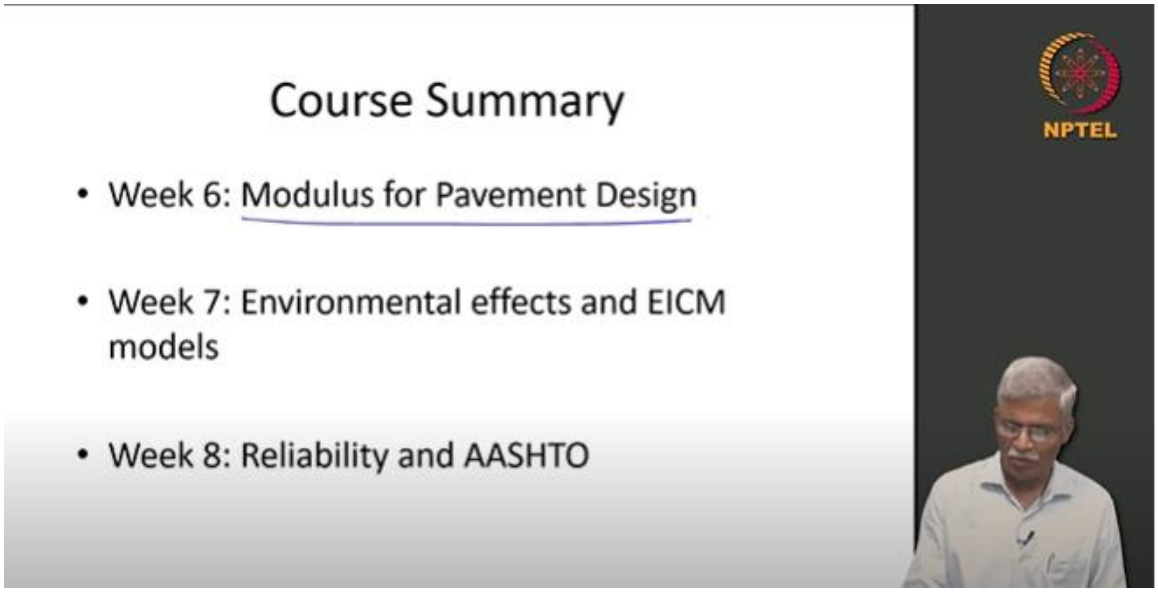

So what are all the material properties for pavement design, the environmental effect and the enhanced integrated climate model how it is. So now this was also finished, this is the material property that is also finished here. Then we talked about reliability and the AASHTO pavement design. So in fact the reliability comes here though it is not explicitly mentioned and AASHTO was designed, pavement design was given. Now why did we introduce AASHTO first because if you look at it in the next one the damage analysis comes.

