

Course Name – Pavement Construction Technology
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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, and the instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. This lecture will be a continuation of our lecture 25, where we discussed the pavement distress types under module 11. So, 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. Now, in the previous lecture, we discussed two major categories of defects that are usually observed; in bituminous or flexible pavements, they fall under the category of surface defects, and the second falls under the category of cracks. Today, we will discuss the distresses that come under the category of deformation, where we will discuss rutting, corrugation, shallow depressions, settlements, and upheavals.

And then again, we will discuss the disintegration where there is some loss of material in terms of stripping; we will discuss stripping, raveling, pothole formation, and age breaking. And as we mentioned previously, it is very important to understand which type of distress has occurred on the pavement surface and to understand what the possible chances are, where these can occur, where those distresses are happening, and that certain measures are in place; classification systems are already available as per IRC-82, which states that these distresses can be classified into different severity levels. Now, let us first talk about the deformation. So, if there is any change happening in the original shape of the pavement surface, then we can call it a deformation.

You can see here in this particular case that the surface was constructed flat earlier. Now, in due course of time, a depression has been created. So, I can call it a deformation. There are some changes in shape. Here you can also see that this material has moved, has shifted, or there is some shifting of the material, and here some big shifts of the material are present, so slippage of the material is occurring.

So, these kinds of distresses come under the category of deformation, where any change in the original shape has happened and which may be limited to one or more bituminous layers, and this may, if it is happening, not be limited to the top bituminous layer; it may have undergone this kind of deformation in the underlying layers also. So, it may be limited not only to one layer or one or two bituminous layers and may extend through the entire

pavement structure, going up to your pavement subgrade as well. So, these defects can appear in various forms: this is a typical slippage distress; then you have rutting distress; shoving distress is shown here; we will also see corrugations, shallow depressions, and settlements. So, the main categories that come under the category of deformation of the pavement structures are slippage cracks, rutting distress, corrugation distress, shoving distress, shallow depressions, settlements, and upheavals. Now, let us first look at the slippage cracks.

So, this refers to the relative movement. So, your top course or the top bituminous layer has moved relative to the underlying course. So, this is what happens if this is observed: you can see there is a relative movement; the top course has shifted and moved compared to the lower surface, which is intact. Here, you can also see that the top course has moved; this has failed. So, it has torn off and then this particular one again here you can see this kind of thing and when this has torn off you can observe these cracks which are there and they form a typical shape; you can see this is a half-moon type shape, or I can say a crescent shape, or U-shaped cracks are there.

So, slippage crack refers to the relative movement between the wearing course and the underlying layer of a bituminous pavement. It is typically identified by crescent or U-shaped cracks. This is a typical shape that is present in the case of slippage cracks, with the open end of the U usually pointing in the direction of the applied forces. So, this is a common feature of how it happens: if you find that the brakes are applied, you will always find this U pointing in the direction of travel. So, if brakes are applied, this kind of shift that will happen in this case will have these U shapes pointing in the direction of your travel, and if there is some acceleration in that particular case, the open ends point towards the rear or the opposite of your travel direction.

So, this is usually when one-layer slips with respect to the other layer, creating this kind of shape. So, we can easily experience where this can occur. This usually occurs along the wheel paths or where some slow-moving traffic is present, specifically where regular stopping and acceleration are happening. So, it may be at bus stops as well, at intersections as well. So, where slow-moving traffic is present, when it stops at the intersections and accelerates at the intersections, these are some of the locations where it can happen.

So, it is mentioned that this specifically happens with heavy vehicles, such as trucks or buses. So, at bus stops at intersections, we can observe this kind of slippage crack. Now, low severity cracking and high severity cracking are mentioned as two levels for it. Slippage cracks are occurring at isolated spots within a lane. So, at some isolated locations, if it has happened, we will call it low severity cracking, and if it happens continuously along the wheel path.

So, very frequently you will see it happening along the wheel path. So, if the top layer is slipping from the bottom layer, we will call it high severity. Now, rutting again falls under the category of deformation. So, it is a formation of a longitudinal depression, or we often call it ruts. So, it is the formation of these longitudinal depressions; you can see this is a longitudinal depression that has been created.

So, it is the formation of longitudinal depressions or ruts in the pavement, mainly along the wheel paths. So, most of the main routes are along the wheel paths and along the lanes that carry heavy or slow-moving traffic. Ruts are typically uniform along the wheel paths, so their depth is usually uniform along the entire length. There can be certain sections where there may also be some localized failures in terms of rutting. It can occur in different pavement layers, and this may not be restricted, as in the case of surface draft, to the top bituminous layers; it may be extending from the underlying layers, which may even include the subgrade of your pavement course.

