

Course Name – Pavement Construction Technology
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Week – 11
Lecture – 40

A very warm welcome to all of you. Myself Rajan Choudhary, Professor in the Department of Civil Engineering, Indian Institute of Technology, Guwahati, Instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by Ministry of Education, Government of India. Our today's talk will be module 11 where we will discuss some of the pavement distresses and their possible causes along with the what kind of treatments can be taken when these distresses occur on bituminous or flexible pavements. So, at the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various test books, codal standards, journal articles, reports, newsletters, and public domain searches. Now, in the previous lecture, we have discussed about the different type of pavement distresses which were clubbed under four main different headings. Here, we will pick up those distresses, we will discuss the possible causes and what can be a good say or what is a usual treatment which is applicable when this kind of distresses occurs on a flexible pavement.

So, starting with as we discussed in the previous lecture bituminous or flexible pavements like any engineered structure undergo a wear and tear with time in due course of its life. So therefore, prone to various kind of distresses which takes place it may be deformation may be there, some cracking may be there, some loss of material may be there. So, these kind of distresses like any other engineered material can happen with these flexible or bituminous pavements also. And these signs of distresses, some fine cracks are there, some loss of fine materials is there, may not be an alarming one unless they occur prematurely in the early years of the life of that particular pavement.

Then so premature distresses are the major concern for engineer. Distress is developed because it is expected it is an engineered structure which is subjected to different environmental conditions, traffic loading during its course of service. So, it is expected that when they approach their near the design life because of the traffic loading and the environmental conditions some distresses are prone to occur but if they occur prematurely in early years of life that is again a major concern for the pavement engineers. Surface distresses may arise from multiple underlying causes, this is one important aspect because the manifestations on the top of the surface which is visible to the user and to the engineers may be because of causes which may be lying hidden in the underlying layers. So, surface distresses may arise from multiple underlying causes.

Therefore, it is important to carefully or properly identify those causes that is important part and then on the basis of that corrective measures are to be suggested because if the correct cause is not figured it out then there are chances that it may reoccur. So, that is why it is always important to investigate properly. So, as to find out for this particular cause because a single distress may have multiple causes, we will discuss those ones. So, in that case we have to figure it out and what can be a possible remedial measure which will be best for that kind of distress occurring because of a one particular reason or a combination of reasons. In other words, for any remedial measure to be effective and to last long, the cause of the problem must be first determined and then addressed.

But always it is important that during the planning stage, during the design stage, during the construction stage, the control has to be more at those different aspects, because it is very difficult at a later stage to do that investigation to work out the individual causes, we will see into these discussions. So, bituminous pavements experience various kind of distresses which we discussed here in the previous lecture over their service life and in some cases they may occur prematurely. So, that is so even when we occur at say a later stage of life also then also some treatment has to be done. So, as to increase to keep the serviceability to a desired level and to increase the service life of the pavement. So, the following points highlight the common causes that often lead to the development of some such distresses.

One is if we are selecting poor quality of materials, then you can observe premature distresses. The poor quality of materials may be your aggregates and the poor quality may be in terms of the shape of the aggregates, may be the strength of the aggregates, may be the gradation of those aggregates. And in case of say binding material like bitumen, it may be a wrong grade of it, it may be a binder which is more susceptible towards aging, it may be a binder which is very stiff. So, these needs to be properly investigated before being used. So, if poor quality materials are used, substandard materials are used, then definitely we expect one or the other kind of distress to occur.

And, even with good quality materials, if the construction is not done properly, if the construction practices which are mentioned, which are clearly specified by our specifications are not followed, we cannot expect a good quality of finished product. Deficiencies in asphalt mix design as we know bituminous mix, the bituminous bond mixes are the mixes which provides very significant structure strength to a flexible pavement structure. So, there if the design is not done properly in terms of the computation of the volumetric properties, in terms of the estimation of the mechanical strength properties, in terms of the estimation of the optimum binder content, then we can expect different kind of distresses taking place that too prematurely. Insufficient pavement structure thickness this is again if we are whatever the thickness which has been designed if the same has not been provided there it has been compromised whatever granular course is whatever the

bituminous bound course is if their thickness is compromised definitely it will lead to premature distresses. The other concern is traffic volumes exceeding the design estimates.

