Mechanical Characterization of Bituminous Materials

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Lecture No - 29
Performance Grading – Part 1

So today we are going to talk about the performance grading of bitumen. And before we start talking about the issues associated with performance grading, we need to understand little bit about why such a specification actually came into force? More or less most of the countries were quite happy with the viscosity grading of bitumen and in some cases even penetration grading of bitumen.

But when the situation in the Middle East changed during their late 70s and early 80s and when many highway agencies throughout the world had to use bitumen that were coming from non-standard crude substantial amount of rutting, breeding as well as fatigue cracking was seen. So it was essentially felt that one should characterize the bitumen not based on properties at a fixed temperature such as 60 degree centigrade viscosity or 25 degree centigrade penetration, but rather from the perspective of the performance.

So more than 50 billion dollars United States dollars were spent in this attempt from 1987 and the 1st set of Super PG specifications were released in 1992 and over a period of time they are being refined. So we will go into this in the following manner.

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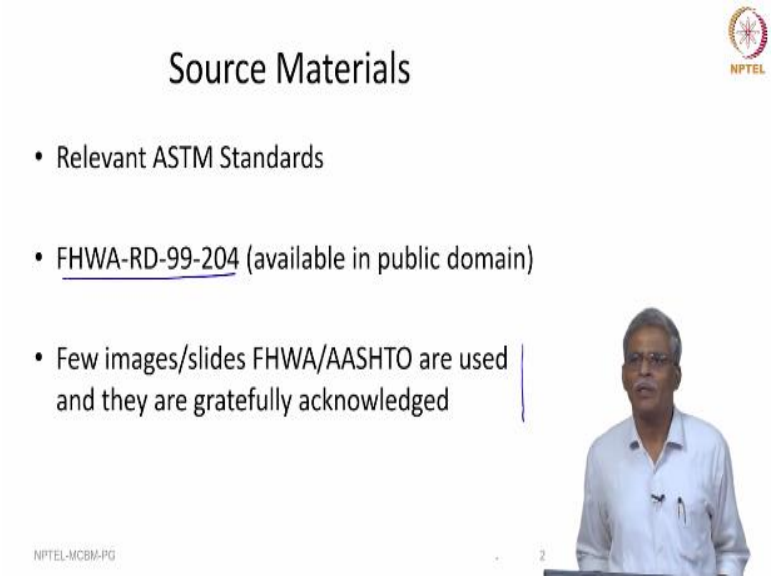

Before we start the lecture the relevant ASTM standards related to this particular lecture will be shared, and it is also expected that the viewers try and see whether they could get a copy available online. The federal habeas administration report, that gives the complete detail about how the PG specifications came about and I have also used some images that are available in public domain in the AASHTO Asphalt institute/ FHWA sites. And I gratefully acknowledge the use of this images ok.

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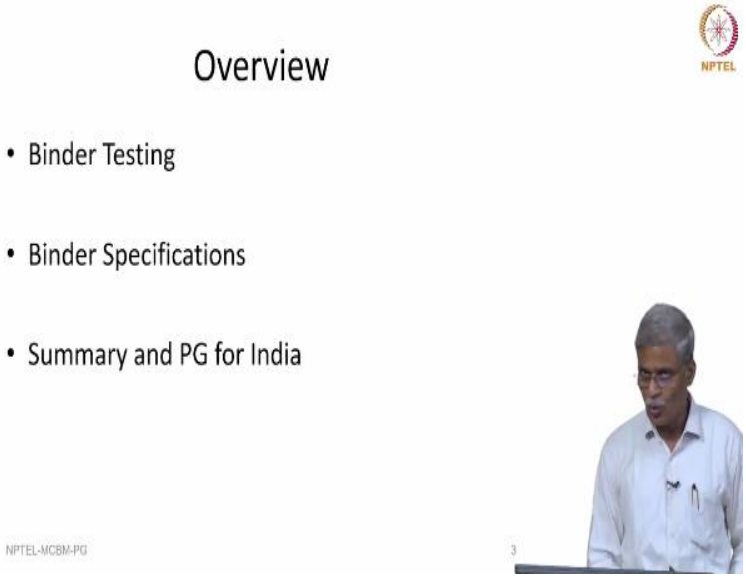

So we are going to do it in the following way, we will be talking first about the binder testing, the binder specifications and we will also have a summary and discussion of what we should do when we want to write PG for India, okay.

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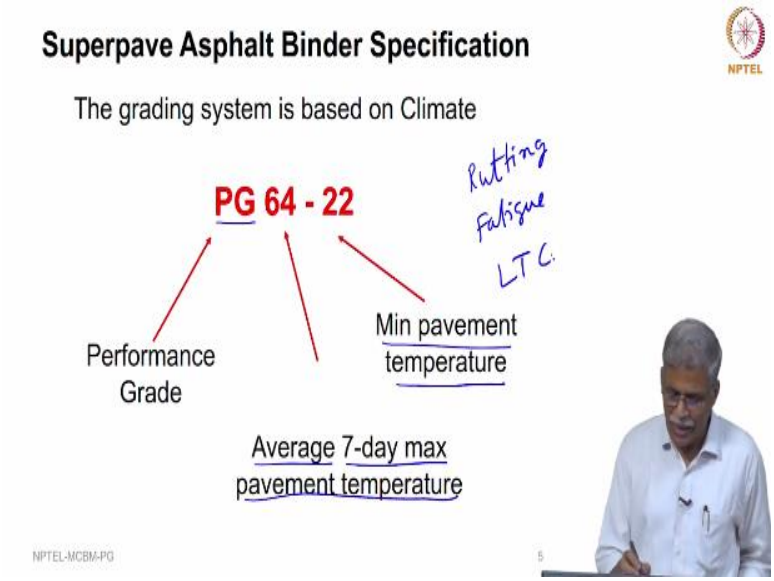

So let us start talking about the binder testing. So let us first introduce what is really called as the PG specification? So PG stands for performance grade. And you are going to see two numbers here. 64 -22. 64 stands for the average 7 day maximum pavement temperature. And -22 stands for the minimum pavement temperature. So what essentially this means is if you use a binder in a geographical location that has 64 degree centigrade to -22 degrees centigrade pavement temperature. This binder in a sense will be resistance to rutting, fatigue and low temperature crack. So this is the issue and we need to understand that this grading system is based on climate. Okay.

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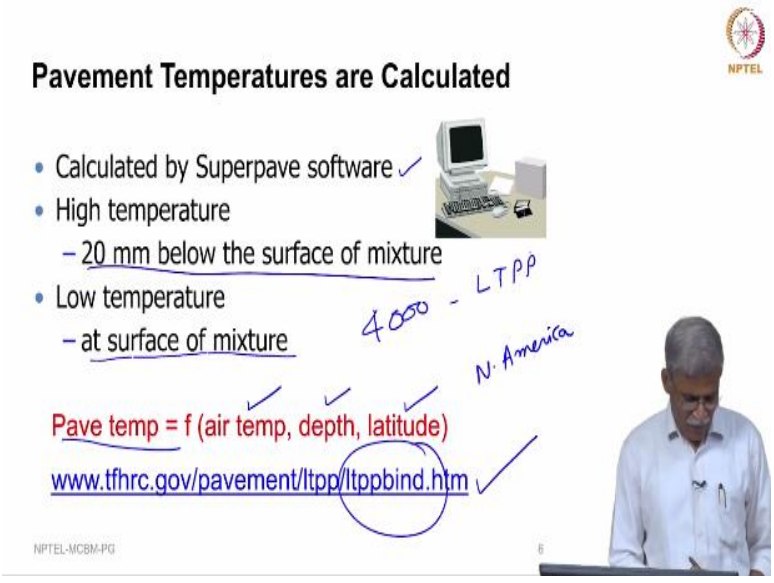

So, how do we do this pavement temperature? Now we realize that one should have a very clear understanding of the pavement temperature and only then we can actually use this performance graded system. So you can use the superpave software that is available and for high temperature, you will need to find out the temperature of the mix 20mm below the surface of the mix and for low temperature this is taken at the surface of the mixture.

