Mechanical Characterization of Bituminous Materials

J Murali Krishnan
Professor
Department of Civil engineering
Indian Institute of Technology Madras

Lecture No - 27
Viscosity Grading – Part 1

So in this lecture, we are going to talk about, the basics related to viscosity grading of bitumen

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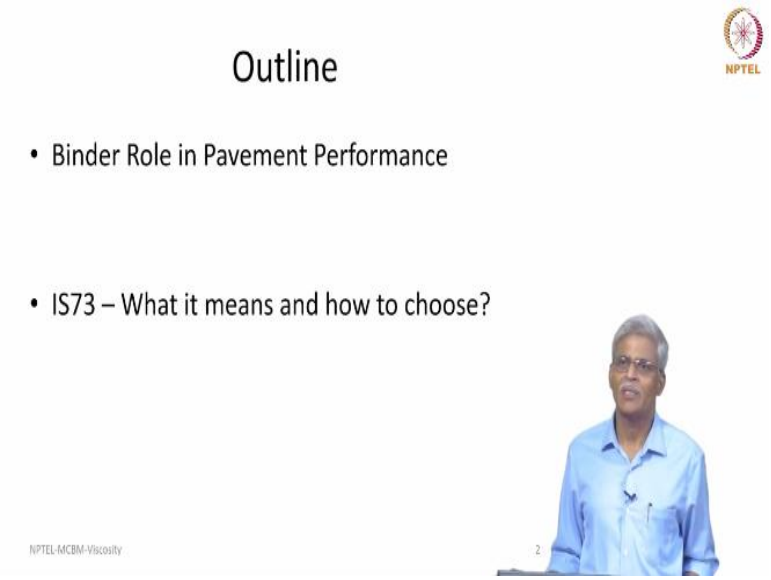

And the outline of this lectures is, we first need to understand what the role of binder in pavement performance. And as far as India is concerned we use the IS73 specifications for viscosity grading. And in fact this specification was written at IIT Madras, based on a generous funding from the Bureau of Indian Standards. And so we are going to see how we have to use this specifications in an appropriate way.

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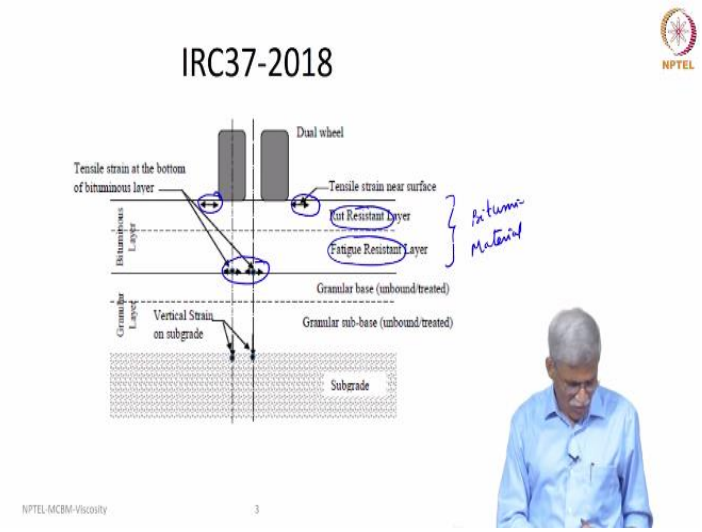

So if you really want to understand, how to choose a specific binder, for a pavement we need to also look into little bit into the, some of the design aspects here. What you see here is the IRC 37 cross section as is given here. So you have two layers of bituminous material, and you can actually see that this layer is called as fatigue resistance, this layer is called as rut resistance. And IRC stipulates that one should not only measure the strain on the top but also at the bottom.

So what it means is if you want to design a bituminous pavement with a specified life, one need to ensure that the required rutting as well as the fatigue damage or well within the specification limits. And for that we need to first understand what really causes rutting? What really causes the fatigue? And what exactly is the role of bitumen in these two distresses predominantly these two distresses? And this will then help us to choose an appropriate grade of bitumen based on the geographical location as well as the traffic conditions.

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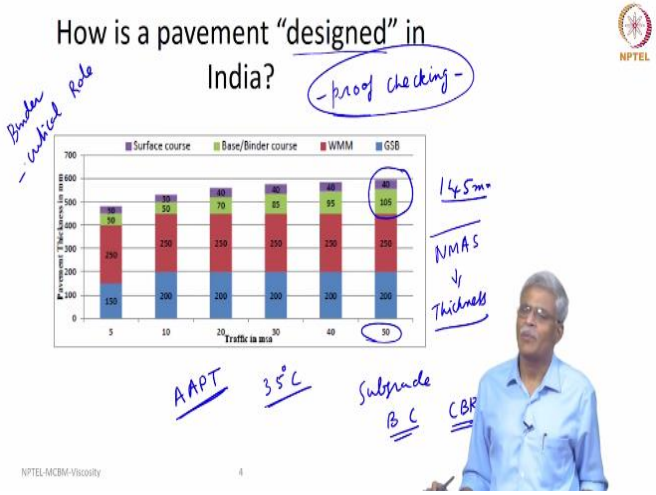

One, so let us just quickly take a look at how a pavement is designed in India. And in fact I have a reason for putting this within quote normally we don't really design a pavement, most of the time what we do is we do what is really called as proof checking. So that means the choice of a specific thickness of a bituminous layer here 40+105, 145 mm of bituminous layer. The choice of this is not only dependent on the actual load and the environmental condition but also based on the various constructability issues.