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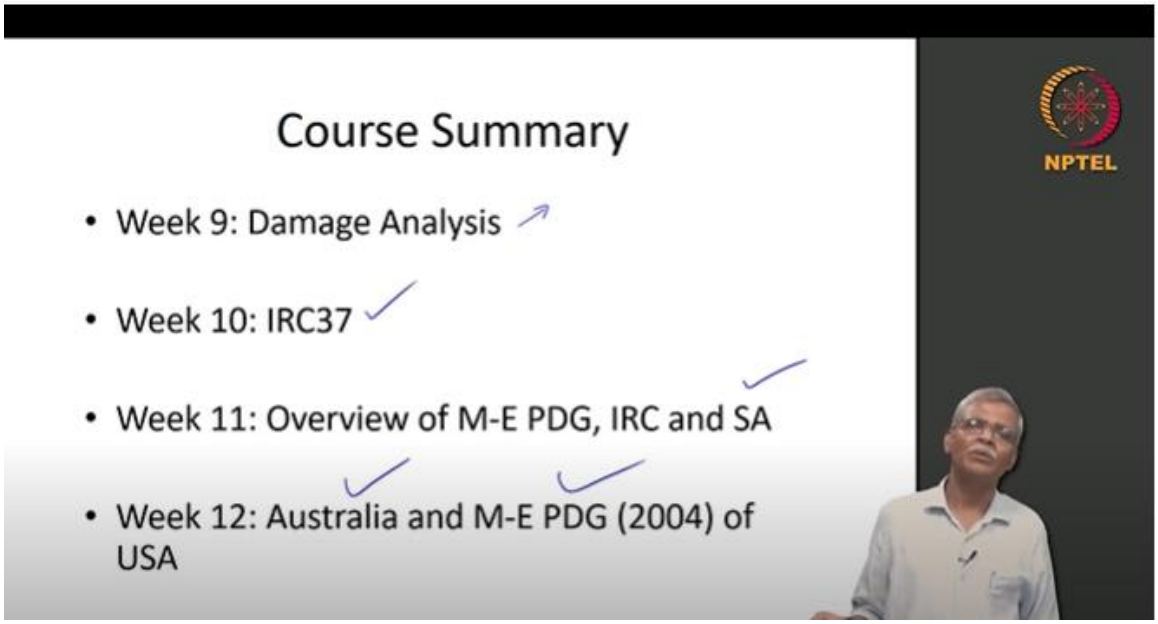

After the damage analysis finished only we talked about IRC 37, South African, Australian and MEP-DG, but why did we do AASHTO before. We did AASHTO before because the old AASHTO does not explicitly talk in terms of damage but talks in terms of some empirical index going from one number to the other number say 4.5 to 2.5 and all those things and it involves overall the functional as well as the structural condition of the pavement. So that is the pavement condition index, pavement condition number, pavement condition rating and all those things. So that is the old AASHTO style. And then we talked about damage analysis, more about rutting, fatigue, then we talked about IRC, then we gave an overview of MEPDG and talked about Indian Roads Congress, then South Africa, then Australia and then MEPDG. So this is what we managed to do in this 30 plus hours of lecture with you in this 12 weeks.

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So now what are all the design projects that you can do and in fact when I say design project I leave it to you because many of you may be students at a different level at the BE, BTech level or ME, MTech level, many of you may be even working professionals. So the choice and the complexity related to doing the design project is something that I leave it to you. As I mentioned before you can always get in touch with me Murali Krishnan at jmk.iitm.ac.in and then in your subject line you can write NPTEL pavement analysis and design course. So then I will be in a position to address your emails one independently. So the choice of the design projects, the data availability, the background that you have got and whether you have somebody to help you in your college or in your institution. So it is this is something that you need to really understand and go. So I am just going to list this in these many ways. First and foremost, thing is the traffic analysis data. So this is one of the major input factor. Second is proof checking of the design and the third is each one of this can be completely a different project and then finally reliability. So let us look at each of these things what to do.