Usually, you design the roads for a period of 15 to 20 years of life. So, you are estimating the traffic which is going to come in those 20 years of life. So that if the design or the estimate is not correct, if the traffic volume is more than whatever you are considering. So, then your pavement structure is going to show some distresses and the other part is usually when we compute these design traffic we take care of the excel loading which is actually happening during the computation of the design traffic we compute a factor which is known as vehicle damage factor. So, that takes care of the axle loadings of different axle combinations which are there.

If that is not properly done, we may encounter traffic which is having higher axle loads compared to what has been considered during the design. So, then this may your structure strength may not be inadequate to carry that particular load. So, again it will show some signs of distresses. Excessive aging of asphalt binders, certain binders are more prone to aging but if you have ensured it through the required specifications of binder. But then also during the construction if these asphalt pavements are constructed with high amount of air void contents as we see when we construct a bituminous mat, we usually target for dense graded one a 6 to 8 percent of air void content which is then expected to come up in the range of 3 to 5 percent after say initial years of traffic that is secondary compaction in 2 to 3 years of life.

But if we compact it, if it is not properly compacted the air voids are more than that 6 to 8 percent may be 10 to 12 percent more than that. Then, those high air void contents leads to excessive aging of the binder. So, the binder then becomes stiff and is prone to distress. Higher variation in temperature and rainfall is again a common concern because you consider what range of temperature this particular mix has to perform within. So, if that is not properly considered, you might have chosen a softer binder or a stiffer binder than actually desired, and the rainfall estimates have to be accurate in order to design for surface drainage properly.

Some preventive maintenance jobs, some regular routine maintenance has to be carried out, and some preventive maintenance activities have to be carried out. In the next lecture, we will specifically discuss those maintenance activities, what treatments are available, and the general treatments. So, they say cleaning your drains has to be done, and maintenance of your shoulders has to be done. These exercises need to be done regularly to ensure uniform performance throughout the design life of that particular structure. So, these are some of the common causes for which one type of distress occurs in flexible pavements.

Now, in the previous lecture, we discussed the different distresses; today we will discuss the causes and the usual treatments that are suggested for those different types of distresses. So, we discussed the surface defects in the previous lecture where fatty surfaces, bleeding, smooth surfaces, streaking, and hungry surfaces were discussed; then cracks under cracking distress, hairline cracks, alligator cracks, age cracks, shrinkage cracks, and reflection cracks were mentioned. So, deformation, rutting, corrugation, shoving were present, shallow depressions were present, settlements and uphill were present, then disintegration was present, wear stripping, loss of aggregates, raveling, and potholes; these are the different stresses that are usually grouped under these four different heads. Now, we will discuss some of these distresses and the possible causes along with what treatments can be applied for these distresses. So, coming to the surface defects, one of the common ones we discussed was bleeding, which usually occurs under hot weather conditions when the bituminous binder, after filling whatever voids are present in the bituminous mat, comes over the top of the compacted layer, migrates upward under traffic, and forms a surface film.

So, as you can see, this is a sign of the bleeding that is present. So, this process is not reversible because if the temperature goes down, it does not go inside it. So, it is not reversible during cold weather, resulting in this binder remaining on the surface itself, and then the surface becomes, we can call it, fatty, slippery, and skid-prone. So, if the presence of water is there over this particular one, it becomes a sticky as well as slippery surface. Now, what could be the possible causes of this kind of binder that has come over the top of your bituminous surface? One is excessive binder that has been in the mix, so while designing the mix, you have designed it in an improper manner with a higher binder content than what is required for that particular one.