And in fact there is a long-term pavement performance bind the software that is available you can freely download it and check it and depending on any geographical location, of course, this will work out only for the North American conditions. You can actually find out what is the grade of the bitumen that you need to really use and the idea is this pavement temperature is a function of air temperature depth as well as the latitude.

And in fact if you recollect the discussion that we had on viscosity graded bitumen specification, you will see that we showed you a chart of high temperature pavement as well as low temperature pavement for Indian condition. It was based on very limited amount of field data. If you, really have to have a substantial amount of pavement temperature data the kind of data that has been collected from more than 4,000 locations as part of the long term pavement performance program in US. So that kind of data needs to be collected for India, right?

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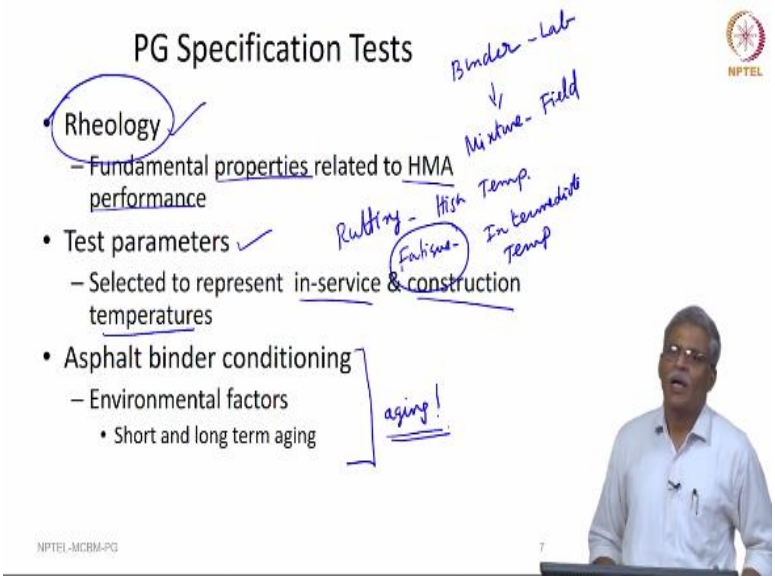

So let us go to the PG specification test. There are three important aspects here as far as the PG specification is concerned. First and foremost thing is the use of rheology we have been discussing a lot about the linear viscoelastic response in time domain as well as the linear viscoelastic response in frequency domain. We also talked little bit about time temperature superposition as well as master curve, okay.

So these are the fundamental properties that are related to hot mix Asphalt performance. So I will go through this each of them one by one. The second is what are the test parameters that are selected to represent the in service as well as the construction temperature and finally the aging part of it. Okay so now let us talk about this rheology part so what essentially it means is we need to understand that whatever test that we are doing in the laboratory are only based on binder.

But what we are trying to now predict is so binder, lab and this is going to be mixture, field. So we need to establish this connection so all the test will be carried out in the laboratory on a binder and the test that we are going to design in a sense should predict what will be the performance of the mixture in the field? So we need to have some idea about how to pick a property of a binder that can be related to the performance of the mixture in the field.

So this is where rheology comes in. The second is having decided that what really are the test conditions that needs to be done, so if you are talking about rutting we know very well that it has to be at a high temperature. So what kind of test conditions should be test parameters and test conditions one should have. If you are talking about fatigue, we are talking in terms of what is really called as the Intermediate Temperature.

So we need to have appropriate test parameters and we also need to realize that as the pavement is constructed and it is in service the property of the material keeps changing. So there is going to be a short term aging due to the construction. There is also going to be a long term aging because of the service conditions due to the weather as well as the traffic conditions. So if I am really interested to find out the fatigue response of a binder that in in a sense could be related to the mixture.

It is necessary that the binder should be the age hardened in the laboratory in in a sense to simulate what can really happen in the field condition, so this also should be considered. So this is the whole summary of what we are going to discuss here right?

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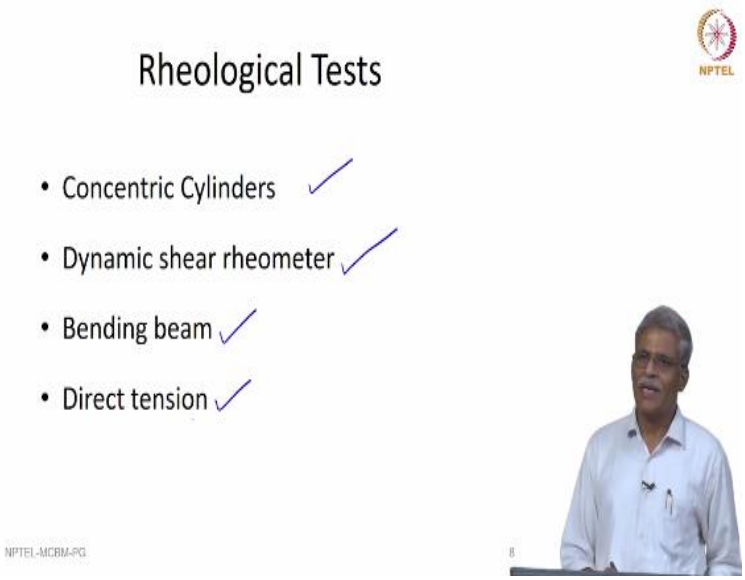

So when we are talking about the rheological test, there are going to be four types of tests that are being prescribed as part of the performance grade. One is the concentric cylinder what is also called as a couette viscometer. Another is the dynamic shear rheometer using parallel plate of different geometries and for low temperature; we are going to use either bending beam or direct tension.

And in fact the theory associated with dynamic shear rheometer the appropriate specification criteria bending beam as well as direct tension will be discussed to separately but in this lecture we will only present only the specification framework that is going to be used okay, right?

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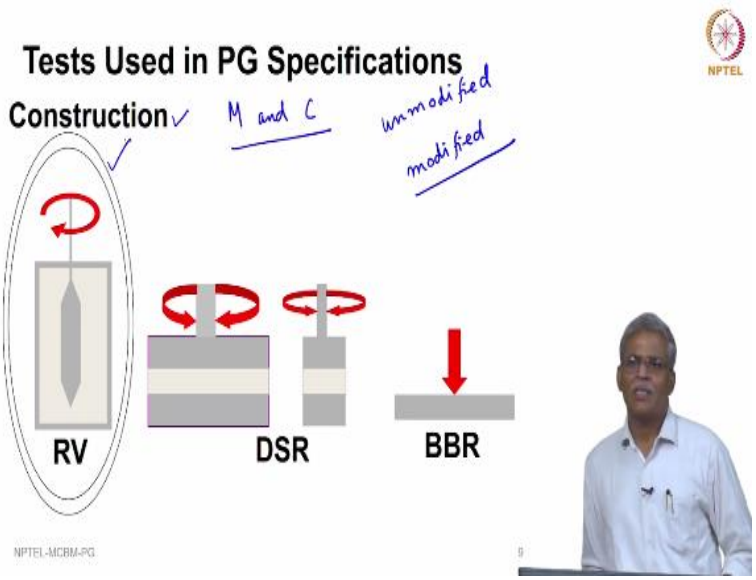

So what are the tests that are going to be used in PG specification? So we talk about construction. So when we are talking about construction, we are talking about mixing and compaction. Now precisely the mixing and compaction temperature that one should use for any types of unmodified and modified binders will be discussed separately. The issue is with the modified binder.

