

Course Name – Pavement Construction Technology
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Week – 11
Lecture – 38

A very warm welcome to all of you. I am Rajan Choudhary, a Professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati. Instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Today's lecture will be under module 11, and we will discuss the different types of payment distress that we observe on flexible pavements. At the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches. So, payment distress can be a measure; this is a measure to evaluate the serviceability or condition of a pavement surface.

So, if there is some distress, then we can say that the ability of a payment to serve the traffic is reduced, and to what extent it is reduced is another important aspect. So, we can say distress is the condition of the payment structure that reduces serviceability, or I can say the ability of the surface to serve the traffic, ultimately leading to a reduction in serviceability. So, the ability to serve in different terms, specifically in terms of, say, the roughness or the safety, if that gets reduced, we can say that the ability to serve the traffic is getting reduced. So, any condition that affects the serviceability of a pavement surface falls under the category of pavement distress.

Now, hot mix asphalt, similar to any other pavement material, is susceptible to the development of some distress, and these can take on different manifestations or forms due to many important reasons, including load and environmental conditions. So, as payment is made and during the course of its life, some amount of distress is definitely expected to occur as the payment approaches its end. So, this is a usual phenomenon, but the problem arises when these distresses occur prematurely or at early stages of the life of the payment; then it is a sign of concern. So, as pavements approach the end of their design life, the development of distress is natural and expected because they are continuously subjected to different environmental conditions along with repeated traffic conditions or traffic loadings. So, the occurrence of such distress is not necessarily a cause for concern unless it occurs prematurely, that is, in the early stages of life.

If that happens in the early stages of life, we can say that in due course of time, some fine cracks may occur in that case, or there may be some loss of fines, or a loss of, say, the frictional resistance and skid resistance of the surface. This will happen after a good amount of life has passed for that particular pavement surface, but if cracks and depressions are

present in the early stages of life, then it is a sign of concern. So, we will discuss these distresses; we will discuss here the types of distresses, the possible locations where these kinds of distresses can happen, and any severity levels that are assigned to these distresses as per our codal provisions. So, some of the important codal standards that are referred to here are the code of practice for the maintenance of bituminous roads, which is IRC 82. We have the orange book specifications with us for road and bridge works.

We have this manual for the construction and supervision of bituminous works. There are many other manuals that discuss the different types of distress, such as the one mentioned here, the Distress Identification Manual for the Long-Term Pavement Performance Program. This is an FHWA report. Now, the different kinds of defects, or as I can say, the distresses in bituminous surfacing are usually grouped into four important categories, or four main categories, as I can call them. The first one is surface defects.

What it includes is, as the word itself says, more concentrated towards the top surfacing. So, it says these primarily include bleeding or fatty surfaces, excessively smooth surfaces, streaking, or lean or hungry surfaces. This is one category that is specifically more related to the surface-related defects. So, surface defects which we can. Then comes the category in which some cracks are observed.

This category encompasses various types of cracking and their corresponding characteristics. Hairline cracks may be present, alligator fatigue cracks may be present, longitudinal cracks may be present, edge cracks may be present, the edges along the pavement, the cracks along the pavement edges, shrinkage cracks may be present, and reflection cracks may be present. So, these are some typical distresses under the heading of cracking. We will discuss these two in today's lecture. Then the other main category is deformation.

This specifically refers to when there is some change in the shape of the pavement structure; that particular one comes under the category of deformation. Here you can see under this particular one the distresses that come are rutting, corrugation, including a part of slippage; we will discuss this one, shallow depressions, settlements, and upheavals. So, these are certain categories that come under the distress of deformation. Then we have the disintegration, where there is some breaking of the structure; pavement materials are breaking. So, what does it comprise? It comprises stripping, aggregate loss, raveling, pothole formation, and age breaking.

So, these are a few distresses. We will discuss the most common distresses that are observed on bituminous or flexible pavements. Now, the important aspect is that the location and severity of pavement distress are critical factors, where it is happening, and to what extent it has happened. These two are very important aspects to determine the appropriate maintenance treatment: what type of treatment, what type of materials, and

what techniques need to be involved to address those kinds of distress. So, that is why it is important to know what kind of distress has occurred, where it has happened, and to what severity level it has happened.

