Basic Construction Materials
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Module No # 10
Lecture No # 47
Pavement material 2 – Part 1

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In the last segment, we saw the properties of asphalt, the composition of asphalt and how asphalt concrete is actually proportioned and what are the layers in a flexible pavement? We also spoke about the temperature susceptibility of asphalt, when you have very high temperature, asphalt starts flowing like viscous fluid. If you have very low temperature, asphalt behaves like a brittle elastic solid.

And because of this you can have a range of different distresses in the pavements. So I am going to talk briefly about some of the distress types that we observe in flexible payments made with asphalt concrete. First and foremost, the most common form of deterioration that we see in asphalt payments is that of rutting. Rutting is nothing but the accumulation of permanent deformation in the wheel path.

So what you can see from here is that right under the track where the wheel is actually going, you see a permanent deformation. You see this depression which has occurred right under the wheel track. And that is because the asphalt has become soft as a result of high temperature and under the loads of the wheel it continues to deform and then you get a permanent depression in the road and that is called rutting.

And rutting is a very common phenomenon especially in summer months when you have significantly high temperatures and that may cause the asphalt to start flowing. Sometimes of course because of repeated bending of the asphalt layer you can get accumulated problems because of fatigue cracking and fatigue cracking is something that is quite similar to what you see here.

So what we are seeing there is that there is bending of the asphalt pavement and because of the repeated loading or multiple cycles of loading the material starts giving way and you get such kind of cracks in the asphalt concrete layer. Thermal cracking can happen because of brittleness at low temperatures. When you have very low temperatures, asphalt starts behaving like a brittle elastic solid and tends to crack. That is a common phenomenon that we observe.

Sometimes the pavement surface may get excessively rough and that may also lead to formation of issues on the pavement which affect the ride-ability and that is also taken as a pavement failure. Because anything that affects the condition of the road as well as the comfort of the driver who is driving the vehicle obviously that is going to be regarded as a failure of the payment surface.

Now of course, this is another example of a combined instance of rutting and fatigue cracking. Because you can see that the damage is essentially confined to the wheel path. Now you may have noticed that in highways although the lanes are broad enough, it is quite common for the vehicles to travel either close to the center line or close to the side line. So mostly what you will see is the wheel tracks are fairly well defined in most highways.

So if you design the highways well enough, you can avoid the problem of rutting and low temperature thermal cracking. That means you need to choose your materials and design them in such a way that they are able to withstand that range of temperatures. We talked about this in the case of polymers also previously. So there we had this important temperature called glass transition temperature. So that is the temperature at which the elastic solid nature of the polymer gives way to a viscoelastic solid nature of the polymer.

And because of that the polymer starts deforming and some of this deformation is permanent. It is accumulated and because of which you have a failure because of excessive strains in the material.

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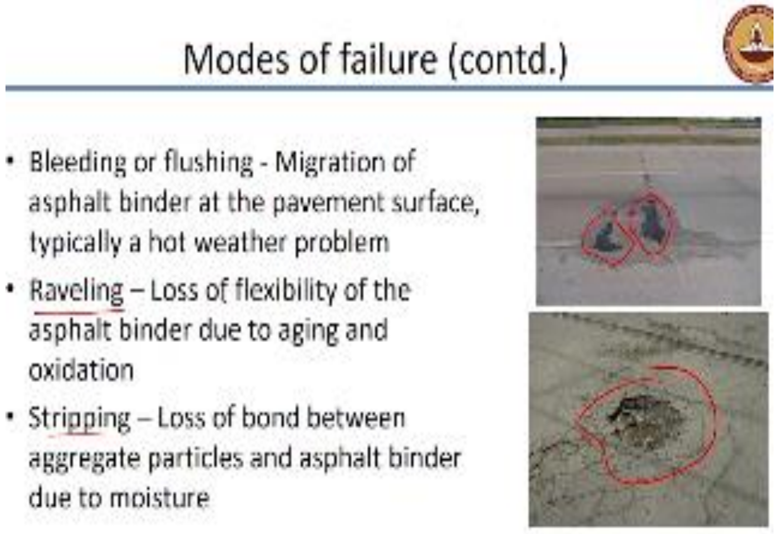

Now let us look at other types of failures. There is of course a problem of bleeding or flushing that may happen if the temperature becomes very high and if you have chosen the wrong asphalt which will cause the asphalt to become almost like water and start rising up to the surface and forming such pools on the surface. These are asphalt pools that have formed on the surface, that is because the asphalt has become very low viscous and come up to the surface and form those pools. It is a hot weather problem.

