Mechanical Characterization of Bituminous Material
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Lecture No 2
Mechanical Characterization of Bituminous Materials Introduction part 01

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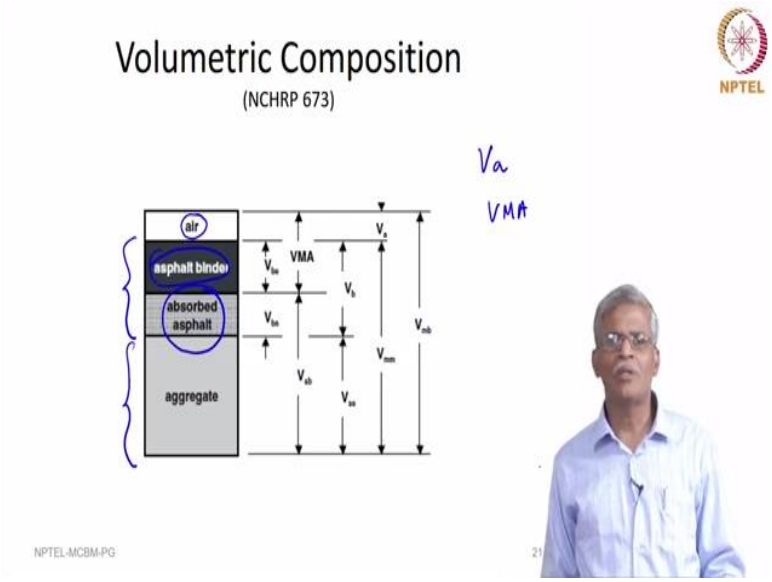

Right, and these kinds of pictures you must have seen in your soil mechanics textbook. And this is something that we need to really understand. So, let us recap again. So, as you take loose mass of aggregates of various shapes and sizes. Mix them together, heat them add binder, at let us say 150, 160 degree centigrade and mix them together. The binder is expected to coat all the aggregate particles. And some amount of binder is going to be absorbed by the aggregate particles.

Now, taking into account the shear design that we have carried out, in which we have put together aggregates of different shapes and sizes. There are going to be air voids. So, what you are seeing here is the air voids. What you are seeing here is the total asphalt that you have added to the material. Out of which some portion is going to be absorbed by the material and this is the effective asphalt that is going to be available. And this is the amount of aggregate that is added here.

Right, so these are terminologies these designations that you see here voids, air voids, voids in mineral aggregates, voids filled with asphalt are some of these terminologies which are very familiar to those of you who have carried out a mix design.

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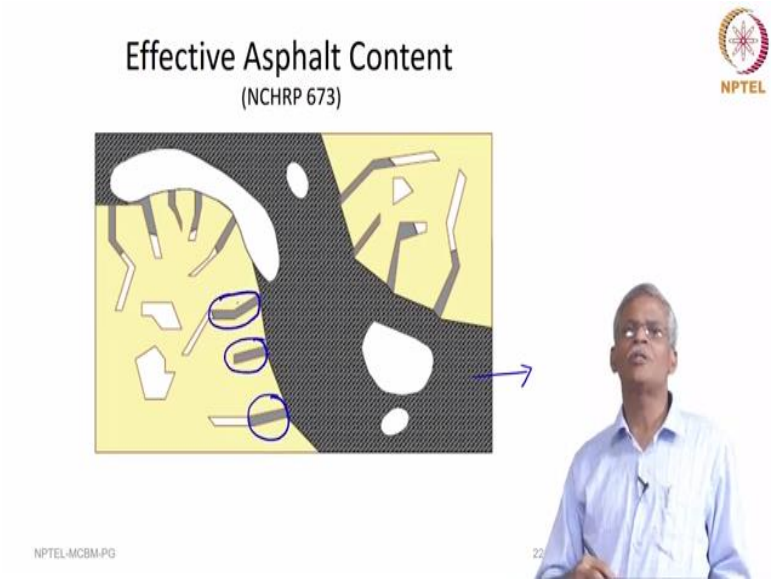

So, that is few things that we need to understand before we proceed. One is what is the Effective Asphalt Content. So, that means what I mean as effective asphalt content is this hashed portion. Dark hashed portion is the effective asphalt content. This portion of the binder that is absorbed by the aggregate particles is really not effective as far as the role of binder in the mix is concerned. Because this has been absorbed by the aggregate particle and they do not really play a key role here.

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Right, what about the voids in mineral aggregate. This is what you can say is one of the very important concepts as far as the bituminous mixtures are concerned. Bituminous mixtures characterization is concerned. Okay, while this is a volumetric issue that is handled very well in the mixed design part. You really need to understand how you are able to put together aggregates of various shapes and sizes in a specific way.

This happens only because of the role played by the binder, during the compaction. Now, how do we really visualize this voids in mineral aggregate. Let us go to your Road, see the surface of the bituminous material there. Take one small unit cross section there. So, let us say 10 centimeters by 10 centimeters, to let us say 10-centimeter thickness. And if by magic mysteriously, if you could take out all the binder that is coated on the aggregate particle.

And take a snapshot of the haphazard way in which the aggregate skeleton is arranged with each other. As well as the voids, that are there in the interstices. The voids that you are going to see because of this haphazard arrangement of the aggregate is called as really called as the voids in mineral aggregate. Okay, so that means these are essentially the voids in the aggregate skeleton minus the binder, the effective asphalt content that you are going to see here.

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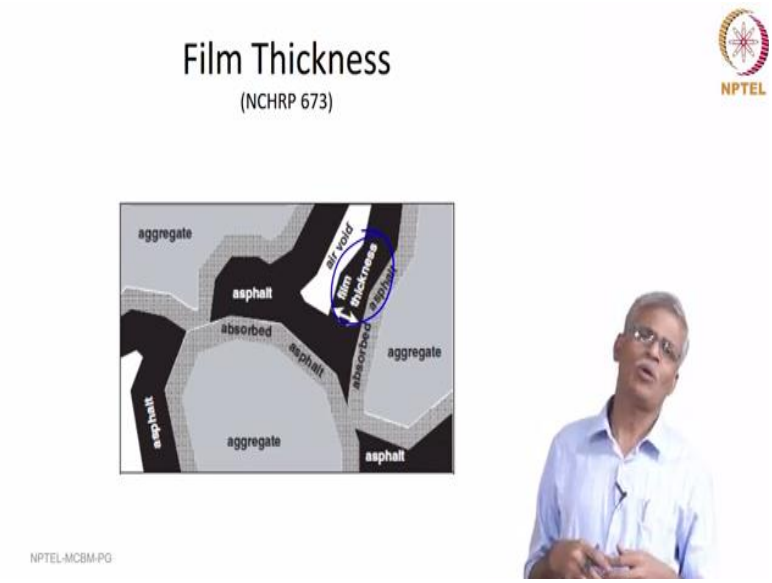

And one very important thing is the role of the film thickness. Now, this film thickness is going to dictate the manner in which the mixture is going to deform at high temperature, let us say 60-degree centigrade, intermediate temperature of 40-degree centigrade and low

temperature let us say 10 degree centigrade or even sub-zero temperature. So, this is the asphalt film thickness that you are going to see here.

