Mechanical Characterization of Bituminous Materials
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Lecture - 44
Rutting Characterization - Different approaches

Hello everyone, today we are going to discuss about the rutting characterization of bituminous mixtures using simulative test.

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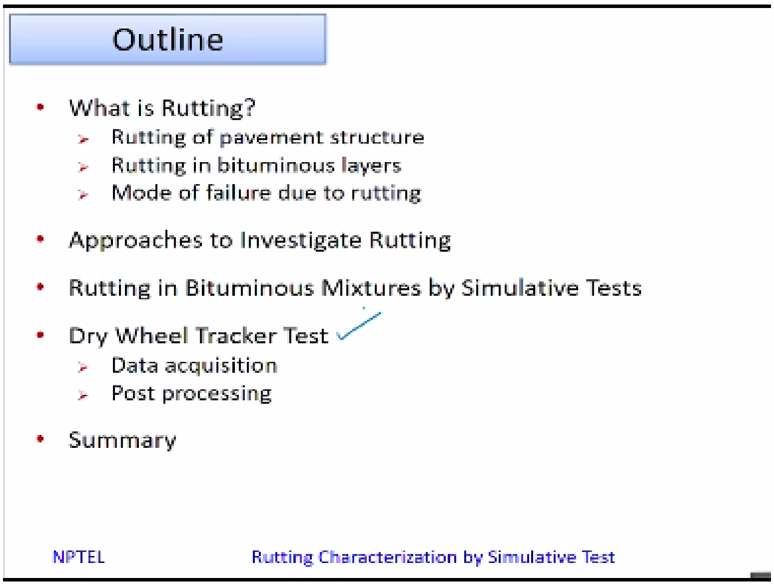

So this will be the outline of this lecture. We will discuss what is rutting? What is this rutting in bituminous pavement and what is the rutting in a bituminous mixture. Then we will see what are the different approaches by which you can investigate rutting. And then we will see the simulative test and in specific we will see a dry wheel tracker test to determine the rutting characteristics of bituminous mixtures.

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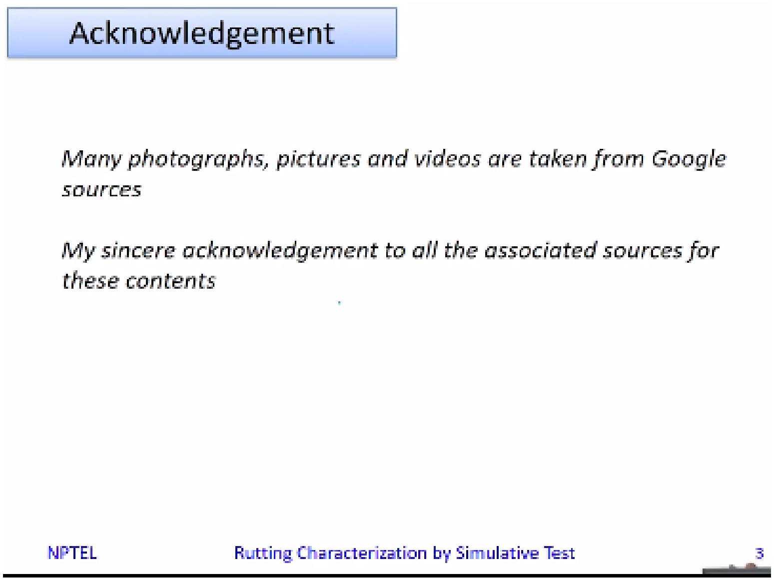

I have taken many photographs, pictures and videos from Google sources for this lecture. So I sincerely acknowledge all those sources for these contents.