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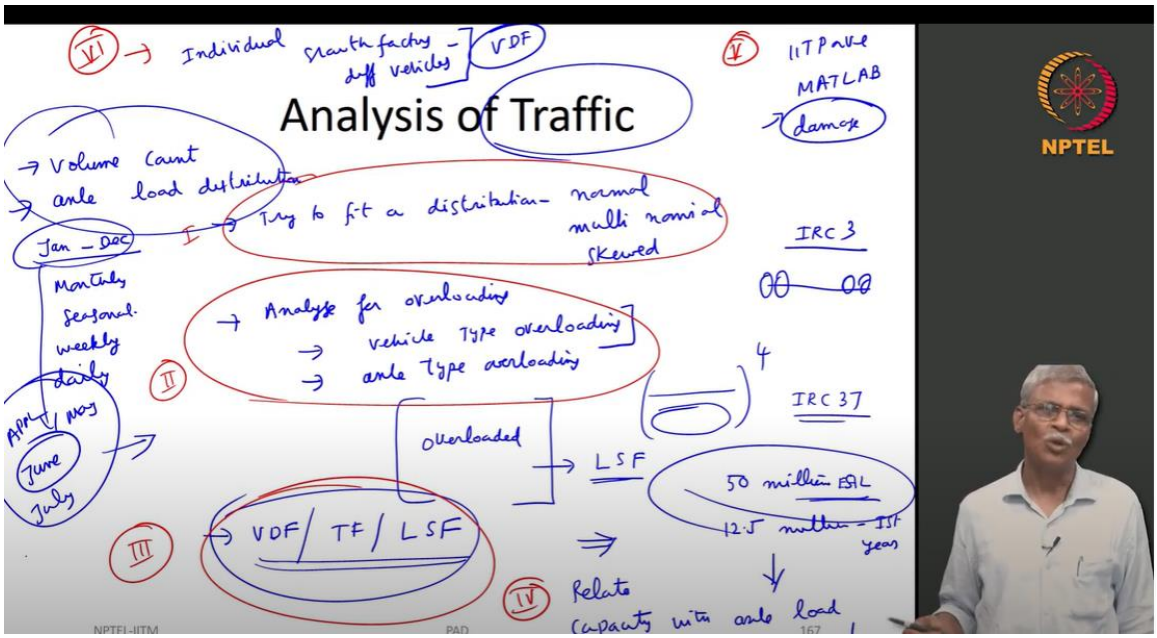

Now what are all the traffic data that you can get? You can get volume count; you can get axle load distribution. If you probe this further and in fact you should be able to get this kind of data from any agency that is constructing the road you know you could approach them and they will be able to do. First and foremost, thing you will notice here is from the month of January till the month of December they would have managed to collect this kind of a data. The axle load is going to vary in a completely different way. There is going to be a monthly variation, there is a seasonal variation, there is also a weekly variation and daily variation. So you will have this much of variability. So the first task that you could do is to try to fit a distribution. So it can be a normal distribution, it can be multinomial two normal distributions, it can be some skewed distributions and so on.

Then what you can actually do is you can also look at the data and analyze for overloading because when you are doing the axle load when you get the axle load data and you analyze you will be able to see that there are some trucks that are overloaded. Now whether overloading is permitted or not whether it is legal or not we are not going to get into it. The fact is your highways are overloaded and as a designer can you ensure that in the event your highways are exposed to overloading from erring truck drivers whether it will handle that. That is the only question that you need to really answer. So let us not get into the legal

issues. So now what I am saying is you analyze for the overloading. Now here you can spend a lot of time on whether this is going to be a vehicle type overloading or whether it is going to be axle type overloading. What do I mean by that? If you take a look at the full gross weight of the vehicle that may carry more weight than what is permitted. So in which case you are talking in terms of vehicle type overloading. On the other hand you can just take a look at only the individual axles.

Just to give an example let us say you have a single axle dual wheel. You go take a look at IRC 3 see what IRC 3 says. If the actual axle that you are looking at carries more load than what is stipulated in IRC 3 then you know that there is an axle type overloading. Now you will immediately ask me when I am doing these calculations as per IRC I am only computing the in terms of axle not in terms of the vehicle. So do you really think we should be doing it in terms of vehicle type what is the sanctity in doing that. You can actually if you take care of the vehicle type overloading it will be easy for you to segregate those vehicles that are overloaded. In fact, most of the regular vehicles that you see truck typical truck single axle single wheel in the front tandem axle dual wheel in the rear may not be that much overloaded. But sometimes some of this tridem axles trucks may be overloaded it all depends on case to case basis. And in fact to correct whatever I have said I have also seen data coming from different highways in the country in which the tandem axle dual wheel rear axle type vehicles are predominantly overloaded. It all depends on the data that you have got.