So, that excess binder has come up to the top, or the quality control was not there because you designed it, but while constructing or producing at your hot mix plant, specifically, that control was not proper. So, the mix was ultimately produced with a higher binder content than what was designed earlier. Low air void content of the mix, as I mentioned, is expected to be around 3 to 5 percent after secondary compaction of 2 to 3 years, and just after rolling, we expect to have air void content in the range of around 6 to 8 percent for dense-graded mixes. Now, if they are over-compacted during rolling operations and then, during secondary compaction, they get compacted to air voids of less than, say, 2 to 3 percent. Then in those cases, the chances are that under the trapping load, the mix will rut and the binder will come up to the surface; the binder will be squeezed on your asphalt surface.

So, that is another case when you have lower air void content. Use a softer grade of binder, as we mentioned, depending on the traffic loading and the temperature range in which it has to perform; we have to select a grade. If a softer grade is chosen, then this binder may also be pushed to the top surface under traffic loading. Overapplication of tack coat occurs

whenever we construct any bituminous course or apply it to the existing surface; a tack coat must be applied. However, if it is not properly applied through the bitumen distributors and an excess quantity of tack coat is used, it migrates under traffic loading to the surface, resulting in observable streaking or bleeding in localized spots.

Loss of cover aggregates occurs in the case of surface dressing, as we discussed when we talked about surface dressing, that a bituminous film is to be applied, and thereafter we proceed with the application of the key aggregates. So, an adequate quantity of the bitumen is to be applied, and then the key aggregates need to be embedded inside it. So, if an excess quantity of bitumen is present, then this will result in bleeding distress. So, this is a specific case when surface dressing is used. Or we can have this when the key aggregates are not properly spread, or when there are flaky and elongated aggregates.

So, they lie flat, and they go inside the bituminous one. So, in that particular case, you may again have these surfaces where excess bitumen is on the top, so bleeding may occur. Now, depending on what the severity level of the bleeding is, different types of typical maintenance measures or treatments are suggested. One says that if there is low-severity bleeding, it can be treated by applying heated coarse sand because we need to specifically pick up what the excess binder is on the top. So, we will go for an application of heated coarse sand, typically the one that passes a 1.18 mm sieve to absorb this excess bitumen; it is heated, and a small rolling is done over it. So, this is when you have these small spots; you can go, so there is low severity bleeding. If there is medium severity bleeding or fatty surfaces, then they can be corrected; what we can do is apply some pre-coated chips, specifically the ones we used in the case of surface dressing. So, the one passing 4.75 mm here and retained over 1.18 and pre-coated means we can go by coating them with 1 percent of bitumen, and we need to give them the due time for when these pre-coated chips are used, and then they can be spread over. You can see the pre-coated chips are getting spread; these are uncoated ones. We can go for pre-coated ones depending upon our requirement, followed by a light rolling to allow them to sit inside this excess bitumen. High-severity bleeding is present; if this bleeding is very severe, then it is preferred to mill out that particular one. We can scrape out that particular portion where it has shown excessive signs of bleeding, and we can reuse that material, or we can put a new layer of mix over it.

And in that particular case, we can even go for a slurry application of a slurry seal or microsurfacing. And even for large fatty or irregular areas, the affected area can be completely removed; this is when you can go for a properly designed new mix. So, even milling can be done for a localized portion; if there is extensive bleeding in those particular areas, we can put up a new mix, and then on top, we can go for a surface slurry seal or micro surfacing. We will discuss this later when we discuss the general treatments of the bituminous mixes. Another defect that exists beneath the surface defect is a smooth surface, where the skid resistance is reduced or the frictional resistance of the surface decreases,

and this is typically related to the characteristics of the aggregates used, particularly when more polishing-susceptible aggregates are employed.

We already have a polished stone value that needs to be ensured when an aggregate is used in a surface course; however, if this kind of distress occurs for any reason, then one of the main primary causes of a smooth pavement surface is aggregate polishing. It polishes prematurely under traffic, and as we discussed during the measurement or evaluation of skid resistance, two factors usually play an important role in terms of pavement surface characteristics: one is the microtexture, which is closely related to the aggregate property. It is aggregate rugosity, or the roughness of an aggregate particle, and the second is the macro texture, which is the mixed characteristics; the gradation of the mix is the one that affects your macro texture. So, if you have inadequate micro texture as well as macro texture, that will lead to reduced skid resistance. So, your microtexture can get reduced along with your macrotexture in due course of time.