You may want to know whether one should use one layer for 40 mm or whether you want to use two layers for 105 mm, so there is an interesting connection between the nominal maximum aggregate size as well as the thickness of the pavement. So these designs hence are already in place and what we only do is to check them for any specified level. So as of now if you look at it you see on the x-axis the traffic in million standard axles.

And on the y-axis you see this the thickness and typically this will depend on the subgrade bearing capacity. In India it is used in terms of the CBR values. So these are thicknesses that are already prescribed and such thickness are normally given based on a specific average pavement temperature. And in IRC templates are given for an average annual pavement temperature of 35-degree centigrade.

So depending on the location in which you want to construct your pavement, as well as the traffic that you are expected to get, you are required to design a new cross-section, design in the sense in which I mentioned and check-in and these are sample templates that are given for us to use. So as soon as we take this thickness we need to find out the appropriate material properties and check for the required fatigue damage as well as the rutting.

And this is where the binder plays a critical role here okay. So if the binder plays a critical role we need to also choose an appropriate grade of binder depending on the temperature as well as on the expected traffic. So let us look at each of these things one by one.

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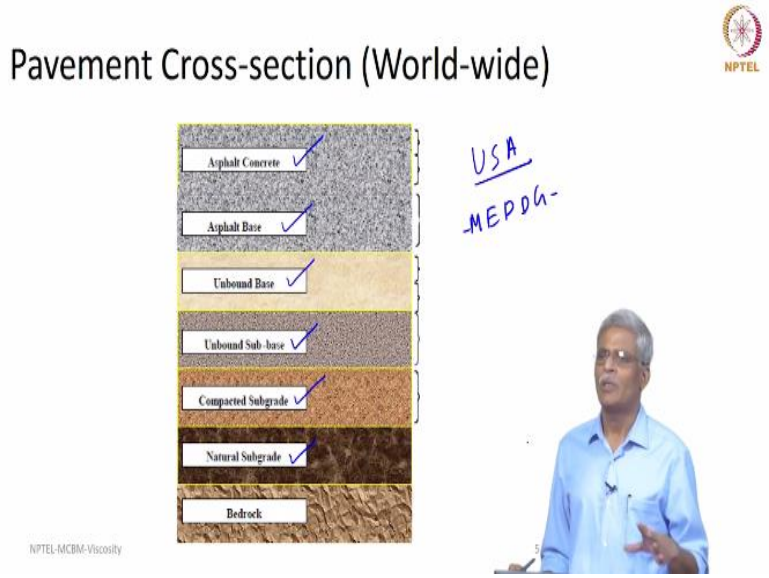

And before we proceed further we also need to have some awareness about, the kind of cross sections that are available throughout the world. So what you are seeing here is a thickness that is given in USA as part of the mechanistic empirical pavement design method. Substantial amount of thickness is provided for the asphalt concrete, asphalt base, then you also have an unbound base, unbound sub base, a compacted subgrade, and a natural subgrade.

So when we compare the cross sections that are provided in United States or in Europe, we always find that the thickness that is provided within the Indian context is slightly less. This has mean there are many reasons related to it the kind of modulus values that we choose, the kind of temperature conditions that we pick and those will not really be discussed in detail in this particular course but that will typically form part of a rigorous pavement design course.

But I just wanted to mention this in passing that one needs to be aware of the fact that not only the binder plays a critical role in the performance of the payment but the appropriate thickness that one needs to provide also plays a critical role.

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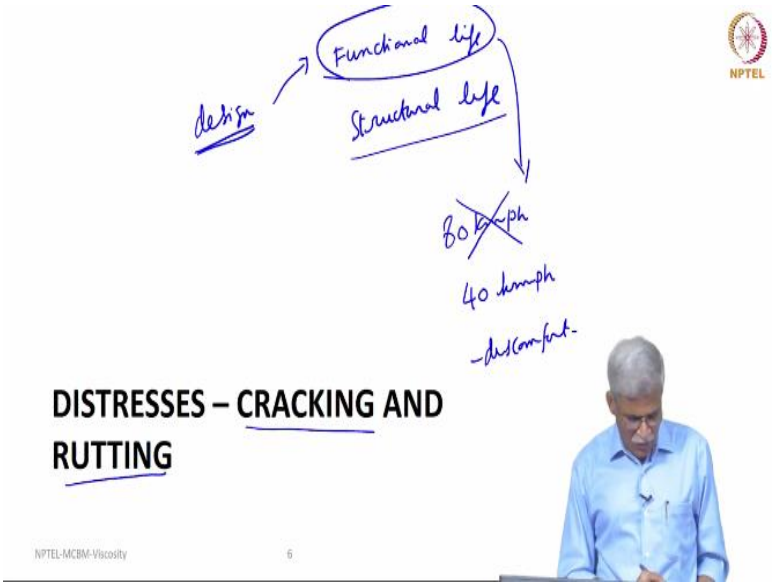

So before we do well deep into how to pick a specific binder grade so let us have a very cursory look at the different distresses that one is likely to encounter in a pavement. And in fact if you really want to do a design for bituminous pavement you are really talking in terms of functional life as well as structural life. The interesting aspect related to bituminous pavement is we worry only about the functional life.

