Mechanical Characterization of Bituminous Materials
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Lecture-50
Fatigue of Bituminous Mixtures Part 3

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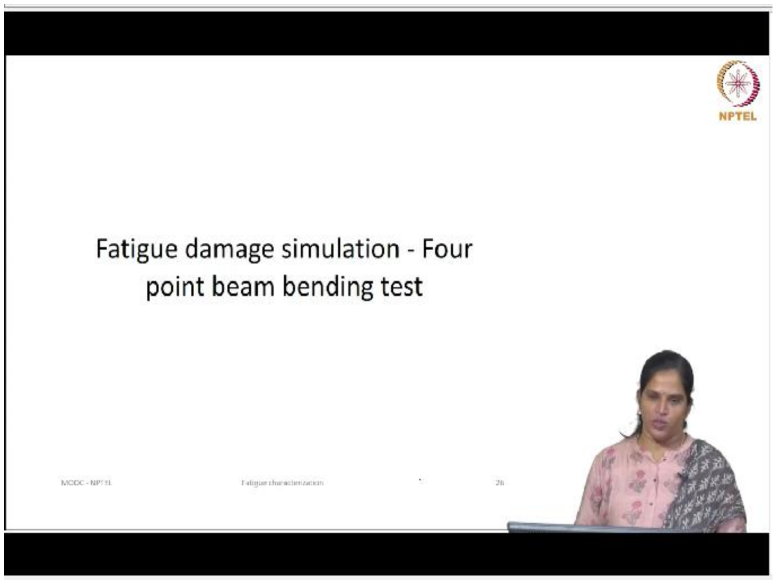

Welcome back. Now, we will see how to estimate the fatigue damage of a bituminous mixture using four point beam bending test, followed by we will see a different post processing methods to determine the number of repetitions to failure. And we will also see a simulation of a fatigue damage using a indirect tensile strength test and we will see how to use this laboratory simulated results in the mixed cycle.

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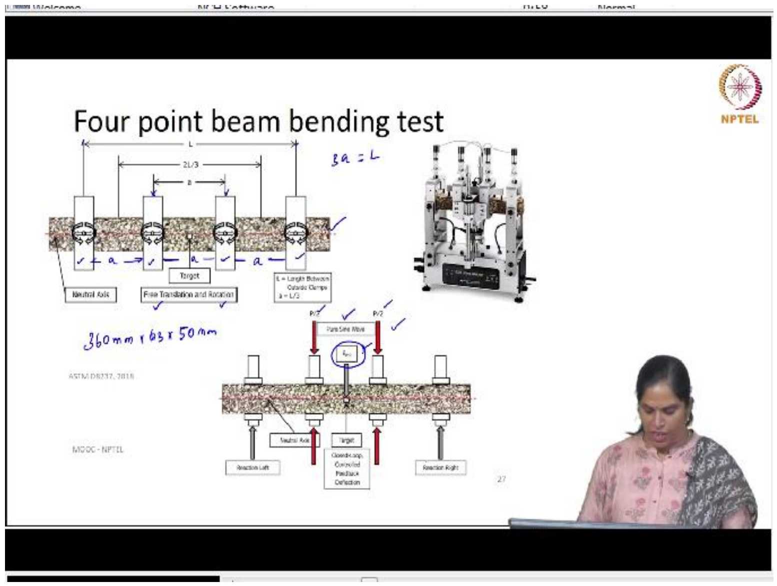

So, four point beam bending test, we test a slender bituminous mixtures B as shown here in a figure, the beam of size, length 360 mm, width 63 mm and depth be 50 mm. So this slender bituminous beam is subjected to a loading as shown here in this picture in a four point beam bending test. So it is a beam bending test, which is supported at four points. So one at the 2 extremes, 2 support are 2 extremes and 2 other supports at the middle.

And the distance between the supports are equally spaced. If you call the distance between 2 support as ***a***, say equally spaced, and 3 times ***a*** will be equal to distance between two end support ***L***. So in this four point beam bending test, we subject the sample to a repeated loading by repeated loading and we apply load at that 2 inner supports, this 2 inner supports, we apply load the 2 inner supports.

Now, if first to subject a beam to a pure bending only in a vertical movement, we do not restrict the rotations. So, it is all the supports are free of translation and rotations. So, this beam setup is subjected to a repeated sine wave. So, you apply a load so, that you can control a deformation, the load is measured here and to measure the deformation, deformation is measured at the center of the beam. So, we apply a load at the 2 supports, measure the load using a load actuator and we measure the deformation using LVDT fixed at the center of the support.