So, in that case, you will have a lower skid resistance. And the other part is that if the binder you have designed is excessive, there is no bleeding, but if the binder is in excess. So, you may not have that much macro texture available with us. So, that will also lead to reduced skid resistance. So, if these are the cases, then the best part is that we prefer to go for a thin surface application in the form of surface dressing, slurry seal, micro surfacing, or even a dedicated course if we desire very high friction resistance; an open-graded friction course can be there.

So, these are typical courses that can be applied over a surface to enhance its skid resistance. But again, it is important that whatever aggregates we are selecting for the surface dressing, and for our open-graded friction courses, we need to ensure that they have good polishing resistance. So, this is again an important aspect of this one, or even if I require it, because if you are going to go for a new asphalt mix, that one will definitely give us better frictional or skid resistance compared to one that has already been subjected to wear and tear by the traffic. So, these are some typical measures that are treatments taken for cases where you find a smooth surface. Now, the other streaking is there; this is again distress that comes under the surface defects, and specifically, they are observed as longitudinal streaking.

We can have transverse streaking as well, but most commonly we observe longitudinal streaking. So, what we see during these streaks are alternating strips of pavement surface that receive uneven quantities of bitumen. So, you can say that at certain portions, you will find the binder appearing more compared to the remaining part of the carriageway. So, that means there has been a non-uniform application. What are the usual mechanical faults, especially with your bitumen distributors, due to improper adjustment or careless operation? So, these bitumen distributors, specifically when you go for, say, the application of your prime coat or the application of your tack coat, are an important part.

So, streaking may also result from spraying the binder at too low a temperature. So, this is again a concern because if you are going to spray at too low temperatures, then the binder is not fluid enough to come from the nozzle. So, at some point, you will have lower binder compared to the other parts in that case. So, from the nozzle, it will not come out in a uniform form when the viscosity of the binder is high. There may be chances of transverse streaking as I may specifically note when spurts are coming from certain noses, especially the spray bars.

So, in some high-pressure cases where these jets are working, excessive binder is coming up from some of the noses compared to the others, which can also lead to transverse streaking. And if transverse streaking is at a higher level or a high amount of transverse streaking is present, then it can lead to corrugations in that case, because at that moment you will have the mix that will get softened with a greater amount of binder present. Now, what can be done specifically is that these are alternate strips which form on the pavement surface. So, one option is to remove the affected surface and apply a new one, but again, this is always a costly aspect. So that is why it is always said that prevention is better than cure.

So, here also prevention is always necessary, so whenever bitumen distributors come for an application of, say, tack coat or, say, in the case of surface dressing the bitumen application, one needs to ensure that the correct quantity of binder is applied. So, that is what a correct quantity means in terms of how much quantity in a unit area is required and needs to be properly controlled. So, we need to look into the temperature; we need to look into the grade of the immersion that has to be used for that particular application. So, when using mechanical equipment for bitumen spraying, the distributor should be properly calibrated specifically because the nozzle openings also change with time, so that also needs to be adjusted, and the speed of the binder distributor has to be properly controlled to ensure a uniform application and operation with cure to avoid streaking. So, this is a big challenge that is specifically present, so proper control has to be in place; otherwise, the surface you need to address must be removed or you need to apply a new course over it.

Then the other surface defect, which is usually experienced as a hungry surface, or what we will call a dry surface, is present; so if we find that this particular surface is lacking in the binder or the fine part of the aggregates, then what is the So, the cause behind this is the use of specifically inadequate bituminous materials because the common practice is to save the binder, as it is a very costly component in bituminous construction. So, if a smaller amount of binder is used than what is designed for a particular course, then you will have these kinds of hungry surfaces, and the fines will not be held properly by the surface. So, in due course of time, the fines will also be lost, and this can later aggravate into unraveling distresses as well. So, if this kind of surface is present, we are finding that a lack of binder occurs because this typically happens when you use a smaller quantity of binder than what is designed, or conversely, if we are using highly absorptive aggregates, such as industrial

waste like steel slag, then they are highly absorptive. So, whether that particular concern is taken care of during the design of these mixes, if not done, a good amount of it may be absorbed by the aggregate itself, and the surface appears to be hungry.