If the structural life is reached, it essentially means that the road is no longer motorable or you are going to see big craters are cracked that situation normally never arises in a pavement. So when I was talking about functional life so, what it means is if you have designed a road for 80 kilometer per hour speed because of the undulations and rutting you may probably be able to drive only at 40 kilometer per hour and there is going to be acute discomfort during driving.

But it is not necessary that the road is going to become absolutely unmotorable. So this is these are some of the issues that also we need to keep in our mind. So let us go into cracking and rutting and I am going to mention that in the full course you will be hearing about this distress again and again for the simple reason that your material characterization, the design and the distress are exceedingly interrelated in a fairly complicated way. So we have to keep referring to them time and again right?

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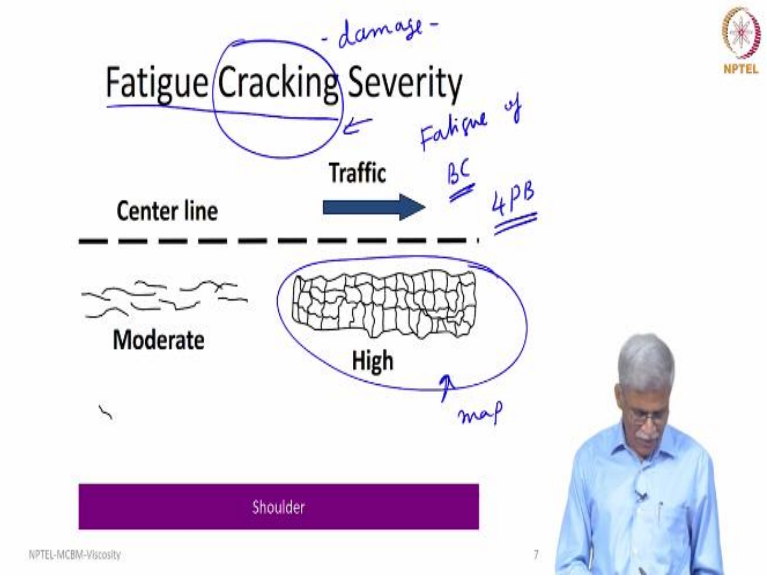

So what you see here is the fatigue cracking in fact I would really call more this as fatigue damage and not really as cracking. There is a specific reason why they are called as cracking and that will be we will be discussing it later when we talk about the fatigue of bituminous mixtures, with four-point bending equipment. So now you see the center line and there is going to be some portion which is going to be subjected to repeated loading.

And we get what is really called as the map cracking or the alligator cracking and most of you are really familiar with such kind of failure.

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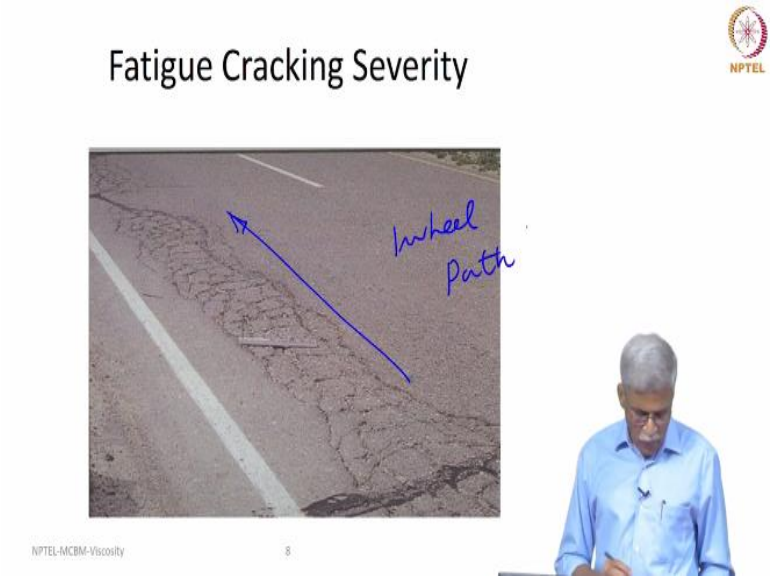

And you are going to see that these cracks appear along the direction of traffic more or less in the wheel path. So why does this kind of cracks develop?

