Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 40
Distresses in Existing Pavement

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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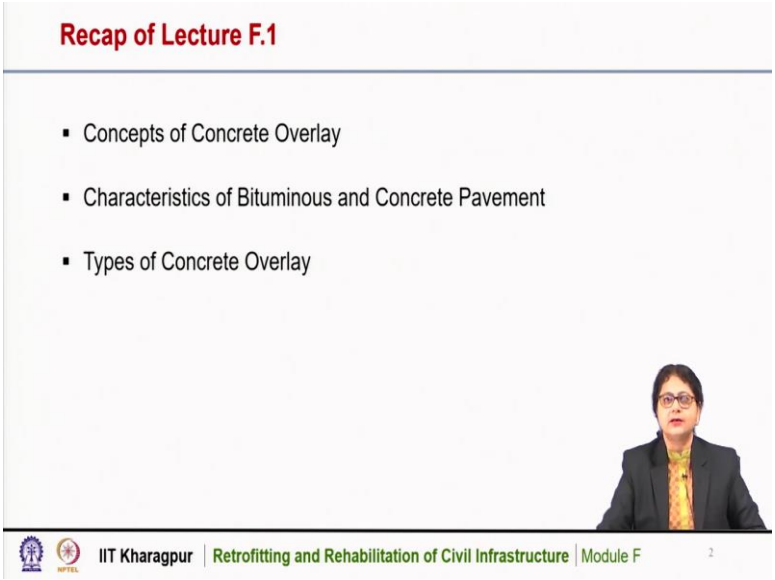

In the previous lecture, we have discussed the concepts of concrete overlay. Concrete overlay is a rehabilitation strategy for existing deteriorated pavement, both for bituminous pavement and concrete pavement. We have discussed the different types of concrete overlay; for bituminous pavement, there are different types of concrete overlay and for concrete pavement there are different types of concrete overlay.

So, for an existing pavement, what type of concrete overlay will be used, that depends on the type of the pavement and how much is the pavement deteriorated on that. So, what type of concrete overlay we will use that depends significantly on the type of pavement and how much it is deteriorated.

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So, in today's lecture, we will discuss what are the different types of distresses and existing pavement may have, both for bituminous pavement and concrete pavement due to which their performance is reduced. So, we will discuss today the different types of distresses in bituminous pavement and concrete pavement and their identification.

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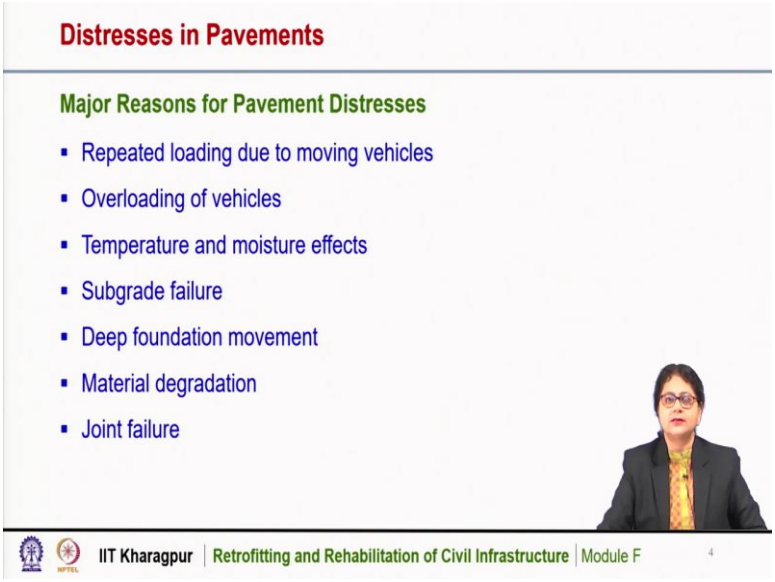

Pavement is a structure that is supported on foundation. The foundation is composed of different layers of base, sub-base and compacted subgrade. And the main load coming on the pavement is the moving vehicular load. Like all other structures, pavement may also get

deteriorated over time. So, the main reasons for pavement deterioration can be repeated loading due to the moving vehicles subjected to moving vehicular loading.

So, repeated loading may cause distress to the pavement. Overloading of vehicle is another issue particularly in our country. And that may cause severe damage to the pavement. Temperature and moisture effects may also affect the performance of pavement, the pavement is a structure which is exposed to the environment. So, the change in temperature due to daily variation or seasonal variation and the variation of moisture that may affect the performance of the pavement.

Subgrade failure is also one of the major reasons for pavement distress. The pavement is supported on compacted subgrade. So, the subgrade has to have sufficient strength to bear the load coming on it due to the load of the pavement and also the vehicular load. If the subgrade is not sufficiently strong, there may be failure of the subgrade and that may affect the pavement performance.

Deep foundation movement, that is also another reason for pavement distress, the subgrade may have differential settlement or there may be unequal movement or erosion type of distress that may affect the performance of the pavement. So, pavement may get distressed due to the deep foundation movement or unequal settlement of the foundation.

Material degradation is also one of the reasons for pavement distresses. Whether it is a bituminous pavement or a concrete pavement depending on the type of material there may be degradation. It has also different layers for base and sub-base. So, the material degradation if it is there, then the performance of the pavement maybe reduced. Joint failure is also another reason for pavement distress particularly for jointed pavement, jointed concrete pavement, because concrete pavement has joints.

So, joints are the location of distresses if they are not properly constructed. So, the pavement may have different types of distresses and the distresses are due to repeated loading due to the moving vehicles, it may be due to overloading of vehicles. The temperature and moisture effect may also affect the performance of pavement. Subgrade failure causes the failure of the pavement like deep foundation movement or unequal settlement or erosion all may cause failure of the pavement.

Material degradation is also one of the reasons for pavement distresses and in case of concrete pavement, there are several joint related distresses that may affect the performance of concrete pavement. So, these are the major reasons for pavement distresses. Now, due to these reasons, the pavement may get deteriorated and its performance is reduced.