So, here we will be discussing these parts in upcoming lectures; later on, we will discuss the causes of these distresses, and thereafter we will discuss the different treatments that can be applied for these various distresses. So, beginning with the first distress, which is the surface defects. So, they are primarily confined to the pavement surfacing, as I mentioned, specifically the top layer, and generally arise due to the use of bitumen, which is either of inadequate quality, the wrong grade of bitumen, or an improper quantity that is used. So, either the grade with the selection of the binder is not good, or you are selecting the grade in terms of, say, tack-out application; we also select definite grades of emulsions. So, either the selection of grade is improper at the application of tack out, or the selection of the binder when the bituminous mixes are produced may not be the right grade of binder.

The other aspect is the application quantity; if you are applying excess bitumen, some kind of distress may occur, whereas if there is a low application, some distress can also happen. So, we will discuss what the common surface defects or distresses that are usually observed on bituminous pavements are; one is bleeding. So, this is a condition you can see in this particular picture. This is a condition where a film of excess free bituminous binder appears on the surface. It looks like this particular part is a comparatively darker color than the remaining surface.

So, it appears that there is a free or excess bituminous binder present, giving it a shiny, glass-like reflective appearance. So, you can see part of the carriageway or along the wheel path where some excess binder appears to be in comparison to the remaining portion of the carriageway. So, such surfaces tend to become soft specifically under hot weather conditions and slippery when they are cold and under wet weather conditions when there is excess binder present. So, this sticks in hot weather conditions, sticks to your vehicle's tires, and in cold weather conditions and during rainy events, it makes your surface slippery. So, that leads to a loss of skid resistance.

So, this raises the concern about the safety of your users on this kind of surface. So, this phenomenon of bleeding is also known as a fatty bituminous surface. So, we are finding that the excess binder is on the surface. So, this is again a fatty bituminous surface. Now, where does it usually happen? It mainly develops along the wheel paths.

So, in a lane, most of the time, vehicles typically try to follow a particular lane, especially heavy vehicles that try to follow a certain lane in the given carriageway. Along with those you can see here, this is happening along these two; you can see in this particular one that this is one wheel path, and this is the other wheel path, along which you can see the signs of bleeding that have occurred. Though it may also appear in isolated spots, here you can

see this is an isolated spot; here also, you can see these are the isolated spots where it has happened. Along the wheel paths, it may occur over a longer length; however, there may be some isolated spots, and it may happen in specific lanes, particularly in areas where there is heavy vehicle movement or slow-moving vehicles. In some cases, this can happen across the entire carriageway.

So, these are some peculiar locations where you can observe bleeding. Severity levels of bleeding—now what? Because this severity level is usually helpful in deciding the maintenance activities. So, the severity of bleeding or fatty surface is classified as low, medium, or high. This is where most of the distresses are classified in terms of low severity, medium severity, and high severity. Now, what is there in the case of low severity? It says that the isolated spots, as you can see in this particular case, are affected areas of less than 5 square meters per lane kilometer.

This is important to understand that this is per lane kilometer. So, one lane has a width of around 3.5 meters. So, one kilometer of that one lane should have an area that is less than 5 meters per square, or if I consider the total area of the carriageway, then it should be below 1 percent. So, if this is there with this bleeding part, I will call this a low-severity bleeding.

The second case is of medium severity when the affected area ranges from 1 to 5 percent of the carriageway surface. So, instead of where it was only less than 1 percent here, when it is from 1 to 5 percent, you can see a large portion of the areas are getting covered. So, if I say this is in the range from 1 to 5 percent of your total carriageway area, then I will call it medium severity. And high severity in this particular case, extensive bleeding or a fatty surface is often accompanied by the initiation of shoving. We will discuss some movement of the mix, the failure of the mix, the shifting of the mix, or the sliding of the mix that is happening, which we will discuss later.

So, when this bleeding extends more than a certain extent, the chances of the initiation of other distresses also arise. So, in this particular case, when it is more than 5 percent of the surface area of the carriageway, it is considered high-severity cracking, and this is as per IRC 82: 2023; the classification of the severity levels is there. Here, you can see that this is covering more than 5 percent of the bleeding that is occupying more than 5 percent of the total area. Now, a smooth surface, if the surface becomes highly smooth and highly polished, raises concerns related to low skid resistance. We have already discussed in the previous talks the measurement of the skid resistance of pavement surfaces and how important skid resistance or frictional resistance is for the safety of road users.