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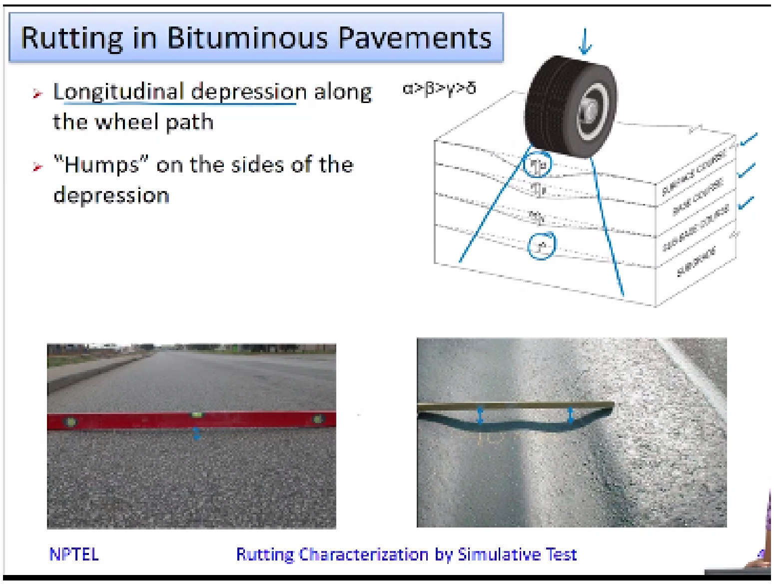

So by now we might have heard this term rutting when we have discussed about the characterization of bituminous binder. We know that rutting is a longitudinal depression that you see in the wheel path of a pavement okay. So these are certain photographs which are taken from Indian highways. You can use a straight edge to measure this rutting. You see that, see here, there is certain amount of rutting. You see it as a bowl along the wheel path, okay. Whereas in certain cases you could see multiple ruts or grooves in the wheel path, in the same wheel path, with humps in between, as you see in the second figure. We will come to this later.

So when you look at a bituminous pavement, it comprises of different layers, right? You have the subgrade soil at the bottom. Then you have granular layers, which is your subbase and base layers. And then you have the top surface course which is bituminous in nature. So you know that these are all mixes which are prepared and laid and compacted and there is every possibility that all of these layers will undergo certain amount of deformation under this wheel load.

Now the bottom subgrade obviously, since granular in nature it has a tendency to deform. So as you can see here this is a deformation shown for the bottom subgrade layer and other layers also will show certain amount of deformation and also the top layer. Now we know that the load pressure or the load intensity is maximum at the top where your wheel load is in contact and it will get distributed down and as you go down the intensity of load is going to be or the pressure is going to be less.

So the chances of deformation to the top layers will be much higher as compared to the bottom layers. And what you see is an accumulation of all these deformations which is manifested on the top surface in the form of a rut.

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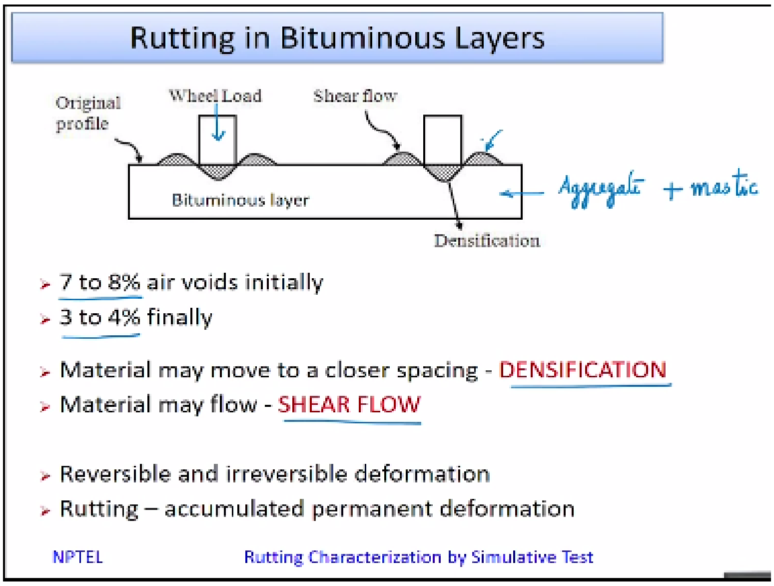

Now let us look at the bituminous layer alone. As I said this is the layer which is being subjected to the maximum amount of pressure or wheel load. Now you know that the bituminous mixture comprises of an aggregate matrix which is combined together with a bituminous mastic okay. So you can consider it as a matrix of aggregate with a mastic in between.

And you normally lay and compact this mixture in the field to an air void of 7 to 8% for the quite obvious reasons. We know that this is to allow for certain amount of deformation to happen or the densification to happen under the wheel loads. So when the wheel loads pass in a year or two, this material will go to a closer spacing and reorient itself to a densified state. So this is called densification and for this densification to happen, this mastic has to move around and there should be sufficient voids available otherwise this mastic will have a tendency to ooze out. So that is the purpose for which you actually lay it with 7 to 8% of air void content and over a period of 2 to 3 years or 1 to 2 years, it will reach a densified state of say 3 to 4% air voids.