Now again like polymers, asphalt also loses its flexibility with ageing. Why is ageing happening? Because, of course not just because of wear and tear caused by natural service conditions but also because of the fact that you have ultraviolet radiation from the sun affecting the pavement surface. So raveling is the term associated with the loss of flexibility of the asphalt layer or asphalt binder because of ageing and oxidation.

Sometimes you may see that the water or moisture may affect the asphalt in such a way that it strips off the asphalt from the aggregate interface. So it breaks the bond between asphalt and aggregate and the result is puddles like this where you see the aggregate pieces almost lying separate from the rest of the pavement. A common problem right after rains for poorly prepared roads. Often times you will see this stripping issue also happening.

So we have looked at rutting, low temperature thermal cracking, fatigue cracking, bleeding or flushing, raveling and stripping. So these are the common failure types that you observe in pavements. Let us look at some more examples of the same.

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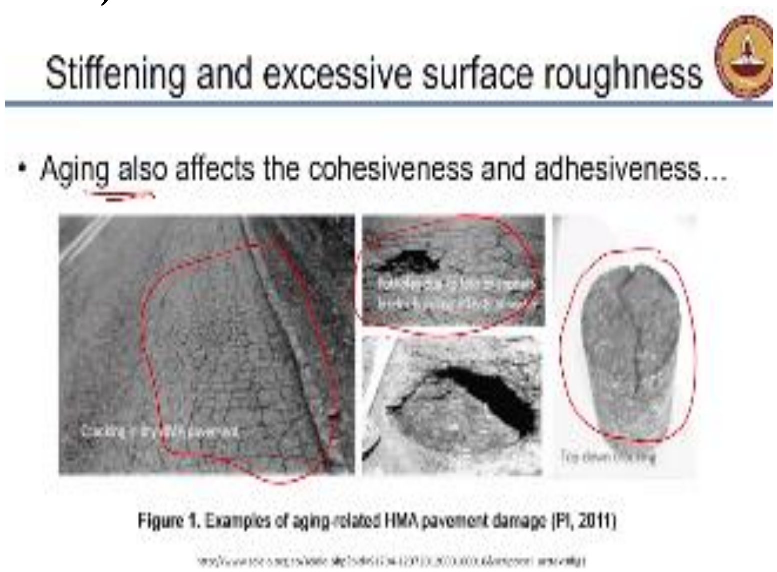

So again, this is an example of stiffening and excessive surface roughness that is caused primarily because of ageing. So here, ageing combined with of course fatigue cracking has resulted in a loss of ride-ability caused by excessive roughness on the pavement surface. Again such potholes can also happen because of stripping. I showed you in the previous page also where aggregate gets completely stripped off from the asphalt.

And sometimes of course you can take cores right through the highway pavement and then examine more closely what could have been the cause of the damage.

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In some cases of course, the asphalt is not applied for a pavement surface. It may be applied, for example for roof top-Tiles on the roof top which are otherwise known as shingles. Because these are getting exposed to ultraviolet radiation, slowly but surely they get degraded and this is a sign of degradation of the shingles that you are actually observing in this picture here.

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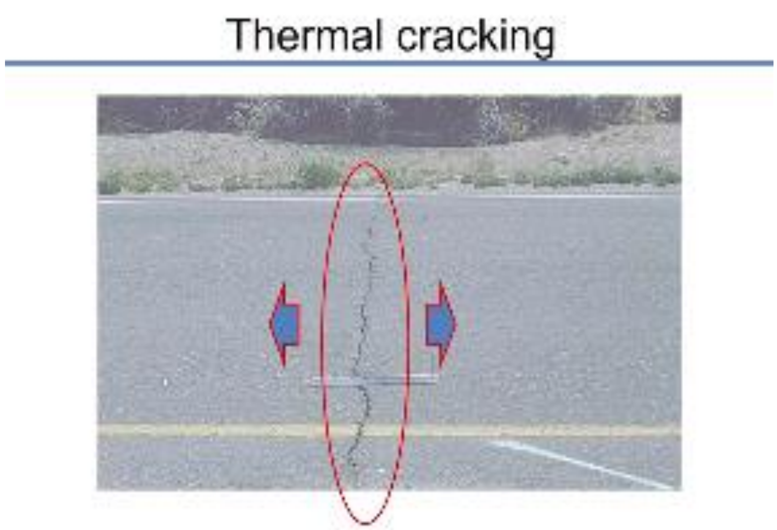

Thermal cracking can happen at very low temperatures when asphalt becomes highly brittle. So when it becomes brittle in response to the loading, the layer of asphalt concrete will bend and that will lead to tensile cracking in the system. So that is something that you need to ensure that it does not happen by selecting the right asphalt which can function over a range of temperatures that are well defined.