So, it can occur in different pavement layers and is mainly classified based on the cause and the specific layers involved. So, I can call it subgrade rutting, or I can refer to it as the rutting of the granular courses or the rutting of the bituminous bound courses. So, the two ways in which it is characterized are the permanent deformation in terms of the upward uplift, which is the uplift that is happening, and the downward movement of the original one, indicating how much the downward movement is occurring. On the basis of it, we can work out how this kind of deformation is happening in the different pavement courses. Shallow ruts usually do not pose a safety risk.

Now, the problem is that if it disturbs these ruts or the depression disturbs your cross drainage and leads to ponding of water along these ruts, then it raises a safety concern. So, shallow ruts usually do not pose a safety risk until the water is able to move off the surface, but when they are deep enough to pond water, then the risk of hydroplaning increases. So, the chances of a vehicle losing its skid resistance over this one. So, when a film of water comes between your tire and the pavement surface, hydroplaning occurs, and the chances of skidding increase; engineers warn motorists that this can happen, and even in cold climates, this water can freeze, leading to slippery conditions again. So, this is quite challenging if water is ponded in these ruts.

So, locations where these chances are most likely to occur are where rutting predominantly happens along the wheel path of the pavement because there you will experience the maximum amount of load that comes over the pavement surface. And on the basis of the amount of ruts, the pavement surfaces are also rated. So, as per IRC 80-2023, it states that even for highways and urban roads, a surface can be rated as excellent to good if the rut depths are usually less than 5 mm, satisfactory to fair between 5 and 10 mm, and poor to fail when it is more than 10 mm. So, similarly, it has been given for the major district roads

and rural roads. Now, the other form of deformation that can be observed on some pavement sections is corrugations.

So, here you can see there is some wave-like structure. So, these corrugations are there, and again the corrugations may be present in your top courses or may originate from your underlying courses; they may also arise from granular courses and even from the subgrade, consecutively getting reflected on the top. So, corrugations refer to the development of regular wave-like undulations or ripples on the bituminous surface, and this is how it gets reflected. Finally, we will be able to see when any distress appears on the surface. So, these ripples are usually shallow, around 25 mm, and are more distinct than larger depressions.

These are smaller depressions caused only by weakness. I will not discuss many of the cases, but I did mention that it can be there in the underlying courses as well. The typical spacing of these waves may range from 2 to 3 meters. So, this is how a corrugation is there. What one concern may be is that the driving discomfort is present, specifically, but when it becomes more severe as these depressions increase, it raises a safety hazard, and it can occur near the wheel path or in the entire carriageway.

So, it can happen along the wheel path, or it can happen along the entire width of the carriageway as well. So, if any kind of surface defect is observed, we can say that corrugation is happening over this particular one, and by seeing how much the depth is and what the spacing of these is, we can figure out whether this is a very extensive corrugation or not. Now, the other form of distress under the category of deformation is shoving. You can see a mix that is pushed to the side. So, there is a bulk quantity of mix that is pushed to your pavement edges.

Here, you can also see the mix is getting pushed towards one side. Even the pavement markings get disturbed. You can see the pavement markings have become wavy. So, from there you can get an idea that there has been some shear failure of the mix.

There has been some shoving. So, shoving is a type of plastic deformation specifically within bituminous layers, resulting in bulging of the pavement surface. So, this has bulged at one particular site. So, location shoving typically occurs at points where traffic frequently stops or makes a turn. So, at curves, also at intersections, and where it stops. So, high shear stresses are generated specifically when braking actions occur, particularly when vehicles accelerate on rising gradients such as intersections, bus stops, hill roads, and sharp curves where they accelerate or brake.

The bulging of the mix can occur in the bituminous mixes, and it specifically mainly occurs along the edges, as the mix gets pushed towards the edges. So, it commonly appears near wheel paths and truck lanes, or on horizontal curves where commercial vehicles slow down significantly, making these locations frequent sites of this kind of shoving distress. Now, in urban sections, specifically where bus stops are located, these are the first locations that

can experience this kind of corrugation, and as I mentioned, you can very well get them detected by the edge line markings where the lines bend. So, you can see the edge line markings when the pavements are there; you have the edge line markings when the shoving is there. These edge line markings will be disturbed.

So, then you can understand that this edge line has become wavy; the markings for the edges have become wavy, which means there is some mix that is getting burst or shoving is happening. Shallow depressions, small amounts of depressions, and localized depressions may be present. So, these low spots in the pavement can be present; as mentioned, it is usually a localized depression, typically around 25 mm or below the surrounding surface. This is a typical depression. And some amount of water is there because it is a depression where water can accumulate for this particular one as it disturbs.