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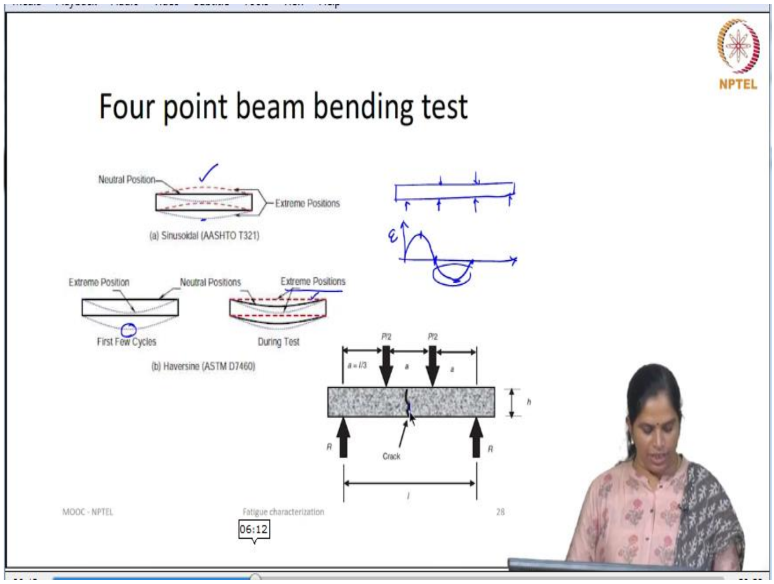

So, now here sinusoidal load means that we are subjecting the sample to a tension compression loading. So, you have a beam support here and the beam is fixed at four points, we apply a load at this inner support. So, the load is again a repeater load in a sinusoidal pattern. So, what we do is apply a tension compression load by pulling and pushing the beams. Now you can see this example for a sinusoidal load at 2 extreme positions.

When you pull the beam down you will have this down position. The bottom will be subjected to tension. So, tension at the bottom. So loading pulls a beam down extreme position that will be subjected to tension coming back to the neutral position here, tension will be zero. Now we pull the beam up. So when you pull the beam up, the bottom will be subjected to a compression. So maximum compression when the beam is at the extreme position.

And then bring back to zero position you will have a compression to be zero. We will come towards original position. So it can be a strain control or a stress control. If it is a strain control, the strain is controlled in the sinusoidal pattern by pulling and pushing the beam repeatedly. So we are applying a repeated load in a sinusoidal pattern by pulling and pushing the beam from with respect to its neutral position.

So in case of a haversine loading, we do not have this part of a loading, it is a half sine wave, the pattern is again, it is a half sine wave. So, the beam is pulled down. So, this will be our extreme position. So, the bottom will be in tension and then pushed back towards neutral positions. So, now if you see this extreme position, at the end of a completion of one cycle, its reference position, which is a beam horizontal position.

So on subjecting this beam to a repeated pull push, you can see a crack initiation that is happening from the bottom of the bituminous beam. So we are subjecting the bituminous beam to a repeated tension compression loading. So that the beam cracks from the bottom of specimen, tension compression loading or it can also be a compression loading. So, that the beam cracks from the bottom of the positions. So, this is what we are doing it in the four point beam bending test.

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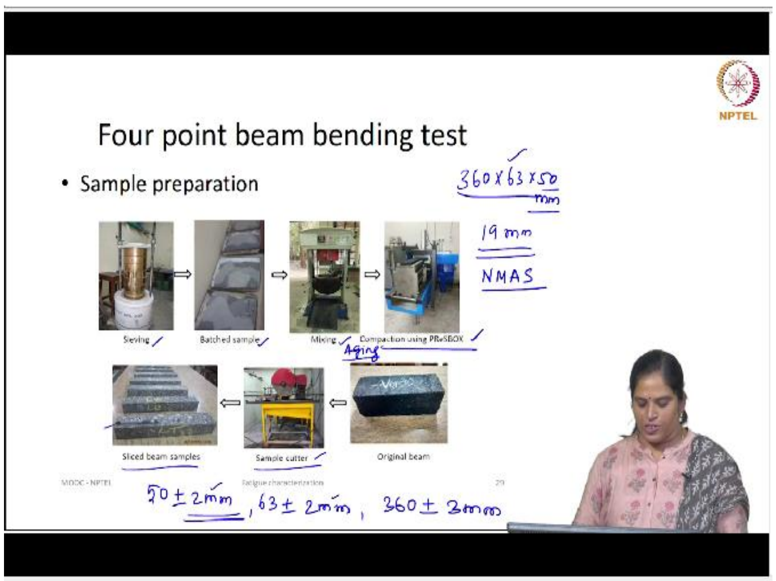

And now what is the result. So, before we look into the result, let us see how to prepare the sample or a beam sample slender beam sample for this four point beam bending test. So, now, for conducting this four point beam bending tests we need a compacted sample of size 360 by 63 by 50 mm. So, this sample has to be prepared in a very controlled environment.