Now when you continuously apply the load or the wheel load, what can happen is that this material which is in this densified state can have a tendency to shear. So this is called shear flow of the material. So in a material which is laid and compacted at 7 to 8% of air voids initially, over a period of time there could be certain amount of densification deformation that can happen and thereafter one can expect certain amount of shear deformation that will happen.

So the shear deformations, one can see that this hump formation on either side of your groove could be due to the shear deformation where there is not much of a volume change in the material, but the material flows. So as you can see that since this is a viscoelastic material, there could be deformations which are recoverable also in nature.

So when a wheel passes, when there is. when there is no load on the surface, there could be a possibility that this deformation is recovered. So it is the accumulation of all those irrecoverable deformations that manifest on the top surface as rutting.

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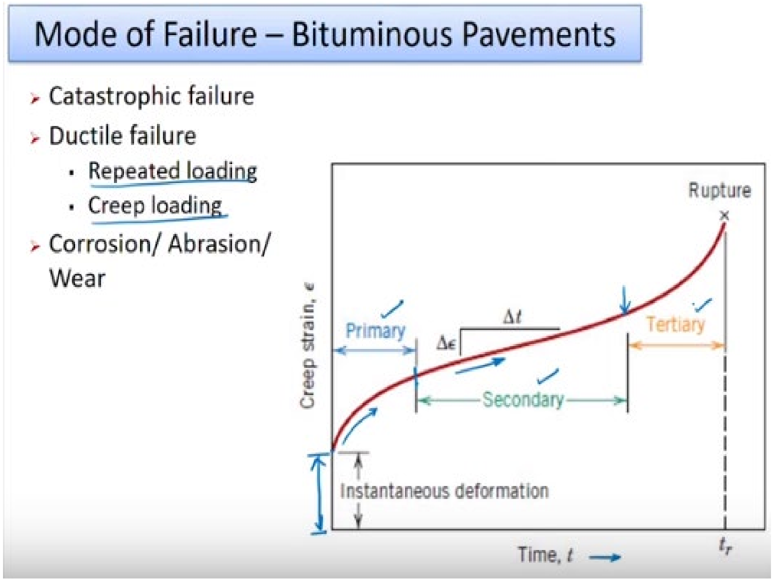

Now what type of a failure is rutting? You can have in a bituminous pavement catastrophic failures which may happen all of a sudden and there could be ductile failures. So what we understand is that rutting is a ductile form of failure under repeated loading as well as creep loading. So when I say repeated loading, it is the loading due to your wheel loads okay. So you have number of trucks passing. So each one of this causes a certain amount of repeated application of load. Whereas, you consider a truck which is stationary on the road surface. This will apply a creep loading or a stationary loading. So a repeated application of such loads or a creep load can cause a ductile failure in the material. There could be other forms of failures like corrosion, abrasion, wear, etc.

When you look at the rutting failure, you see that initially as I said this is laid to a higher air void content. So when the load passes there could be an instantaneous deformation that may happen during the initial stages. This is a plot which is drawn with time in the x axis and creep strain or the strain in the y axis. Or you can say it is the deformation in the y axis.

Initially when the load passes there could be an instantaneous deformation as you see here. Then thereafter the deformation increases, but what we see is that this happens at a lower rate or that increase in deformation happens at a decreasing rate over a certain period of time. Thereafter a stage will be reached when the deformation happens at a constant rate.

Then, after a certain point of time, when you continuously load the material, a stage will be reached when the material suddenly starts flowing or you see that the strain increases at an increasing rate. So this behavior or a three stage behavior is called a three stage creep behavior for the bituminous materials.

And the primary stage wherein, the increase in strain is at a decreasing rate is called the primary stage and the second stage where this increase in strain happens at a constant rate you call it as a secondary stage and thereafter when the material deforms at an increasing rate, you call it as a tertiary stage okay. So if this happens over a period of time you call it as a very ductile behavior.