And again we are not going to consider the absorbed asphalt. So, when you are going to see some fracture of the bituminous pavement at a low temperature. The fracture is basically facilitated due to the influence of the asphalt film thickness that you see here. If you are going to see the aggregate flowing out at high temperature, again it is something to do with the influence of the film thickness that you are going to see here.

When you are trying to measure the modulus value of this bituminous mixes, dynamic modulus, resilient modulus, flexural modulus all this will be discussed as we go along. Again, it is dictated by the influence of this specific film thickness.

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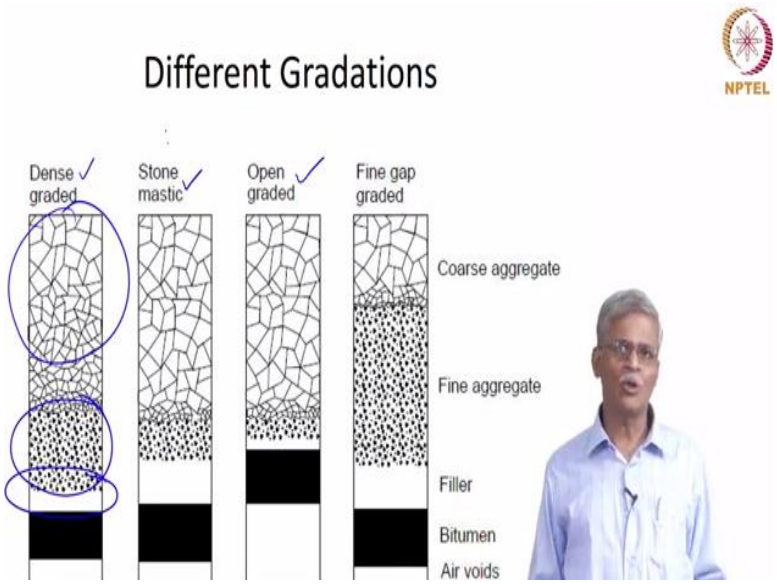

So, we need to really understand this. Now comes the next step. So, having understood what are the various important aspects are of the volumetric. What we really need to do is, how do we even choose this different size of stones. From the, let us say 1 inch or 25mm all the way up to the 75 micron below, are there any particular choices that we have. That is completely a different topic altogether.

The gradation design of the aggregate be it with the Bailey method or the Barons method or the Fuller Thompson method is something that we will not really be discussing here. Because, our interest here is more on the material characterization part. So, you could go on

to design a aggregate gradation appealing to Fuller Thompson type or appealing to particle packing approaches or use any software.

But what this course will teach you is after having design the aggregate gradations, how do we characterize them. What is the stress strain time response of the material? But while we are going to do that it also is necessary that substantial amount of advancement have been made as far as the different gradation designs are concerned. So, you have a dense graded material, you have a open graded material.

The moment you use this word dense and open graded. And, if you look at the amount of the fine aggregate between dense and the open graded you will actually see the difference. You will also see the difference between a stone mastic and the dense graded material. The typical idea of a dense graded material is to use a coarse aggregate skeleton that you see here. And the voids within the coarse aggregate skeleton are filled by the fine aggregate.

And the voids within the fine aggregate skeleton. So basically, you have a coarse aggregate skeleton that has voids in it that are filled by the fine aggregate. And the voids within the fine aggregates are filled by the filler. Okay, and in bituminous mixes what will normally happen the filler and the bitumen will get mixed together what we really call as the mastic and we are talking about the mastic. Not only providing a coating on the aggregate surfaces.

But, also filling up the interstices. So, this is your typical dense graded. But there is always a discussion on how do we really avoid rutting. So, if there is a way in which we could provide aggregate stone to stone contact. So, that there will not be any subsequent densification one could avoid rutting and for that purpose different kind of mixes have been designed. So, what is really called as a stone mastic, in which you can actually see that the coarse aggregate skeleton is a slightly more.

These designs are quite involved. And we will be doing it in a separate course altogether. You will also see a open graded mix and there are also what are called as the fine gap graded mix. And depending on the mix that you use the amount of bitumen that you will be using will also really vary.

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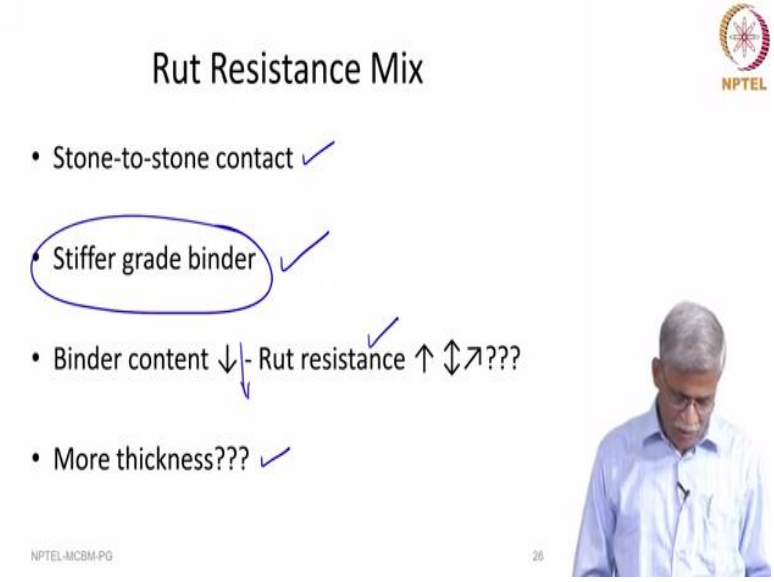

Right. So, if you are talking really about a Rut Resistance Mix. We are looking at a stone-to-stone contact and the most important thing is we should be able to use a stiffer grade of the binder. So, if the binder content is reduced, then the rut resistance is expected to increase. And so what we should do doing is can we go for more thickness.

