**Retrofitting And Rehabilitation Of Civil Infrastructure**
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**Module: F**
**Week: 8**
**Lecture: 42**
**Design Considerations for Concrete Overlay**

Hello friends, welcome to the NPTEL Online Certification Course Retrofitting and Rehabilitation of civil infrastructure. Today we will discuss Module F, the topic for Module F is Concrete Overlay for Pavement Rehabilitation.

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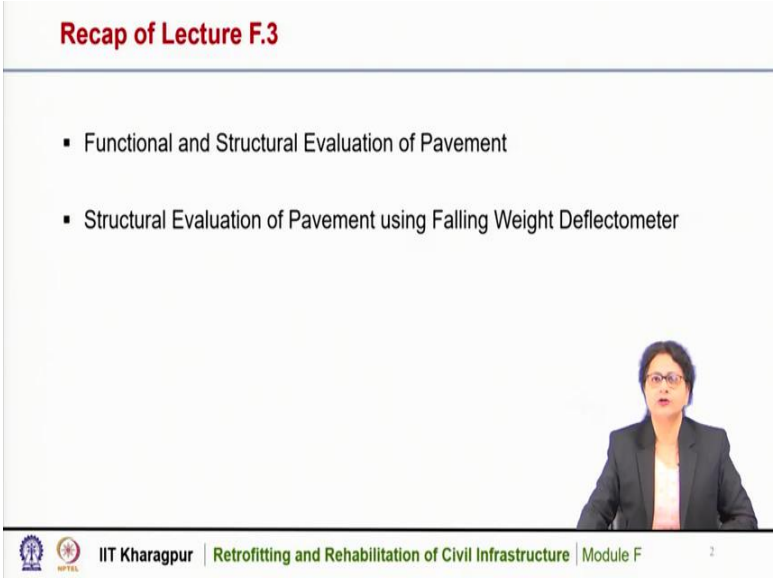


In the previous lecture, we have discussed Functional and Structural Evaluation of Pavement and Structural Evaluation of Pavement using Falling Weight Deflectometer.

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Today, we will discuss Design Considerations for Concrete Overlay and Distresses in concrete Overlay.

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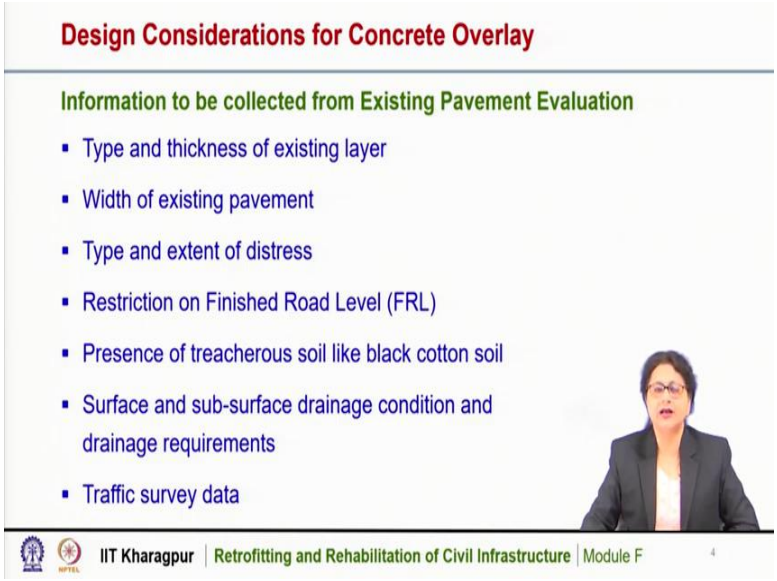


While designing a concrete overlay it is important to carry out pavement evaluation. Pavement evaluation is an important component for any maintenance and rehabilitation work of infrastructure. For pavement therefore, it is also important to carry out a systematic evaluation of the existing pavement and from the evaluation of pavement we can get several informations which are useful for the design of concrete overlay.

To know that whether maintenance is required or not or if it is required, how much is the extent of repair or rehabilitation or overlay that can be obtained from a proper evaluation of pavement. So, we can get several information from pavement evaluation, these are type and thickness of the existing layers of a pavement.

The width of existing pavement, the type and extent of distress, what type of distress is there on the pavement and how much is the amount of distress or how much is the extent of distress the pavement is suffering that can be obtained from a proper pavement evaluation. Restriction on Finished Road Level - So, this is also very important particularly for overlay purpose, because, if we provide an overlay then there will be a change in the Finished Road Level.

And for a number of maintenances works if one or two layers of material is to be placed, then there is a change in the Finished Road Level. And that may cause problem because the road level may increase but the adjacent area is still in the previous level. So, there may be a problem of drainage and other issues.

So, sometimes particularly in urban areas, there may be a restriction on the finished road level. So, that we have to consider while designing our overlay. Presence of treacherous soil like, black cotton soil if that type of soil is present below the existing pavement that we can know from the pavement evaluation.

Surface and sub-surface drainage condition and drainage requirement. Drainage is also important for pavement because if the surface water or sub-surface water is not properly drained, that may cause damage to the pavement. So, what is the drainage requirement for the pavement that we need to assess from the pavement evaluation. And the traffic survey data. So, this is also important to get the traffic that will be moving on the road which requires a rehabilitation or so.

So, these are the informations, that need to be collected or that need to be obtained from pavement evaluation and those are required for the design purpose of concrete overlay.