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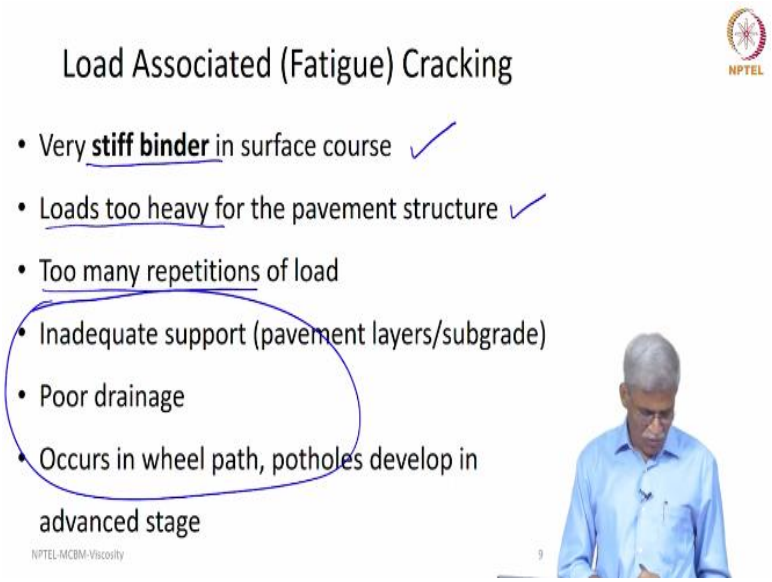

And what is the role of the binder here, and since our lecture is about the choice of bitumen and how to pick them depending on the traffic and temperature conditions. We will focus our attention only on the role of the binder here. So I am going to pick only this first portion as well as the second portion. The rest of the things will not be discussed here, so you are going to see that you are going to have a very stiff binder in the surface course and the loads that are too heavy and too many repetitions of the load. So this is the reason for your fatigue damage okay.

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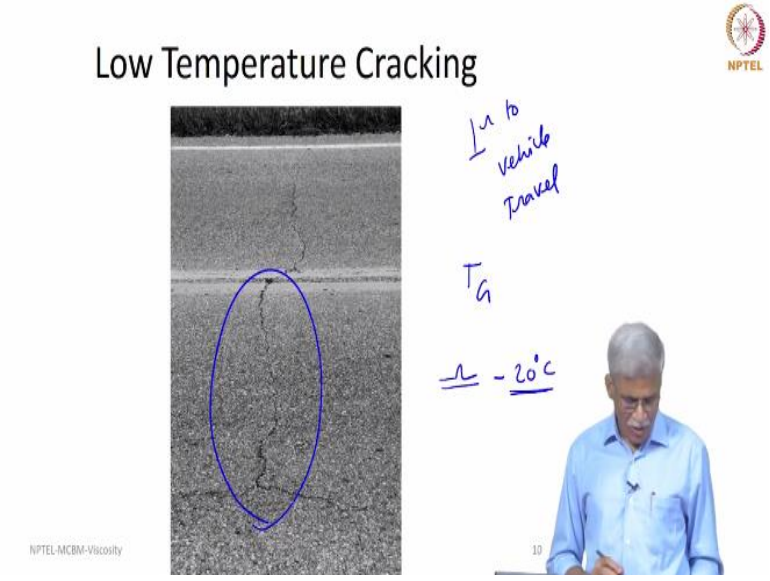

Now, let us talk about the low temperature cracking. The low temperature cracking in fact has something to do with the glass transition temperature, so if the temperature at a specific location goes below the glass transition temperature of bitumen approximately minus 20 degree centigrade. You are going to see this crack and these cracks are perpendicular to vehicle travel. You can actually see that the cracks developed in this specific direction. So these are also called as block cracking

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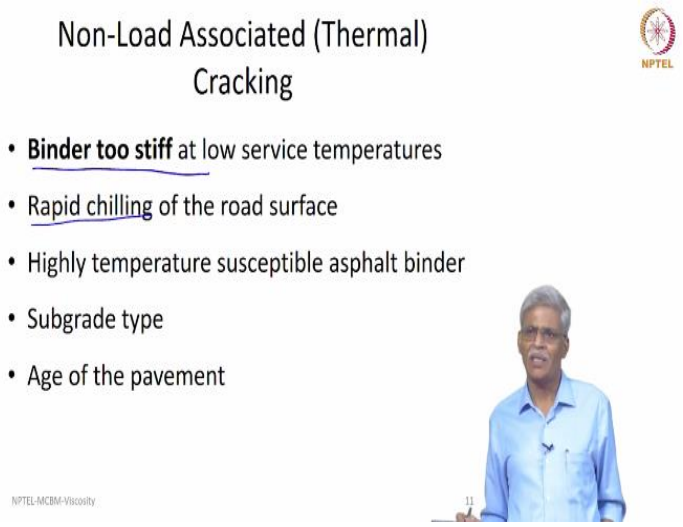

And why this happens is the binder is becomes extremely stiff, at the low surface temperature and this also due to the rapid chilling of the road surface. As far as India is concerned other than few locations near the Himalayas we are not really going to get low temperature cracking in the manner in which you have seen here.