And when PG was proposed most, in fact, it was felt very much that the performance creates specification can completely mask the influence of the modifier over a period of time after 10 to 15 years of use in the field, they realized that for modified binders, one needs separate set of specifications test methods starting from the construction site. So that will be discussed separately. So as of now, for construction purpose we are going to use a rotational viscometer and what are we going to do with this?

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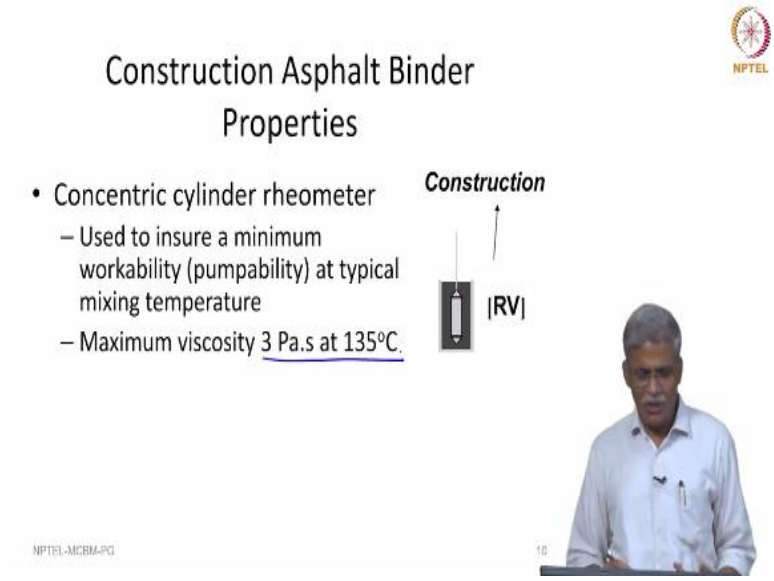

So we will be finding out the viscosity at 135 degree centigrade and we expect that to the maximum viscosity will be three Pascal second and in fact. This, at this temperature the material is expected to be in Newtonian. So this three Pascal seconds is just a straight forward implementation in S.I unit in the old and viscosity based specification it was given in centistokes using kinematic viscosity. So there is absolutely no change in this except that super prescribes that you have to measure it with rotational viscometer, right?

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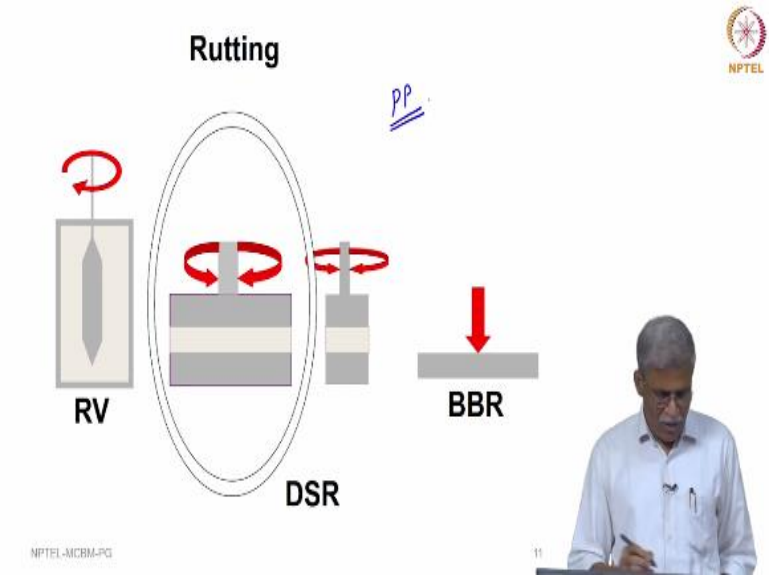

So when we now talk about rutting. That, dynamic shear rheometer is proposed you can actually see that so we are going to use a parallel plate a measurement geometry here.

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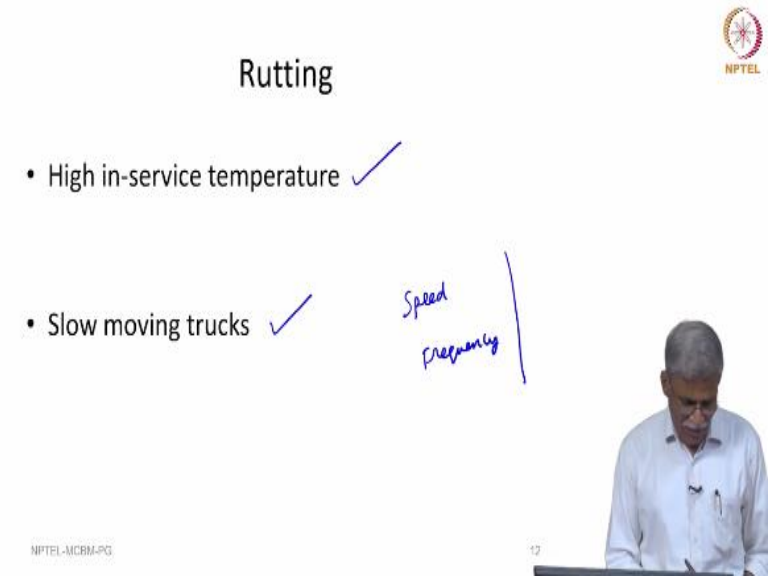

So what are we going to do here as far as the rutting is concerned there are going to be two important issues. In fact, these are the two main issues here. One is the high in service temperature and another is the slow moving traffic. Now the connection between the speed of the truck as well as the frequency of testing will be discussed separately in the next lecture on the theory behind the DSR testing okay?

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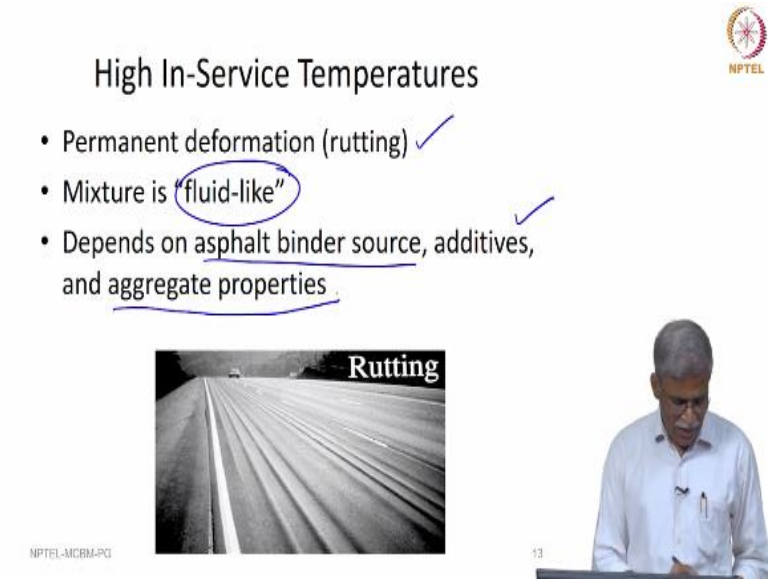

And we must have seen these pictures many times in this course, but it is we always useful to keep seeing it again and again because the first and foremost thing to think is the permanent deformation. The material is more a fluid like material. Okay. And by this time we should also understand when we use the word fluid like what we really mean because in the lectures on

viscoelasticity linear viscoelasticity, we have clearly defined what is it fluid like as well as a solid like behavior. Such behavior depends on the type of binder rather the binder source where it will be use any additives as well as the aggregate properties, okay.