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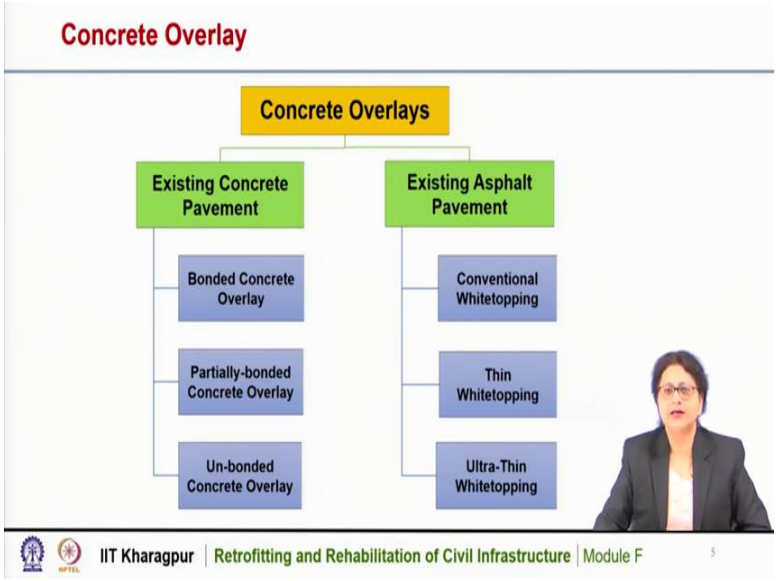


We have discussed in the previous lecture that there may be different types of concrete overlay. For existing concrete pavement, we may have Bonded Concrete Overlay, Unbonded concrete overlay or Partially Concrete Overlay. And in case of asphalt or bituminous pavement, we may have conventional overlay or conventional white topping.

Because the concrete overlay over a bituminous pavement is also called White topping. So, the concrete overlay may be termed as conventional white topping, thin white topping or ultra-thin white topping. In India, we have much less amount of concrete pavement till today, it is approximately 2 to 3 percent of the total road length that is concrete the rest is Bituminous Pavement.

So, concrete overlay over an existing concrete pavement is much less in our country. Whereas, the concrete overlay over an existing bituminous pavement is now gaining popularity and many of the existing deteriorated bituminous pavement are being rehabilitated by placing concrete overlay. So, white topping is becoming popular and gaining interest to the practicing engineers as well as to the research community.

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So, we will discuss the concrete overlay over bituminous pavement or whitetopping and as we have just mentioned that it is of 3- types conventional white topping, thin whitetopping and ultra thin whitetopping depending on the bonding condition and their applicability and thickness. So, in case of conventional whitetopping just a recapitulation.

It is an unbonded overlay over an existing bituminous pavement and applicable when the existing pavement is heavily damaged. So, the Bituminous pavement does not contribute anything to the load carrying capacity to the conventional whitetopping and it is designed as a new pavement.

Thin whitetopping is bonded or partially bonded or unbonded to the existing pavement. And it is applicable for the pavement which is of moderately fair condition without wide cracks and without material or sub-grade related distresses, there should not be any sub-grade failure in case of thin whitetopping and the thickness is obviously less as compared to conventional whitetopping.

In case of Ultra-thin white topping, the thickness is even lesser and it has to be bonded to the existing pavement and it is applicable for pavements having condition fair to good, but requires structural capacity enhancement. So, concrete overlay provides a structural strengthening to the existing pavement and its service life is also extended. Depending on the extent of distress, we can select a conventional whitetopping or thin whitetopping or ultra-thin whitetopping.

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Now, we will discuss the design considerations for whitetopping. Concrete overly provides the necessary strength to the deteriorated pavement. Entire existing bituminous pavement with its different layers and the sub-grade below it is considered as the foundation as a whole for the concrete overlay.

So, in case of a concrete overlay over a bituminous pavement, the existing bituminous pavement with its different layers behave as the foundation for the overlay. The existing bituminous pavement should have moderate to fairly good strength to act as the base layer. Since the existing pavement behaves as the base layer to the concrete overlay.

So, it should have sufficient strength and that is why a minimum thickness is also desirable. So, a minimum thickness of existing bituminous layer is kept as 75 to 100 millimeter after the surface preparation or milling. So, for concrete overlay a top a bituminous pavement, the existing pavement should have a sufficient strength to behave as a base layer and that is why a minimum thickness is also desirable.

The subgrade with sufficient strength also is necessary and there should not be any major distress or subgrade failure. So, for the whitetopping, it is important that subgrade should have sufficient strength and there should not be any subgrade failure or major distress to the subgrade. In locally there may be some distresses to the subgrade as well. But there should not be any major distress to the subgrade.

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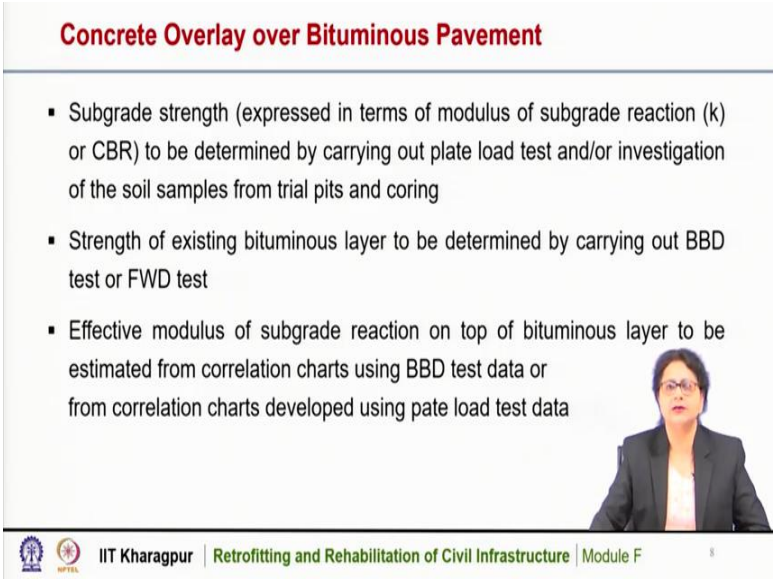


The subgrade strength, which is generally expressed in terms of modulus of subgrade reaction, or CBR to be determined by carrying out plate load test or investigation of the soil samples from trial pits and coring, the strength of the existing bituminous layers to be determined by carrying out Benkelman beam deflection test or falling weight deflectometer test.