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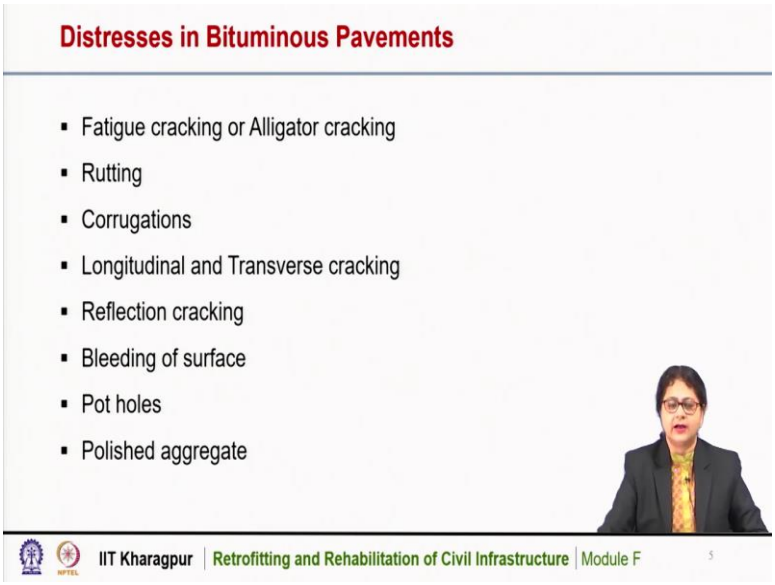

So, now we will discuss the different types of distresses pavements may have. So, we will discuss first the distresses in bituminous pavement and then the distresses in concrete pavement. In bituminous pavement, the distress is maybe due to all these reasons what we have discussed and there are different types of distresses that need to be identified, distresses maybe fatigue cracking or alligator cracking, it may be rutting, corrugations, longitudinal and transverse cracking, reflection cracking, bleeding of surface, potholes, polished aggregate etc. There may be some other but these are the major distresses of bituminous pavement has.

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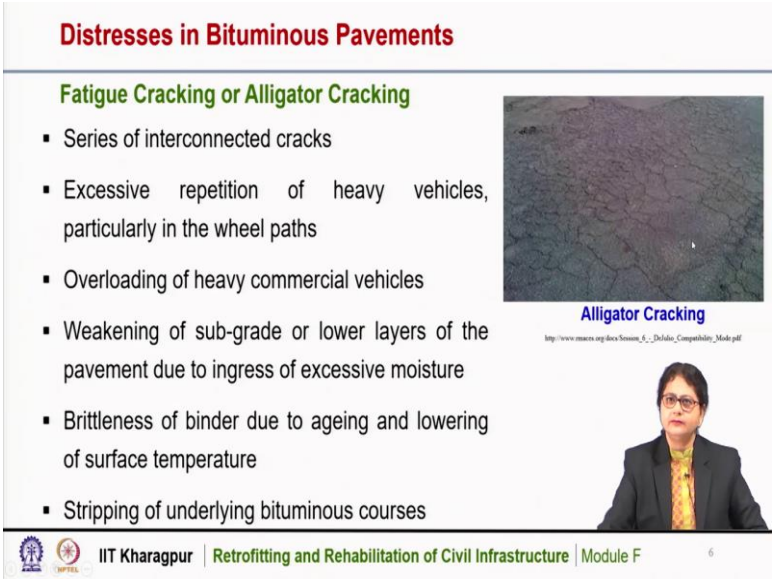

Fatigue cracking or sometimes called alligator cracking is due to the formation of interconnected cracks on the surface of the pavement. So, here is a typical picture of fatigue cracking or alligator cracking, we can see that there are a number of cracks are there and that causes deterioration of the pavement.

So, series of interconnected cracks are there which reduces the performance of the pavement in terms of its load carrying capacity and riding quality also its service life. Now, this type of alligator cracking occurs due to excessive reputation of heavy vehicles particularly in the wheel path. So, this is due to repeated number of loadings that means of fatigue.

So, excessive reputation of heavy vehicles may cause this type of cracking on the pavement. Overloading of heavy commercial vehicles that may also cause this type of cracking, weakening of subgrade or lower layers of the pavement due to increase of excessive moisture. So, subgrade may get distressed due to increase of excessive moisture that may affect the upper layers. Brittleness of binder due to ageing and lowering of surface temperature.

The binder material that is the top bituminous layer is a material which is susceptible to temperature and moisture and over time the material may get brittle. So, if the material is becoming brittle due to ageing, that may cause this type of cracking or if the surface temperature is much less, that may also cause cracking on the surface.

Stripping of underlying bituminous courses, because the top layer is a mixture of bitumen and aggregates and if the bitumen is stripped out of the aggregates that may cause cracking on the top surface. So, fatigue cracking or alligator cracking is quite common in Indian roads. And that occurs due to various reason. The major reason is repeated loading or overloading or due to subgrade distress or due to the binder problem that is brittleness of the binder may cause this type of cracking.

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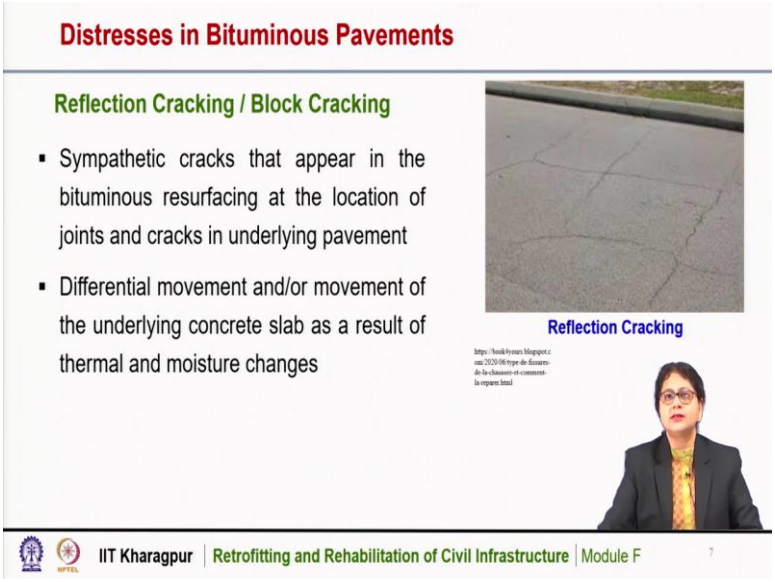

Another type of cracking is also found on bituminous pavement that is called a reflection cracking or block cracking. These are sympathetic cracks that appear in the bituminous resurfacing at the location of joints and cracks in underlying pavement, sometimes, bituminous layer is put on the existing concrete pavement. So, this is this type of distress is particularly seen on a bituminous overlay when it is on a deteriorated concrete pavement.

So, concrete pavements have joints and it may be cracked and that is why it requires resurfacing. So, on those location of cracks or joints these cracks may appear on the top layer. So, that is why it is called reflection cracking, because of the joints or cracks present in the underlying layer that is reflected on the top surface if not proper interface treatment is taken. So, these are the reflection cracking and, in this picture, we can see that this reflection cracking on the surface of the road.

Differential movement or movement of the underlying concrete slab as a result of thermal and moisture changes may also cause cracking on the upper layer. So, concrete pavement may have differential movement due to seasonal variation of temperature. So, due to thermal

and moisture changes there may be a differential movement of the underlying concrete slab that may cause cracks on the pavement which appears on the top surface.