So, in that case, what is usually done is that we can go for a fog seal or liquid resonating materials may be used for the treatment of these hungry surfaces. So, a fog seal may be applied over these hungry surfaces to meet the requirement of the inadequate binder present. Slurry seal or micro surfacing can also be used as a repair option specifically, and the thickness is not much; we usually target a thickness of around 2 to 4 mm when we use slurry seal and micro surfacing to address the challenges related to hungry surfaces and dry surfaces. Then the other surface defect is the hairline cracks that can be observed. And this usually happens simultaneously when you have insufficient binder.

Excessive filler means that your mix is quite stiff. Oxidation of the surface bitumen is occurring. This surface bitumen may be oxidized because it is produced at higher temperatures in the hot mix plant. It is stored in the storage silos for longer durations. So, it gets aged, even excessively aged, during the production itself. And because of this, the binder becomes stiff and starts showing fine cracks or excessive moisture in the granular layers under traffic loading.

If the granular layers are holding water, they are soft, so if some work has been done over an existing pavement that is weak and has water in its layers, then these fine cracks also appear on the surface. In the gradual course, when the binder in due service life becomes stiff, definitely after 10-15 years, it is going to stiffen. So, during that particular course, fine cracks may also appear, but if they occur prematurely, then it is possible that excessive aging occurred during production itself or that the underlying surface is not providing the required support from beneath. And this may happen if these mixes are rolled when the mix is still tender; that is, the mix is quite soft enough. Usually, as we discussed earlier, that is a good amount of compaction.

Initial compaction is done specifically by your pavers, where they give some vibrations to your loose mix. So, and then you start with your rolling operations. So, when you start with your rolling operations, the mix should be in such a condition that it can be compacted; otherwise, it will start flowing in front of the rollers. So, that is a case where tender mixes are present, or even when you go for over-compaction; in those particular cases, fine cracks also develop on your surface. Now, an important part is that whenever there are some cracks, one important aspect is to immediately seal those cracks.

So, if hairline cracks are observed, in that particular case, one application is a fog seal; this is a thin application of a bituminous binder, usually with slow-setting emulsions. So, there you can see that these emulsions are being applied over it. Many of these hairline cracks, fine cracks, can close up when warm weather is present, but otherwise it is always preferred

that we seal these cracks by applying a fog seal or other liquid regenerating agents, and other surface treatments may include slurry seals or micro surfacing to address these hairline cracks, but they should not be left untreated. Now comes the cracking, where we discussed the different kinds of cracking in the previous lecture; we will discuss their main causes here. The load-associated cracking, alligator cracking, MAP cracking, and fatigue cracking are some of the terms that are used synonymously with each other.

So, this is one of the common types of distresses that are usually seen on bituminous pavements, and it usually begins along the wheel paths because those are the sections that experience maximum traffic loading. Once these cracks are present along the wheel paths, secondary cracks start generating from them. So, this finally forms these secondary cracks that create these block patterns, and that is why they are also known as alligator cracking. At an extensive stage, these materials may be picked up with the traffic, and this may lead to the formation of potholes in due course of time if not treated. So, one possible cause of these alligator cracks is insufficient pavement thickness.

So, a greater amount of deflection will occur. So, the material will deflect to a higher level, and this will induce tensile stresses that will be greater than the strength of the material, causing cracks to be initiated. Overloading of heavy commercial vehicles, as I mentioned, was that during the computation of the traffic, the heavy axle loads were not considered properly. The axle loads that are coming are much higher than those that were considered in computing the pavement crust thickness. Then you will also have these load-associated fatigue cracking, which will happen. Excessive deflections of the pavement usually occur along the wheel path because the maximum stresses come there.