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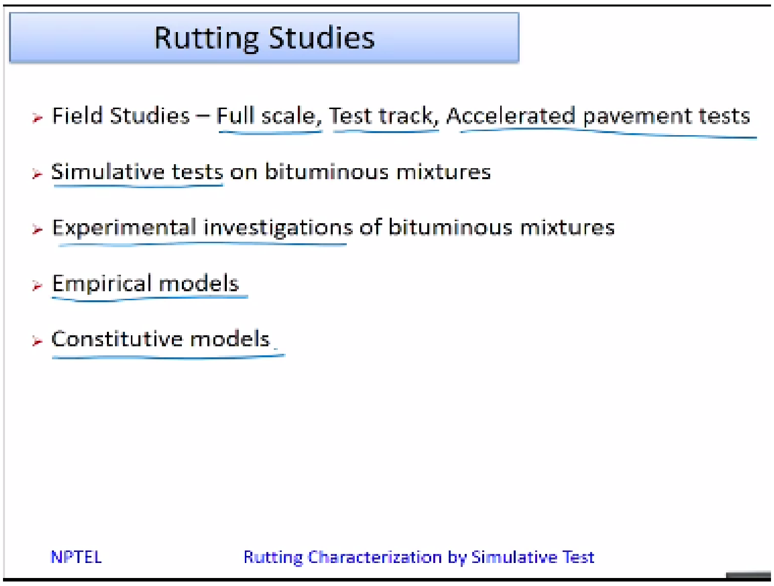

Now how to study this rutting that is happening in the bituminous pavement as well as in the bituminous mixtures. There are various approaches. The first one is a field studies. You can do a full scale field study or an in-service pavement study. Then you can have test tracks or you can have accelerated pavement test studies.

Then, as far as the bituminous mixtures are concerned, you can have simulative tests in the laboratory or you can do an experimental investigation of the bituminous mixes using the loads and the conditions which are going to be prevailing in the field. And the next approach is that using such information you can have empirical models which can predict the rutting behavior of bituminous mixtures.

Or you can have constitutive models also which actually capture the mechanistic behavior or the mechanical behavior of the material.

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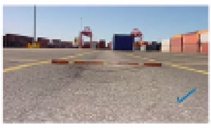
Rutting Studies using Field Data

	In-service Pavement Survey	Test Tracks	Accelerated Loading Facility
Loading	Random	Controlled	Controlled
Environment	Random	Random	Controlled
Time period for useful information	Minimum 3 to 4 years	Few Months	Few Days
Measured characteristics	Rutting over a period of time	Rutting on surface and in different layers	Rutting on surface and in different layers



NPTEL Rutting Characterization by Simulative Test

So let us discuss these one by one. The first one is the rutting studies using field data. Do a survey of the existing pavement. You call it as an in-service payment survey. So this is a pavement where you can collect information about the rutting over a period of time say for example, 3 to 4 years of time you can collect the information. Now the two major aspects that contribute to rutting is one is your environmental conditions. When I say environmental conditions, it is not only the climate, but the pavement temperature, which means the temperature of the pavement at different layers of the pavement structure.

So that is one aspect and the second one is the loading. What is the wheel load? When I say loading it is the axle load spectrum, what is the speed of the vehicles? What is the loading duration? What is the rest period that is there between the load applications? So all this contributes to rutting. So in an in-service pavement survey, when you consider the loading it is random in nature because it is the existing field road or a pavement. So that is random in nature and it will be very difficult to collect information regarding all these aspects of loading when you consider an in-service pavement survey.

And the second one is environment which is also random in nature because it is exposed to the atmosphere. So it will be subjected to random environmental conditions. And the time required, as I said will be 3 to 4 years. And what you can measure is the rutting, the progression of rutting over a period of time. You can measure the rutting at different locations over a period of time and you can see how it progresses.

An another important aspect that you can collect is that you can take cores from the field if possible from the wheel path as well as from the adjacent to the wheel paths and see how the air void content of this material is changing and you can correlate it to the rutting that has happened due to densification or it is rutting that has happened due to shear flow and so on.

And the second one is test tracks. You can have test tracks constructed with controlled loading conditions. Say a test track is built, with the design mixes and the pavement structure and then with different sections with different type of materials or with different type of air void contents and so on. And then the loading is applied in a controlled manner. Whereas, this the environment in which it is conducted or the data is collected as random in nature.