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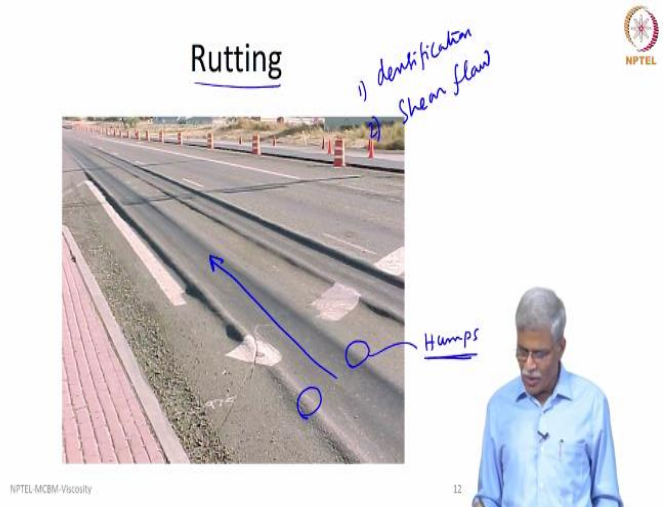

So then we go to one of the well-known failure that is often seen in in the Indian roads what is really called as the rutting. Basically this rutting is the longitudinal depression that you are going to see in the wheel path. You will also notice that on either side of this depression or the bottom most you will see some kind of a humps. So typically when you use a very soft binder or when the daytime temperature is exceedingly heavy in addition to vehicles that are moving at a very slow speed, there is going to be some kind of a densification that is going to happen.

And the second aspect is what is really called as the shear flow that is going to happen. So because of these two phenomena you are going to see such kind of behavior. This is probably one of the well-known failures for most of the pavements in India.

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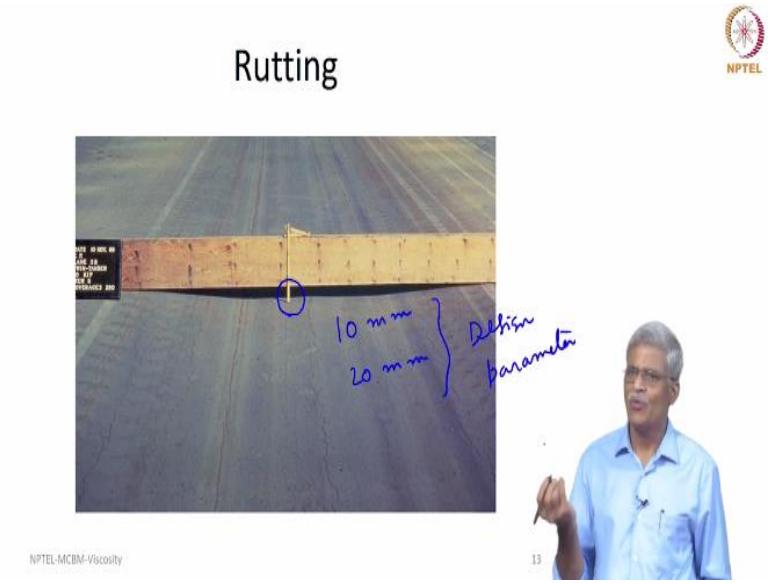

And you can actually see when you place a straight edge across the wheel path you are going to see how much the dip is. And depending on the country where we live this is considered either a 10mm or 20mm as the design parameter. So, that means if this value exceeds 20mm you are going to say that your pavement has functionally failed.

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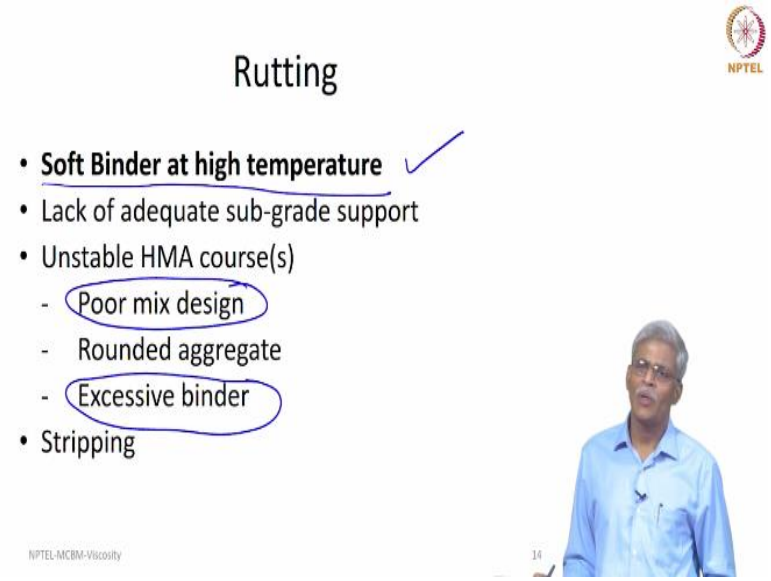

So now let us understand, what is the reason for this? The reason for this is you are using a very soft binder at high temperature and I will also mention one specific aspect here which is something to do with poor mix design and using excessive binder. So again our intention is to highlight the role of the binder here. So you are going to use a soft binder at high temperature and during summer you are likely to end up with rutting in your pavement right?