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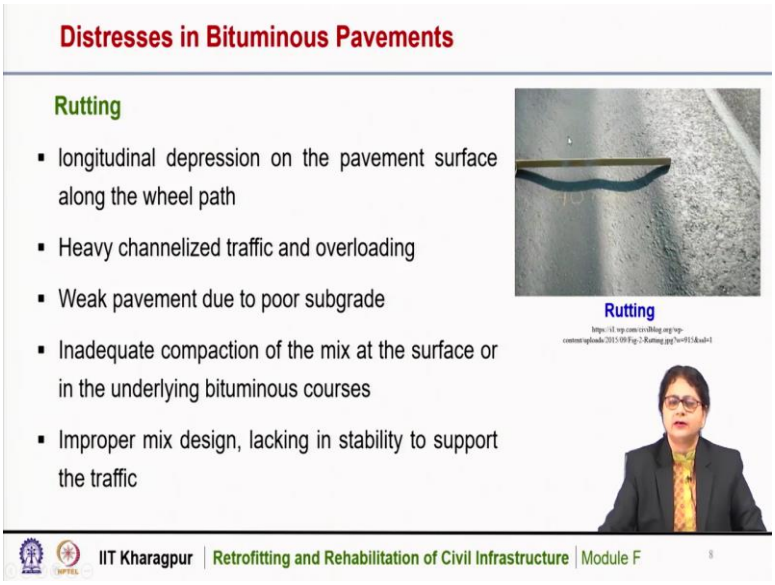

Rutting is also another major distress in case of bituminous pavement, this is also called permanent deformation. It is the longitudinal depression on the pavement surface along the wheel path. So, here we can see that this is a typical picture of rutting and this is along the length of the road the vehicle is moving along this path. So, these are typical wheel paths.

So, there is a depression along the wheel path along the length of the road. So, this is called a rutting or permanent deformation. This is mostly due to subgrade failure; the traffic is generally moving along these paths. So, these are more or less the wheel path and if there is overloading that may increase the damage, the rutting is due to the poor subgrade, when the subgrade fails there is a deflection and that causes the deflection of the upper layers also.

So, the performance of the pavement is reduced due to the failure of the subgrade. Rutting may also cause due to inadequate compaction of the mix at the surface or in the underlying bituminous courses. So, there are different layers of bituminous mixes. So, if the compaction of the mix is inadequate, then also the bituminous layer may get deformed like this. Improper mix design, lacking instability to support the traffic may also cause a rutting type of distress in bituminous pavement.

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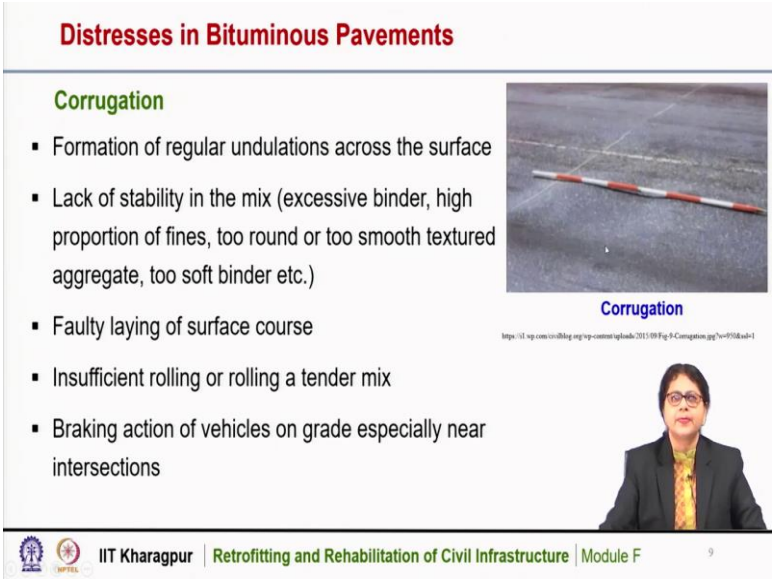

Corrugation is also another type of distress in bituminous pavement. It is the formation of regular undulations across the surface. So, here this is the typical picture of corrugation, this is across the surface there is undulations, whereas in case of rutting it is along the length of the road. Here it is across the surface.

Lack of stability in the mix may cause this type of corrugation that means excessive binder maybe there or high proportions of fine aggregates or two round or two smooth textured aggregates if it is used or too soft binder if it is used, then that type of mix may cause corrugation type of distress in bituminous pavement.

Faulty laying of surface courses there if there are construction deficiencies cause this type of distress in the pavement. Insufficient rolling or rolling a tender mix may cause corrugation type of distress, braking action of vehicles on grade especially near the intersections may increase the corrugation type of distress in bituminous pavement.

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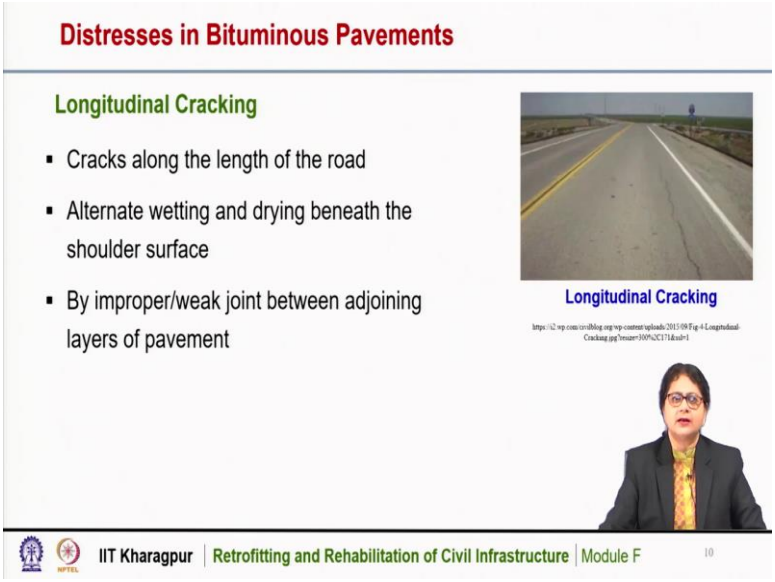

Cracking may be there in bituminous pavement. The cracking may be longitudinal or transverse, this is a typical picture of longitudinal cracking, the cracks are along the length of the road.

There may be different reasons for the formation of longitudinal cracking. Alternate waiting and drying beneath the shoulder surface may cause longitudinal cracking by improper or weak joint between adjoining layers of pavement may also cause longitudinal cracking in the pavement. So, if the construction is not properly done or there is weak joint between the adjacent layers, then there may be a formation of longitudinal cracks on the pavement.