So, a smooth surface is characterized by inadequate skid resistance, resulting in slipperiness under wet conditions, and this becomes even more challenging when the surface is wet. This poses a significant safety risk, particularly on gradients, curves, and

intersections where frequent braking occurs or where some turning moments are present along the curves, where you need a good amount of lateral friction. This smooth surface raises concerns regarding the safety of the users. So, where this usually happens, a smooth surface may occur over isolated lanes or across the entire carriageway. So, again specifically, many times these distresses take place in the lanes that are subjected to heavy movement of heavy axle loads or that are subjected to slow-moving traffic.

Especially, the heavy vehicles move at a slower speed compared to the passenger cars or light motor vehicles. So, in those lanes that accommodate the movement of heavier vehicles, you will usually experience these distresses more on those lanes. In India, the lane pattern is usually not followed. So, in that particular case, you can find this distress, or if the surface is experiencing distress along the entire width, then there may be some challenges; there may be a localized problem, or it may be a problem with the entire width of your carriageway. So, a smooth surface may occur over isolated lanes or across the entire carriageway; this can be a concern.

Here you can see that along the wheel paths, the smooth surfaces may be present, or they may be present along the entire width of it. So, this entire width may become smooth or slippery in that case. Again, severity levels of smooth surfaces are there; only two severity levels are mentioned, and that too in terms of the skid number. We have seen that a desirable skid number is 50 if a good surface is expected to have a skid number of 50. So, here it says that when a low severity of this challenge is present with respect to a smooth surface, we call the skid number to be in the range of 30 to 40, while the desirable value is always around 50.

Now, high severity occurs if the skid resistance or the skid number goes below 30; this is the log build tester, which we discussed in the previous lectures. So, this usually will vary based on the latest guidelines issued by our MoRTH and IRC, which specifically address different kinds of surfaces; high-speed expressways may have a higher requirement for skid numbers compared to this one. So, in that case, these ranges may also vary. Now, the other kind of pavement surface distress, or the surface defect, is streaking. Now, it is mainly characterized by alternate lean, and you can see here that there are heavy lines of bitumen; there are light lines as well, and these are some heavy lines.

So, it is mainly characterized by alternating lean and heavy lines of bitumen that may appear either in the longitudinal or transverse direction. The causes we will discuss in the next lectures, but here is how it appears. It appears that in this particular one, there are streaks; there are certain lines where some portions show heavy lines of bitumen, while in the other part, you can see lean bitumen that appears to be present. A streak may occur along a single lane or across the carriageways. So, throughout the carriageway, you can, at various parts, experience this particular one: there are certain sections that have heavy lines and certain sections that have light lines.

This is another streak; then the other surface defect is a hungry surface, which looks hungry, meaning we are finding that there may be some loss of fines or inadequate binder. So, those kinds of surfaces, specifically when fines are less, appear to be hungry because the fines are the ones that have the highest amount of binder, as they have a high surface area. So, if there are inadequate fines, then the surface appears to be hungry. So, a hungry surface is mainly characterized by the loss of fine aggregates if the fines are not present. It appears that it is a dry surface often accompanied by fine cracks.

Now, these kinds of surfaces can also develop some fine cracks, specifically hungry surfaces, because the cohesion of this matrix is less. Now, the location where these hungry surfaces may be is in the full lane or the entire carriageway. So, one particular lane may be affected, or the entire carriageway may be affected by it, and specifically, like now for these hungry surfaces, there are as such no severity levels defined by IRC-82. Now, the other major defect that comes under the distress is cracking. So, the different types of cracks observed on the pavement surfaces need to be understood, identified where they are occurring, and, on the basis of severity levels, the causes of those cracks and treatment measures have to be worked out.

So, here we will discuss what those different types of cracks are, where the chances are that they occur, and what the severity levels could be, if they need to be categorized under different severity levels. So, the first of the distress is the important distress that is cracking. So, one of the most common forms of distress is permanent deformation, which is another important form of distress that usually occurs in bituminous and flexible pavement. And these cracks may develop due to reasons such as repeated axial loads, temperature variations, moisture, temperature fluctuations in the underlying layers, inadequate pavement thickness, poor quality construction, or poor quality of materials. So, here we will not discuss the causes of these cracks; we will discuss the types of cracks that exist.

So, timely sealing is necessary now; if there are some cracks here, you can see that these appear to be closely spaced cracks. So, it is very important to prevent or seal these cracks, which we will further discuss during the maintenance part; otherwise, they may widen further and allow the ingress of water through these cracks to the underlying layers, which will affect the structural integrity of the entire pavement course and its long-term performance. So, the different types of cracks that are considered under this particular distress of cracking are hairline cracks, alligator or map cracking, fatigue cracking, longitudinal cracking, transverse cracking, age cracking, and reflection. These are some of the common types of cracks that are observed in the bituminous and flexible pavements. Now, the hairline cracks, as the term itself says, are very fine cracks, usually less than 1 mm in width.