So, maximum aggregate gradations for preparation of a sample as for ASTM specifications, this 19 mm. So, for a 50 mm deep sample, the maximum aggregate size is 19 mm. So, nominal maximum aggregate size for a 50 mm sample is 19 mm. So, we have to provide a controlled setup because the fatigue light depends upon the aggregate gradations amount of bitumen, we add air voids in a sample.

And all these volumetric properties of bituminous mixtures. So, we need to prepare a bituminous mixtures in a very controlled way, keeping an aggregate gradations constant for all types of beam cast. So sieving followed by a batching of sample then mixing. So, with this mixing again at a predetermined mixing and compaction temperature. So, after mixing we do aging, to simulate the short term aging of mixtures.

This short term aged sample or a mixture, this has to be compacted, here it is given as a PReSBOX compactor, there is not necessary that you have to stick to a PReSBOX compactor it can be any compactor which is available, but you need a beam size of after slicing to be the size 360 by 63 by 50 mm. So, now, with this PReSBOX sample, this is a bigger sample it has to be sliced to their required size.

So, now we use this, we use a sample cutter to slice the beam. Here while slicing the beam we have to be careful about the dimensions ASTM mentions 50 plus or minus 2 mm. So, the tolerance here provided is only 2 mm. So, 63 plus or minus 2 mm and again 360 plus or minus 3 mm. So, the tolerance range is only a 2 mm or a 3 mm which is very small. So, slicing plays a very critical role in obtaining the required to beam samples.

So, once you get the beam sample, wrap it up and keep it so that there will not be any steric hardening of a sample and then use it for testing.

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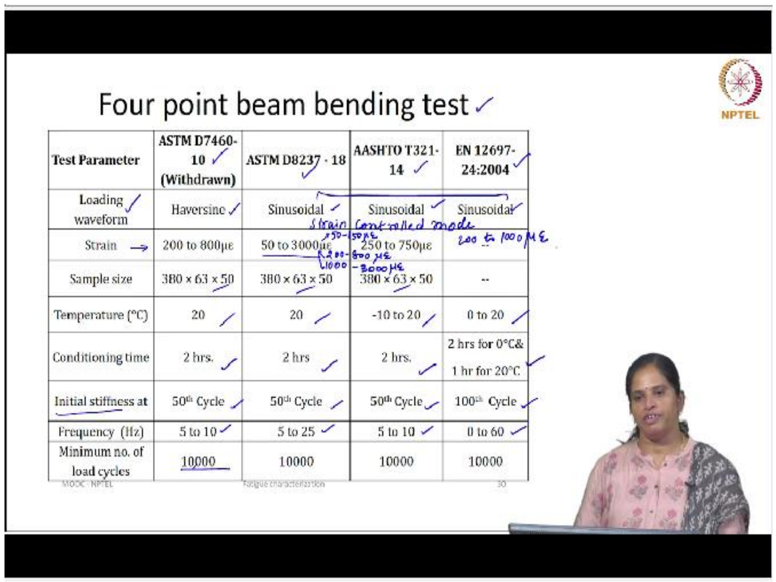

There are 4 standard test methods, standards available for conducting a four point beam bending test. So, if you see the four standard test, one is ASTM D7460. And this is 2010 standard, but it has been withdrawn now, other is a ASTM D8237, it is a recent standard 2018 standard, and the next is AASHTO T321 2014 and European standard which is 12697 24. So now let us compare this four standards across the various test parameters.

So, one is loading waveform. So, ASTM D7460 recommends the test to be conducted using a haversine wave form. Other test you have a sinusoidal waveform. Now for strain magnitude to be adopted, all these tests are to be conducted on a strain controlled test. All these 4 standards recommend to conduct the experiment in a stain control mode of testing. So, we control a sinusoidal pattern in the aspect is 3 tests.

It is an haversine pattern as per ASTM D7460. You know what will happen when you apply a haversine deformation. So over a period of time the haversine deformation will result in a sinusoidal stress or a sinusoidal load. The strain magnitude to be used as per ASTM is in the range of 200 to 800 micro strain. Now, if you see a recent standard ASTM standard, so, it is 50 to 3000 micro strains.

So, 50 to 150 micro strain, very small strain level is used in checking the endurance limit, that is how does the bituminous mixture behave when you test it at very low temperature. So, from 150 or 200 micro strain to all the way to 800 micro strain, we use it for testing a normal bituminous mixture, at a very high strain like from 1000 to 3000 micro strain. This is recommended when you test a bridge tech material a kind of thing.