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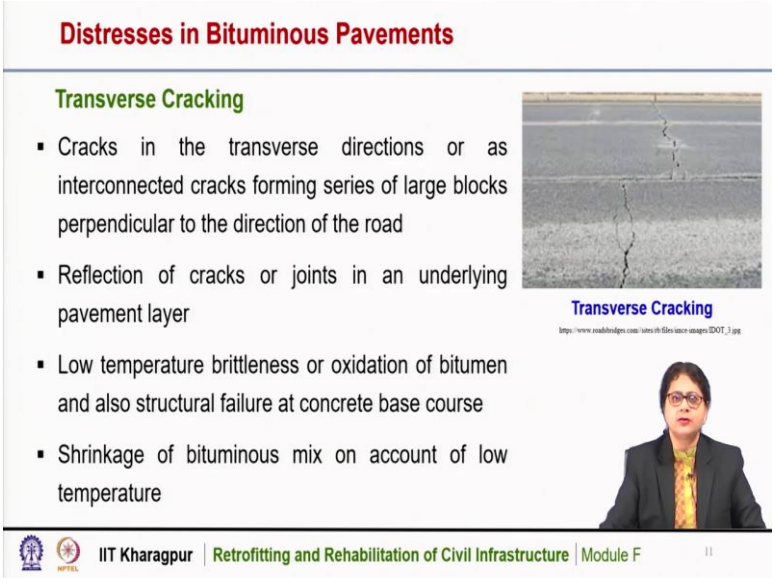

Cracks may be there in the transverse direction of the pavement as well. This is a typical picture of transverse cracking on the pavement. Cracks in the transverse direction or as interconnected cracks forming series of large blocks perpendicular to the direction of the road. So, these are perpendicular to the direction of the road, this is the direction of the traffic. So, if number of cracks are there that may form large blocks, a reflection of cracks or joints in an underlying pavement layer.

So, this type of cracks may be due to reflection cracking as well. Low temperature brittleness or oxidation of bitumen and also structural failure at concrete base course, if the base course is cement rigid or so, then that may also cause cracking on the surface. Low temperature brittleness of the mix may cause transverse cracking and shrinkage of bituminous mix on account of low temperature may also result into transverse cracking of the pavement.

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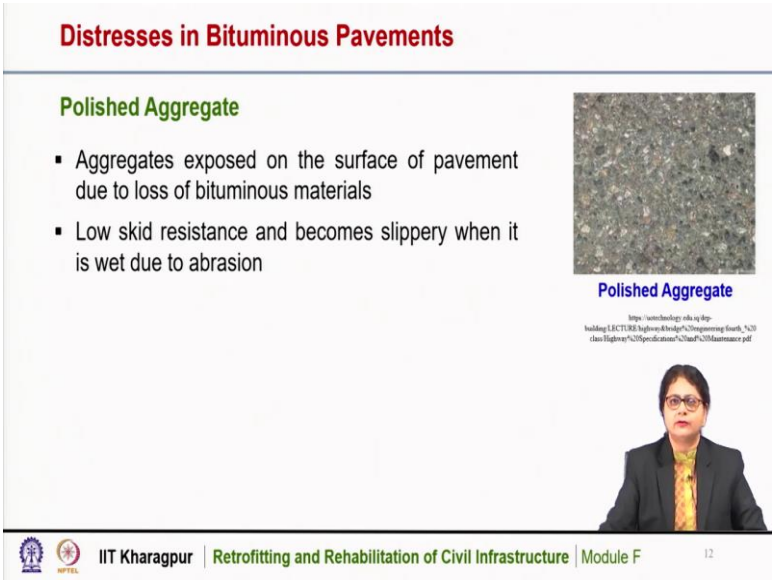

Polished aggregate is also another type of distress, here in this type of distress, the aggregates are exposed on the surface of the pavement due to loss of bituminous materials. So, bituminous mix as composed of the bitumen and the aggregates, but with time due to abrasion, there may be loss of bituminous material and the aggregates may get exposed on the surface. That results into low skid resistance and this is not good for the safety of the vehicles and it becomes slippery when it is wet due to abrasion.

So, there should be sufficient friction on the surface for the safe movement of the vehicles. And if the aggregates are exposed and due to abrasion, they get polished by the moving

vehicles then that may cause low skid resistance which is not desirable. So, this is a typical picture of polished aggregate on the existing pavement.

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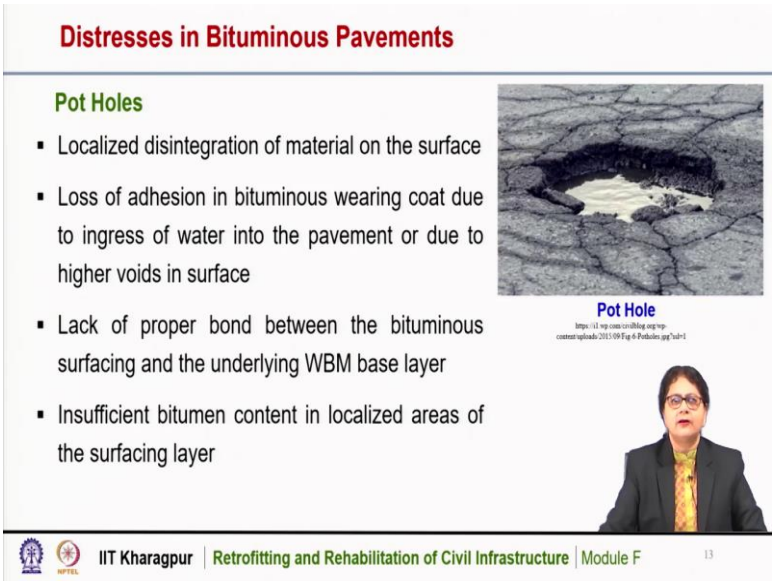

Pot Holes are also very common in case of bituminous pavement. Potholes or localised disintegration of material on the surface of the pavement. It is the loss of adhesion in bituminous wearing coat due to ingress of water into the pavement or due to higher voids in the surface. So, this is a typical picture of a pothole and very common on Indian roads.

So, this is localised disintegration of the material, loss of addition of the bituminous wearing coat and that causes distress to the pavement. Lack of proper bond between the bituminous surfacing and the underlying base layer may also be there due to the formation of potholes. Insufficient bitumen content in localised area of the surfacing layer, result into potholes in bituminous pavement. So, potholes may be due to localised distress of the material.

And that may be due to loss of adhesion in the bituminous wearing coat, which causes ingress of water and water affects the material which results into a poor performance of the pavement, loss of riding quality and the overall surface life of the pavement.