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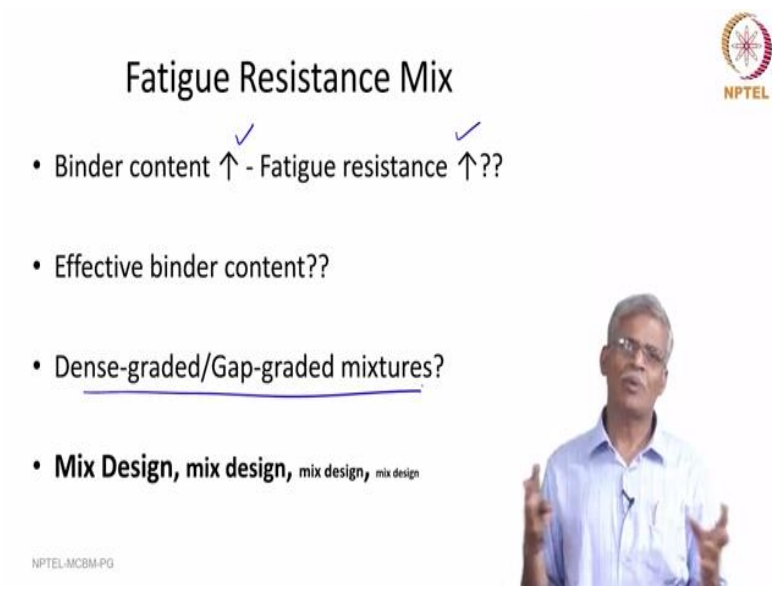

Right. So, as far as the Fatigue Resistance of the mix is concerned. As the binder content is increased the fatigue resistance also seems to be increased. And what should be the really the effective binder content that one should be using it. So, should I go for a dense graded or a gap graded mixture. So, this is where the mix design plays a key role. Because, if you actually look at only the binder content between rutting and fatigue.

You notice that if you put more binder there is going to be more rutting. But the same binder will be helpful to you for giving an excellent fatigue resistance. So, how do we really do all those things so that forms a complete separate aspect on the mix design part. The idea here is to introduce you to different facets of the bituminous mixes and focus our attention only on the mechanical characteristics.

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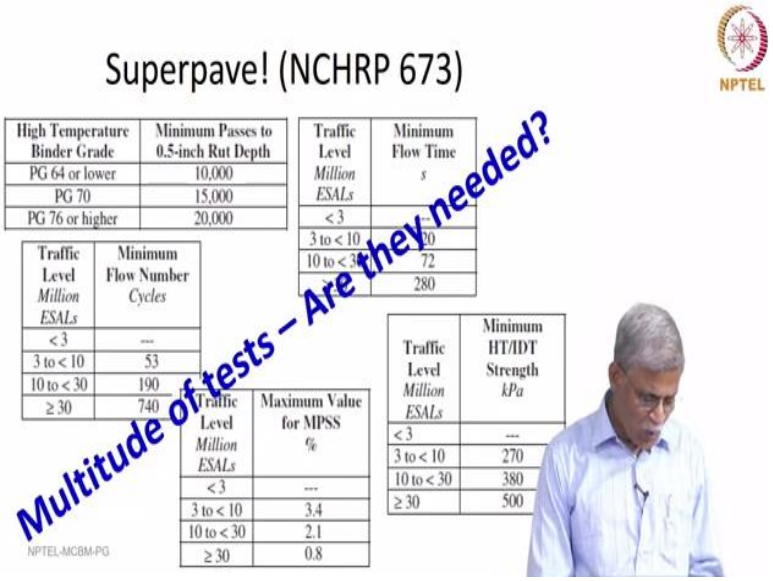

When I started introducing this, I mentioned about marshal stability Marshall flow. And I also talked about super pave and I mentioned about gyratory compactor. But then I also mentioned at passing about the AASHTO T 283. Now, you will actually see that there is a multitude of tests that are being proposed. These details are available in NCHRP 673. So, if you go to your favorite search engine type in NCHRP 673. You should be able to download this report.

These are available in public domain. So, depending on the expected performance, different kinds of tests are needed .There are multitude of tests .Really different varieties of tests , that are made are available whether these tests are needed, whether this all these tests give us the same value or contradictory value is something that we will be able to explore as we go along in this course.

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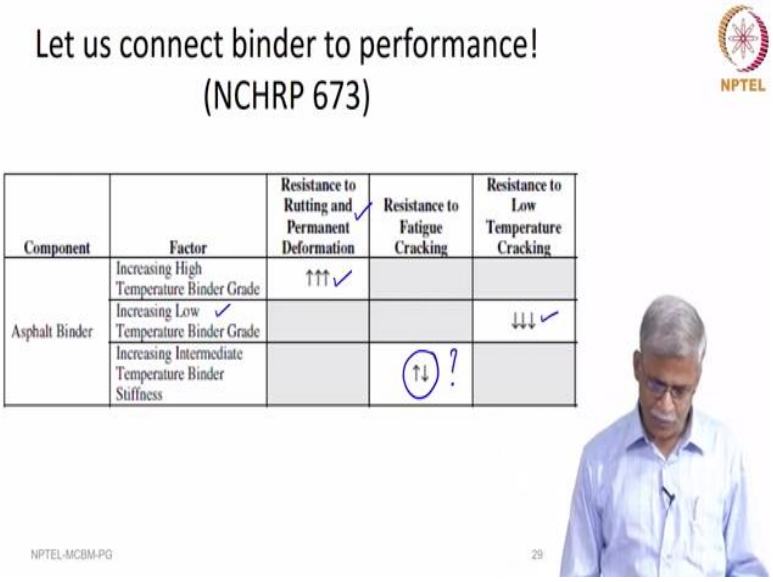

So, now comes the important thing so when I talked about the material characterization, I said bituminous mixtures you have aggregates, you have binder and then you have the mixture. So, let us try and see whether if there is any connection between the binder to the performance. So, what it means is if you actually see resistance to rutting and permanent deformation will the resistance if you increase the high-temperature binder grade.

So, that means if you make the binder to be very stiff. Okay, you are going to get an excellent resistance here. And similarly, if you increase the low temperature binder grade, the resistance is going to decrease because the material is going to be extremely stiff. If you increase the intermediate temperature binder stiffness, this is questionable we do not know whether it will increase or decrease.

And in fact as you will discover later, in the last part of this course, fatigue of bituminous mixes and fatigue of bituminous binders needs lot more work, in terms of material characterization, model development validation of the laboratory tests with the field, validation of the binder tests with mixtures. So, lot of work needs to be done here. But we will introduce whatever is available as it is in the standard here.

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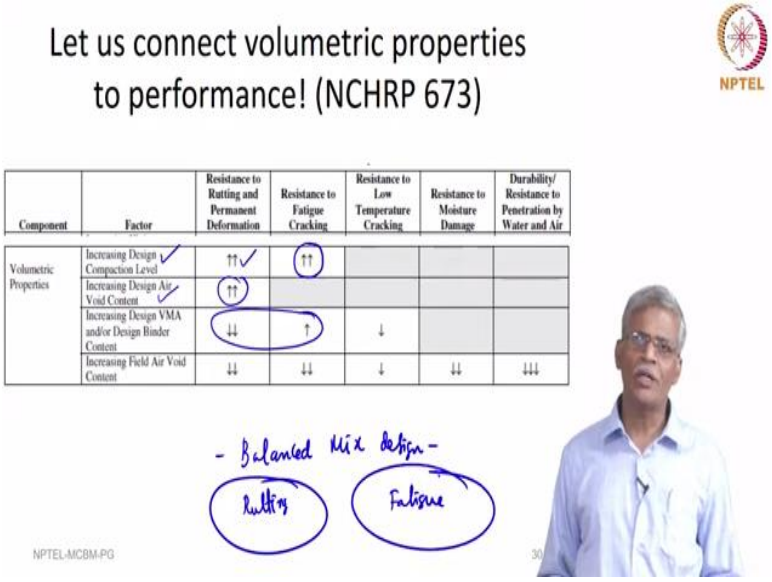

So, what about the volumetric properties to the performance. Looks like they seem to be the same but they are not really. So, if you could increase the compaction levels, you know if you make your material compacted very stiff. Then you can actually have a resistance to rutting and permanent deformation. But this is slightly dubious, because what will really happen is you can actually have resistance to fatigue cracking.