So, it can be in the transverse direction, and it can be in the longitudinal direction also. May occur or may not be accompanied by surface cracking; if this depression occurs many times, you can also see some cracks getting initiated along with these shallow depressions. They may create uneven, uncomfortable, potentially unsafe driving conditions because the water can pond in these particular shallow depressions. So, shallow depressions are generally restricted to wheel paths; heavy traffic lanes are where you can see this age marking; this is a shallow depression that has occurred. Settlements and upheavals are present at certain locations; you will see that some settlements are there and some upheaval of the pavement layers is occurring, with bituminous layers upheaving.

So, that is another kind of distress that is present and will fall under the category of deformation. Our permanent deformations larger than shallow depressions occur because we consider a depth of around 25 mm; if it exceeds that, we will call it a settlement. They pose a significant hazard to traffic, often causing reduced vehicle speeds, unsafe driving conditions, and cracks that are also associated with these settlements and upheavals. So, these defects are usually accompanied by extensive cracking in the affected area. So, they then further allow the water to go into the underlying layers.

Settlement and upheaval may be along the wheel path or in isolated locations on a carriageway. Now, the fourth important category of the different types of distresses is this disintegration. So, that means there is some loss in the breaking of the pavement material. So, which disintegration is the progressive breaking up of the pavement surface into small loose fragments, if my pavement is material or if the surface is breaking into small loose fragments, often involving the separation of individual components of the bituminous mix? So, what are the individual components? We have the aggregate and binder with us in aggregates; we have fine aggregates and coarse aggregates, along with which are bound together with the binder. So, if some loss of material is happening, then it comes under the category of your disintegration.

It typically manifests as raveling. Now, there are few distresses that come under the category of disintegration, breaking of the material, which are raveling, stripping, or pothole formation. Pothole is a very common term that you all might have observed at some moment on a particular surface while driving your vehicles. So, if not addressed early, disintegration can accelerate, ultimately necessitating complete reconstruction. So, the categories that usually distress which come under disintegration are stripping, raveling, potholes, patch repair or patch deterioration, and age breaking. Stripping, as the word suggests, means something is getting stripped off.

So, what is being stripped off? The binder is being stripped off from the aggregate surface. So, stripping is the separation of the bitumen film from the aggregate particles, and this usually happens in the presence of moisture. Once this water enters, the binder film is stripped from the aggregate surface. Because most of our aggregates are hydrophilic in nature, they have a higher affinity for water. So, the binder film gets stripped off from the surface, which leads to a reduction in the cohesiveness of the mix, or the mix strength is lost in that case.

So, there is a loss of bond between the asphalt and aggregate, and a reduction in mixture cohesion will occur. So, this distress usually begins at the bottom of the HMA layer and progresses upward. Usually, whatever water comes from the underlying layers and comes into contact with your bituminous surface due to the traffic moving over it creates a good amount of pore water pressure, and the water that reaches the bottom of your bituminous layers and remains there strips your binder film from your aggregate. So, many times, usually from the top of the camber, the water goes out, but whatever is coming up from the underlying layers is usually one of the main reasons for the stripping that is observed. If it happens from the top, then it takes the form of a raveling that we will discuss in the next slides.

So, this stress usually begins at the bottom of the HMA layer. So, if you can open it up, take out any core, and observe from the bottom, you will see that the binder is getting stripped from the aggregate surface, and you can find this strip, these aggregate surfaces without any coating of the binder. So, the location where this usually happens is specifically a lane; it can happen in a lane or the particular lane along the wheel path, or it can happen for the entire carriageway. Specifically, on multi-lane highways, stripping often happens in the slow-moving lanes where the heavy traffic moves over it. Now, as I mentioned, the next is when this is happening; from the top, this is the other case when water is on the surface, and because of this, if there is some loss of binder, then there will also be a loss of aggregates.

So, that kind that comes under the distress that is unraveling. Now, what is unraveling is the progressive separation and loss of fine aggregate particles. So, when the fine aggregate particles are not able to be held in the mix. So, this kind of separation of the fine aggregates

usually initiates a process. So, when is the progressive separation and loss of fine aggregate particles and binder from the bituminous surface? So, one of the reasons may be if water is standing on the surface.