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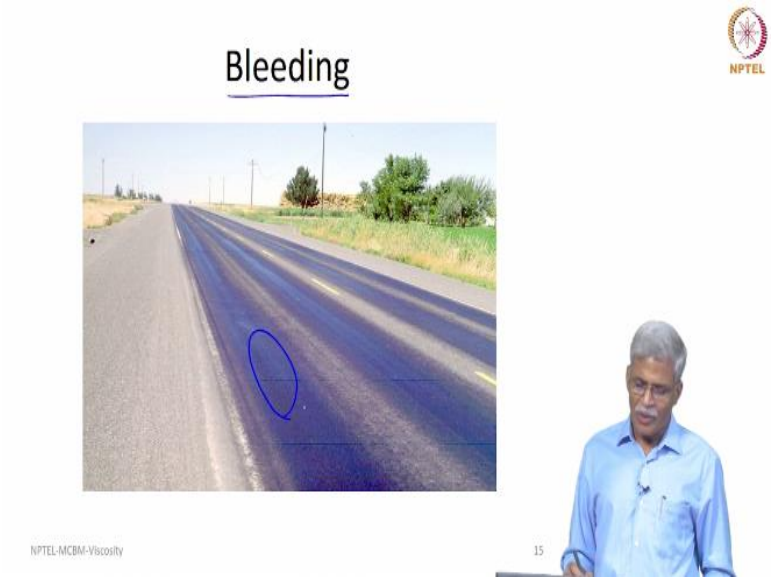

Another important failure, more from the perspective of wrong mix design or mostly using a very soft binder or using excessive binder is something really called as the, bleeding. You are going to see bitumen oozing out from the interior and coming to the surface this phenomenon is

irreversible, so that means after the summer is over the road is likely to be like this and this is going to have problems related to lack of friction. Right?

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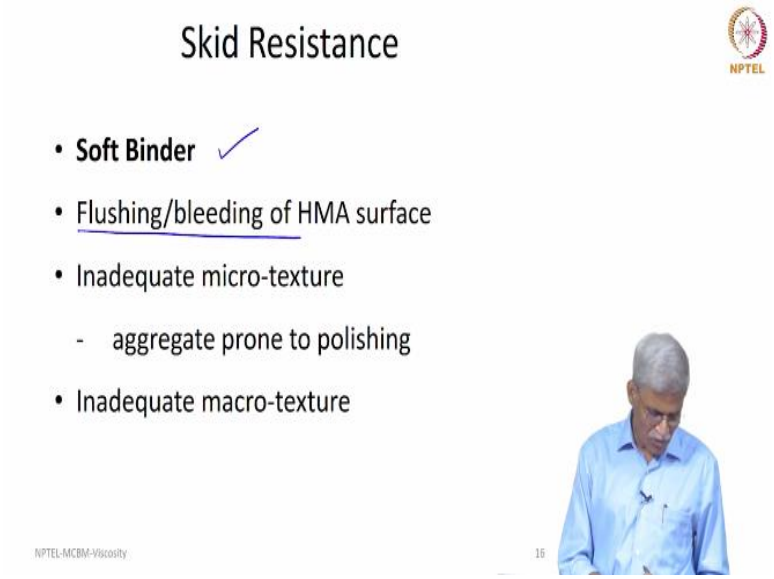

So the another failure that we can talk about is the skid resistance this is due to the soft binder as well as flushing and bleeding of hot mix asphalt surface. Right?

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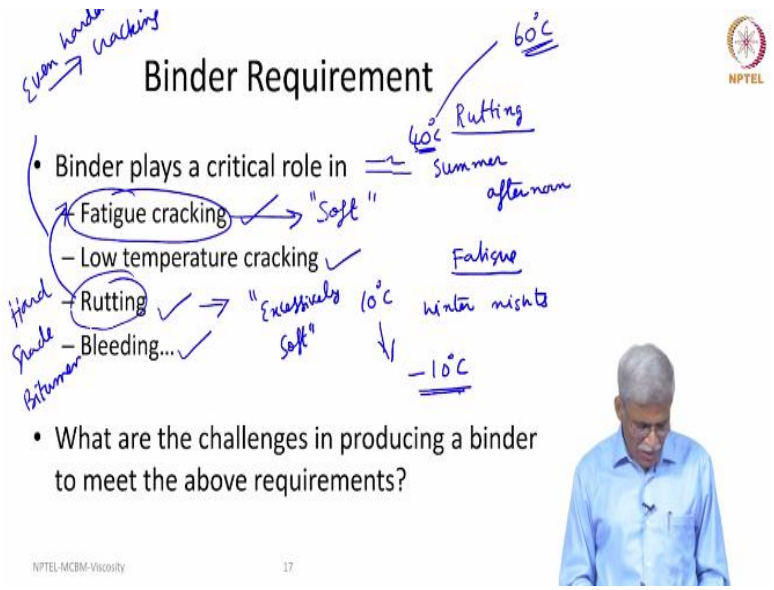

So to summarize we talked about fatigue, we talked about low temperature cracking, we talked about rutting as well as we talked about bleeding. So in all this the binder plays a critical role. So now let us try and understand where the rutting is going to be maximum it is going to be

maximum on summer afterwards. And what about fatigue this is going to be maximum during winter nights.