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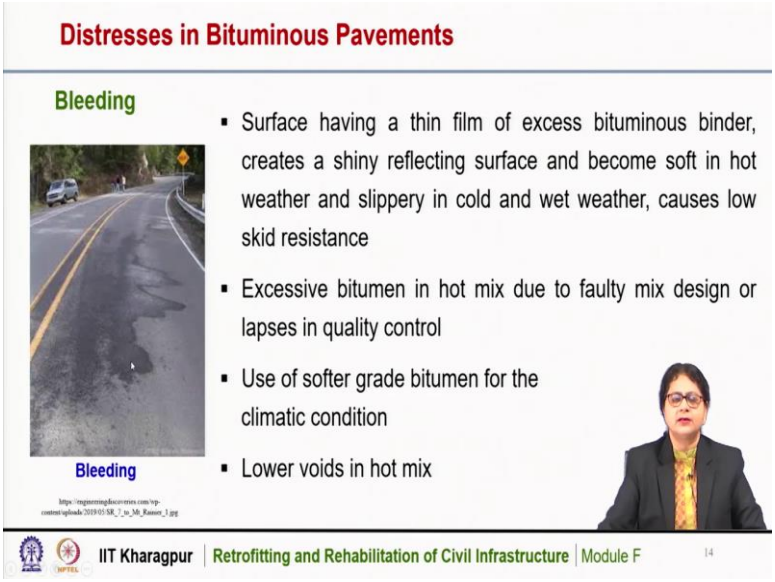

Bleeding is also another type of distress in case of bituminous pavement. Here the surface has a thin film of excess bituminous binder that creates a shiny reflecting surface and become soft in hot weather and slippery in cold and wet weather, which causes low skilled resistance. So, here in this picture is a typical picture of bleeding.

This is due to the excess bituminous binder that is coming out on the surface of the road that creates a shiny reflecting surface of the road. And this becomes soft in hot weather and sticky so, it causes a problem for the vehicle to move and slippery in cold and wet weather, which results into low skid resistance. Excessive bitumen in hot mix due to faulty mix design or lapses in the quality control may result into bleeding type of distress in bituminous pavement.

Use of softer grade bitumen for the climatic conditions. Bitumen may be of different grades depending on the type of structure and where it is to be placed. So, if we use a very soft grade of bitumen, then that may also cause bleeding of the pavement, lower voids in hot mix if the void is much less in the mix, then that may also cause bleeding of the bituminous pavement. So, these are the different types of distresses in bituminous pavement.

And because of these different types of distresses like say fatigue cracking or reflective cracking or bleeding or potholes, etc., the performance of the pavement is reduced significantly. The strength of the pavement is reduced, the riding quality is decreased and the service life of the pavement is decreased significantly.

So, often we require an overlay to improve the riding quality and to extend its service life. So, these are the different types of distresses there may be cracking on the pavement and the extent of cracking maybe also different depending on the type of loading, the number of vehicles so moving on it. So, depending on the extent of distress, we have to select the type of overlay on the pavement.

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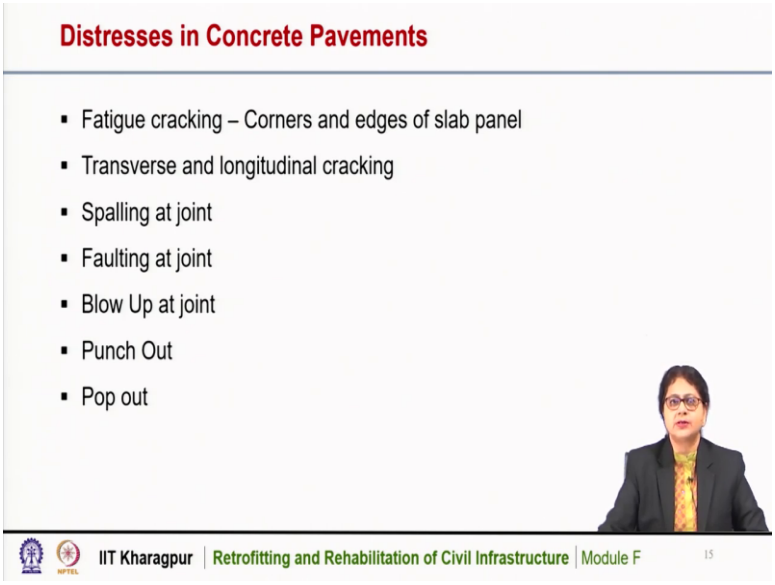

Now, we will discuss the distresses in concrete pavement. Concrete pavement also may have different types of distresses due to loading or environmental effects. The type of distress are fatigue cracking and these cracking's may occur at corners or edges of the slab panels. They may be transverse and longitudinal cracking as well. Joints are the location of distresses sometimes in concrete pavement.

So, there may be spalling of concrete at the joint, faulting at joint, blow up at the joints and punch out and pop out type of distresses may also be there in case of concrete pavement.

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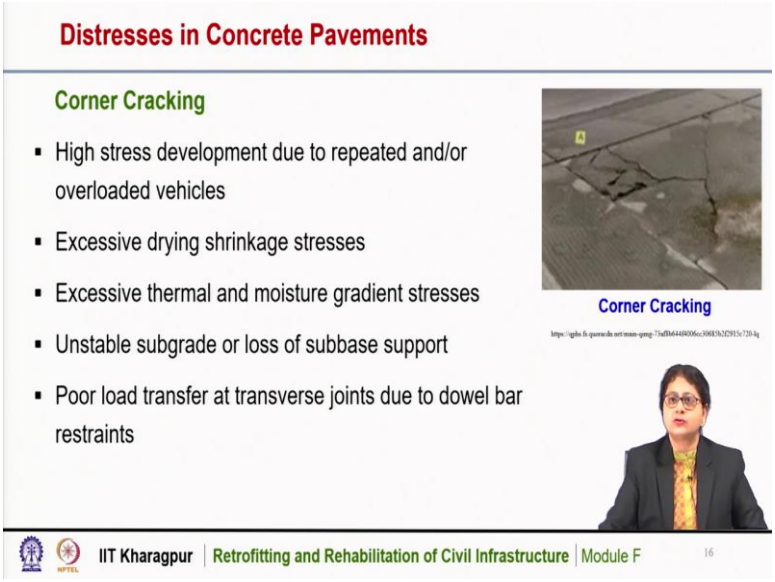

This is a typical picture of corner cracking in concrete pavement. This type of cracking is due to the development of high stresses and that is due to the application of repeated loading or overloading of the vehicles. So, these are mainly due to the load associated distress like in bituminous pavement we may also have fatigue cracking, in concrete pavement also we may have fatigue cracking because the moving load is the main load on the pavement.