But the problem is there is also a traffic densification that will really happen. So, if you initially compact your mix to a substantially higher level .Then what can really happen is the mix can become way two densified and the modulus value can increase and the fatigue response of the resistance to fatigue cracking will actually come down. So, if you are looking at increasing the design air void content, you can see what will really happen here.

And similarly if you increase the design VMA, under the design binder content. So, if you increase the binder content or if you increase the design voids in mineral aggregate this is what is going to happen here. So, balancing this between rutting and fatigue cracking is always a difficult task. And these days the concept of balanced mix design is being introduced here.

But if we have to really interpret and use this balanced mix design we should first know how to characterize in the laboratory for rutting, how to characterize in the laboratory for fatigue. And this course will teach you how to do that. Okay, right.

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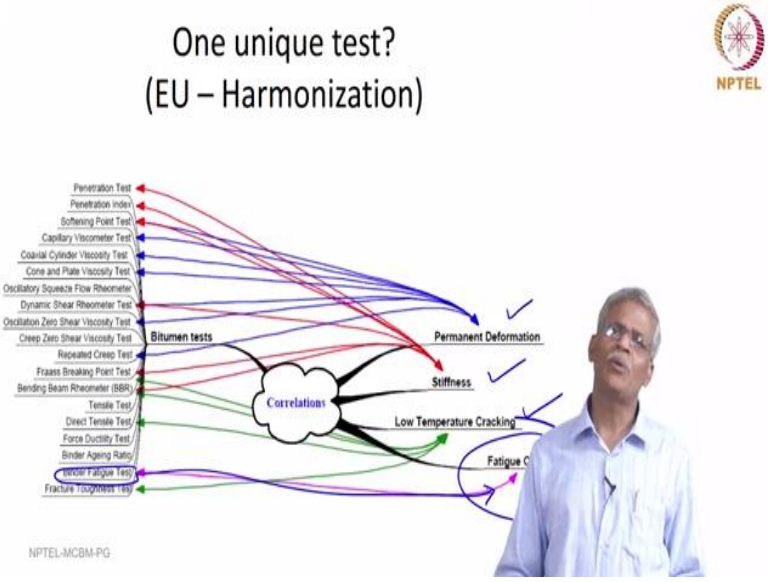

So, is there a way in which one could develop a binder test straightforward that will give a correlation to the permanent deformation to the stiffness, on to the low temperature cracking as well as the fatigue cracking. And as I mentioned before you will see that there is only one test that relates to the binder fatigue cracking. There are a multitude of tests, each of them tried to give contradictory view. So, we need to be very careful when we are picking this kind of test. Okay.

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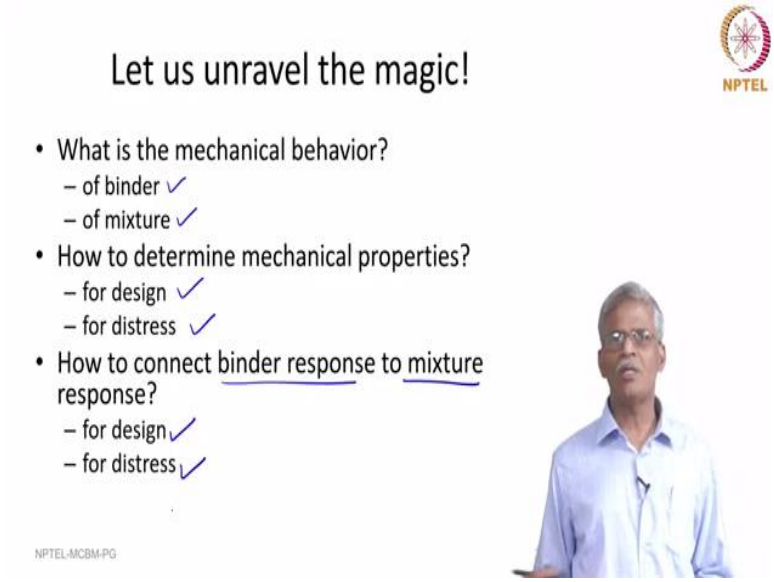

So, let us start our course that is unravel the magic one by one. What is the mechanical behavior of the binder? What is the mechanical behavior of the mixture? Okay. So, we need to understand that, we have discussed in detail the complexity of the mixture in terms of the

volumetric properties. Right, then as we discussed in the design, when I looked at when I showed you the MEPDG design framework.

How to determine the mechanical properties for design? How to design it for determinate for distress? And then how do we really connect the binder response to the mixture response for design? As well as for distress. So, this is the procedure that we are really going to follow in this course.

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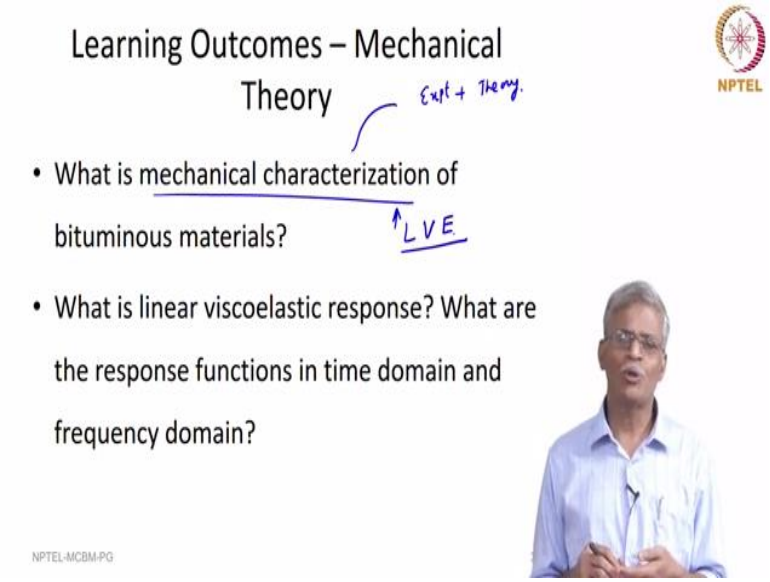

So, if you take this course, continue in this course what really are the things that you will actually learn as part of this course. So, what exactly is the mechanical characterization of bituminous material. So, that means you are really looking at so when you use the word mechanical characterization you are talking about experiment plus theory. Both the things put together he is used for the mechanical characterization of bituminous material.