So when there is an overloading there now the point that you now need to really ask is if there is this much of overloading can I still use this fourth power equation. Because there is a value that is given in here denominator here if you go take a look at IRC 37 you will know what I am talking about. Will this value actually correspond to it? So what you may want to do is to segregate those axles that are overloaded. So identify first the vehicles and then from those vehicles segregate those axles that are overloaded and try and see whether you can use some of these methods such as load spectra factor or you can do the following. Take the individual axles and then apply it on the highway compute what is the strain that is coming and then do this exercise and then try to compute the cumulative damage that is happening. So that is one easily possibility that you can actually do.

Now continuing on whatever I said you need to also use this opportunity to explore this concept of vehicle damage factor, truck factor, load spectra factor. They may not necessarily give you the same ESAL value. They will give you completely slightly different value and in some cases completely different value also. So if that is because why we are now talking about traffic because this is the most important input that you are giving it your pavement design. So you need to understand this and do this carefully. Then yet another topic that you can actually work for. So I will draw maybe you know I should start giving numbers here. So try to fit a distribution. So this could be one project, analyze for overloading, this could be another project and then use this could be another project. Then what you can think in terms of that is if you recollect I mentioned once during the when I was explaining the South African loading. What is the saturation flow for signal design? It is only the peak overflow. But what about the saturation flow for the highway? 24 hours. So that means what you really want to do is to ask the following.

So let us say I design something for 50 million standard axle load. So let us say 12.5 million comes in the first year. Can you back calculate what is the actual traffic corresponding to it? Instead of trying to compute this in this particular way you can go back to the volume count under the axle load distribution, project it for the first year and for that first year find out what will be the volume count and you will be actually surprised. Because you when you do these 50 million standard axles for let us say for 4 years or 5 years you are you might actually end up loading the pavement much less than what they carry because there is a capacity associated with the highway much less than or in some cases much more than what you can. So that means in real life if you have a two-lane highway and if you are trying to compute the axle load distribution and if you are not careful about the geometric capacity and relate it with the axle loads you might end up with doing a design which is highly inappropriate. That kind of a check has not really been done and that is something that you could do. So relate capacity with axle load distribution. That will be very interesting for you to do it and another thing that you can do is you know you can just keep on writing projects after projects because there are so many interesting problems to be solved here. So if you are savvy enough in computers like you know you know how to play around with the system you know what you can do is to integrate IITPAVE inside MATLAB and see for all the volume count and the axle load distribution that you are

getting whether you can use the source MATLAB and compute for each and every load application what is the damage. Instead of just doing it like what you have done here you know because you just take one number and then say that this is what is the damage. So in fact you can do something similar to what the Americans do but just with doing IITPAVE and MATLAB interface think about it. So that is something that could be really done.

Another project that you can think of doing is let us say we want to give individual growth factors for different vehicles. So you can actually search for the data you might get it you will be able to see that different vehicles have different growth rate. So when you use that what will happen to your vehicle damage factor. So these are some of the topics that I can think of at this point in time. There are many more interesting topics that can be done only with the traffic alone. See for instance you could relate the summer month as I said you know January to December. So let us say focus more on month such as April, May, June, July. You can say that these are the months in which the temperature in this country is going to be considerably high. The pavement temperature is going to be high. The failure due to rutting is going to be high. So you may want to say that I will worry about the distress equation only for this 4 months as far as the rutting is concerned and in the month of let us say October, November, December, January where the temperature is low I will use that information for fatigue. So those kind of splitting up also one can do. So I will just call that as 6, 7. So as of now these are all the things that you can really look for. So let us go to the next one which is to proof check the design.