So, these are specifically short cracks that are observed on the surfaces. So, they generally occur as short, small-length, fine, and closely spaced cracks. With a close look, you can

see that there are certain fine cracks that are usually present, and they are isolated; there are not many interconnected cracks. And usually, they even disappear specifically during hot summer conditions. These fine cracks, which may be visible, also disappear specifically because the material becomes soft under hot weather conditions; they disappear due to the thermal expansion of the bituminous layer.

So, then when the material expands, these cracks also disappear. So, these are narrow, fine cracks that come under the category of hairline cracks. These cracks may be in isolated places, in a lane, or throughout the entire carriageway. This is the first category. Now, the second most common cracks that are usually observed are alligator cracks, which are also known as fatigue cracks or map cracks.

So, fatigue cracking, or alligator cracking, is commonly referred to as map cracking and is characterized by a series of interconnected cracks forming small, closely spaced, irregular blocks on the pavement surface, which is why it is called alligator cracking, because these cracks resemble the skin of an alligator. So, that is why they are very commonly referred to as alligator cracking, closely spaced block patterns that are formed. Now, where do they usually happen? Most of the time, you will find them happening over the wheel pass, where the wheels of heavy vehicles come over, or whatever category of vehicles comes over your lane; those wheel passes are the ones where you have the maximum chances of fatigue cracking. Now, again, they are classified into three categories as per IRC 82: low severity fatigue cracking, medium severity fatigue cracking, and high severity fatigue cracking. How are they classified? Low severity indicates that when very narrow cracks of width 1 to 3 mm are present, and with little or no surface deterioration, these isolated cracks, which are not interconnected, exhibit negligible distortion, and there is no change in the shape of the surface.

So, we can have these low-severity cracks. When the crack width ranges from 3 to 6 mm and forms small blocks, small blocks appear because earlier there were not many interconnected cracks under the low severity; then they start forming. So, in due course of time, if they are not at rest, then the low-severity cracks may get converted or may move to medium cracking as well. So, the crack width expands, and they become interconnected. But still, at this moment in time, you will see that there is no loss of the edge materials, spalling is not present, and there is no pumping; there is no soft soil or fines coming from these cracks in the underlying layers. So, up to this particular one, we considered it medium-severity fatigue cracking or alligator cracking.

Now, the one that comes is of high severity if a surface is observed where the crack width exceeds 6 mm and is often associated with moderate to severe spalling; breaking of those edges is happening. Loose or missing pieces of the bituminous surface can be observed; there are also certain pieces that are lost here. Signs of pumping some mud suggest that a small amount of fines may be coming out through these particular cracks. If these are

visible, then this is the kind of surface. So, you may be witnessing the surfaces experiencing different levels of fatigue cracking or alligator cracking in different cases.

So, depending on the extension of the crack width and the severity of these cracks in terms of how the cracks are interconnected, how closely spaced they are, and whether there are some signs of pumping or spalling, you can categorize them into low, medium, and high severity levels. There is another form, which is longitudinal cracking; as the term itself says, it mainly runs parallel to the pavement centerline or along the roadway. So, this is usually what a longitudinal crack is; any crack that is found to run parallel to the center line comes under the category of longitudinal cracking. On high-traffic volume routes, these cracks may act as an initiation point for fatigue cracking because, as you can see here, this is a single crack that is occurring, but in due course of time, if not addressed, this will be converted into fatigue cracking. You will have a more interconnected number of cracks developing from this single crack.

Longitudinal cracks can permit water infiltration because if the width of the crack is greater, even fine cracks allow water to penetrate down into the underlying layers, causing softening and accelerating structural deterioration. So, this raises a major concern: if the crack width is good enough to allow water to penetrate, it raises other concerns as well. They often develop in joints. Now, longitudinal cracking is present; it often happens at joints because when we do the construction, we are not able to lay the entire width in one go. We may have to use it multiple times, or adjacent pavers have to be moved.

So, there may be some chances of longitudinal joints that may arise. So, they often develop at the joints between the adjacent paving lanes. So, when pavers are run, either one paver is run or the second paver is run. So, wherever that joint of the asphalt mats comes up, that can be a place where these longitudinal cracks can be observed. Or along the edges of the wheel paths specifically, where it appears that if it is the wheel path, then along the edge of the wheel path, you are observing this particular one, or near the interface between the pavement and the paved shoulders.