So, that is bituminous mixtures and bituminous binders. So, we are going to assume that the response of the material is linear viscoelastic (LVE). LVE stands for linear viscoelastic. So, if we start with the notion that, based on lot of investigations experimental data collected. Without any loss of generality, we can assume that the response of the material is linear viscoelastic in nature.

If this is indeed linear viscoelastic nature. We need to understand what is this linear elastic response? what are the response functions in time and frequency domain? Because the moment you start talking about linear viscoelasticity, you are talking in terms of time

dependent response. So, that means you could do a test in time domain, you could do a test in the frequency domain also.

Right, now if you know that the response of the material is indeed linear viscoelastic. What kind of experiments should be conducted? Because since the response of the material is going to be time dependent, you really cannot take a material apply a load measure only the deformation .You also need to measure the time duration in which the load is applied, time duration in which the load is removed , and the associated recovery.

All these things have to be put together and study. Only then we can understand what is really called as the mechanical characterization. To summarize, the first learning outcome is the mechanical theory. We are going to use linear viscoelasticity. We are going to measure response functions in time domain and frequency domain. We will also show what kind of experiments should be conducted and how the experimental data should be analyzed for this.

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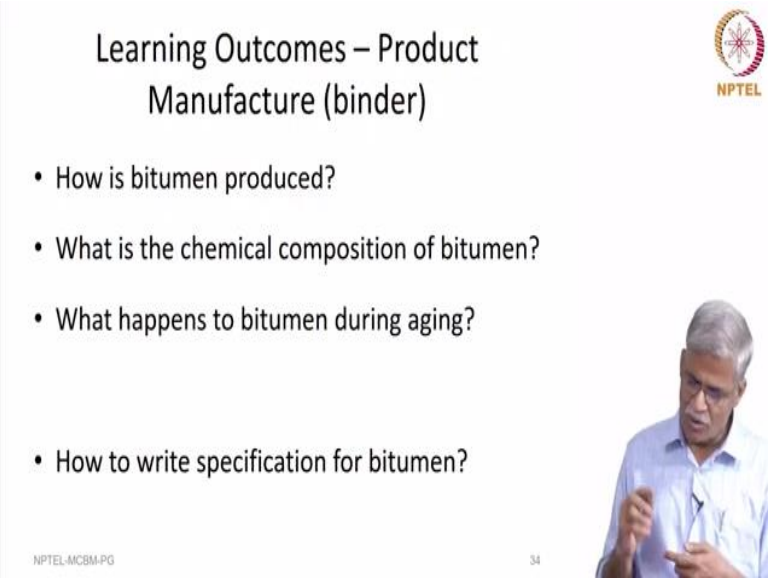

So, this is your first learning outcome as far as this course is concerned. Now, what is the material that you are using in your bituminous mixtures, the most important material is bitumen. Now based on your background from your undergraduate civil engineering your introduction to bitumen is probably one or two pages with some simple refinery flow chart. What we are going to do in this course is we are going to go a little more into the detail into the refinery production process.

So, what does that mean it essentially means if I write say it in a very simple language. Yeah, bitumen produced from Vishakhapatnam refinery or a Mumbai refinery, though being designated with the same grain can behave in a completely different manner. If you have to substantiate this statement, you need to understand what is the refinery production process that is being followed here. And how the refinery production process influences the raw material that is coming out.

And then, that is the first thing. The second thing is what exactly is the chemical composition of bitumen? What does it contain? What does it make this material so complex, so intriguing? So, that you know we are getting very interesting responses due to loading, due to temperature, and due to different aging conditions. Right. So, what is the chemical composition of bitumen? There is no one final answer.

So, we will be exploring that. And one important thing that happens to this material is it ages during production, it ages during service. And because of this aging lot of interesting manifestations of the behavior also takes place. And so this will be discussed in the second learning outcome. So that means and put together all these things put together if they will be linear viscoelasticity plus the chemical composition plus aging. All these factors tell you how to write actually specifications for bitumen.

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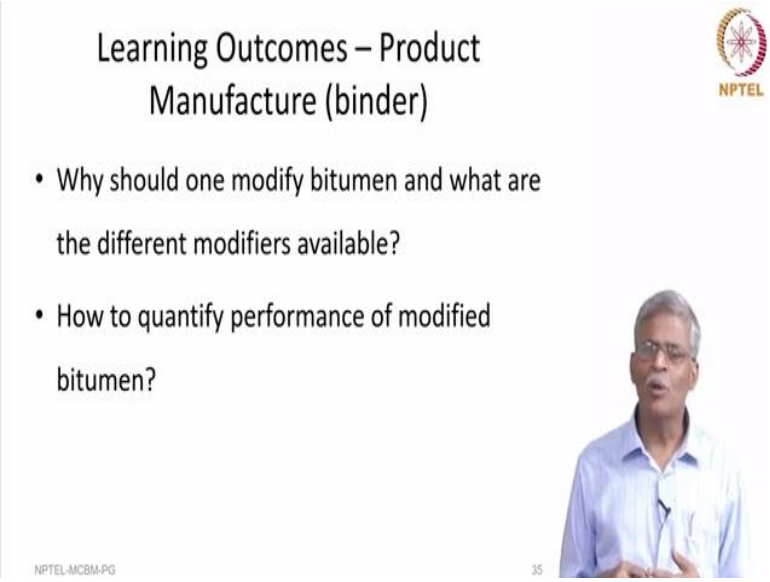

The learning outcome the 3rd learning outcome is, everybody knows that the existing unmodified binder that we use is not really very good in terms of the high temperatures. That we see in this country, as far as the low speed and the overloading that you see them. So,

most of us would prefer to use modified binders. So, why should one modify the bitumen? What are the different types of modifiers that are available? How these modifiers actually interact with bitumen?

Are each and every modifier the same or are they different? And again, if I take and let us say a Styrene Butadiene Styrene (SBS) polymer mix it with one type of bitumen. Let us say air blown material or mix it with another type of bitumen which is a blended bitumen will they give the same performance? When the performance be different? So, these are some of the issues that we need to discuss.

So, we also now need to know how to quantify the performance of modified bitumen. So this is not going to be very straightforward. Because, we need to now change the testing methods, procedures and our interpretations also should change. Most likely we will want to discuss the response of this material in terms of time domain for instance. What is really called as the multiple stress creep and recovery.