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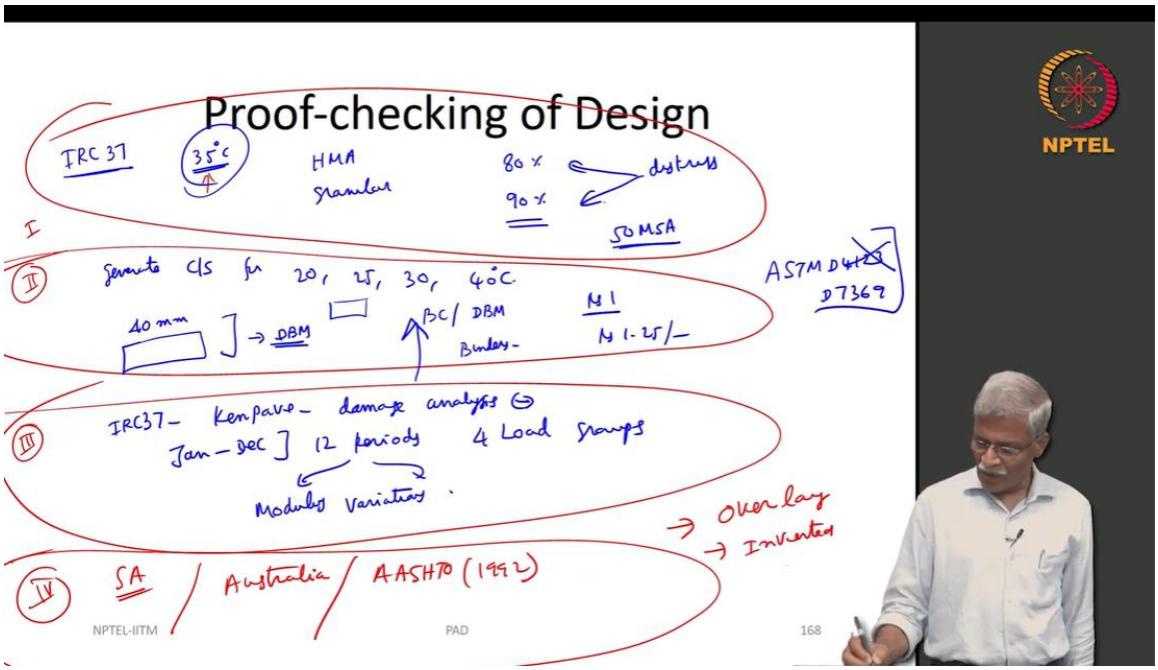

What do I mean by proof checking the design? So you have IRC 37 templates. These some templates are given for 35 ºC. So what you should do is to take all the cross sections that are available. Suppose the values that are tabulated there, material properties are tabulated, HMA values are given, granular values are given, then 80 % reliability, 90 % reliability is given. Use KENPAVE or IITPAVE or something like that and check whether that distress equations for this different reliability that you got whether this distress equations are satisfied, whether whatever cross section that you have for let us say for 50 msa can actually take 50 msa. If you do that exercise this will be really wonderful. This is something that I will call that as first because you do not need anything, you do not need any data, you use only the IRC 37 data, you have IITPAVE which you can download or you can use KENPAVE which you can download and then substitute the values, sit and calculate the whole thing using this. So this is one thing. Now but this is all done for 35 ºC. What should I do for other temperatures? So generate cross-sections for 20, 25, 30 and 40 ºC.

How smart we are in generating these cross-sections. So you can still say that okay let me do the following. I will keep the foundation that is my thickness of my base and subbase the same and I will only play around with the bituminous layers. In fact, you can even take

the attitude saying that I am going to keep 40 mm for BC everywhere and I am going to only change the DBM or you can do the following is since there is so much of variability there you can play around between BC and DBM thickness okay for different binders. So in fact if an unmodified binder is let us say a unit cost is 1 rupee modified binder is going to be 1 rupee 25 paisa. So what you can do is you can set up an optimization, understand what is the cost of the bituminous binders, you know what is the density of the material, you know the kilometer cost, you can do the cost calculation and then use the cost calculation and try and see what is the different level of layer thickness that could be used for DBM layer or BC layer. So what you need to do either keep the BC layer thickness constant vary the DBM layer for any given binder and then keep the DBM layer thickness constant vary the BC layers for the various binders, compute the cost and then try to minimize the cost maximize what is the design life that you will get. So this will be a wonderful exercise that you can do because most of the time what I have seen is practicing pavement engineers just to take 35 °C and because they do not want to really spend this much of time trying to do this exercise.