ASTM recommends to test a normal bituminous mixture recommends a strain level in the range of 200 to 800 microstrain. AASHTO T321 again the strain level recommended by AASHTO 250 to 750 micro strain. And EN does not specify any strain limit, but if you see a test results of an EN again the strain level varies all the way from 200 to 1000 micro strain. So, sample size same as mentioned before, temperature 20 degrees Celsius as per ASTM. AASHTO any temperature from - 10 to 20 degrees Celsius.

EN standard says from 0 to 20 degrees Celsius. So, this temperature has to be attained over a period of time. So, if you want to test the bituminous mixtures at any specific temperature, you have to give a time for so, that the material reaches a thermal equilibrium, the time specified here or we call it as a conditioning time. So, nearly 2 hours, so, if you test it at low temperature.

So, maybe you may have to give a higher time period and this initial stiffness 50th cycle 50th cycle and here it is 100 cycle, let us hold for a while what we call it as an initial stiffness. I will explain you later what this 50th cycle is an initial stiffness. So, we test it at different frequency from 5 to 10 hertz frequency. Keep in mind that the fatigue light varies with frequency. So 5 to 25, 5 to 10 and here it is very high from 0 to 60 hertz.

So, now, you need to pick a strain value or a strain amplitude in such a way that the minimum number of load applications should be 10,000. So, based on this, you restrict your strain application, strain amplitude higher limit of a strain amplitude. So, before a failure to reach you need to subject the sample to a minimum of 10,000 cycles. So, we have a comparison between different standards, all these standards are a strain control test. Now, we need to recollect here that strain control test, we cannot see a crack pattern clearly.

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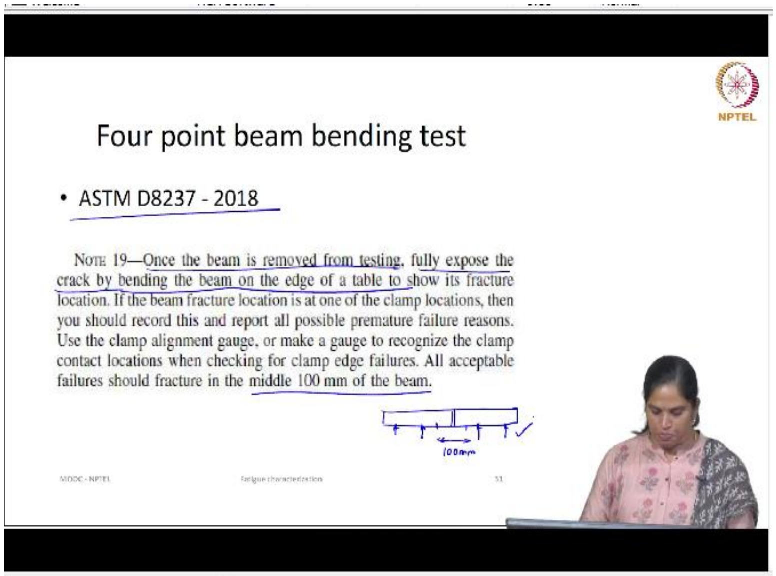

So, in that case, how do you visualize the crack. Now, if you read ASTM D8237 code, so, beam sample after testing, once the beam is removed from a testing, you need to check for the crack pattern. So, fully expose the crack by bending the beam on the edge of a table. So, if you do that, there will be a you can see the damage in the beam and the damage has to be in the middle 100 mm of the beam.

So, the position of damage when you take a sample and bend it you have to see a crack after testing should be the middle 100 mm of the sample. If it occurs somewhere near the supports, you have 4 supports, if it occurs somewhere near the supports. So, this may be due to a clamp edge failures. So, this we should not consider it for the results.