The effective modulus of subgrade reaction on top of bituminous layer is to be estimated from the correlation charts using BBD test data or from correlation charts developed using plate load test data as prepared by American Concrete pavement association. So, we need to express the strength of the foundation in a proper way.

Because now the existing pavement behaves as the foundation. The bituminous pavement with its different layers the base layer, sub base layer as well as the subgrade now behaves as the foundation to the concrete overlay. So, it is important to express the strength of the foundation in a proper way.

The subgrade strength can be expressed by modulus of subgrade reaction or CBR. The strength of different layers of the bituminous pavement can be found out from FWD testing. And from that we can correlate the subgrade strength with BBD test data or from other plate load test data and we can get the strength of the entire foundation for the concrete overlay.

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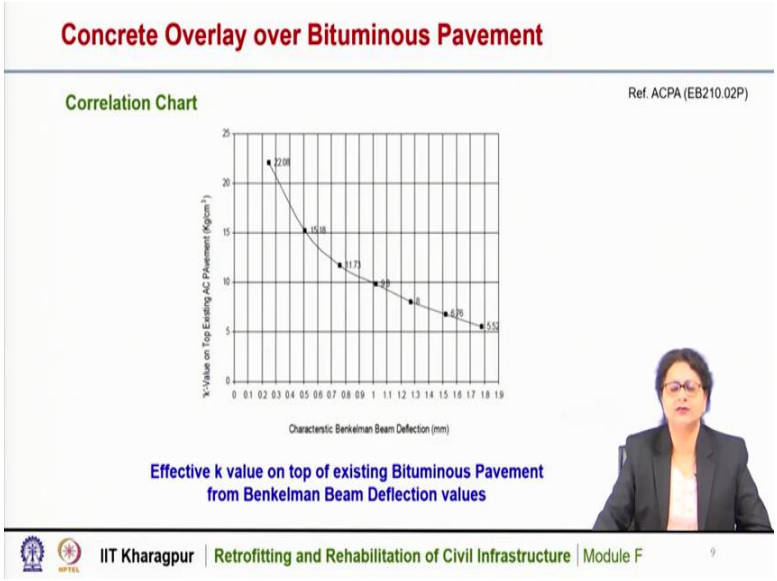


This is a correlation chart developed using Benkelman beam deflection data. So, this is the effective k value that has been plotted in the y-axis and the Benkelman beam deflection data is plotted in the x-axis. So, this gives the correlation between the BBD deflection values and the effective k value on top of existing bituminous pavement.

So, this gives the effective modulus of subgrade reaction that is the subgrade strength or the effective strength of the foundation from the BBD test data. So, using this correlation chart, we can get the effective strength of the foundation or effective modulus of subgrade reaction for the concrete overlay design.

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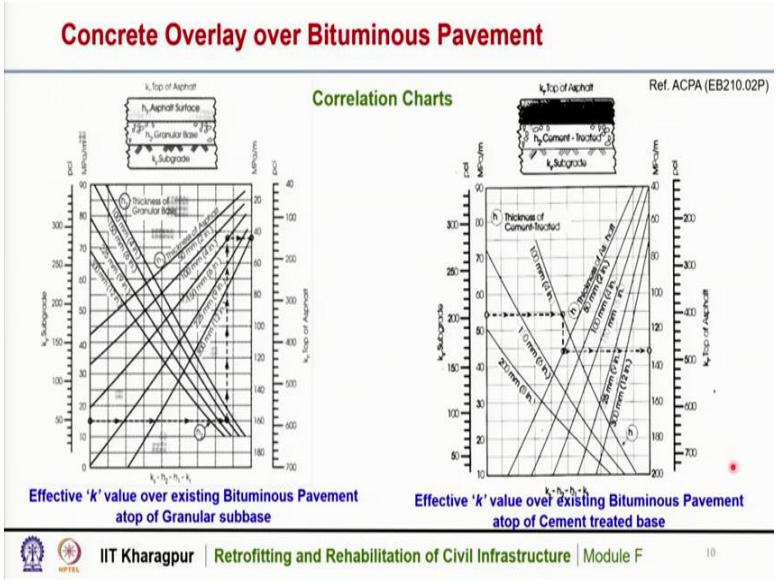


These are the Correlation Charts that has been developed by an (ACPR) American Concrete Pavement Association. This chart gives the effective k value over existing bituminous pavement on top of granular sub base. So, if the existing pavement is shown here, it is schematically shown. So, this is the existing asphalt layer and this is the granular base which is the sub base for this pavement and this is the sub-grade.

And now, if we want to find out what is the effective k value for all these layers, then we can use this chart this has been developed based on plate load test data. So, with this correlation chart, we can get the effective k value, effective modulus of sub-grade reaction for this condition and this chart gives the effective k value over existing bituminous pavement a top of cement treated base.

So, here in this case, it is the bituminous layer and the base layer is cement treated and then there is sub-grade layer. So, we can find out the effective modulus of sub-grade reaction for this case using this correlation chart. So, it is important to have this effective modulus of sub-grade reaction to represent the foundation strength.