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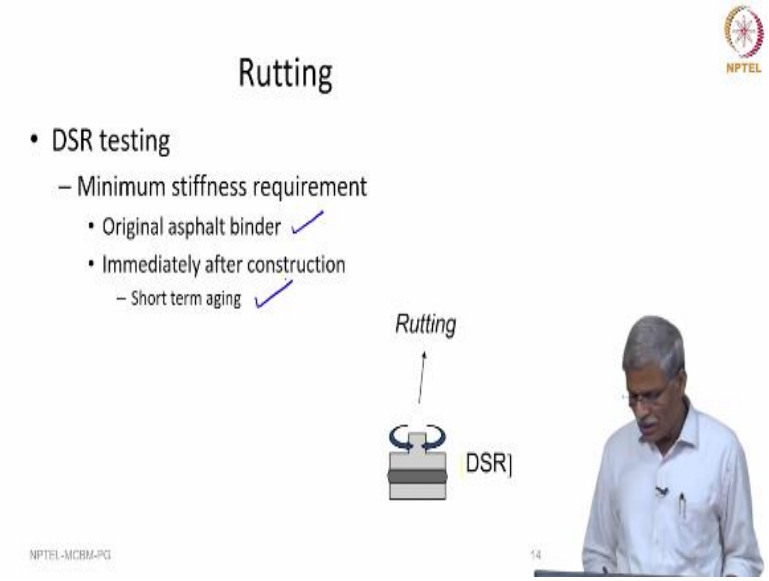

So, how do we do this test? We will be doing this test under two conditions. In the original condition and as well as after the short term aging conditions, so this is what we will be doing this test here.

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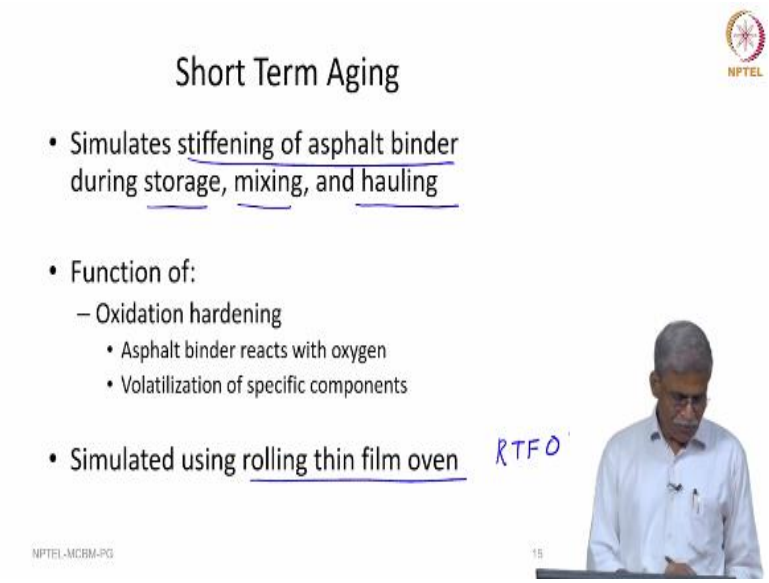

So now let us take a short detour here and talk little bit about this short term imaging the details associated with the short term aging has already been discussed by Dr. Nivitha when she talked about the aging of bituminous material. So this will simulate the stiffening of the binder during storage mixing and basically hauling and we will be using simulating with respect to using it what is really called as a rolling thin film oven, okay.

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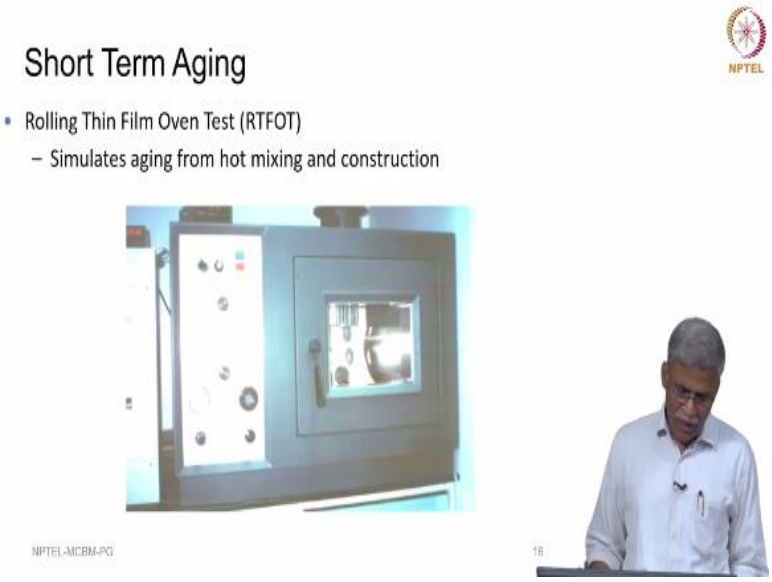

A typical rolling thin film oven will look more or less like this and.

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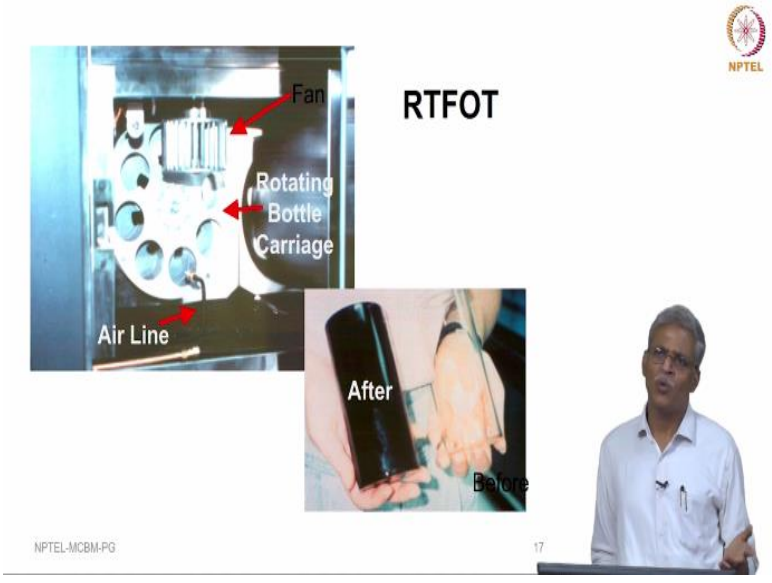

These are representative pictures different rolling thin filling ovens will look slightly different so what you really see here is you see this empty glass bottle and we feel it up with around 30 to 35

grams of bitumen and you have this central carriage that is rotating the temperature is maintained at 163 degree centigrade, we do the aging for 85 minutes. So there is an associated ASTM standard for this you can go through it for the actual specification associated with short term aging.