So what really happens on summer afternoon when the air temperature is let us say roughly of the order of 40 degree centigrade or above, the pavement temperature can go above 60 degree centigrade. And in the winter when the night time temperature that I say it goes to 10 degree centigrade the pavement temperature can go even up to minus 10 degree centigrade. So when you are going to have this kind of a wide range of temperature maximum as well as the minimum you are going to have such kind of a failure.

But there is a small problem here now if you really want to design a pavement, so that there would not be any fatigue cracking. You would really expect that at the winter nights you want a bitumen to be more or less soft, in the sense it is not become very stiff. But the same bitumen during the load rutting that is at summer in the afternoon, can even become excessively soft. And hence can lead to lot more rutting.

So if you try to balance fatigue you are going to have problem with rutting. And we can argue on the other side also. If you really do not want any rutting, then you are going to use a very hard grade bitumen. But that hard grade bitumen when you are talking about fatigue, can become even harder and lead to crack. So if this is the situation, how do we really handle it? So let us first try and understand what the scenario here is.

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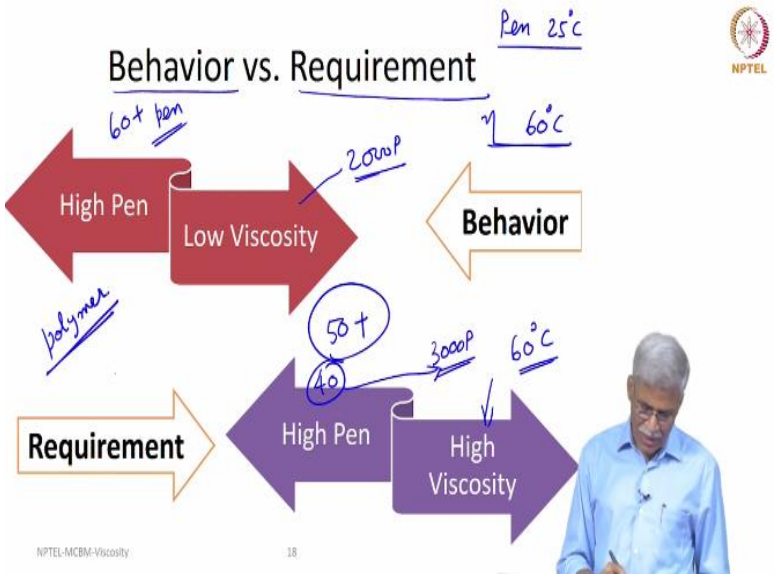

So if we understand talk in terms of what is really called as what is the actual binder behavior and what is the requirement? I am going to illustrate it with respect to two parameters, one is the penetration at 25 degree centigrade all of you are familiar with penetration at 25 degree centigrade. Another is viscosity at 60 degree centigrade. So the actual behavior is at 60 degree centigrade, if you have a low viscosity, let us say 2000 poise the same material is likely to have 60 plus penetration at 25 degree centigrade. But what do you really need you really need a very high viscosity at 60 degree centigrade. So let us call it as 3000 poise and at 25 degree centigrade, you expect that this will have let us say you want it to have a very high penetration of, let us say 50 plus but in reality what will happen this will be only around 40 to match this viscosity.

So that means the behavior is of bitumen is something but the actual requirement is something else. And in fact this is one reason why we normally add a polymer because a polymer can balance what is really called as the temperature susceptibility.

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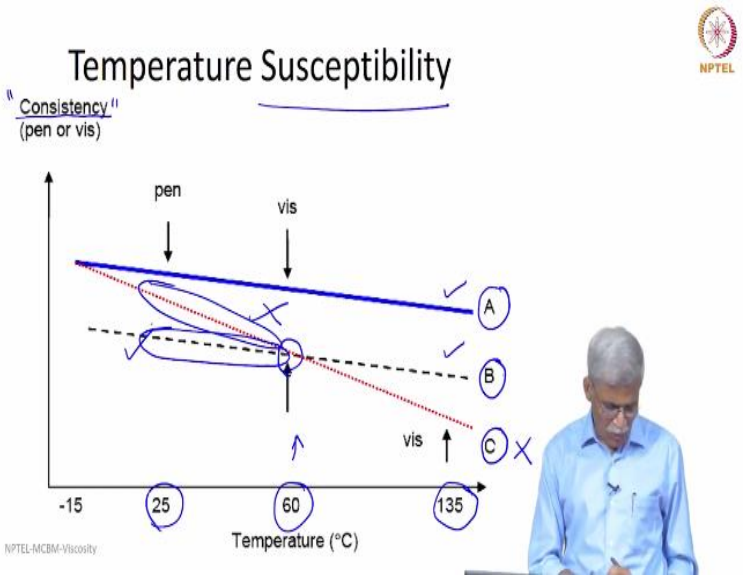

So now let us understand what is this temperature susceptibility. What do you see here in this graph is in the x-axis 25 degree centigrade 60 degree centigrade 135 degree centigrade. And in the y-axis we call it as a term called consistency, it can mean anything basically this kind of measures are used to check the variability between the bitumen at a different stages for instance if you get a bitumen from the refinery steps. What was the penetration that you measured and as you subjected to repeated heating and cooling and by the time it is used in the road construction, how much its value has changed while there is a tendency to relate penetration or viscosity to how the material will behave in the field in terms of its performance that is an something that we should desist from doing it. Because these parameters are mostly empirical in a specified way. So we will be discussing it as we go along.