The advantage here is that you can collect information within few months of time. And there is also possibility that you can take trenches at regular intervals of time. And you can see how the rutting has happened in the different layers of the pavement structure. So that is the advantage of having a test track.

And the third one is an accelerated loading facility where the testing can be done in a controlled environment, so that your loading also will be controlled as well as the environment will be controlled and you can collect information about the rutting behavior in a few days of time. Here also there is possibility of making trenches in the pavement structure that you have built and you can collect the information as where or which layer contributes more to the rutting and so on. Let us discuss some of this in detail.

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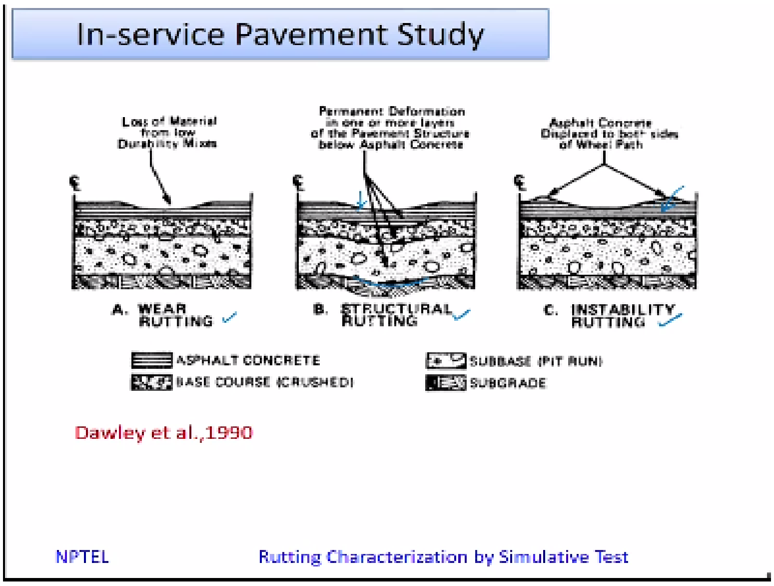

As I said, in the in-service payment survey, you can collect information about what is the kind of rutting that has happened in the field under the prevailing conditions of environment and traffic, okay. There is different classification technology, methods that are adopted to classify the kind of rutting that is observed in the pavement. Say for example, Dawley et al. has classified the rutting as seen on the pavement as wear rutting, structural rutting, and an instability rutting.

Say for example, this is wear rutting wherein there is a loss of material or aggregates from the top surface. That is also classified as rutting in the first figure as you see. And the second one is called as a structural rutting whereas the rutting has happened right from the subgrade. So you can see that there is a subgrade deformation which is reflected on the top surface. So this is termed as a structural rutting.

And the third one is called the instability rutting, wherein there is a rutting that has happened in the top bituminous layer alone. So that is due to the instability or the instable mix that is used as the top bituminous layer. So such a classification is done by Dawley et al.

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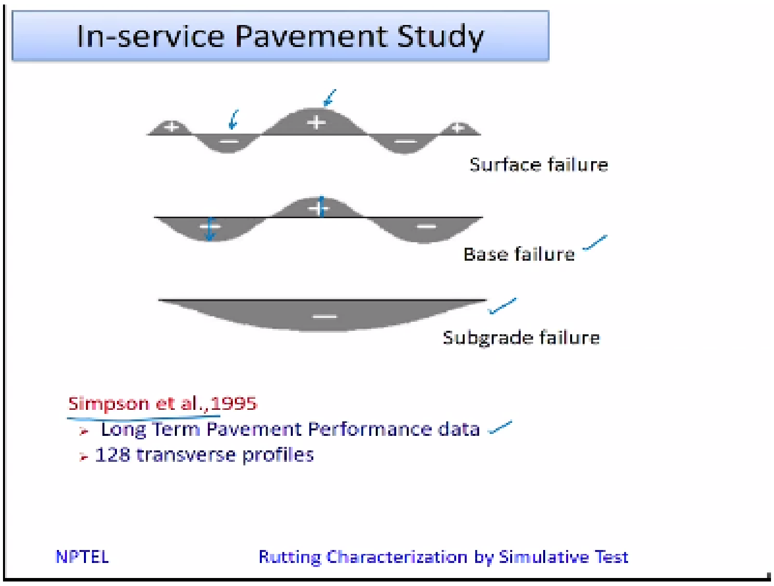

And this is another classification that is done by Simpson based on extensive amount of data that is collected as part of the Strategic Highway Research Program that is called the Long Term Pavement Performance data. This data is collected for over 128 transverse profiles on in-service pavements and also trenches are taken at these locations to see what has contributed or which layer has contributed to the rutting and certain classification schemes are suggested by Simpson.