So, fatigue cracking is the main structural distress in the pavement. And this type of distress may cause cracks at the corners or at the edges. So, here we will discuss the corner cracking. Corner cracking may be also due to excessive drying shrinkage stresses at those locations, excessive thermal and moisture gradient stresses, the effect of temperature and moisture is also significant in the pavement.

So, that may also cause stresses. So, if these stresses are significantly high, then this may also result into cracking of the pavement at the corners, unstable subgrade or loss of subgrade support if the foundation is not proper, not sufficiently strong, then it may cause cracking on the pavement. Poor load transfer at transverse joints due to dowel bar restraints, concrete pavement has dowel bars.

So, the transverse joints and dowel bars are there for load transferring. So, they are the load transferring device. However, if the dowel bars are not properly functioning, so that means, there is poor load transfer that may cause distress at the corners, because here this is the

transverse joints. So, if the dowel bars are not properly functioning then there will be poor load transfer and the concrete at these locations may get cracked.

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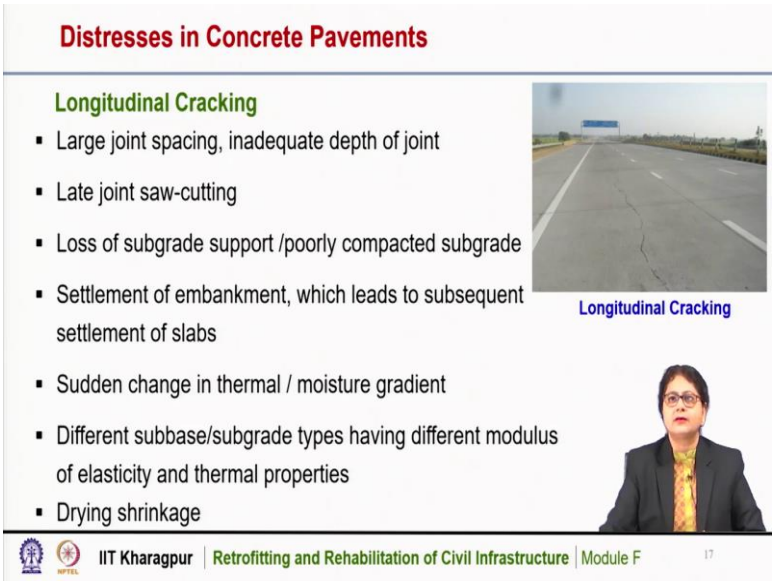

Longitudinal cracking may be also there in case of concrete pavement. This type of cracking may be due to large joint spacing, inadequate depth of joint etc. Generally for concrete pavement, the joints should be placed or saw-cut at regular interval but sometimes if the panel size is quite large, then cracks may appear in between.

So, these types of longitudinal cracks may appear in concrete pavement when the joint spacing is large, and the joints are made by saw-cutting the concrete slab up to one third of its depth. However, if the depth is not adequate, then longitudinal crack may appear in the pavement. And this saw-cutting is to be done within 18 to 24 hours of concrete casting, but sometimes the joint cutting is done quite late maybe after 2 days or 3 days or so.

So, in that case also there may be cracks appearing on the pavement. Loss of subgrade support or poorly compacted subgrade may affect the performance of the pavement. So, that may also cause longitudinal cracks on the pavement. Settlement of embankment which leads to subsequent settlement of slabs. So, if there is a settlement of the embankment, that may also cause longitudinal cracks on the pavement.

Sudden change in thermal or moisture gradient because the performance is affected by the temperature gradient or moisture gradient. So, if there is sudden change in the thermal gradient then that may cause curling stresses and if that stress exceeds its strength, then this

type of cracking may appear on the pavement. Different sub base subgrade types having different modulus of elasticity and thermal properties.

So, there may be a difference in the thermal properties of concrete and base materials and other materials other layers, due to which there may be cracks, there may be differential expansion and that may cause cracks on the pavement. Drying shrinkage is also another reason for cracking in the pavement.

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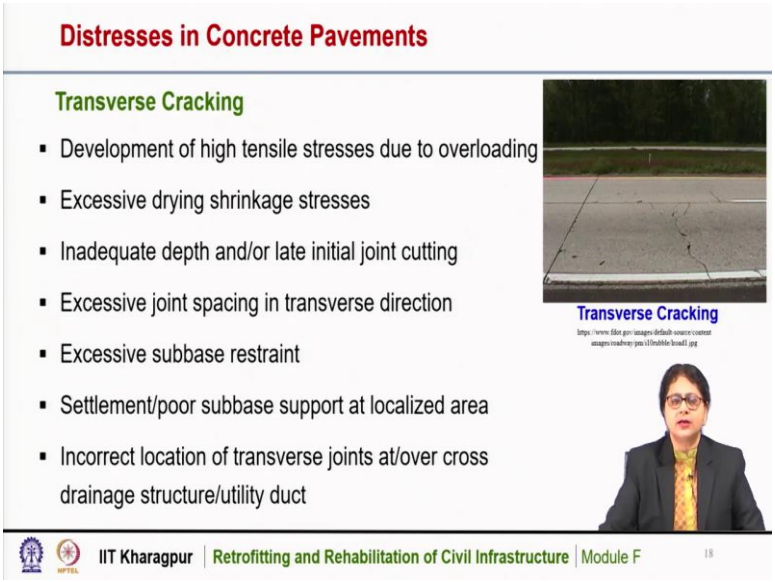

Transverse cracks may also appear in concrete pavement. This is a typical picture of transverse cracking into concrete pavement and these cracks are due to load associated. So, when there are high tensile stresses developed on the pavement due to excessive loading or overloading that may cause cracks on the pavement and it may propagate. So, this type of transverse cracking may appear on the pavement.

Cracks may be also due to drying shrinkage, inadequate depth or late initial joint cutting. So, joints are saw-cut in the transverse direction as well as in the longitudinal direction. So, like longitudinal cracks, here also if the joint cutting is late, then random cracks may appear on the pavement. Excessive joint spacing in transverse direction similar to the longitudinal cracks. Here also if the spacing is large, then random cracks may appear in between.

Excessive sub base restraint may also cause cracks. Settlement or poor sub base support at localised area in some places some localised area, if there is settlement of the sub base that may cause cracks on the pavement. Incorrect location of transfer joints at or over cross

drainage structure or utility duct may cause transverse cracks. Normally, incorrect location of transverse joint at or over the cross-drainage structure or utility duct may cause transverse cracking on the pavement. So, these are the reasons for transverse cracking in concrete pavement.