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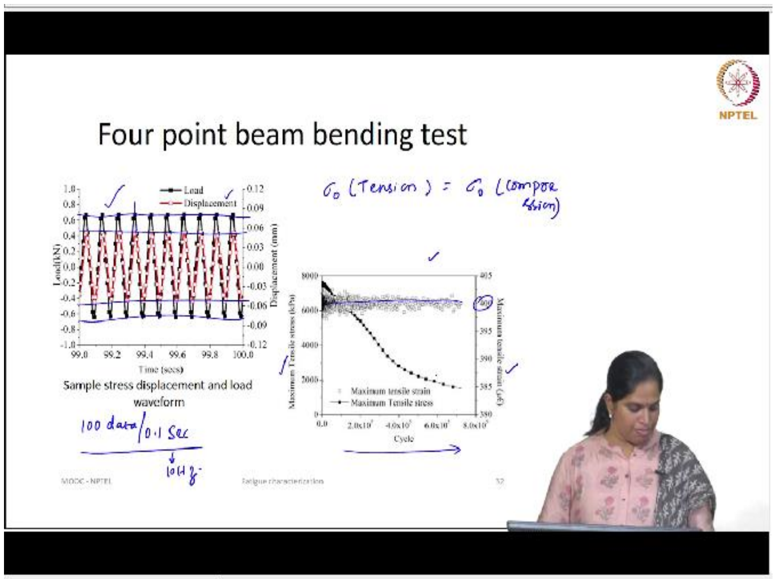

So, we apply a repeated displacement as shown here, you can see a sample waveform. So, we apply a repeated displacement and we measure load. ASTM recommends to measure or collect at least 100 data points per cycle. So, if you conduct a test at 10 hertz frequency 100 data points per 0.1 seconds. This is specific to 10 hertz frequency. So, you collected displacement and the load waveform.

So, if you look into the sample displacement and a load waveform, you can see both are a sinusoidal with the lag between the load and the displacement waveform. So, now with this load and the displacement waveform you identify a filter only the peak point. So, tension compression peak on a tension side should be equal to on a compression side. So, you identify a peak point.

So, now this maximum tensile strain or a peak tensile stress and a peak tensile strain as a function of cycle on a repeated loading as shown in this figure. Now, if you see this figure, this, figure corresponds to a maximum strain amplitude of 400 micro strain. So, you keep a strain amplitude constant. Now, if you see this stress amplitude, the stress amplitude decreases as you increase the loading cycles. So, this decrease happens as the damage in the beam progresses. So, you have a pattern of decrease.

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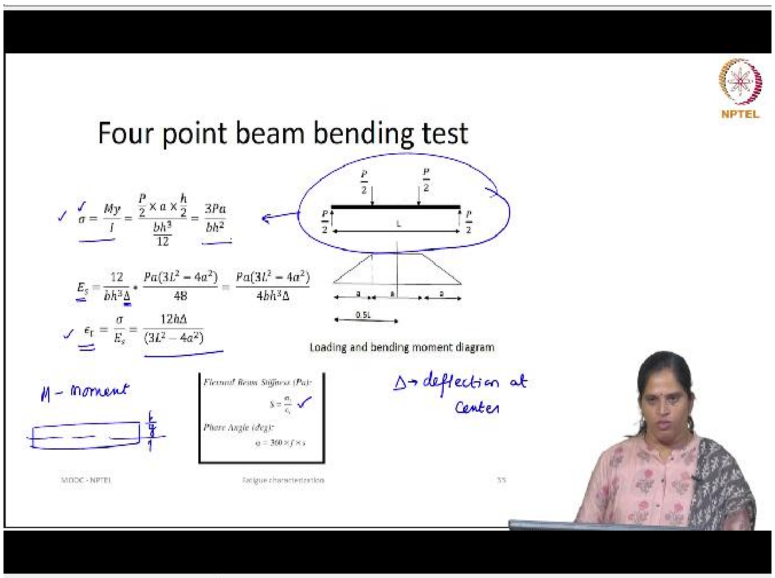

Let us discuss the pattern of decrease for a while before that we will see how to calculate the flexural stiffness of a material. So, it is a beam bending test, we will use a conventional elastic beam bending equation sigma is equal to ***My*** by ***I*** where ***M*** is a bending moment and ***y*** is a distance from a neutral axis to the extreme fiber of a beam. So, if this is your neutral axis, this is ***y*** and ***I*** is a moment of inertia.

So, with this ***My*** by ***I***, if you substitute for this loading conditions, if you substitute you will get for a peak stress ***P by 2*** you will get ***sigma*** to be ***3Pa*** by ***bh square***. So, this is again an equation, the same equation is used in all the standard for calculating the peak stress value. So, now with a deflection equation for this beam, where here we can calculate the modulus where this equation here this ***delta*** is nothing but the peak deflection, at the center.

So now, with this ***E*** as elastic modulus can calculate the strain value to be dependent on ***h***, which is a height of a beam. Delta as deflection at the center, ***L*** is a length between two end supports, ***a*** is the distance between adjusting supports. So, we calculate the strain value and the stress value, if you apply a peak load, if you calculate all this corresponding to the peak load, you will get a peak stress and the peak strain value.

Now, the ratio of peak stress to peak strain is what we call it as a flexural beam stiffness. So, we calculate the flexural beam stiffness for all cycles of loading.