So, if not properly designed, you will experience that the cracks will first appear along the wheel paths. Weakening of the subgrade or the pavement layers is caused by the underlying layers being weakened specifically due to the presence of moisture, saturation by water from a rise in the water table, improper side drainage, or improper subsurface drainage. Then it will lead to a loss of strength, and a greater amount of deflections will occur, resulting in cracks forming mainly along the wheel path. Selecting a stiffer binder than required can lead to issues because if you choose a very stiff binder, these bituminous surfaces are also prone to cracking. So we need to ensure, as we have seen, that the binders, when we do viscosity grading, show that we are ensuring the viscosity, which we measured at 60 degrees centigrade, and we also ensured for penetration, which we checked at 25 degrees centigrade.

And when modified binders are present again, we conduct different tests at their low temperatures, as well as for their maximum temperatures for which they are considered. So selection is important; if a wrong grade is selected, or if a stiffer grade is chosen when a softer one is required in that particular region, fatigue cracking can occur, especially if it becomes highly oxidized. Or there may be a stripping of the underlying bituminous layers;

if the stripping happens in the underlying bituminous layers, they lose their strength. So, the support is reduced from the underlying base or binder courses, and then these kinds of cracks are initiated. Now, as I mentioned, there are so many cases and causes which are present.

So, it is very important to know whether it is the inadequate thickness of the pavement that is creating a problem, the presence of moisture in the underlying layers that is creating a problem, or specifically if it is related to the stripping of the underlying bituminous courses that has occurred. So, then the treatment has to be looked into so that it can survive for a good period of time. So, since cos is often deep-suited, what the investigation usually requires in the case of a strip is that you take out the cores and look into the thickness and the presence of any moisture that is there. So that you can ensure the structure's adequacy, we can also proceed with the structure evaluation in this particular case. Any structure of this kind that has experienced fatigue cracking needs to be strengthened; then, the structural evaluation in terms of either a Benkelman beam deflection study or a falling wave deflection study has to be carried out, and the overlay thickness has to be computed on the basis of that structural evaluation.

The repair needed is also based on the severity and extent of the cracking, as well as how much cracking is present in that particular case. Here it says, but as I mentioned immediately, whenever some cracks are observed on any particular surface, the cracks need to be sealed up. And depending upon the severity of the cracking, it will not happen all of a sudden, leaving some specific cases where all of a sudden you will have wide cracks in your pavements. Initially, the cracks will be initiated. So, if the cracks are fine enough, they can be sealed using some bitumen emissions, or some rubberized and modified bitumen can be used.

If the cracking is extensive, then we need to remove it because the material has already lost its strength. So, there is no benefit in putting up a new layer over it; whatever the earlier existing distressed material is, it should be removed, taken out, and we can recycle that material using the existing recycling techniques. And as I mentioned, if this structure is not adequate enough, the structure evaluation has to be done to compute what the overlay thickness should be to strengthen this particular one. Now longitudinal cracks, which usually run parallel to the centerline of the road, are specifically caused by the joints not being properly constructed, mainly at adjacent lanes. Because when you construct those lanes with the help of pavers, the joints between the adjacent lanes are not properly constructed; because of this, we usually have these longitudinal cracks.

This is one of the main reasons for longitudinal cracking. So, it occurs mainly due to the density gradient between the existing one and a new layered one, or between two adjacent mats that are present when some density gradient exists. This density gradient arises at the joint because the first lane is compacted without any lateral support. So, because there is

no support, when the second lane or the adjacent lane comes, it already has lateral support. So, in this particular one, its density at the edges is greater compared to the first one. So, this leads to a density gradient at the joint; that is why this is one point where you will have lower tensile strength in your mix.

So, the lower mat density is associated with the reduced tensile strength, making the joint more vulnerable to cracking; when it gets deflected, it cracks there because the tensile strength is less at those joints of adjacent lanes. It may also result from alternate wetting and drying beneath the shoulder, specifically because if the shoulders are constructed with inadequate materials or poor-quality control has been present, then this wetting and drying may create these longitudinal cracks. From the weak or improper bonding between adjoining pavement layers, many times some widening has been done. So that those joints are not properly constructed, we can also experience those joints; they may show cracks which are reflected on the top. So, treatment depends again on the severity and extent of longitudinal cracking, including how much width and how much depth it has.