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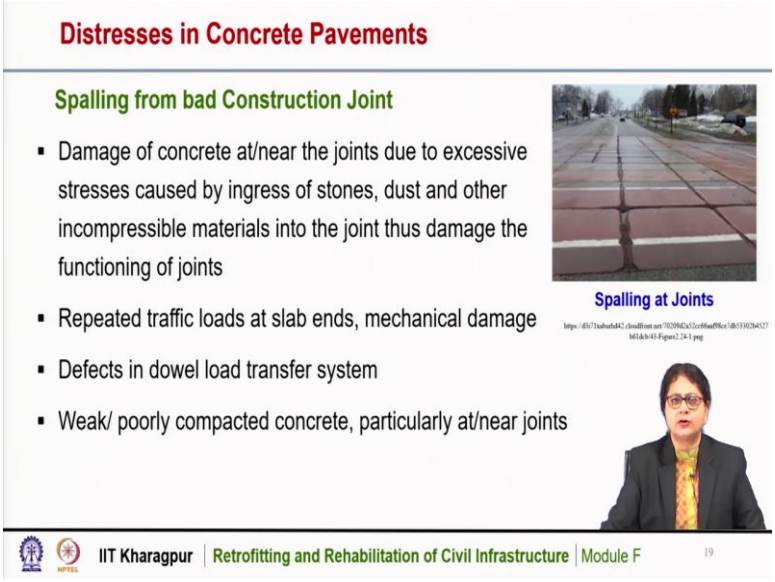

Spalling is another type of distress in concrete pavement, particularly at or near the construction joints. Damage of concrete at or near the joints maybe there due to excessive stresses caused by ingress of stones, dust and other incompressible materials into the joint thus damage the functioning of the joints.

So, joints are provided to take care of the thermal expansion and contraction, but over time, if the joint is filled up with stones or dust or by some incompressible materials, then there is insufficient space for the thermal expansion and contraction to accommodate. So, that may cause damage to the concrete and with repeated application of load there may be distress at the joint location.

So, repeated traffic load at the slab ends may cause the damage to the pavement near the joints. Defects in dowel load transfer system, if the dowel bars are not properly placed or they are restrained to some reason, then that may cause excessive stress at the joints and due to which there is concrete crushing or there may be high bearing stress and that may cause spalling of the concrete at the joints.

We call poorly compacted concrete particularly at or near the joints may cause spalling of concrete at or near the joints. So, this is a picture of spalling of the joints we can see here that there are a number of joints transverse and longitudinal joints and the joints are damaged due to spalling of concrete.

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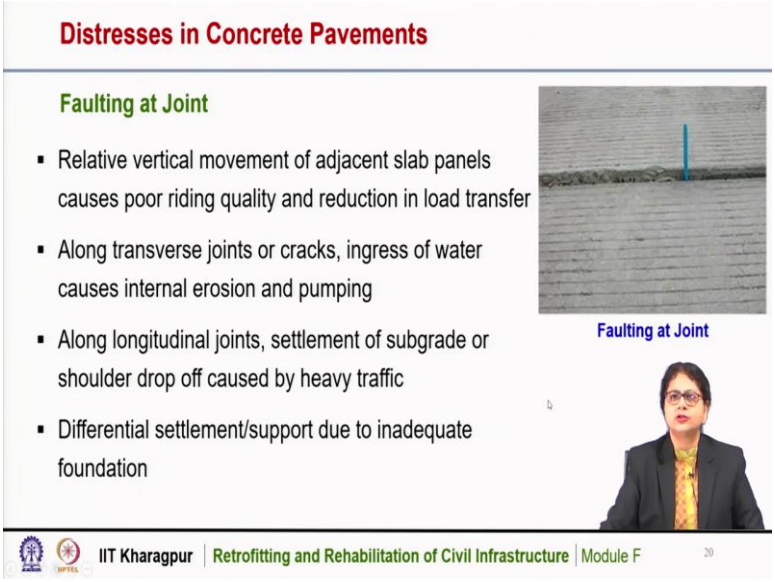

Faulting of joint is also another type of distress in concrete pavement that hampers the functionality of the pavement that means the riding quality is reduced significantly due to faulting of joints. It is the relative vertical movement of the adjacent slab panels that causes poor riding quality and reduction in load transfer.

So, here is our typical picture of faulting at joints, this is the relative vertical movement of the adjacent slab panels. In concrete pavement there are slab panels and they should be in one line. So, if that is not there due to differential movement of the subgrade or any other reason, then there is a difference in levels of the adjacent panels, that may cause serious reduction in the riding quality. It may also cause poor load transfer at the joints.

Along the transverse joints or cracks ingress of water causes internal erosion and pumping. If the water or other materials can go inside and slowly that may affect the base layer or sub base layer or subgrade and which results into erosion or loss of material below the slab. So, if that type of distress occurs, then there will be differential settlement of the two panels, along the longitudinal joints there may be settlement of subgrade or shoulder drop off caused by heavy traffic.

So, along the longitudinal joint also there may be differential settlement due to the subgrade and that may cause this type of faulting or shoulder drop off or particularly when there is heavy vehicle on the road. So, here is this picture shows that faulting of joint and there is a significant difference in the levels of the two adjacent panels.

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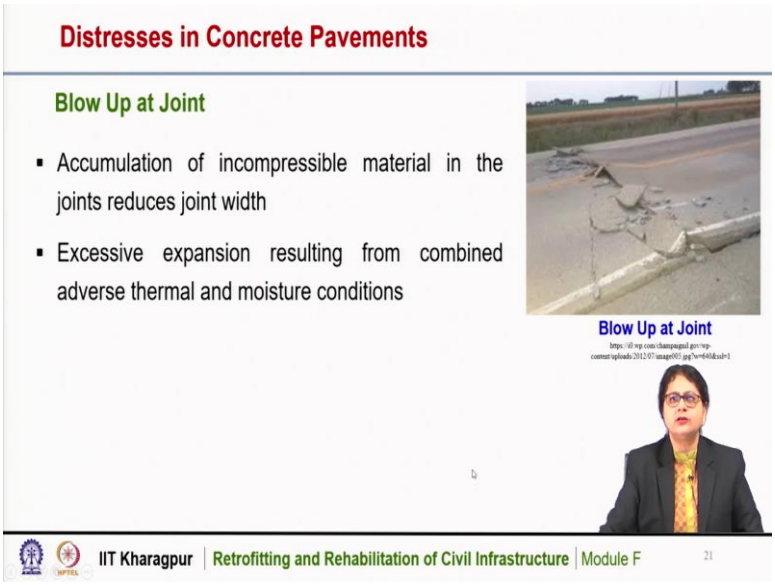

Blow up type of distress is another type of joint related distress in concrete pavement. Here also if the joint is not having adequate width, then due to expansion of the pavement with seasonal increase in temperature, that may cause a collision of the two adjacent panels. So, that results into this type of blow-up type of distress of the pavement.