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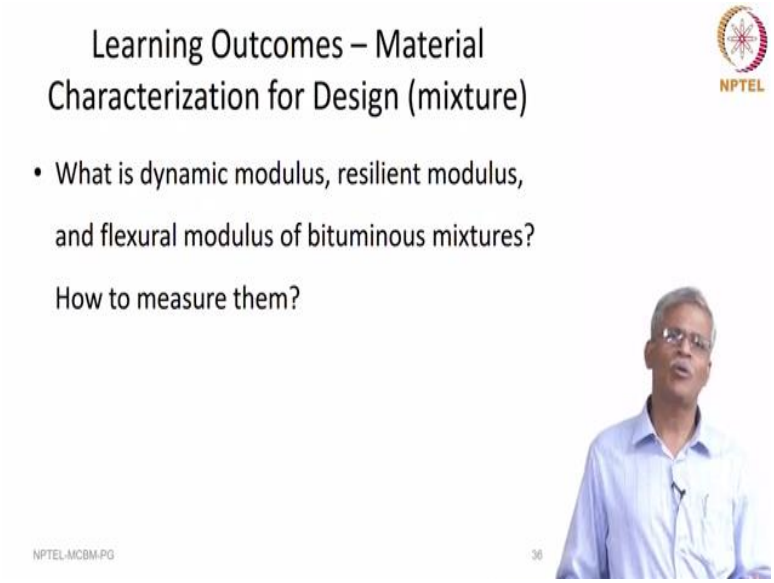

Which you will discuss as we go along. Now comes the mixture part. So, we talked about the binder, we talked about the mixture. And as far as the mixture part is concerned, we started the course with saying something about material characterization for a design, material characterization for distress. So, what is dynamic modulus? resilient modulus? flexural modulus? Different countries use different modulus values for the pavement design purpose. In India, for instance you use resilient modulus.

In United States they use dynamic modulus and in some portion of the Europe they use flexural modulus. So, how do we measure them, how to conduct the test, what is the post processing method to be followed all this will be discussed in the learning outcome in the material characterization for design .

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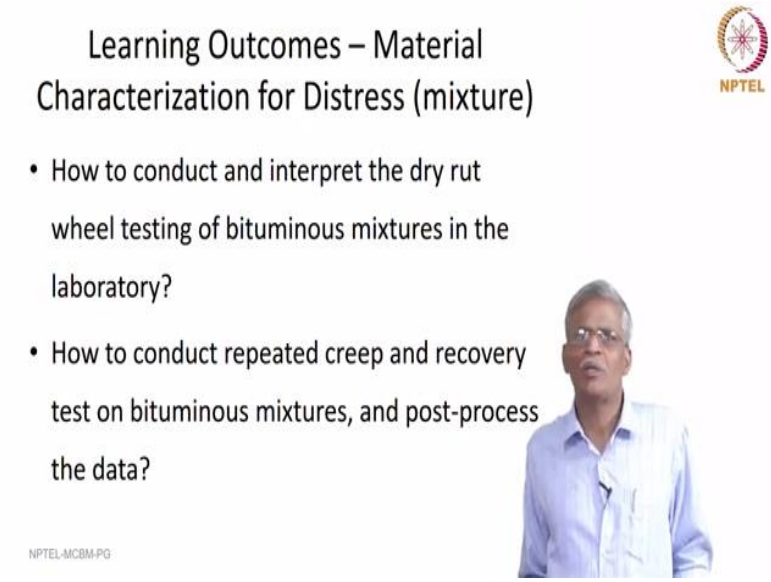

As far as the material characterization for distress, for mixtures, how do we really conduct and interpret the dry rut wheel testing of bituminous pictures. This is for rutting how to conduct creep and recovery test on bituminous mixes and post process the data. Again, this is for rutting.

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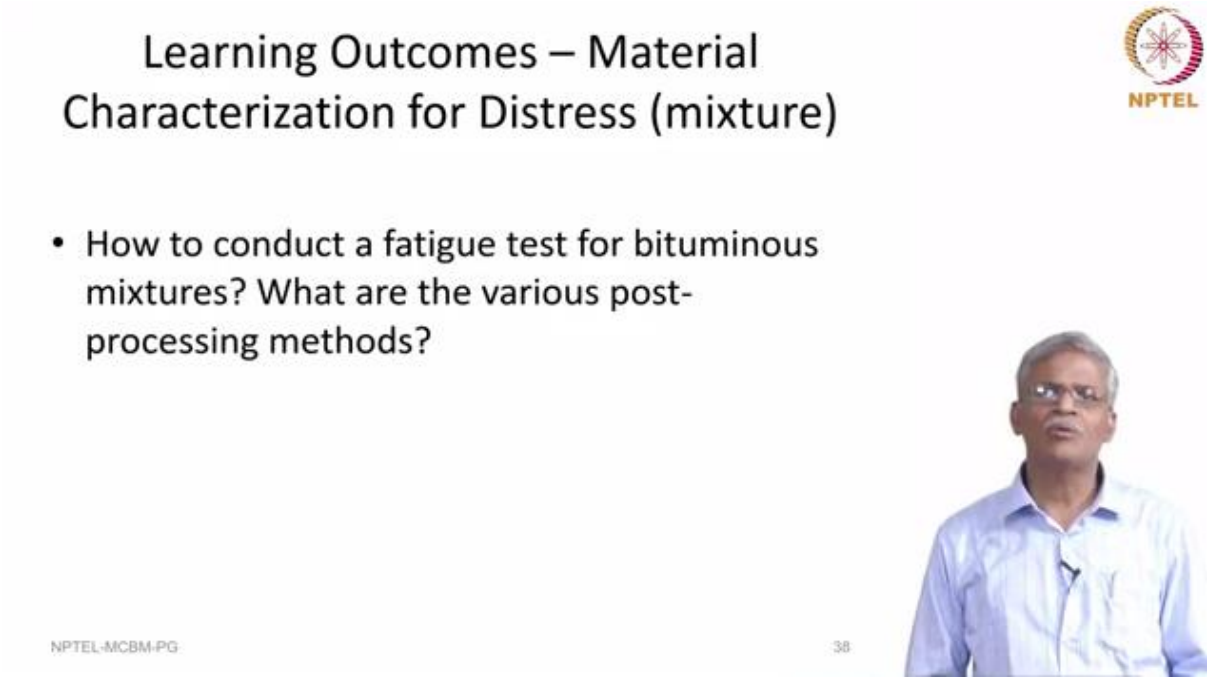

And similarly, how do we do the fatigue test for bituminous mixtures and what are the various post-processing methods that are available. All this is for the mixture. So, these are some of the learning outcomes that we are going to do.

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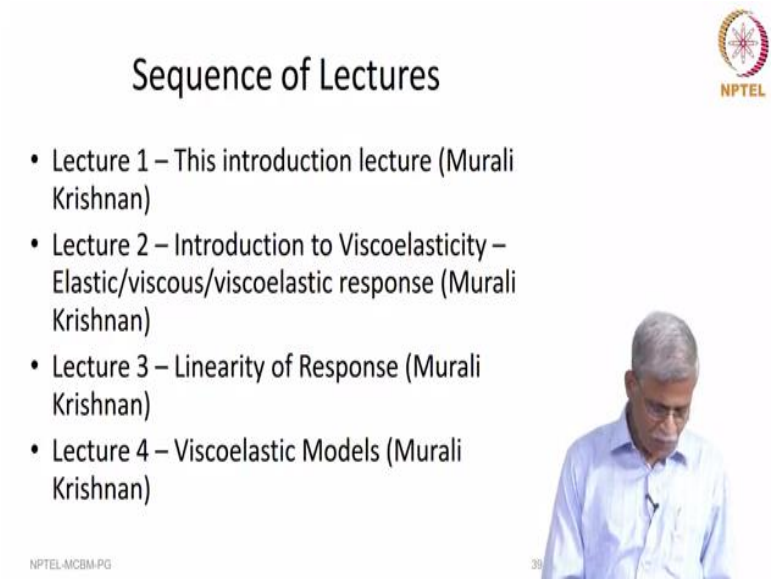

So, what is the manner in which the lectures are going to be arranged here. So, when I say lecture, I am not talking in terms of the time duration. I am talking in terms of the concept. So, the first lecture is this introduction lecture that is being given by me right now. Then the lectures, there will be 3 lectures. In the 2nd lecture, we will talk about viscoelasticity, elastic, viscous, viscoelastic response. And in the 3rd lecture, we talked about the Linearity of response. And the 4th lecture, will talk about the viscoelastic models to be used.