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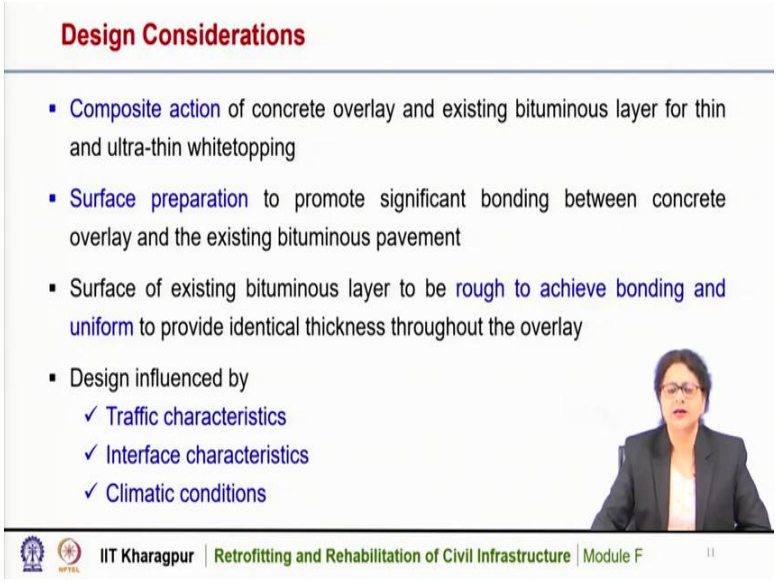


Now for the design consideration the concrete overlay and the existing bituminous layer for thin and ultra-thin white topping, a composite action is taking place. So, the concrete overlay and the bituminous layer behave such that there is a composite action and for this it is important to have a proper surface preparation.

So, surface preparation is needed for the existing pavement to promote significant bonding between the concrete overlay and the existing bituminous pavement. Surface of the existing bituminous layer needs to be rough to achieve adequate bonding between the two-layers and uniform to provide identical thickness throughout the overlay.

So, it is important to have proper bonding, so that the composite action is achieved. So, to get a proper bonding, the surface of the existing pavement need to be prepared and we will discuss how we can do surface preparation later. Now, we will just discuss that the design is influenced by traffic characteristics, interface characteristics and climatic conditions. So, for the design of concrete overlay, it is important to know the traffic characteristics, the interface characteristics and the climatic conditions.

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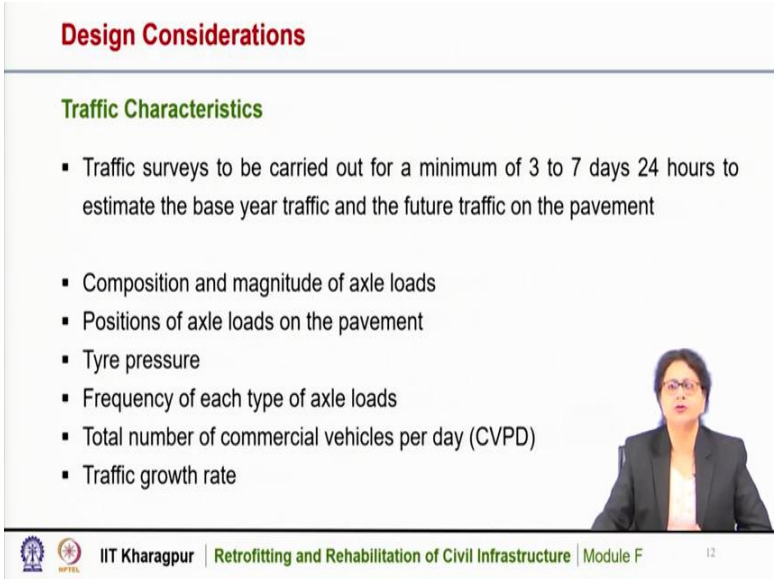


The Traffic Characteristics include the composition and magnitude of axle loads, the position of the axle load on the pavement, the tyre pressure, frequency of each type of axle load, total number of commercial vehicles per day or CVPD and traffic growth rate, the traffic loading is the main loading coming on a pavement.

So, it is important to carry out proper traffic survey. So, traffic survey needs to be carried out for a minimum of 3 to 7 days and for 24 hours to estimate the base year traffic and also the future traffic on the pavement. So, when the traffic survey is carried out that time what is the traffic on the pavement and what will be the future traffic on the pavement that we need to estimate and several traffic characteristics that need to be found out from the traffic survey.

The composition of the different vehicles, the magnitude of axle loads, the position of axle load on the pavement, what is the tyre pressure on it, what is the frequency of each type of axle load and what is the total number of commercial vehicles per day. We also need to know what is the traffic growth rate and from that we have to calculate the total design traffic on the entire design period.

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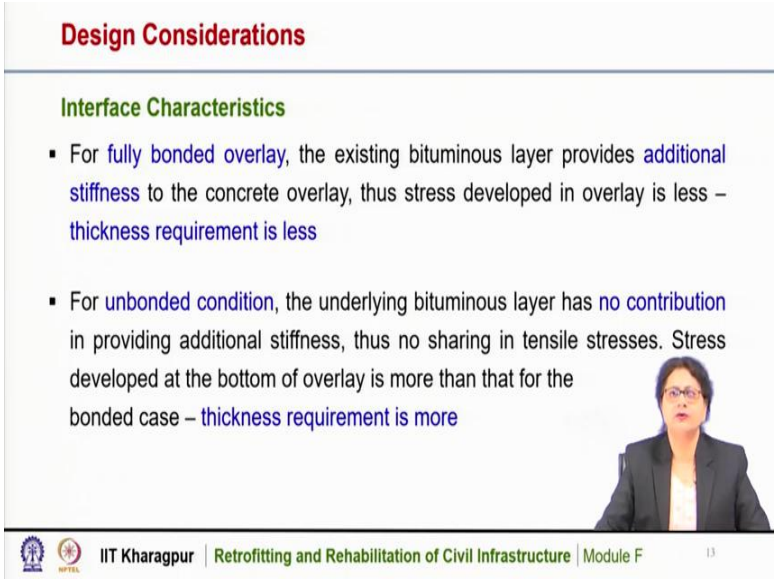