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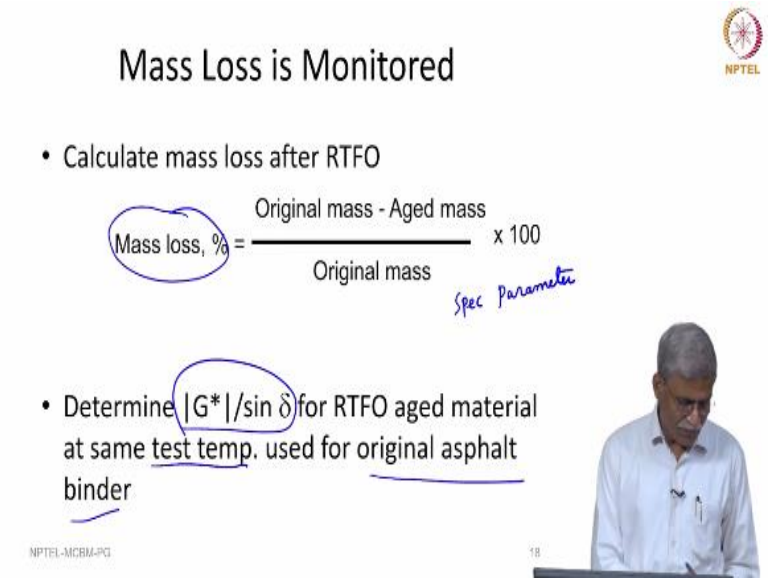

We also find out what is the mass loss that actually happens during this RTFO and in fact, this mass loss is also a spec parameter so we need to actually measure it. So the original mass minus the aged mass divided by the original mass. And then what we will do is, on this short term aged material we will be determining G star by sin delta for RTFO aged material at the same test temperature that we used for the original asphalt binder, okay.

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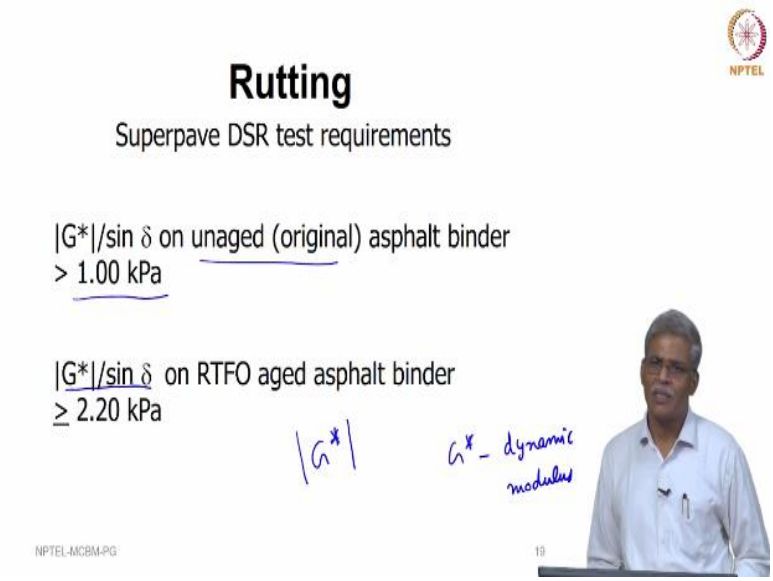

And what is the spec requirement here, the spec requirement clearly says that the G star times G star by sin delta on unaged the sample should be at least one kilo Pascal. There is a caution that I need to exercise here as far as this specification is concerned. Normally, in most of the ASTM as well as AASHTO specifications as well as in published literature the G star is written as it is without this two vertical lines around it.

What is ASTM or AASHTO specifically means is when they write it as G star they mean only the, dynamic modulus which is the mod value of the complex number. For reasons for convenience, they have just drop this two vertical lines surrounding it but I have introduced it here again so that at least the students here will understand that this is the correct way of writing, if you read the European specifications, they are always written as the mod value of the complex modulus, okay.

So now as far as the DSR test requirements for rutting is concerned for short term aged asphalt binder 2.2 kilo Pascal prescribed, okay.

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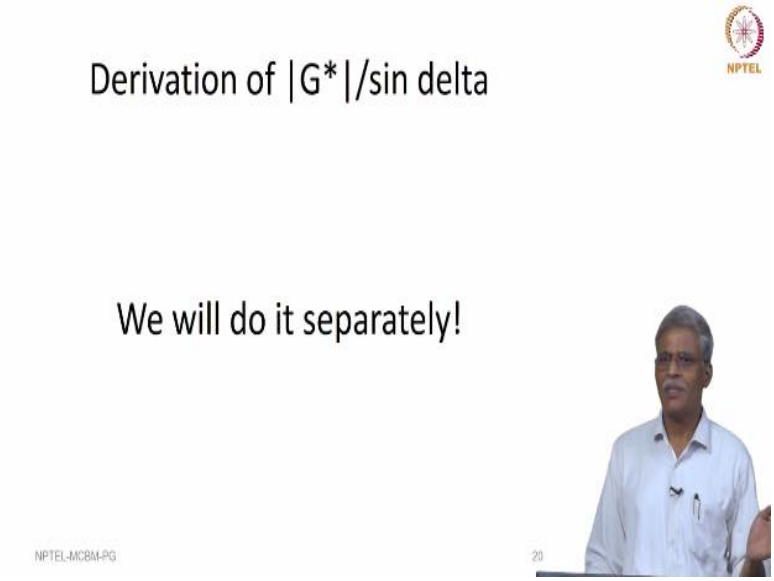

Right, so how to do this? What is G star by sin delta? What is the connection with 1 kilo Pascal to 2.2 kilo Pascal? What actually they may? We will do the derivations separately in a separate lecture but as of now we will just lay the specification framework here, right.

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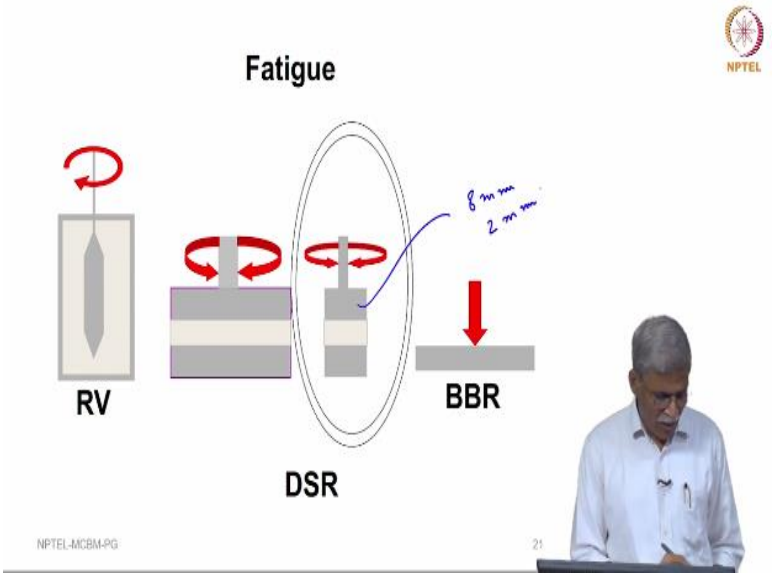

Now let us talk about the fatigue here, so when you are now when you look at the fatigue, it is the same DSR dynamic shear rheometer except that you realize that that plate diameter is slightly less and you also notice that the sample thickness is slightly more okay.