Now another thing that you will notice is in bituminous mixtures for BC and DBM as well as so the most the same modulus values are given they will not have the same modulus value bituminous concrete and dense bituminous macadam the resilient modulus or dynamic modulus that you want to really use will be completely different. So there are published literature related to this in fact I have couple of papers related to measurement of resilient modulus of bituminous mixtures following IRC used in the IRC procedures and again you also need to understand that ASTM D4123 or ASTM D7369 do not measure the resilient modulus in the same way ASTM D4123 is withdrawn it cannot really be used for measuring but however if you measure it look at the modulus values that are available for BC separately, DBM separately and use them also in your simulation. So you will be getting lot of interesting thicknesses this could be the second exercise.

Now the third design project that you can do is I want to use IRC 37 KENPAVE and do a damage analysis how will I do that. So I need month by month traffic volume because if you are talking about damage analysis in can pave what is that they want they want you to input the material properties for 12 months can be done we will assume that this as the

temperature increases and decreases the modulus values also vary in one particular way again some of my publications have this kind of a data you can take a look at it and use it. And then based on the input that you got from the previous one about a traffic you will have monthly variations. So you can go up to four load classes in KENPAVE so you give all those values give the distress functions generate the damage and you will be surprised that some of the cross sections may not really pass this damage analysis please find it out. So this could be a very interesting so you can have 12 periods, 4 load groups and for this 12 periods modulus variations all those things can be done. So this will be a very useful important interesting design project trust me. Then we can go to the next one.

Now that you have understood how South Africa works what if you take one of the IRC 37 cross-section and proof check it with the South African method. You can do the same thing with Australia you can do the same thing with the old AASHTO 1992 version. So it is just to use the same cross-section knowing the traffic everything is known to you cross section is already given you need to only check if this cross-section will it pass the South African method of pavement design will it pass the Australian method of pavement design will it pass the reliability based AASHTO method of pavement design. So this is something that you should be able to check and find out it will be a very interesting very amazing experience and you can always integrate whatever we discussed in the earlier one with this.

So this is something that you can immediately do and again you know we did not talk much about overlay design we did not talk much in terms of inverted pavements. The reason we did not say much about inverted pavement is the analysis of this inverted pavements are tricky you really cannot do those kind of analysis the way in which you perceive using layered linear elastic theories you may have to do it with either the Australian or the South African method of pavement design. I think if you download CIRCLY a trial version you can do it for one month and then you can do all this inverted pavement analysis with it whatever I am not really sure but whatever you want to do it with a KENPAVE you might be able to do it much better if you do it with the CIRCLY especially for inverted pavement design. So that is what I was continuing to say here applicability of the South African.