Interface characteristics is an important consideration for design of overlay. For fully bonded overlay the existing bituminous layer provides additional stiffness to the concrete overlay. Thus, stress developed in the overlay is less and that results into a lesser thickness requirement. So, for fully bonded condition, the existing bituminous layer provides additional stiffness to the concrete overlay.

So, the stress developed in the overlay is less and the thickness requirement is less, whereas in case of unbonded overlay, the underlying bituminous layer has no contribution in providing the additional stiffness. Thus, no sharing in the tensile stresses, the stress developed at the bottom of the overlay is more than that for the bonded case. So, the thickness requirement is more. So, this we have to consider while designing concrete overlay.

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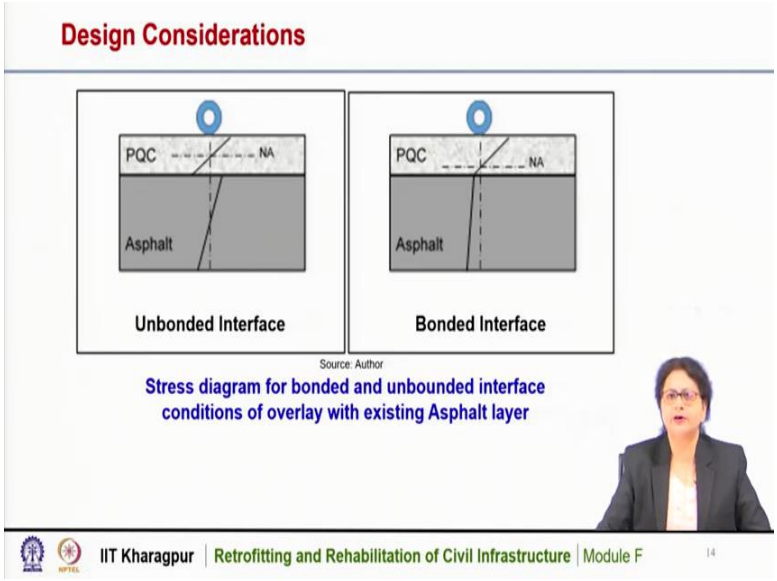


This is the stress diagram for Bonded and Unbonded Interface conditions of overlay with existing asphalt layer. So, here in this case, it is the Unbonded Interface. So, this is the existing asphalt or bituminous layer and this is the concrete overlay. Now, if there is no bonding, then the existing bituminous layer does not contribute anything to the load carrying capacity to the overlay.

So, the stress developed is much more. So, here this is the tensile stress that is developed in the overlay. And here this picture shows the stress diagram for bonded interface. So, this is the overlay and this is the existing pavement, they are bonded to each other. So, the existing pavement contributes in carrying the load.

So, it adds to the stiffness of the concrete overlay. So, here the neutral axis is shifted towards this layer. So, the stress developed at the bottom of the overlay is much less as compared to the unbonded case. So, here in case of bonded interface, the existing asphalt layer contributes in the stiffness. So, the stress developed in the overlay is less as compared to Unbonded Interface.

So, we can remember that the conventional whitetopping is applicable when the existing pavement is heavily damaged. So, there is no contribution to the existing pavement and all the load is carried by the concrete overlay. So, the Unbonded Interface is provided for conventional whitetopping and the concrete overlay is responsible for carrying the entire load, the contribution of the existing pavement is not considered.

And that is why when the existing pavement is deteriorated significantly, we prefer Unbonded Interface condition or conventional whitetopping. Whereas, thin or ultra thin white topping the contribution of the existing asphalt layer is there and there is composite action, the interface is bonded, the existing layer adds to the stiffness to the overlay. So, when the existing pavement is moderately damaged, we prefer bonded interface or thin or ultra thin whitetopping.

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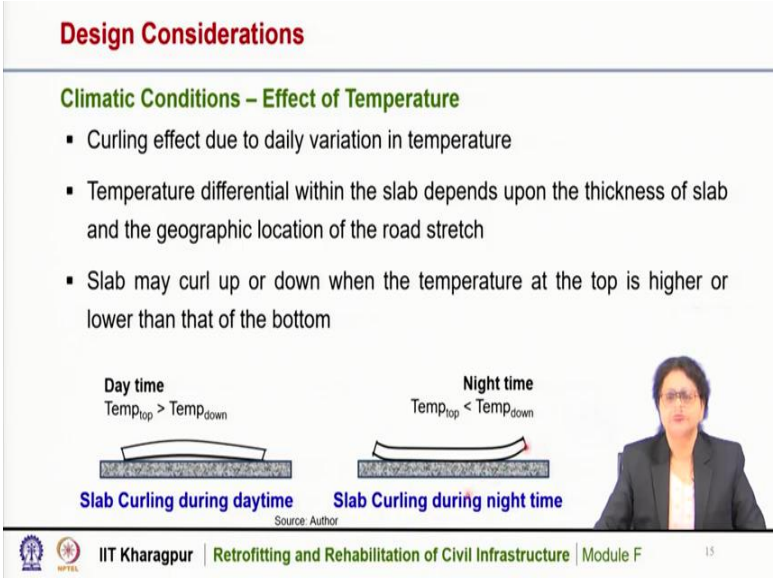


Now, we will discuss the climatic conditions; particularly the effect of temperature, the temperature effect is also significant in case of concrete overlay, there may be curling effect due to daily variation of temperature, temperature differential is there within the slab due to the daily variation of temperature in day time or night time and that depends upon the thickness of the slab and also on the geographical location of the road stretch.