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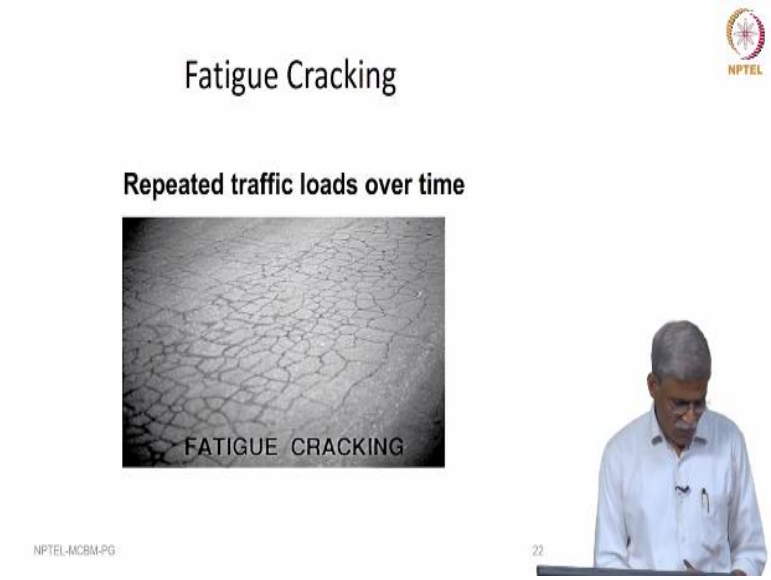

So when we now go to this you can actually see this you are going to have repeated graphic loads over time and this is what is shown here as the fatigue cracking please understand that to emphasize again what we are trying to measure in the laboratory is one parameter on a binder and this parameter on the binder is expected to tell us how the mixture will perform in the field for this specific condition, okay? Right?

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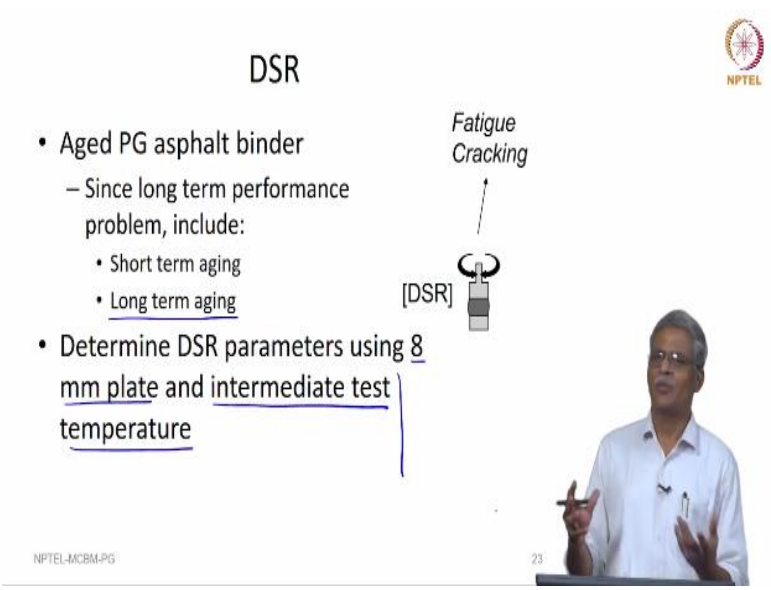

So we do this testing under different aging conditions. Since it is generally expected that these kind of cracks that you saw in the earlier slide happens after some period of construction, this is this test is kinds carried out on bituminous binders that have been subjected to long term aging

and using an 8mm plate. Now, what is the temperature at which this has to be tested? Superpave prescribes it as intermediate test temperature.

Now what is this intermediate test temperature? We will see as we go along. So what we now need to do is to take the unmodified unaged binder, do a DSR test on unaged binder short the term, age the binder to the DSR test again. So these two test will tell you some idea about the specification parameters required for rutting. Now from the short term aged material, do a long term aging test and then in the long term aged material again carry out a DSR test. And that will give you some idea about the expected fatigue damage of the material, okay.

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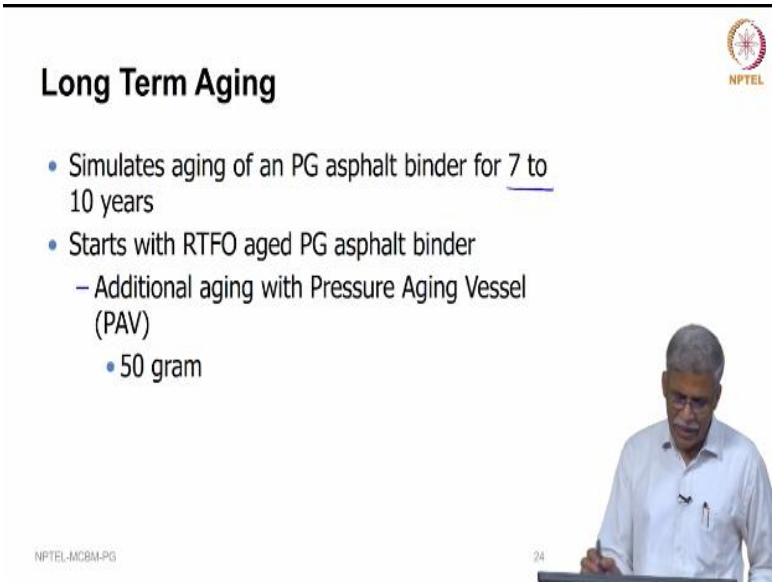

So this long term aging again, let us take a short detour here and understand what this long term aging is. So this is going to simulate 7 to 10 years, and you can actually you basically you need to do it with the pressure ranging vessel.

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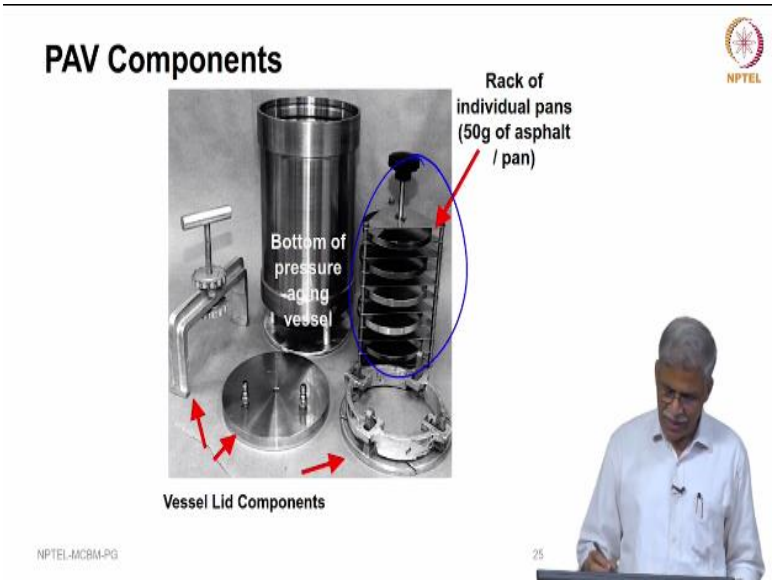

The pressure aging vessel looks something like this and in fact, it is just nothing but a pressure cooker. You can maintain the required pressure at a temperature for a fixed duration of time, you can actually see these are the trays that are shown here and this is kept inside and the whole thing is subjected to very high pressure.