So, that is why it was mentioned in the previous discussion that if this loss of material is happening from the top because of water, then it will be referred to as raveling; otherwise, usually stripping goes from the bottom part. But this loss of fines may not be only because of water; it can happen without the presence of water as well. So, for traveling, water may be one contributing factor or may not be a contributing factor. So, it leads to the disintegration of the HMA layer from the surface downwards. So, it moves from the surface to the lower portion of your bituminous layer.

So, typically fine aggregates are lost first if they are not held. So, for example, if any adequate binder is present and it is not able to hold your fine aggregates, then first the fine aggregates are lost, and finally, it may proceed with the loss of your coarse aggregates as well. Usually beginning at the surface or edges results in a rough, uneven, jagged pavement surface because, as you can see, the fines are lost from this particular one course appearing on this one. Severe ravelling can create depressions that pound the water, and if more depressions are present, this can also lead to pounding of the water, which can result in a loss of skid resistance. Additionally, loose aggregates reduce skid resistance and may be thrown by vehicle tires.

This again raises concerns related to road safety. Then where can the locations be? It can be in a particular lane or across its entire width. There are again low severity, medium severity, and high severity; low severity is the one when there are minor losses of fines. So, usually, this is the initial stage of binder deterioration. When we call it, some fines are lost, and then, in that particular case, if there is a noticeable loss of fines, you can see it on this particular surface. Then this becomes medium severity, and the binding wears out to expose a rough surface.

And if it further goes where you have the significant loss of aggregates, which is happening, then this comes under the category of high severity ravelling. Now, the other form is pothole formation. This is an extended form of distress. So, if any kind of distress becomes very severe, it can at least lead to the formation of a pothole as well. Potholes are bowl-shaped cavities that typically penetrate the HMA surface and may extend into the binder or base course.

It may go down depending on the depth of the potholes, but they usually occur on pavements with thin HMA layers. Usually, this is true in most cases when you have the thin bituminous layers that are present. Many times, they occur very frequently during the rainfall when water enters, especially into the closely spaced alligator cracks or any other cracks, and then some loss of material starts taking place; in due course, some pothole will

be formed. So, the dislodged pieces of pavement are removed by tire action, causing the growth of potholes. So, if some say alligator cracks are present and they are in high-severity condition, then some of the pieces get dislodged by the tires, water gets accommodated, and it further damages your surface, ultimately leading to the formation of a pothole.

Now, it can occur along a crack, including longitudinal or transverse cracks, especially where a wheel repeatedly crosses, to make a count of its severity; usually, certain units are used, which we call pothole units. So, for this particular one, especially, I mentioned it is there; it is to define having a surface area of 0.1 square meters and having a depth of around 10 centimeters. So, this leads to a volume of around 10 liters. So, if a pothole with a volume of 10 liters is present, it is counted as one unit of potholes.

So, on the basis of it, for the maintenance activities, the intensity of the potholes can be classified by how many pothole units are in this one. Now, the patch deterioration many times you have seen; some patches are made to repair localized distresses, but then these patches also deteriorate over time. So, there is also now kind of distress in the existing pavement surface. So, patching involves repairing damaged or excavated areas in bituminous material to restore serviceability and prevent further deterioration.

So, this is a patch that has been done over it. Now, timely patching of defects such as potholes is crucial to prevent delays because this allows for the prevention of water infiltration and protects the underlying layers from damage. But in due course, these patches may also get disintegrated or deteriorated. So, on the basis of it, we can classify the severity of these patches. This is a patch that is quite intact. So, I can have a patch that is low severity, which is a patch in good condition performing satisfactorily with no loss of material.

So, it is a low-severity case; there may be some discomfort, but it is a low-severity case. Then, medium severity, when it usually happens at the edges, you will have some minor issues occurring. So, some loss of material may be occurring at the edges of this. So, the patch exhibits moderate distress of any type, including some cracks that may be present, and it occurs along the boundaries. And when there is sufficient deterioration, it significantly affects your riding quality, indicating high severity.

Now, the last one is under this category is the edge breaking. Many times, you see this is a carriageway age; when this gets damaged. You can see that the material is getting removed or dislodged from the pavement edges. So, we call it edge breaking. Edge breaking is a defect in bituminous pavement characterized by irregular fracturing. This is irregular fracturing and disintegration of the pavement edges that are present.

Usually, it happens very close to the pavement edges, around, say, 30 centimeters from the pavement edges. If left untreated, this condition worsens over time, and these chunks are removed in due course, which effectively reduces your pavement width. So, this is what

age breaking is; it is typically confined to the pavement edges and extends 30 centimeters inward. So, these are some of the typical distresses that we discussed today under the category of deformation and under the category of disintegration. Thank you so much.