So, the slab may curl up or down when the temperature at the top is higher or lower than that of the bottom. So, here it is shown schematically the effect of temperature, the daily variation of temperature during daytime that top temperature is more as compared to the bottom temperature. So, the slab make curl like this.

Whereas in case of night time, when the top temperature is less as compared to the bottom temperature. So, then the slab may curl like this. So, this is the slab curling during night time and this is slab curling during day time due to the variation of temperature throughout the day.

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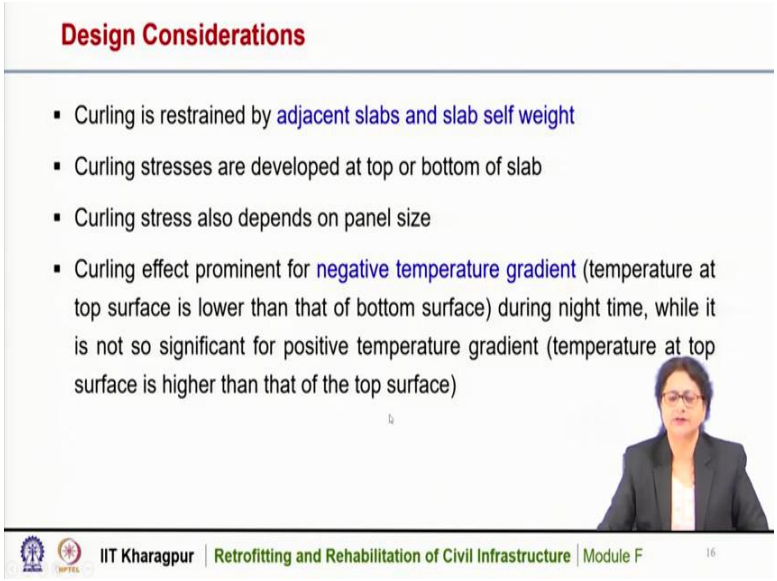


Now, due to variation of temperature, there may be curling effect, but this curling is restrained by the adjacent slabs and the self weight of the slab. So, because of this restraint, there is curling stresses that are developed at the top or bottom of the slab. The curling is restrained by the adjacent slabs as well as by the self weight of the slab.

And because of this restrained, these curling stresses are developed on the slab, the curling stress may develop at the top or at the bottom of the slab and the extent of curling stress depends on the temperature gradient as well as on the size of the slab or size of the panel. The curling effect is more prominent for concrete overlay for negative temperature gradients.

That means when the temperature at the top surface is lower than that of the bottom surface that occurs during the night time, while it is not so significant for positive temperature gradient, when the top surface is higher than that of the bottom surface, while it is not so significant for positive temperature gradient when the temperature at the top surface is higher than that of the bottom surface.

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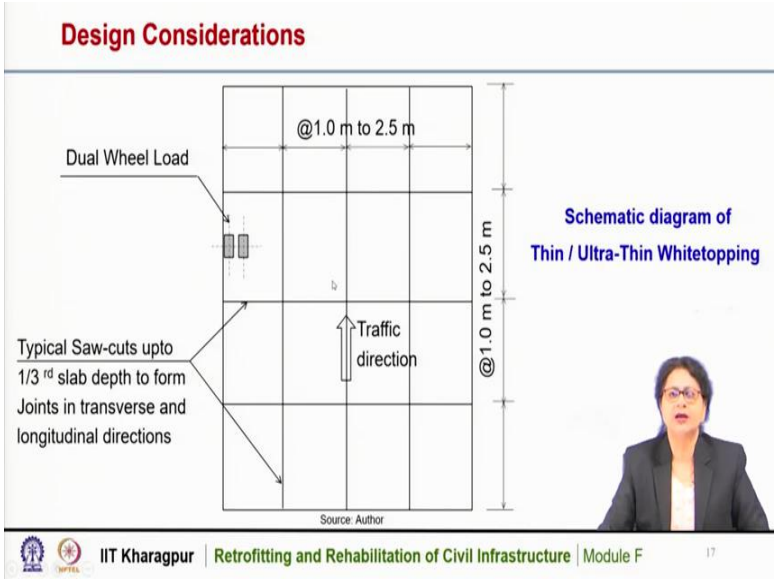


This is a schematic diagram of thin or ultra-thin white topping; here the panel sizes are much less as compared to conventional concrete pavement. In case of conventional concrete pavement, the standard panel size in India is 3.5 meter × 4.5 meter. Whereas, for whitetopping or thin or ultra thin whitetopping, it is much less maybe 1 meter × 1 meter or maximum 2.5 meter and to be square or rectangular panels.

These are the typical saw cutting lines and this saw cut is done up to 1/3$^{rd}$ the slab depth to form joints in transverse as well as longitudinal direction and this is the same traffic direction, the load can be on any place it could be at the edge of the pavement edge of this panel or at the corners. So, we have to estimate the effect of load on different positions of the pavement.