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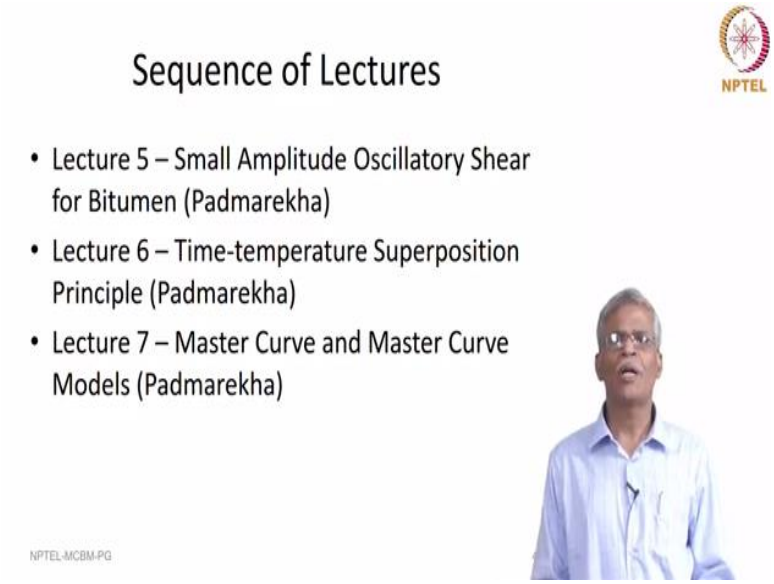

And in the 5th lecture, Padmarekha will talk about small amplitude oscillatory shear for bitumen. And the 6th lecture, she will introduce you to time temperature superposition principle. What exactly it means and in the 7th lecture, she will talk to you about the master curve and the associated master curve models.

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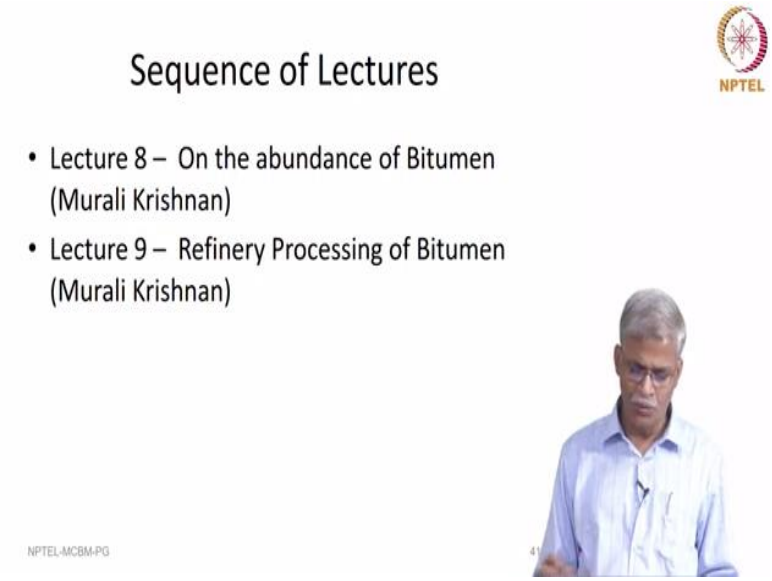

And in the 8th lecture, I will come back to the material part. So, whatever we have seen in the first 1-7 lectures, talks more about the model. Now, let us understand the material. So, where is bitumen? What is bitumen? And how it is available? Also, the refinery processing of the bitumen will be explained in the 8th and the 9th lecture.

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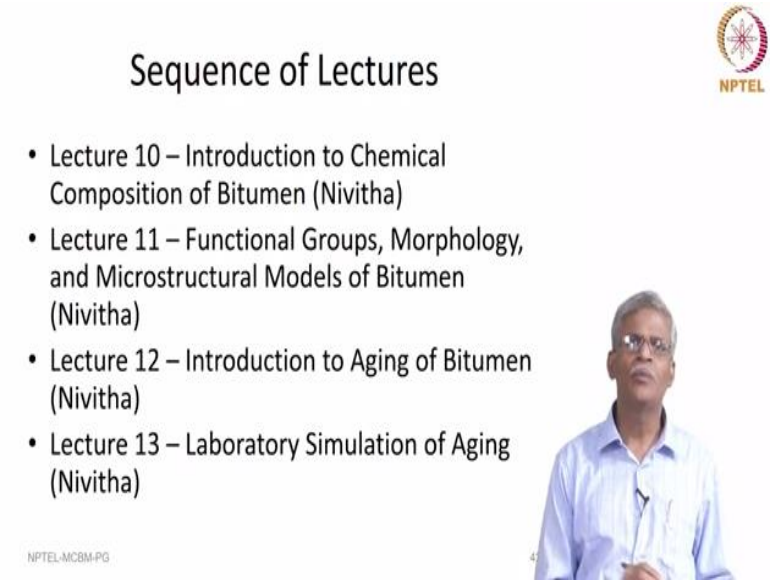

Then, as we discussed the earlier, we will talk about the chemical composition of bitumen will be carried out by Nivitha. She will also talk about functional groups, morphology and

micro structural models of bitumen. And she will introduce you to aging of bitumen. Aging in a sense, will take us many lectures to really explain the required amount of chemistry background that is needed is substantial. So, we will try and see whether we could introduce it in a fairly simple and straight language. She will also talk to you about the various laboratory simulation of aging for bitumen.