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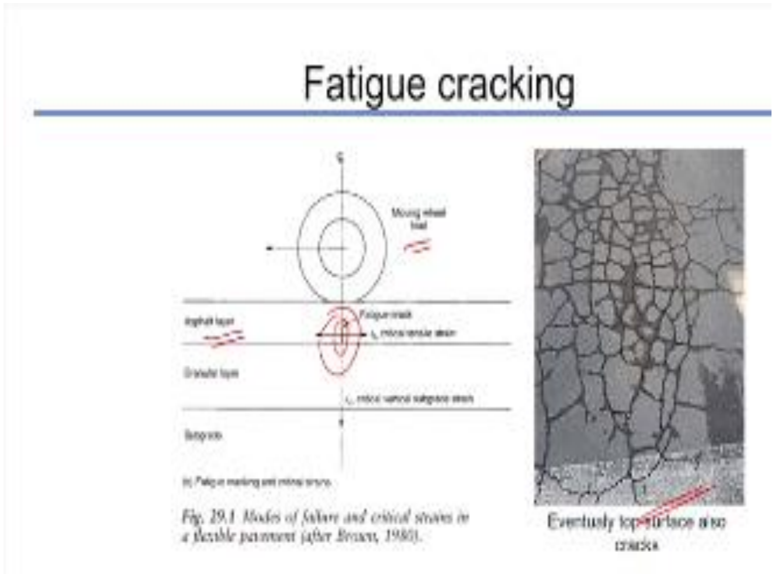

Fatigue cracking as I said is because of repeated bending of the asphalt concrete under the multiple cycles of load. So this is the moving wheel load and you can clearly see this is the asphalt layer and since the layer is going to bend like this, the crack is going to initiate at the bottom and that is what you are seeing here. The crack initiates at the bottom and then proceeds all the way to the top, which is a fatigue crack.

And that happens whenever the critical tensile strain capacity of the asphalt concrete layer gets exceeded. So you need to ensure that you are testing this aspect of the asphalt concrete before utilizing it in a specific pavement. Also the needs of the asphalt control will obviously depend on the type of pavement that you are making. Is that a national highway? This is because there we expect all kinds of vehicles.

The heaviest vehicles will be there and we need to consider the tonnage brought in by the heaviest vehicles and convert that to the equivalent number of units of vehicles that will pass over that given cross section in a certain period of time. Based on that, you need to select your material properties in such a way that it is able to match the requirements of that particular road.

Again you see here, the bottom starts cracking first but eventually you get cracking all over. In real life you do not get damage due to a single problem at once. You typically get damage because of a combination of different types of problems. So very often it is difficult to just see the cracking and say it is because of this or that. You need to investigate the causes a little bit more closely and do a proper repair to ensure that you are solving the problem completely.

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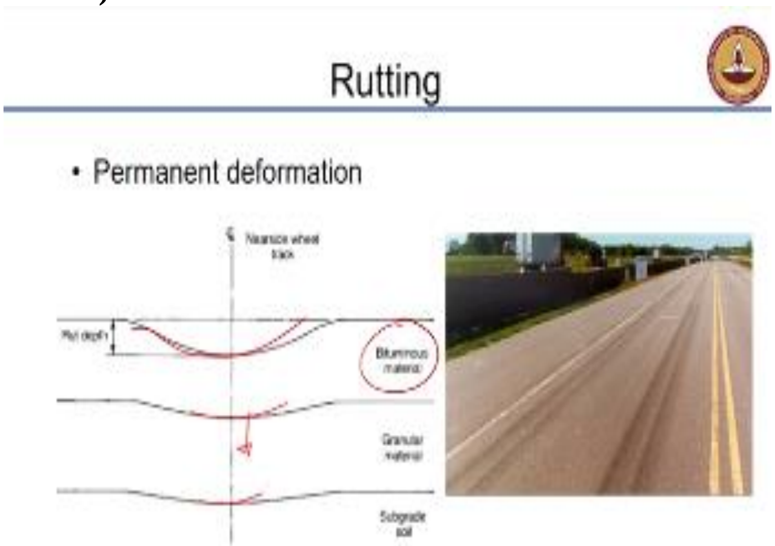