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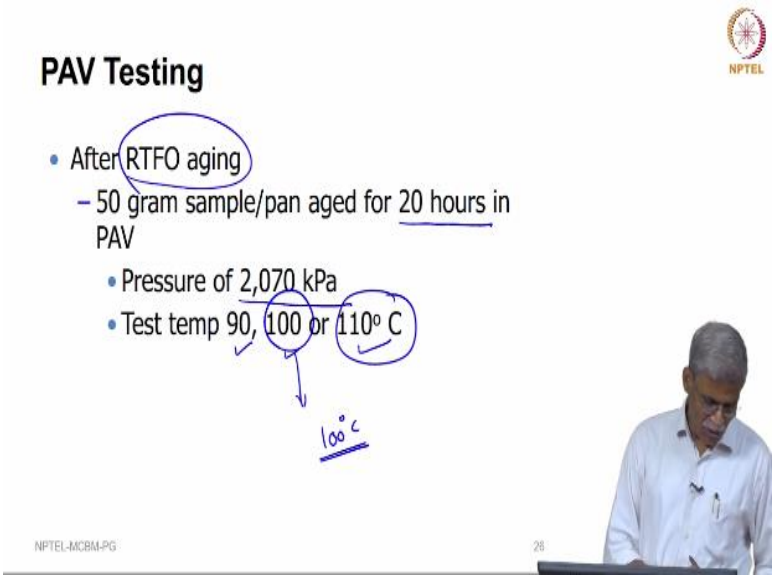

So what is the pressure? We are talking about 2007 kilo Pascal and it depending on the geographical location in which you are going to construct your pavement one should pick a test temperature of 90, 100, or 120 degree centigrade. For conditions that exist at Chennai, we normally expect we do it at 100 degree centigrade. We might do at let us say in locations such as around Rajasthan, were the summer temperature is also high as well as the winter temperature is

also low, one should be able to do it at 110 degree centigrade. So this aging goes for 20 hours and this is the material that should be aged after the binder is subjected to short term aging in RTFO, right?

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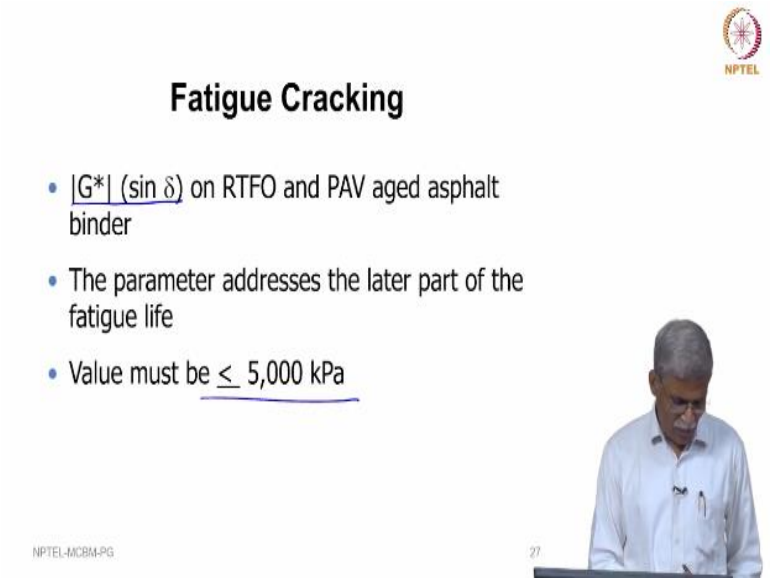

And what we do here after doing this ageing we, find out what is the G star sin delta value and this is prescribed as around less than or equal to 5000 kilo Pascal now what exactly is the reasoning behind this? We will discuss as we go along ok.

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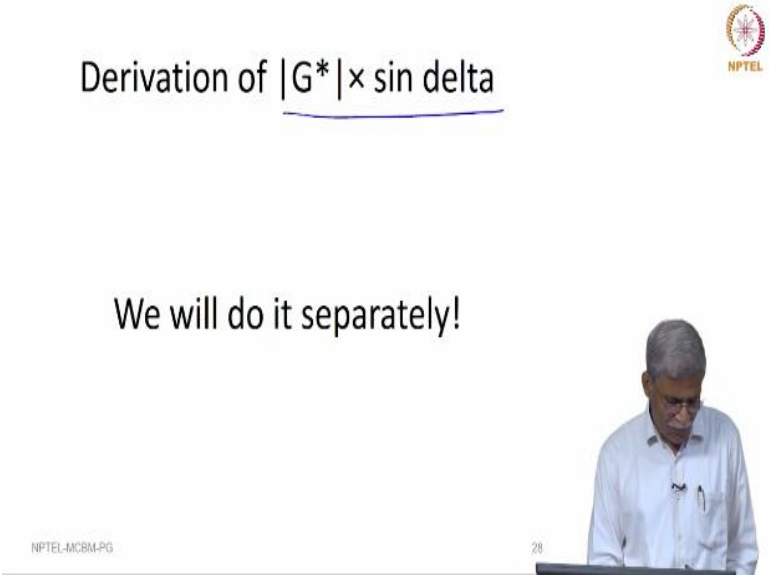

So the derivation of what G star times as sin delta? and what it has got to do with the fatigue damage? Will be done by me separately, okay.

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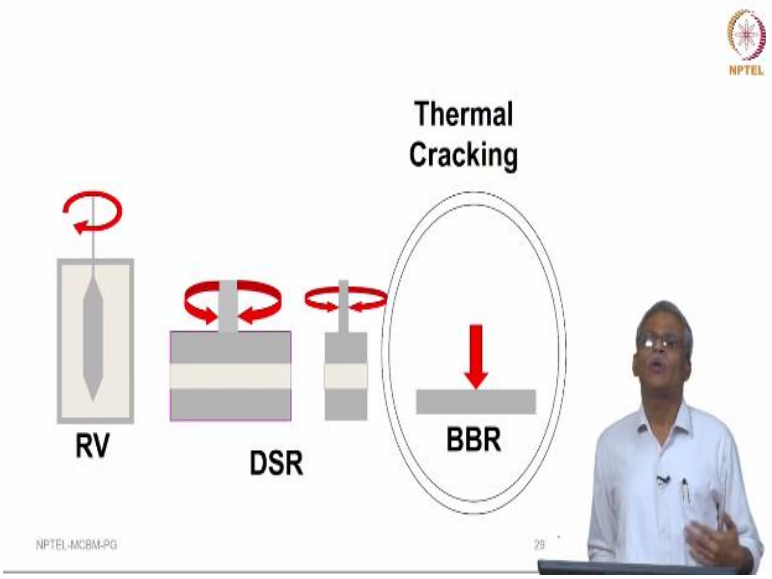

Now finally we come to the thermal cracking. The thermal cracking part is still under development. There are many standards that are being developed. Some of the old standards are also being revised.

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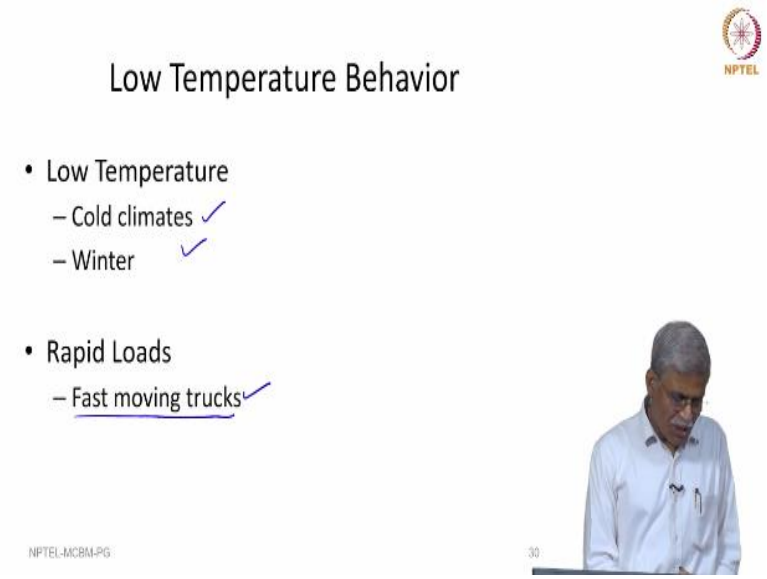

See for instance, the low temperature behavior basically is a cold climate winter and it could also be due to fast moving trucks. And in fact in the original a low temperature, behavior only the glass transition temperature was taken into account, but when it is coupled with the fast moving traffic the cracking tendency of the pavement also substantially increases.