So, for low and medium severity, we can normally go for crack sealing. You can see here that crack sealing can be done, but it depends on the width of it. As we discussed, when the severity is present, rubberized bitumen can be used, and a fork seal can be used for filling up those longitudinal cracks. If high-severity cracking has occurred, then definitely it needs to be removed, and a new overlay has to be provided. So, that is another case in it. Now, transverse cracks, also known as shrinkage cracks or low temperature cracks, usually run perpendicular to the direction of travel, and these cracks usually get initiated at the surface and then propagate downwards.

So, one of the main reasons is the low temperatures experienced by the pavement courses, and usually, the gradient of the temperature or the rate at which the temperature falls is the one that plays a larger role. If there is a sudden fall in the temperature, then the shrinkage stresses that are developed in the mixes are greater than the tensile strength. So, the mix shows some of these cracks, and they may be closely spaced; once squared, it forms a shape similar to some blocks. So, there is again low temperature cracking. So, they can be formed when surface temperatures drop enough to induce shrinkage cracks in HMA, which then exceed its tensile strength.

So, this transverse crack can get initiated specifically when temperatures fall and there is a sudden drop in temperature. So other cases may be if some say cracks are there, say the extensive cracks are there in the transverse direction in the underlying layer; then also it may get reflected or it may get transverse because of the action along those cracks. These cracks get moved up to the surface; we can also call that particular case reflection cracks. The presence of excessive stiff or highly brittle and aged binder makes them prone to low temperature cracking specifically. So, this is again a case when we are using very stiff binders or the binders are excessively aged.

So, the binders that are more susceptible to production temperatures can age because of improper production practices, or they can age if the mat has a higher air void content than what is targeted for it. So, if the binder becomes stiff, then under low temperatures it will show these transverse cracks. Now, transverse cracks are widely repaired by sealing them with liquid asphalt or other suitable materials. So, we can apply some fog seal or any other liquid regenerating agents, or the rubberized binders can be filled in these particular joints. They can also be treated with slurry seal or rubberized bitumen; this depends on the width offered, and we can also go for an application of a slurry seal.

And if this is, again, definitely the last option, if these distresses grow beyond a certain limit that reduces the serviceability of the road and its ability to accommodate traffic, then we have to go for an overlay for these kinds of distresses. Another type of cracks is the age cracks, which we can usually see occurring at the ages of your pavement sections. So, this is specifically happening if the ages are not properly supported; you can see if the shoulders are not properly constructed and the underlying courses near the ages, because usually heavy traffic moves along the outer lanes, and then the wheel path, which is near the outer edges, may experience significantly higher stresses compared to the inner part of your carriageway. And if it is poorly constructed, having inadequate support from the shoulders and inadequate support from the underlying layers, we can see these edge cracks, which also run parallel to your centerline. So, typically, they develop parallel to the pavement edge, especially where road widening occurs.

This is because widening is a very challenging exercise; how you match up the existing layers with the new construction is very important. This matching is specifically crucial for the drainage courses because it plays a significant role. If the layers are not properly matched and the joints are not properly constructed, and the drainage is not properly maintained, then you may experience distresses such as longitudinal cracking or edge cracking. So, the main causes include inadequate lateral shoulder support, which is present if the shoulders are not properly supported by the edges. Poor drainage or water accumulation on the sides occurs if the side drainage is not good; the water will stand on the pavement, edges will go inside the pavement layers, and will weaken those layers.

So, the edge, specifically the edges where high stresses are already occurring, will experience more deflections, and these cracks are going to be initiated. Accumulation, or water accumulation, occurs even if the drains are present; if they are not properly maintained and cleaned, water will stand in those drains. Settlement of underlying layers may occur specifically near the pavement edges, shrinkage of subgrade soil, or insufficient pavement width at curves; usually, these are other terms because where horizontal curves are present, we prefer to go for some extra widening. If that is not done, then we experience some heavy stress, especially at the edges of horizontal curves, if that extra widening is not provided. Inferior or thin shoulder material is provided if its shoulders are not properly maintained and constructed.