So, accumulation of incompressible material in the joint may reduce the joint width and that may cause a blow-up type of distress, excessive expansion resulting from combined adverse thermal and moisture conditions. So, there may be excessive expansion and that may cause the two slabs to collide and blow-up type of distress and due to which there is complete disintegration of the pavement at the joint.

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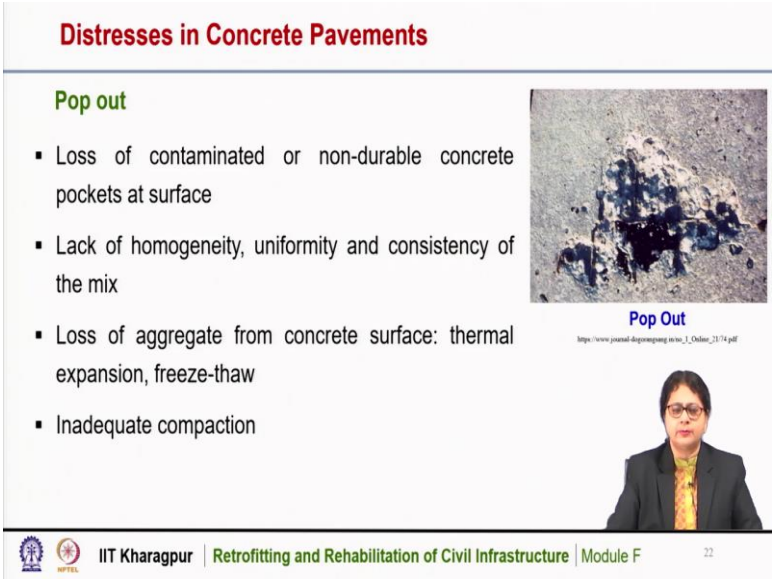

Pop out is another type of distress. This is loss of contaminated or non-durable concrete pockets at the surface. So, some material is lost and aggregates are exposed, lack of homogeneity uniformity and consistency of the mix results into this type of distress and when it is subjected to vehicular loading more and more this type of distress will appear.

Loss of aggregate from the concrete surface, thermal expansion or freezing and thawing may cause this type of surface disintegration and pop out type of distress. Inadequate compaction of the mix may also result honeycombing and then pop out type of distress in concrete pavement.

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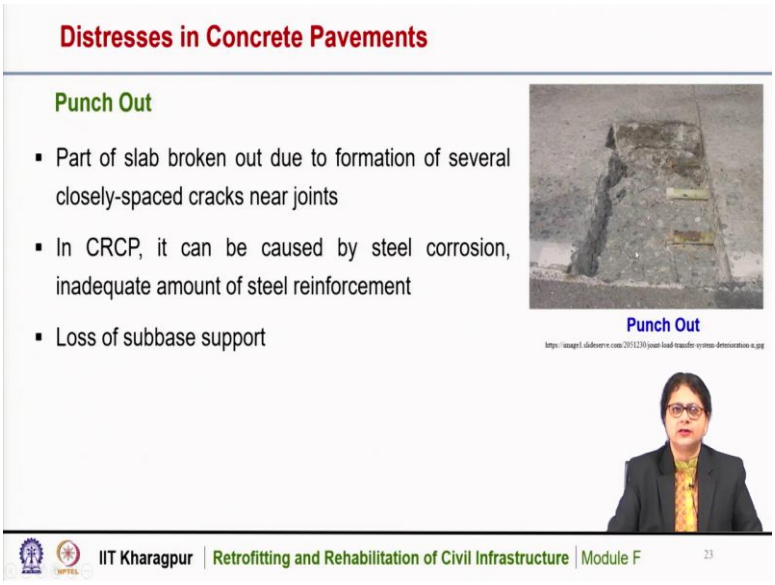

Punch out is another type of distress in concrete pavement and particularly it is seen when the pavement is reinforced. Here this type of distress is found when there are a number of cracks appear on the pavement and in between several cracks, the portion of the slab is broken out and that is shown here if there are a number of cracks on the pavement, that may cause the loss of material within that region.

So, part of the slab broken out due to formation of several closely spaced cracks and this is also occurring near the joints. So, here we can see that this is a joint with dowel bar. So, this type of punch out type of distress is there and the dowel bars are exposed due to the slab portion taken out for punch out type of distress. So, in CRCP or continuously reinforced concrete pavement where the reinforcements are there.

So, there may be cracks on the pavement and in between several cracks this type of punch out distress may occur. It may also cause due to the corrosion of the steel reinforcement because if the pavement has reinforcements and if the reinforcement is corroded that may also cause more and more cracks on the pavement.

So, because of those corrosion of reinforcement there may be spalling of concrete and then punch out type of distress. Loss of sub-base support may also cause punch out type of distress when the pavement is subjected to moving loads. So, punch out type of distress may also be there in case of concrete pavement particularly when it is reinforced.

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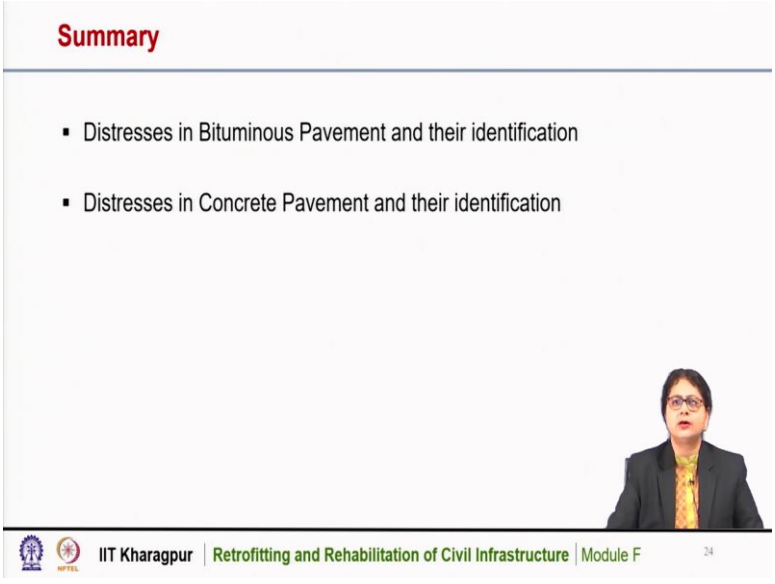

So, to summarize we have discussed the different types of distresses in bituminous pavement and concrete pavement and how we can identify. There are different ways the pavement may get deteriorated and the main deterioration is due to the repeated loading or overloading or due to moisture effect or due to foundation problem.

So, all these may cause destresses of the pavement. The distresses may be of different extent and depending on the type of extent of distress, we have to select the type of overlay on it. So, it is important to understand the type of pavement and its distress so that based on that we have to take necessary measures for its improved performance and rehabilitation. Thank you.