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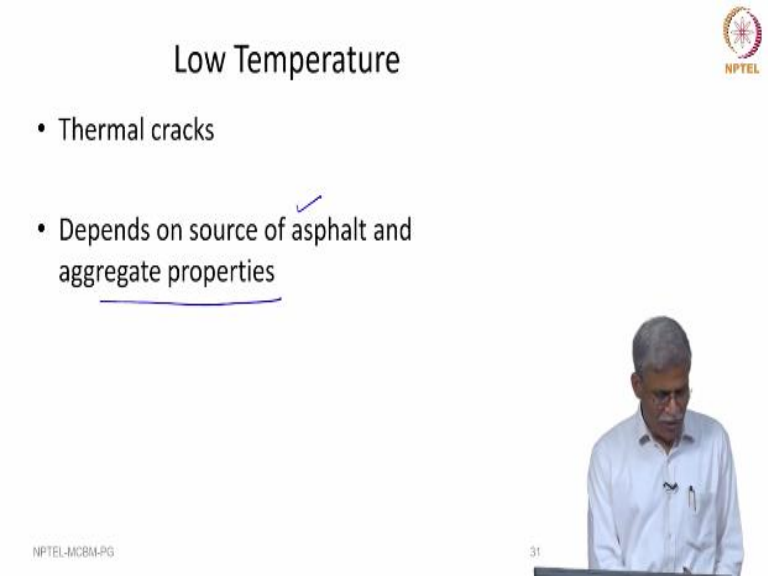

So this thermal cracks basically depend on the source of the asphalt as well as on the aggregate properties, okay.

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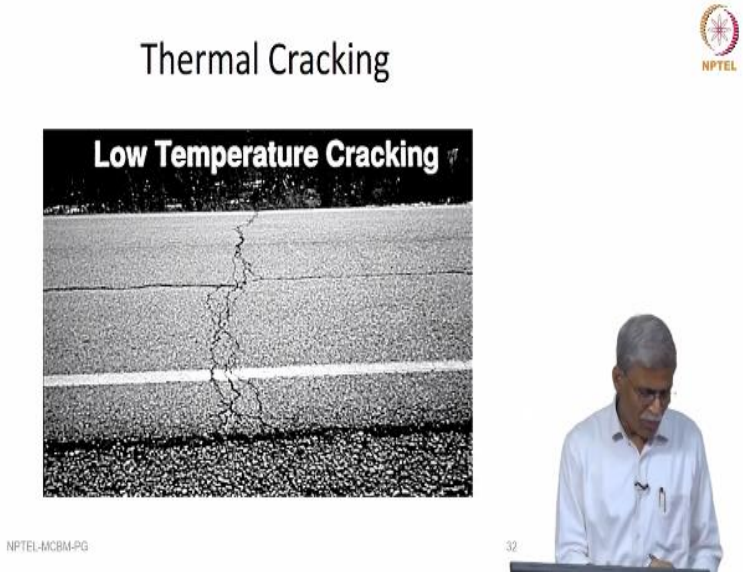

And you have seen this picture earlier but again it is good to revisit this pictures because this low temperature is perpendicular to the flow of traffic more or less like a you are going to see cracks that are going to be in blocks right?

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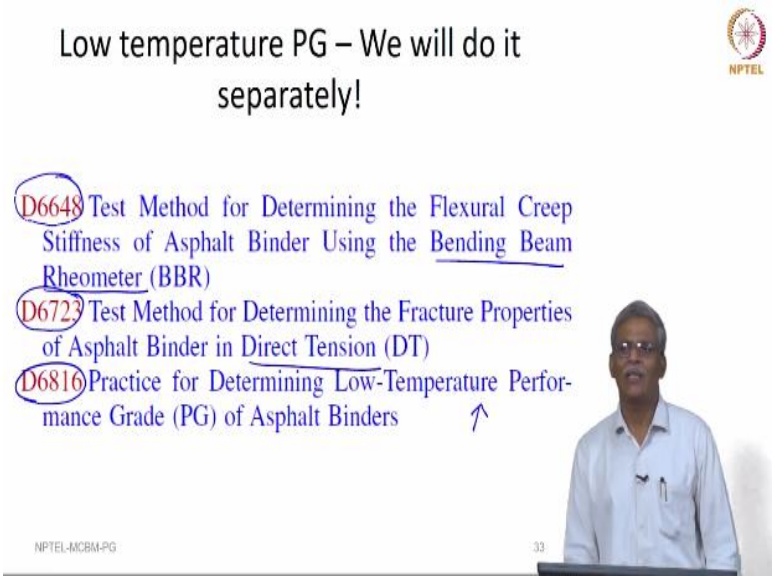

Now, these are the test methods as of now that are available one is D6648, which uses Bending beam rheometer, okay. Then there is another one which is D6723 which talks about direct tension and very recently a, D6816 has been introduced which tells you how to use these ideas and pick the low temperature behavior, low temperature grade of asphalt binders. So all these three will be discussed in detail separately, okay.

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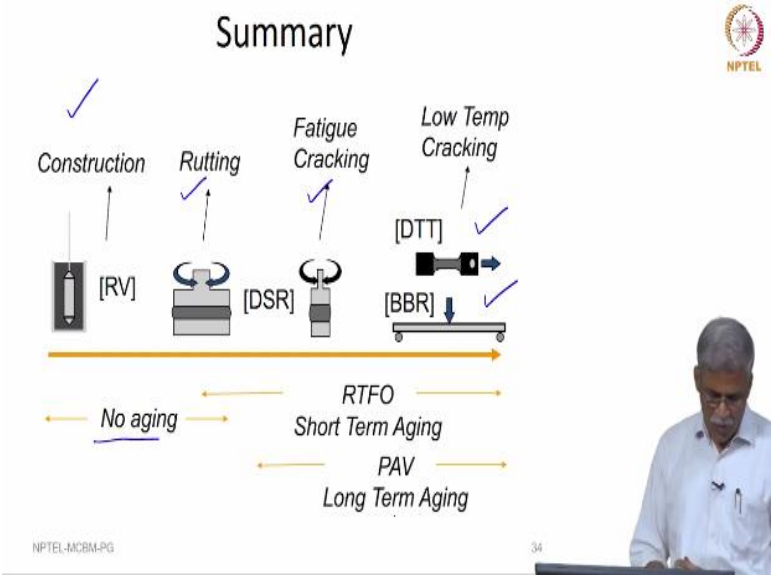

So the summary here is the following so we are talking about construction so we will be taking the binder subjecting into rotational viscometer and finding out checking whether the viscosity of the material at 135 degrees centigrade is within the prescribed limit, right? So there is no aging here then what we do?

We take them material subjected to short term aging check it for unaged conditions as well as the short term conditions for rutting. And then the short term aged material is subjected to long term aging and then we check it for fatigue. And then the long-term age materials are subjected to either the direct tension test or the bending beam rheometer test. So, this is the overall summary of what PG more or less is.