Rutting, very easy to understand, you have the top layer of the asphalt concrete which is becoming soft as a result of high temperature and when the wheel passes right on top of that, there is deformation. So deformation in the bituminous material is transferred to some extent to the granular material also. Because the granular material also is packed but then still it is not packed in such a way that it does not move at all. There can be some depression forming in the granular material also.

As the loads increase more and more, as more and more repetitive cycles of loading happen, this permanent deformation will keep on increasing. So you need to ensure that you design the highway payments with asphalt which is able to sustain the temperatures. Now one thing you need to understand asphalt pavements are black. So in the daytime they are going to absorb more and more heat radiation. As they absorb more heat, the temperature on the road surface will be certainly much higher than the ambient conditions.

Sometimes when the ambient conditions are 40 degree Celsius, the temperature of the asphalt payment can be as high as 60**.** So because of this aspect you need to ensure that you consider not just the ambient conditions but what could be the temperatures which may happen in the asphalt payment beyond the ambient conditions and design adequately for that.

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Stripping, as I said is the loss of bond between asphalt and aggregate due to moisture. So you can see in this case you have aggregates that are perfectly coated there is no stripping and in this case you see aggregates that are visible, asphalt has been completely removed from the surface and that is an example of stripping. So this here is a combined problem caused due to stripping as well as due to fatigue cracking.

Because you have multiple loads, multiple repetitions of the same load, you can have different causes of failure attributing to the same problem.

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So now we talked about asphalt as a polymer and the fact that asphalt needs to be mixed with the aggregate causes the asphalt to be either heated up to a temperature where it is almost like water or it is very low viscosity so it can mix with the aggregate or we make cut back or emulsion and then use that for the production of asphalt concrete. Now once the pavement surface becomes degraded to a large extent, we have to replace the pavement surface.

But one of the advantages that asphalt presents is that all you need to do is take this surface, asphalt concrete layer, and heat it up so that the asphalt again loses its viscosity and starts becoming fluid like and then you have the chance to actually reuse this material in a new pavement. So that is what is the idea of recycling of the asphalt pavement, you cannot do this with concrete of course. Because once the cement is reacted with water and hardens you cannot retrieve the cement back from it.

Asphalt on the other hand as I said does not undergo a chemical reaction with the aggregate. All it does is increase its stiffness or increase its viscosity to have a very solid like structure. So in this case all you need to do is just heat it up to cause it to start flowing again. So you can have different types of asphalt recycling, one is called surface recycling. So here we just take the top 25 millimeters of the pavement surface and rework it using a heating system as well as a scarifying system.

You can also take the material to a central plant and then grind the old asphalt pavement to a smaller size and then remix it to make the new asphalt payment. In place recycling can also be done that means in situ can also be done where recycling is done by using a machine that is ripping the pavement and then putting the material back into a hopper where there are facilities for heating and mixing.

And then the back of the truck basically is connected to a paver which can relay the new surface of the pavement. So all these equipment are actually available to do this kind of work.

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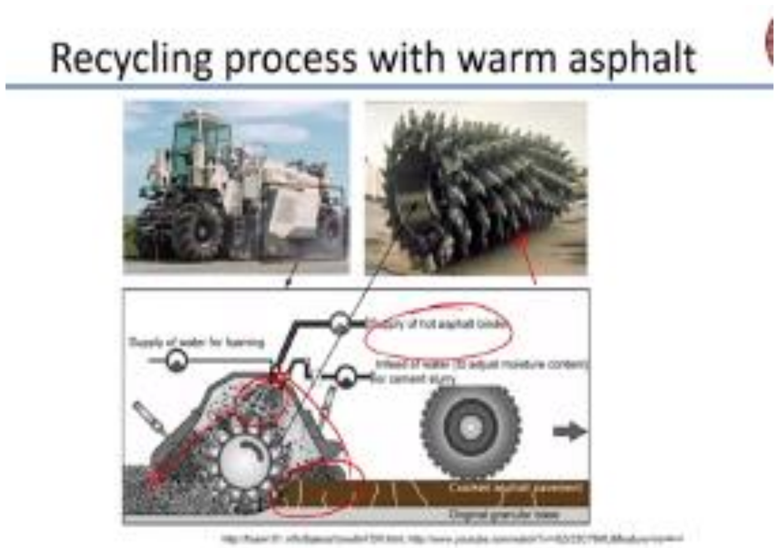