As you can see, if you see a rut on the top surface like this as a single bowl, it is actually attributed to the subgrade failure and if you see deformation like this say grooves like this with humps in between it is attributed as that of a base failure. Whereas, if you see like this with the grooves as well as humps on either side that was attributed as a surface failure or it is the failure of the top bituminous layer, okay.

So such classifications or such information can be gathered when you collect in, when you do an in-service pavement survey.

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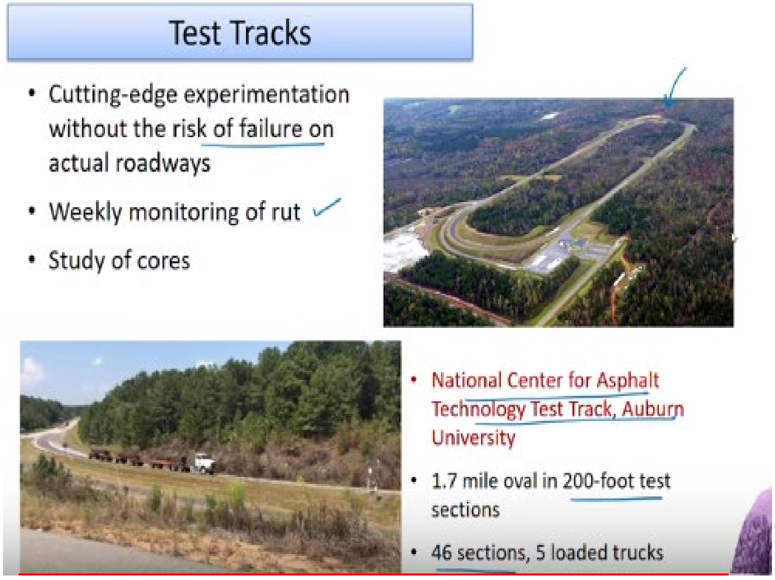

And the next is a test track. As I said this is designated test tracks which are constructed wherein you can do an experimentation, a lot of experimentation without the risk of failures on the actual road survey. So suppose you want to study about new materials, new technologies, new compaction equipment and so on you can have a test section constructed on the test track and get it tested.

And it is a possibility of weekly or a daily monitoring of rutting is possible. And also you can take the cores or trenches along the wheel path and also adjacent to the wheel path on the hump sides also you can collect the cores and you can examine what is the kind of rutting that has happened, okay. So this is one, there are many tests tracks that are prepared and researches are conducted by many agencies, transportation divisions and Universities.

Now this is one example of a NCAT test track. So this is a National Center for Asphalt Technology by Auburn University. This is essentially a 1.7-mile oval shaped test track with 200-foot test sections are given for each type of material. And there are 46 sections and 5 loaded trucks actually move on this and the data are collected regarding what is the deformation that is happening, what is the temperature, the pavement temperature is collected regularly, the rutting the cracking and all these aspects are collected on this test track on a regular basis.

As I said, the advantage of this is that your loading is controlled, the load, the axle load, the load repetitions, the rest period between wheel load applications is controlled in this case whereas, the environmental factors will vary.

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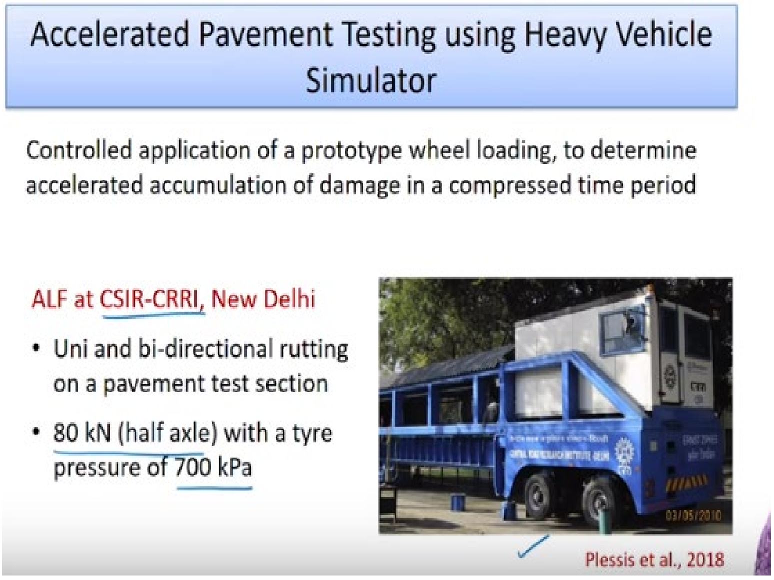