Thinner bituminous surfaces at the edges occur because the thickness of the bituminous surface should remain uniform throughout the width of your carriageway. It should not happen that, as it goes towards the edges, the thickness of your mat typically gets reduced; then again, this kind of edge cracking gets initiated, and wet subgrade will always be a problem for it. So, these are some of the typical causes of age cracking. Then what can be done? As I always mentioned, it is important to seal edge cracks with suitable material. This is the first thing: when these small cracks develop, ensure that surface water flows to nearby drains without ponding at the pavement edges.

So, shoulders need to be properly maintained in that case, and the water from the surface should go to your side drains. A poorly draining shoulder material is replaced with permeable material. You can see if whatever your shoulder material is there, as we have seen during earlier lectures that your drainage course needs to be extended so that the water from the drainage course can be directly sent to the side drains. So, it needs to be extended to the entire width of your shoulders. So that needs to be properly taken care of, and we have to ensure that the material is not choked; your subsurface drainage layer is not choked.

A poorly draining shoulder material is to be replaced with a permeable material. In case extensive cracks are present due to heavy truck loading, a structural overlay is to be designed for the entire thickness of your carriageway. Now, the other part of this particular one is that under the cracking is the common one we call reflection cracking, because it is the one that gets reflected from the underlying layers to the top surface course. So, underlying joints or cracks that propagate through the asphalt layers, HMA overlays are present. So, if there are certain discontinuities in the existing surface and we go for some overlay, specifically a thin overlay, then those discontinuities, joints, or cracks get reflected on the overlay as well. So, joints or cracks in an underlying cement concrete pavement, if that is overlaid by HMA, can cause these cracks to propagate to the top surface.

Cracks in soil cement base courses, or specifically when stabilized courses are used over which bituminous courses are constructed, are reflected when thin overlays are present. Cracks in existing asphalt layers, even in an existing pavement where extensive cracking, such as fatigue cracking, is present, can be exacerbated if that pavement is overlaid by a thin layer of HMA. Then, those cracks will, in due course of time, be propagated to the surface. So, then the overlay if it is not adequately designed or properly designed.

So, then those alligator cracking or fatigue cracking occur in due course of time. So, it means it is not an engineered overlay; it is not a properly designed overlay. We have just gone for a thin overlay, but it is not able to address the main cause of your inadequate structural strength. So, crack initiation occurs due to the actions in the underlying layers; whatever actions of expansion or contraction happen, those particular ones get propagated to the top surface because these actions produce stress in the HMA layers that exceed their tensile strength, causing the top surface to crack. So, what can be done in this case is that

if we are experiencing that the structure is sound enough, then the cracks can be filled with low viscosity bituminous binder. So if we find that the structural adequacy is good enough, the thickness, which is the crust thickness, is also good enough; this has happened because there is only any structure over, say, concrete pavement.

Then, what you can do is fill up those areas with low viscosity bituminous binder, and a light sand can be applied; specifically, heated sand is applied to prevent the binder from being picked up, which can otherwise happen when the traffic moves over it. If there is extensive cracking, that means the overlay is not properly designed. In that particular case, what we can do is go for the design of the overlay, and preferably, it is good to provide a stress-absorbing membrane interlayer. Or we can go for a geotextile geocomposite, which can serve both purposes; it can add to the structural strength and the flexural strength, especially if it is a combination of, say, geotextile and geonet. Whatever water that is present from the underlying layers can be taken out from those geocomposite geonets.

And so, it will also add to the structure's strength if we apply for a geocomposite. This stress-absorbing membrane interlayer, which is specifically an elastomeric modified binder, is applied. This will seal the existing cracks and will not allow water in; it will make your surface overlay resistant and will create a barrier between the overlay and the existing cracks. So, these are some typical cases specifically for reflection cracking. So, this is all for today's talk; in the next lecture, we will discuss the disintegration and the possible causes of disintegration, deformation, and their treatments. Thank you so much.