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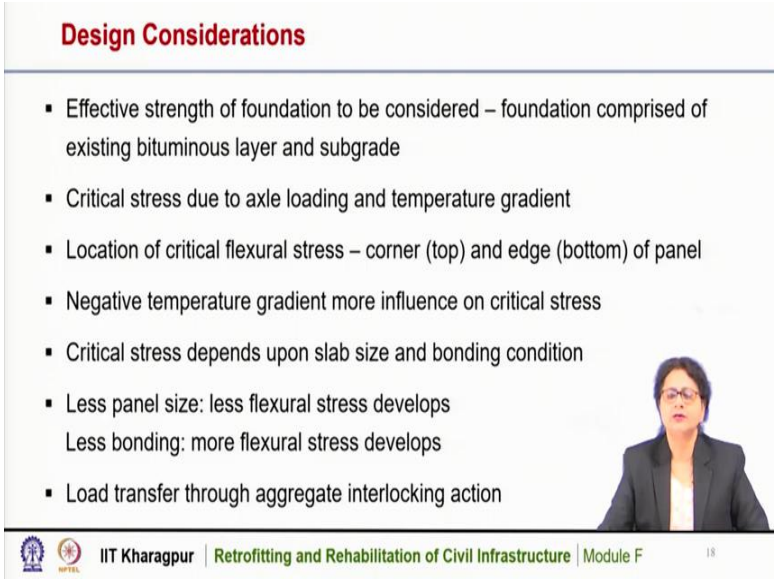


Now, the effective strength of foundation is to be considered and foundation now is comprised of the existing bituminous layer and the sub-grade. So, here in this case, for whitetopping, the foundation is the existing bituminous pavement, that is the bituminous pavement, the top layer with base or sub base layers and the subgrade.

So, the entire thing forms the foundation to the overlay. The critical stress that is developed on the pavement is due to axle loading and also due to the temperature gradient that is the curling stress, and location of the critical flexural stress at corners and edges of the panel. So, depending on the location of the axle load, the critical stress may develop at the corner or at the edge of the panel.

And with that, there may be curling stresses due to the effect of temperature gradient, the negative temperature gradient influences more as compared to positive temperature gradient on the critical stress; the critical stress depends upon the slab size and the bonding condition. So, more is the slab size, more is the critical stress developed or more is the stress developed on the pavement.

And it also depends on the bonding condition as we have discussed that if the bonding is not achieved it is unbonded, then more stress will be developed on the overlay. And when it is bonded, less stress will be developed. And in case of overlay there are joints in transverse and longitudinal direction and these joints are closely spaced at say 1 meter to 2 meter apart in both

transverse direction as well as longitudinal direction. So, the load is transferred from one panel to another panel by interlocking action of the aggregates.

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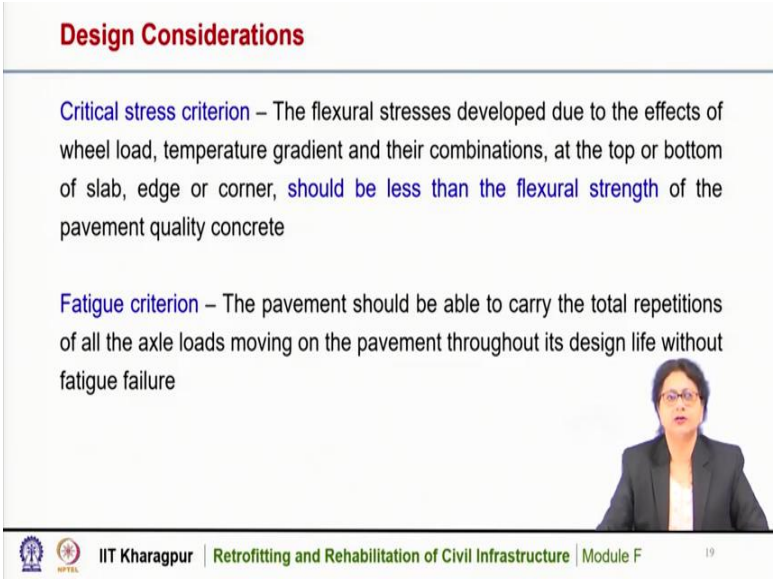


So, we have to consider the two criteria for design of overlay, one is Critical stress criteria and the other is Fatigue criteria. In critical stress criteria, the flexural stresses that are developed on the pavement due to the effects of wheel load, temperature gradient and they are combinations at the top or bottom of the slab. And the edge or corner of the panel that stress should be less than the flexural strength of the pavement quality concrete.

So, this is the first check for the design that means, the stress that is developed on the concrete overlay due to the effect of wheel load or temperature load or their combination, that should be less than the flexural strength of the concrete. They also have to check another thing that is fatigue, the pavement is subjected to repeated load throughout its design life.

So, the pavement should be able to carry the total repetitions of all the axle loads moving on the pavement throughout its design life without fatigue failure. So, the pavement should be able to carry all the loading that is coming on to it throughout its design life such that there is no fatigue failure and this we can check by cumulative fatigue damage principle using minor's hypothesis.

So, the total fatigue life that is to be consumed should be less than 1 and this has to satisfy for the design of overlay. So, for the design of overlay, we have to consider two criteria, one is critical

stress criteria and the other is fatigue criteria. The stress that is developed on the overlay should be less than the flexural strength of the material that is of the pavement quality concrete and the fatigue criteria, that is the pavement should be able to carry all the loading coming on it throughout its design life.

And we can check it by cumulative fatigue damage principle such that the total fatigue life consumed is less than 1. So, both the conditions should be satisfied for a safe design.