If this is again a concern, there are many times when you have a paved shoulder. So, where you have this interface between your main carriageway and paved shoulder, it is also observed many times. So, the severity of those is decided when the crack width of these longitudinal cracks is in the range of 1 to 3 mm, occurring infrequently. So, at some locations far away, if it is happening, we call it low-severity cracking. If the width is 3 to 6 mm occurring with moderate frequency, then it is classified as medium severity; high severity is indicated when the width is more than 6 mm and occurs very frequently on the surface, in which case we can call those longitudinal cracks high-severity cracks.

Now, transverse cracking, as the term says, appears perpendicular to the direction of travel. So, many times we call those transverse cracks low temperature cracking when it is related

to the stresses or the failures, considering the low temperature. So, they may also be called low-temperature cracking. So, transverse cracks appear perpendicular to the direction of the traffic. And may occur either as an isolated crack, which you can see as one single crack, or as interconnected cracks forming a series of blocks.

There may be interconnected cracks that form a single crack, and there may be interconnected ones like this as well. So, blocks may be formed. So, this is known as block cracking. So, this is how the transverse cracking may occur at isolated points or across the entire carriageway. So, these are the cracks that are perpendicular to the direction of travel.

Again, depending on the width of the cracks and how frequently they occur, we can call them low-severity cracking. Medium severity cracking occurs when there is a void of 3 to 6 mm, high severity cracking occurs when there is a void of more than 6 mm, and when they frequently occur. So, this is how the transverse cracking is classified into different severity levels. The age cracking, the word itself, says it occurs at the pavement ages. So, the age cracking refers to the cracks that usually develop parallel to the outer edge of the pavement.

So, you can see this is the outer edge. So, usually these will be parallel; here, you can see these are occurring parallel to this particular one. So, when this is happening, we call it age cracking. So, they are typically located about 0.3 to 0.5 meters inside the pavement edge. Now, their severity level is again what it mentions here, with no breakup or material loss; if there is no loss of material, then that will be called a low severity. If it is accompanied by some breakup, it affects 10 percent of the cracked leg. So, some material loss is present, which is affecting 10 percent of this particular length, we can call. So, this is a visual exercise where we have to see how much the length of it is affected by the loss of material or the breakup of material. And then, high severity, specifically significant breakup of the material is present and affects more than 10 percent of the cracked length.

So, these are the cracks that are along the pavement edges. So, typically, along, you can see that the remaining surface appears to be intact; only the cracks are there on the pavement edges. Now, the last type of distress related to cracking is reflection cracking. So, these are also called sympathetic cracks because they are reflected from the underlying causes. So, that appears in the bituminous surfacing, especially over joints. If we construct a bituminous mat over an existing concrete surface, then they can occur over joints or underneath pre-existing cracked pavements; the existing surface already has severe cracking, which may be alligator cracking or transverse cracking.

If that is getting reflected on the top, we call it reflection cracks. So, these cracks may follow longitudinally depending upon the underlying crack pattern; they may be longitudinal, transverse, diagonal, or block patterns, mainly related to how the crack pattern is present in the underlying courses. So, now the location of reflection crack occurrences

in bituminous pavements, where the chances of these cracks being reflected from the underlying course to the surface course are greater, is where we will find these reflection crackings happening more frequently. So, it is most frequently observed in bituminous surfacing, concrete pavements, or cement-treated soil bases. So, wherever there are some contraction joints, there will be expansion joints. So, over those joints, when these cement-treated bases are present, or when the cement concrete pavements are there, or when you have these bituminous overlays, you can observe these kinds of reflection cracks.

You can see this is a reflection crack that is being reflected on its surface. Cracks can occur in overlays on flexible pavements where existing cracks were not properly treated and may develop at the junction when pavements are widened. This is also usually the case, that many times pavements are widened. So, on both sides, they are widened specifically where the edges are formed with respect to the old and new pavements; you can see these things reflected in the old. So, existing is having, so when the pavements were widened, cracks occurred precisely along the interface between the old and the widened portions. Reflection cracks and definitely all cracks may allow water to enter the underlying layers, which may hamper the strength of the underlying courses, your granular courses, and your subgrade courses, and finally impair the structural integrity of the pavement courses.

So, these are the distresses that specifically come under the two categories: one is the surface defects, and the second is the cracks. So, these are the commonly occurring distresses falling under the category of surface defects and cracks. Thank you so much.