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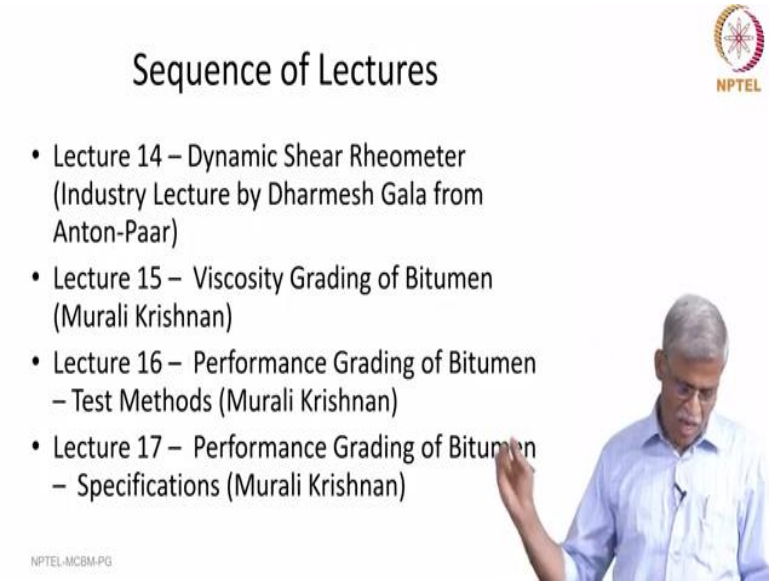

And before we started talking about the grading, we will be introducing what exactly is this Dynamic Shear Rheometer. And this will be an industry lecture by Mr. Dharmesh Gala from Anton Paar. Then, I will talk to you about viscosity grading of bitumen, performance grading of bitumen and the testing methods as well as the specifications. Then, since we talked about the material that is going to be the bitumen as well as the modifiers for bitumen.

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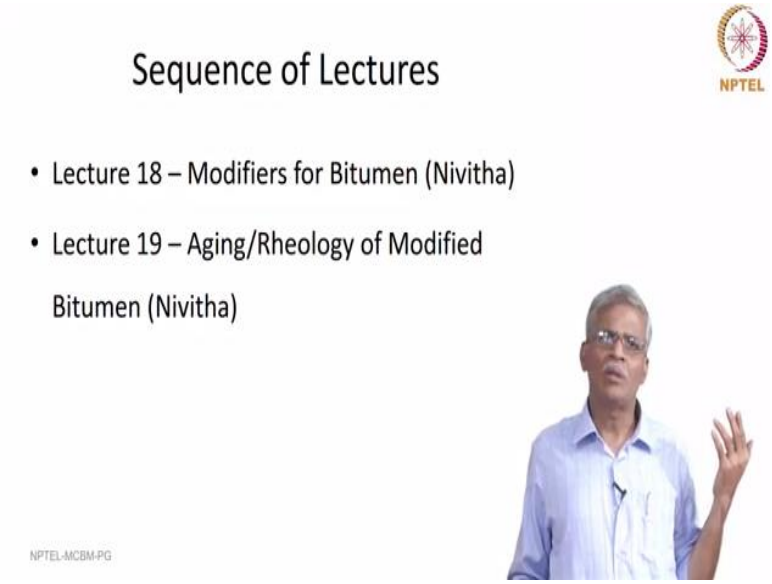

So, Nivitha will talk to you about elastomers, plastomers, ter-polymers, rubber modified binders. What are all the different types of modifiers for bitumen? What are the manner in which each of them interact and how their aging and the rheology is influenced? In lectures 18 and 19.

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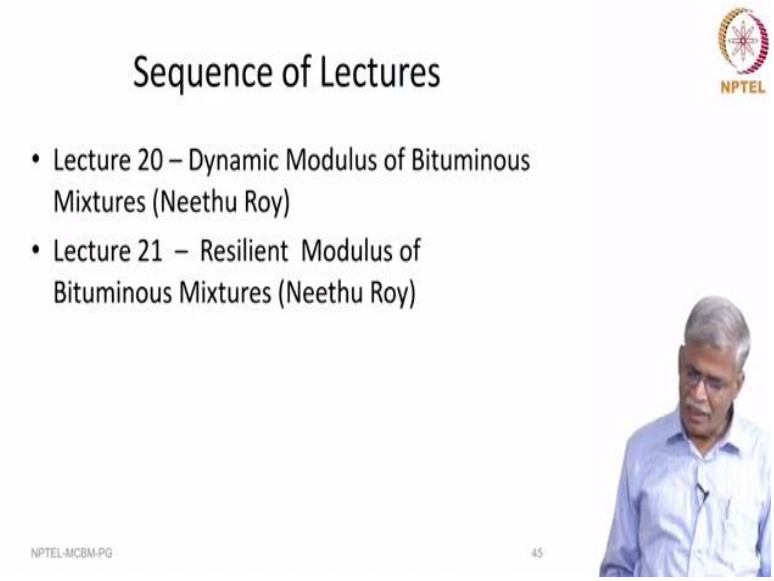

And as far as the material characterization of the mixtures for design. Neethu Roy will talk to you about dynamic modulus of bituminous mixes, resilient modulus of bituminous mixtures.

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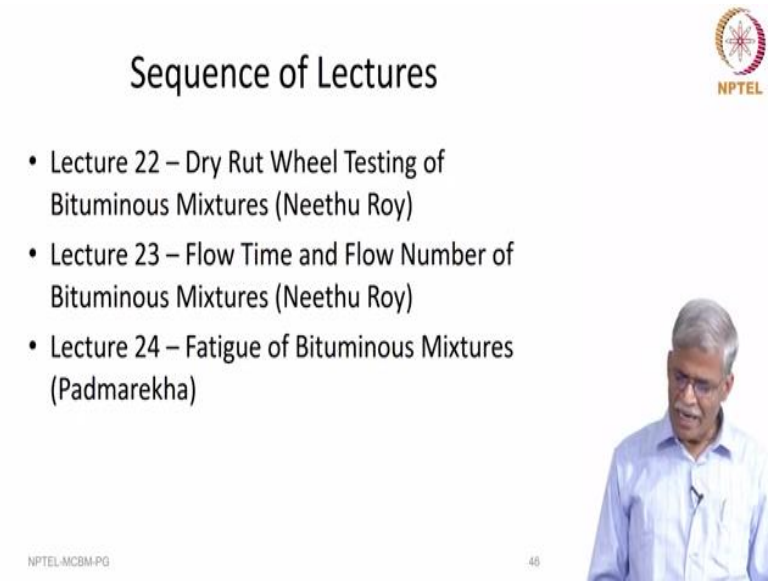

And then, she will also talk to about dry rut wheel testing of bituminous mixtures, flow time and flow number of bituminous mixtures as far as the, rutting part is concerned. And the fatigue of bituminous mixtures will be the last lecture by Padmarekha will be given here. So,

this is the first introductory lecture on mechanical characterization of bituminous materials and mixtures.

So, in this lecture we introduced this course, we outline the various learning outcomes, we also outline the various lectures that will be given in sequence. So, in a nutshell this course is about mechanical characterization of bituminous binders and mixtures. By mechanical characterization, I mean experiment and model. The model that will be used in the full lecture this course is linear viscoelasticity.

And what we are going to do is, we are going to differentiate between material characterization for design as well as material characterization for distress. We will talk to you about how bitumen is produced? How different types of modifiers are added to bitumen? We will talk to you about the bituminous mixtures, the characterization that is done for design purpose as well as the distress purpose. Okay.