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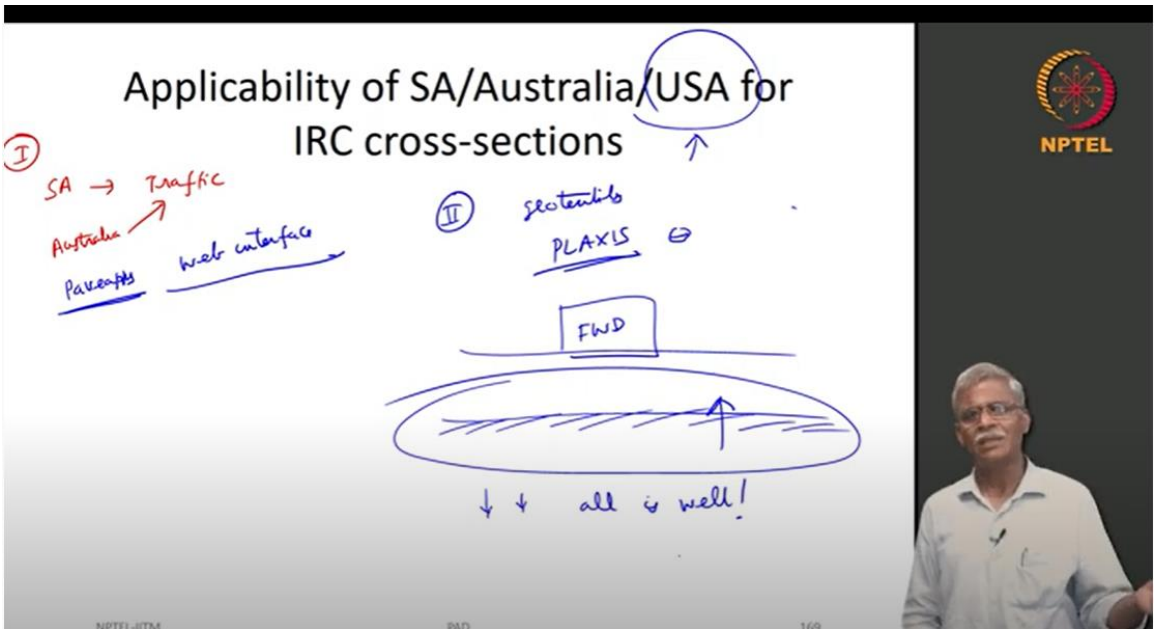

So how I will do it that is again I will call it as the first problem analyze the traffic same thing for Australia because these are the two countries in which detailed analysis is carried out here. And there is another what you can say online available it is there it is called Paveapps you can go search for it and it is not very complicated like what we discussed in AASHTOware this is something that you can do it the database related to this has been generated from AASHTOware but it gives you a nice interesting web interface and you can do the design accordingly. So that is something that you should be trying to do then if you really want to have any of this geotextile grids. So let us say you want to talk in terms of reflect and cracking and all those things you cannot use any of the existing IITPAVE or KENPAVE or anything like that you may have to use some of these things like PLAXIS is where this glass grid will be introduced as a new element only then you can do it and in fact you need to also understand this very carefully so let us say this is the glass grid that you are introducing here and if you subjected to falling weight deflectometer most of the load will be taken by the glass grid and the FWD back calculation procedure might tell you that all is well below all may not be well below but that is morphed by the intercepted by this glass grid that you are really seeing here. So these are some of the things that you can think about doing it and then try and see what are the ways in which the cross-sections are varied nominal maximum aggregates is thick lift so try to link the constructability aspects

with the cross-sections with the mix that are being used and how one can keep optimizing it here and then finally we come to the reliability part.