Now the next type of investigation is the accelerated pavement testing using a heavy vehicle simulator or an accelerated loading facility. Here what you do is a controlled application of a prototype wheel loading to find out how much is the accumulated damage, but this damage is collected in a compressed time period. So the loading is done at a higher rate so that you can collect information about the behavior in a short span of time.

So you can see here this is the accelerated loading facility that is available at CSIR-CRRI, the Central Road Research Institute, New Delhi wherein, you can apply a wheel load either in single direction or you can have a bidirectional load application. And as in this case, there is an 80 kilo Newton load is applied at half axle as compared to the 80 kilo Newton full axle load in actual. So it is actually an increased load application with a tyre pressure of 700 kPa. So the tyre pressure as well as the load is much higher than actual so that you can get the information in a shorter span of time.

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So this is an accelerated loading facility by the Australian Road Research Board as you can see here on a test track. What you note here is that, when it moves in one direction it is applying the loading whereas, the wheel is lifted when it goes back, okay. So this is a unidirectional load application.

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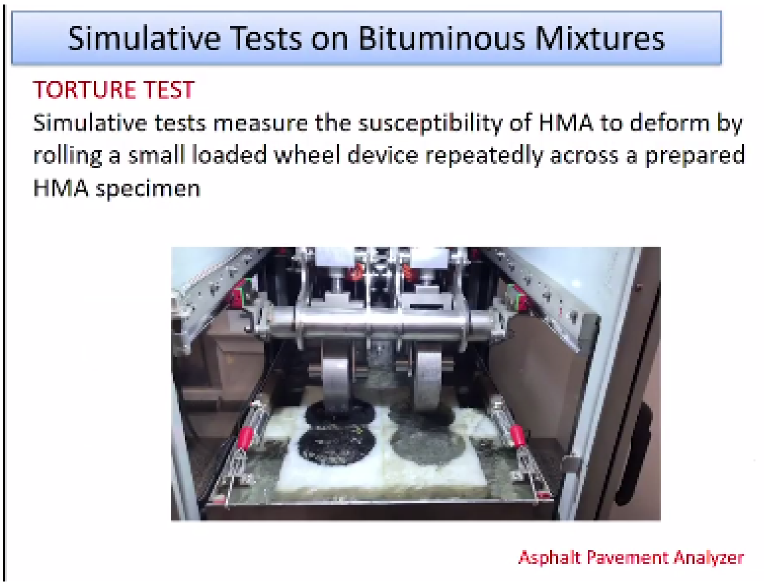

Now coming to the next test which is the simulative test on bituminous mixtures, okay. Here what you do is that you find the susceptibility of a hot mix asphalt mixture or you can do it for warm mix asphalt as well; what is its susceptibility to deformation under a rolling wheel load or a repeated application of wheel load on a small specimen of the bituminous mixture alone.

What we have discussed so far is the pavement structure as a whole whereas, here you are dealing with a bituminous mixture alone and to identify what is its rutting susceptibility. This is essentially called as a torture test because you repeatedly load this material, so as to find whether it reaches a failure criterion. So as you can see here you have those, here you have the specimens.

You have 4 core specimens are there and a wheel travels to and fro on this specimen. And also what you can see here is that this test is done under submerged conditions. So here you can do it in air or you can do this testing in water.