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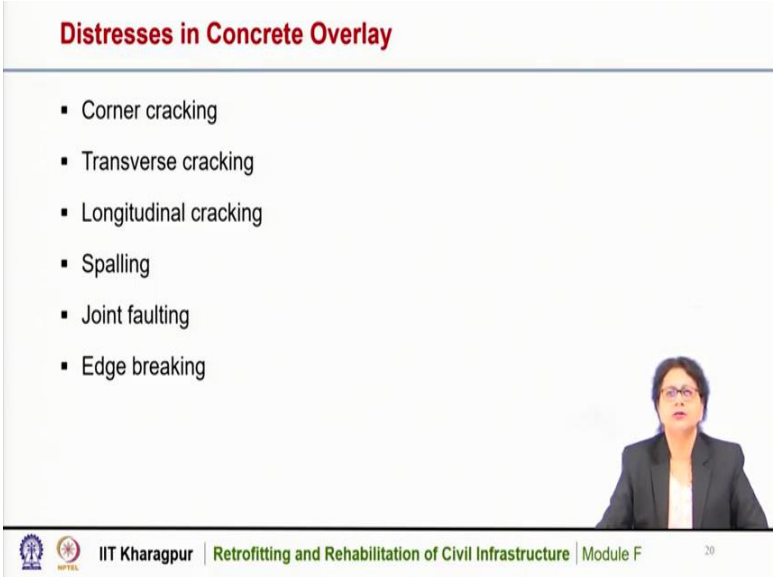


Now, if the design is not properly done or if there are some construction deficiencies or so, the concrete overlay may get distressed as well. So, there may be distresses like cracking at the corners or the Transverse direction or in the Longitudinal direction of the pavement, there may be Spalling of concrete, there may be Joint faulting or Edge breaking.

So, all these types of distress may be there, if the construction is not properly done or the design is not properly done or if there is overloading, more loading or more repeated loading. So, all this may cause damage to the concrete overlay.

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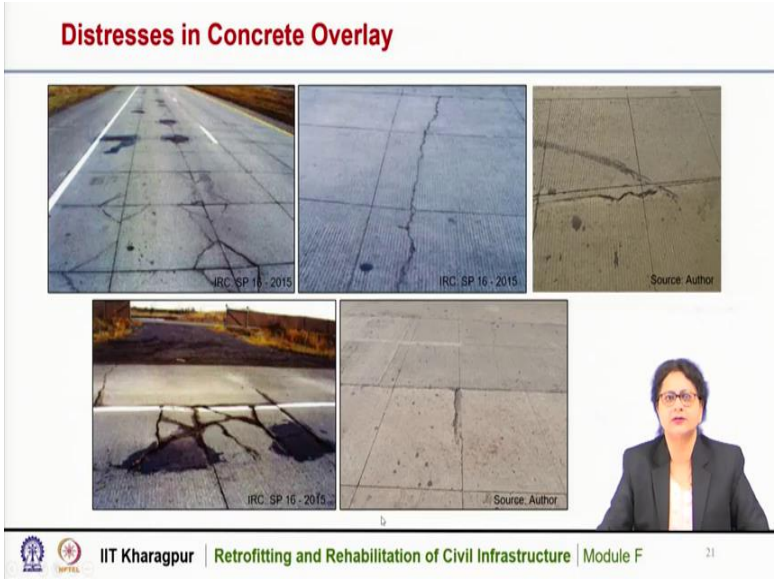


So, these are some of the pictures of distresses in concrete overlay. Here we can see that corner cracking, the concrete overlay or whitetopping is suffered from several corner cracks at these locations we can see very clearly that corners are getting damaged and corners are the location of maximum stresses. So, if the stress is more than the flexural strength, then the cracking may occur at the corners.

This is a typical picture of transverse cracking as we can see here this is a transverse cracking on the overlay and that may occur also due to load associated distresses, higher stress may develop when the load is placed at the edge of the panel or it may be due to late joint cutting. So, this type of cracking may occur. This is longitudinal cracking. This may also be due to late joint cutting or any construction related issues.

This is spalling off the concrete near the joint and that results into poor construction practice, this is a shattered panel that may be due to the distress of the below layers that is bituminous layer or in the sub-grade and that may cause several cracking on the overlay. So, these are some of the pictures that some of the pictures we have taken also where this type of pavement has been constructed.

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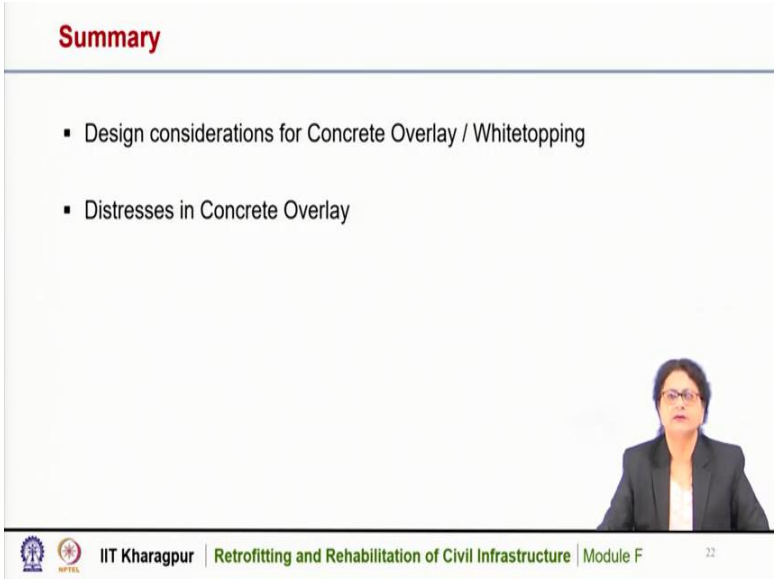


So, to summarize, we have discussed the design considerations for concrete overlay, particularly the whitetopping over existing bituminous pavement and we have also discussed the distresses in concrete overlay.

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Thank you.