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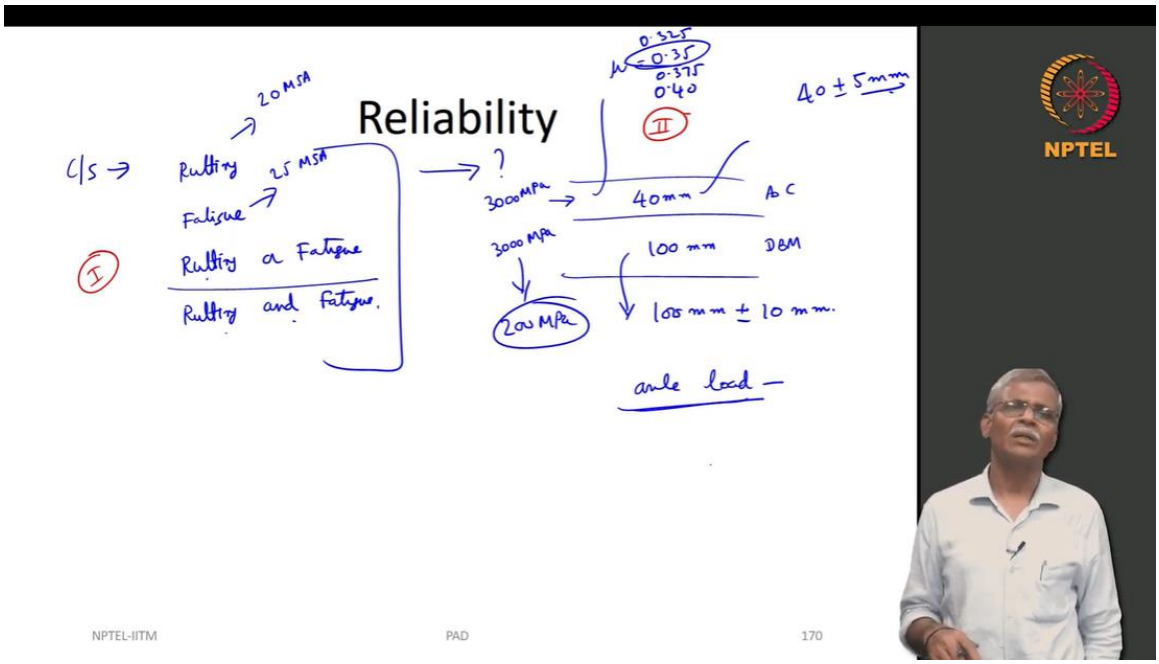

So what do we do mean by reliability so let us ask the question so if you have a cross-section and if it fails by so you want to ask rutting only fatigue only rutting or fatigue rutting and fatigue so estimate the reliabilities so that means you are given a cross-section you apply the appropriate load compute the strain compute what is the estimate related to rutting what is the estimate related to fatigue. So let us say you say that this will fail in I will talk in terms of million standard axle load 20 msa let us say this will fail in 25 msa now the question that you want to ask is either rutting or fatigue which one you want or rutting and fatigue so that means if we are going to be rutting and fatigue most likely you are going to say that 20 msa traffic will fail this pavement if you say rutting or fatigue you can actually say okay so let me go for a take a risk so I can go up to 25 msa so what is the reliability related associated with all these things so that is something that you can do.

Then so this is could be one interesting problem another interesting problem that you can work on which I am sure you know Dr. Nivitha in her lectures would have explained this is so let us say the layer thickness this is bituminous concrete this is dense bituminous

macadam let us say 40 mm this is 100 mm. So let us assume that this thickness is normally distributed with this in this particular range so and let us assume that this distribution yeah normally distributed and this is what is the range the same here how will your reliability change so this is as far as the thickness is concerned so now let us take 3000 MPa here you will also take 3000 MPa here and let us assume that there is a it is also normally distributed and the standard deviation is let us say 200 MPa here so if that is the case when the material properties are also varying what will happen to the reliability.

Now when the material properties as well as the thickness is also varying what will happen to it you can even talk in terms of Poisson's ratio so it can vary from 0.35, 0.375, 0.4, 0.325 these variations could be there the mean value can be taken as 0.35 and so what will really happen to the reliability and then you are doing some axle load survey okay and now let us say in how reliable is this axle load survey so you can again have a problem so if you link it up with whatever we discussed in the traffic part you can fit a distribution to it and then you can say that okay so I am talking in terms of heavy vehicles these heavy vehicles are going to be having this much variability this is the normal distribution that you are really looking at how will the reliability change okay. So these are all some of the interesting aspects that one can look into it I mean I can just keep going on and on but you have enough ideas here now you can take it and you will also form your own ideas related to doing it but my sincere request to all of you is I am sure you have some axle load data that was shared already with you so use that try to compute the vehicle damage factor try to design a pavement on your own at least with the IRC method and see what are all the obstacles that you face please do write to us email us and we will be very happy to answer all your questions okay. So thank you so much and I wish you all the very best in whatever you are doing in your life thank you.