So now you look at three binders, binder A, binder B and binder C. You can actually see that binder A and B are parallel to each other as a function of temperature. And when you look at binder B and binder C at 60 degree centigrade, both of them seem to have the same viscosity, same consistency. But binder C seems to be showing a drastic variation in its behavior as a function of temperature.

So this is a binder that should be highly avoided because what can actually happen at 135 degree centigrade more related to the compaction temperature, the binder may be very low viscous but

as the temperature goes all the way down to minus 10 or 25 degree centigrade, the material can become extremely stiff and it can lead to the issues related to temperature susceptibility.

So that means you should have a binder, that if it is stiff at 60 degree centigrade it should not become too stiff at 25 degrees. So you may want to take a look at the slope of binder B you can actually see that the slope is very gradual but if you compare it with binder C you are going to see that the slope is considerably substantial. And that is a binder that you do not want to use whereas you want to use only such kind of a binder. So this is a issue that we should be aware of when we design when we choose bitumen.

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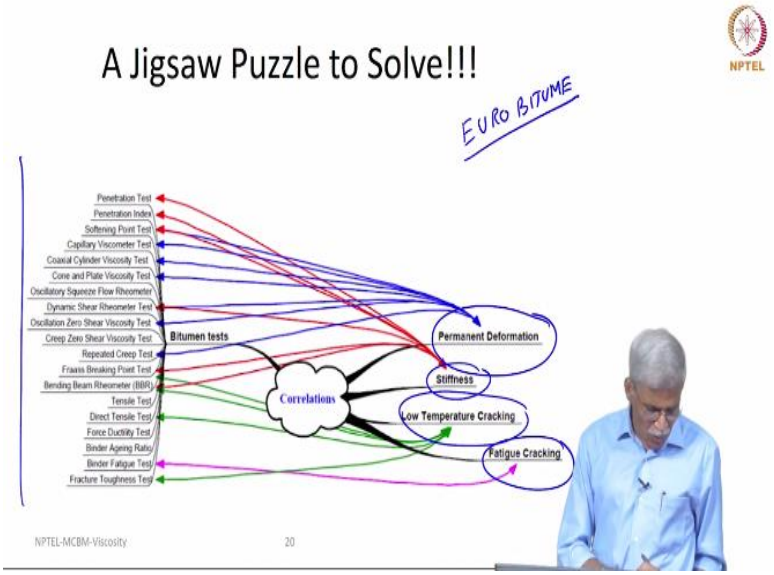

This is a puzzle to solve in fact what you see here is a part of the Euro Bitum wherein they have been trying to see what kind of tests are available and how many tests can actually be used for fatigue damage, low temperature cracking, stiffness? And different types of correlations are available as can be seen from this side. This is really a puzzle to solve. So let us see how we are going to handle it here.

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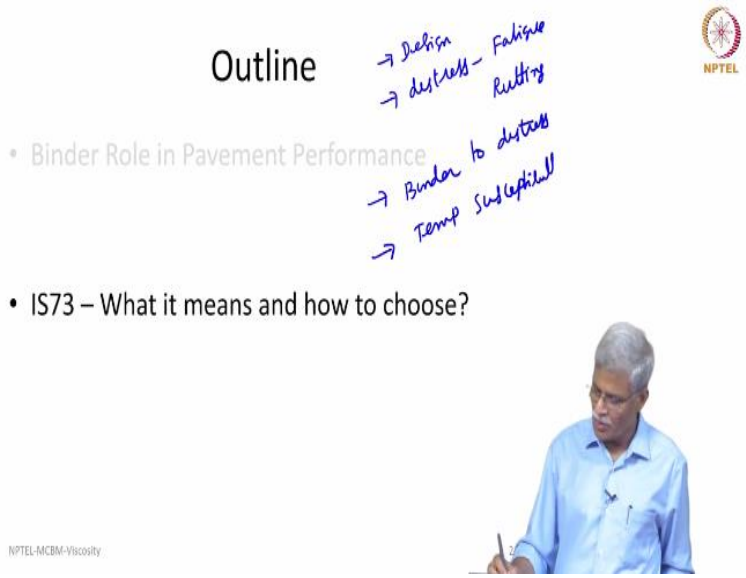

So this what we discussed it till now is, what is the design of pavement number one, what really are the distress, and when you are talking about distress, we talked about fatigue, we talked about rutting, and what is the relation of binder to distress? And we also understood what is really called as temperature susceptibility. So that means we do not want a bitumen to show drastic variation in its properties as a function of temperature.