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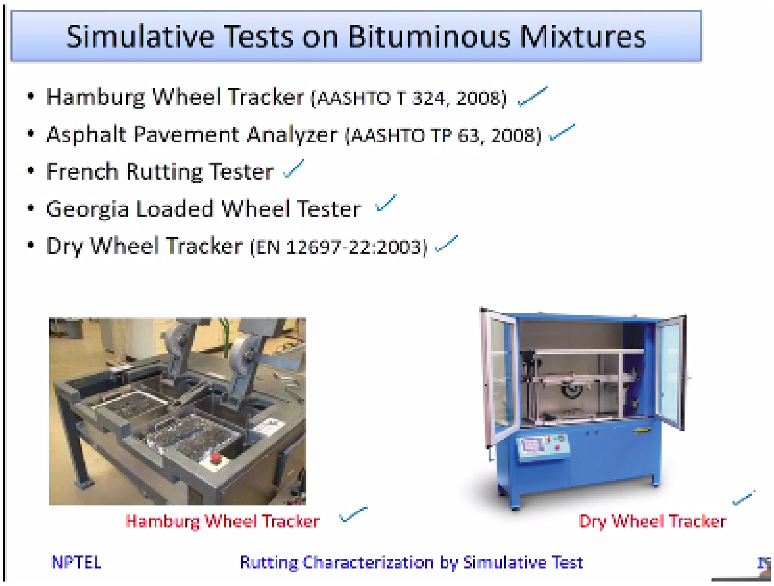

There are different test apparatus available for doing this simulative test. Say for example, the Hamburg Wheel Tracker test which is as per the AASHTO protocol AASHTO T 324. You have a Hamburg Wheel tracker, then you have an Asphalt Pavement Analyzer, which is using the AASHTO TP 63. Whereas you have a French Rutting Tester. Then there is a Georgia Loaded Wheel Tester. Then there is a Dry wheel Tracker, which is as per the European standards.

Certain pictures are shown here of a Hamburg Wheel Tracker and a Dry Wheel Tracker.

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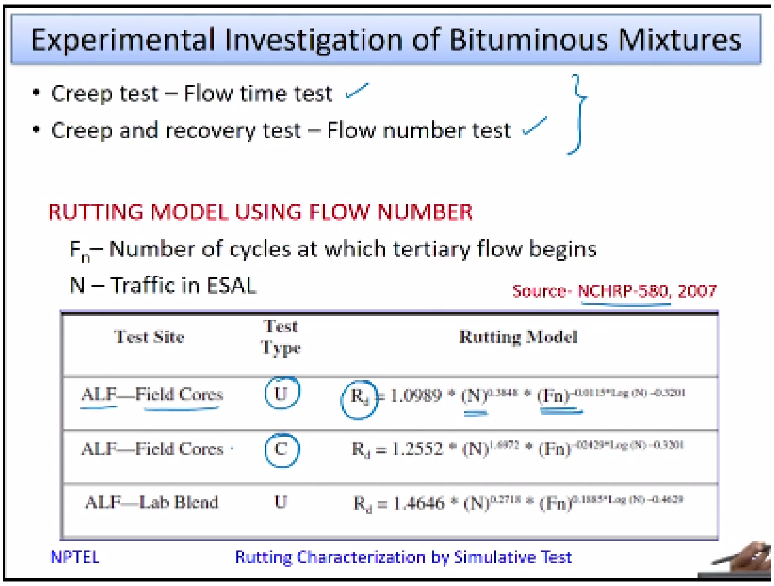

So now coming to the next investigation, which is the investigation of bituminous mixtures for its rutting or fatigue cracking related behaviors okay. Such tests are developed as part of the Superpave mix design methodology and also to be used in association with the Mechanistic Empirical pavement design. You have a flow time test or it is a creep test and then you have a flow number test, which is a repeated load test. And flow number tests are called simple performance test, which we will be discussing in the upcoming lectures.

Now the advantage of these tests is that this after getting sufficient information about the deformation behavior of the mixtures, this can be correlated to rutting in the field. Now there has been substantial amount of work done as part of the National Cooperative Highway Research Program.

And there are models developed which relates the rut depth to the flow number of the mixture. And here N is the traffic in equivalent standard axle load. So this is some sample models that are taken from the NCHRP report. You are, this is accelerated loading facility or the flow time, flow number test, correlated to the field specimens. Then this is done in an unconfined condition or a confined condition.

So we will discuss all this in the flow time flow number test in that lecture. So the advantage as I said is that you can correlate the rutting or the deformation that is observed in the bituminous mixture to the rutting in the field. You can have such distress transfer functions being developed, provided sufficient data is collected from the field as well.