This is an example of the ripper. So the ripper basically is breaking up the cracked asphalt pavement which is damaged in the front. Then it sends it to a system where it can be mixed up with supply of hot asphalt binder and made into a new asphalt contract payment and then relay it on the portion where the material has already been ripped off. So these are modern equipment that has made recycling of asphalt payments quite a good proposition.

You do not have to waste the material, you have to recycle it. But please remember the asphalt has already undergone ageing because of exposure to ultraviolet radiation and other environmental factors, moisture and so on and so forth. Now this same asphalt is now getting removed from the existing pavement and recycled into a new pavement. So you have to imagine that whatever asphalt you are getting in the new payment because of the old broken up pavement is going to be already an aged material.

So you may have to add additional hot asphalt to ensure that you are satisfying the needs of the pavement material. So you have to ensure that you are causing the formation of a new pavement surface where the functionality or the performance can be guaranteed for a required period of time.

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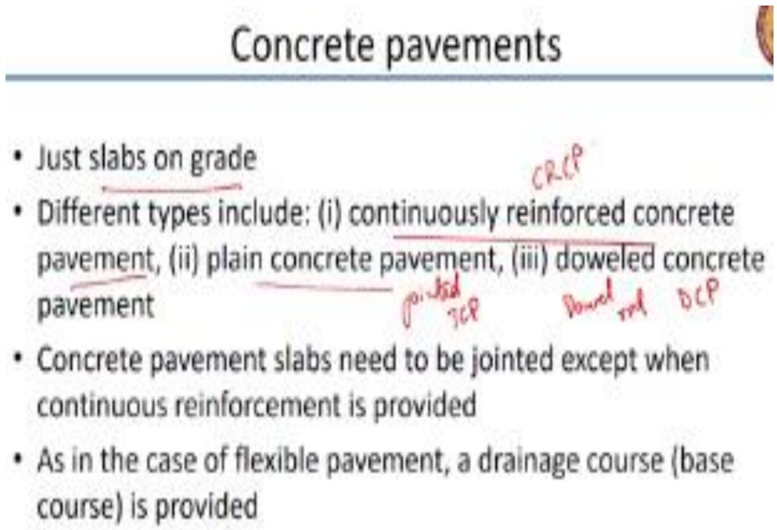

Now we talked extensively about asphalt and asphalt pavements. Now let us come back to the discussion on concrete. We looked at how concrete is applied in buildings? Now let us look at what we do with concrete pavements? So in the beginning of this chapter, we discussed about how a concrete pavement is different from an asphalt pavement? And asphalt payment is a layered system where the top layer is the most high quality layer.

And it distributes the stress in such a way that the subsequent layers below it feel lesser and lesser of the stress. But then the entire pavement accommodates the deformation because of the loading and is able to function satisfactorily because of that kind of an approach. That is why we call it as flexible pavement. On the other hand, the cement concrete layer is rather rigid and it has to take up the loading by its slab-like behavior.

So that is why cement concrete payments are called rigid payments. So, rigid payments are basically described as slabs on grade. That means you take a concrete slab put it on soil that is basically like a rigid pavement. Most of your sidewalks and pavement slabs like that are also slabs on grade. Now of course you do not place it directly on the soil, you need to prepare the surface first and you need to also have the granular material as a base course just like what you did with the asphalt pavement and then you have the concrete slab coming on top.

Now what are the different categories of concrete pavements? As I said earlier, in the beginning that asphalt pavements do not have any joints. But if you want to make a concrete pavement, you will need to introduce joints if it is plain concrete that means if it is not reinforced. Why do we need to put in joints? If you do not have joints in concrete, it will crack because of temperature and shrinkage effects. When temperature goes high it expands, when temperature becomes low it contracts and that creates tension in the concrete pavement.

So if you have a long strip of concrete pavement and you do not provide any joints in it, in a few days you will see that the joints automatically get created because the concrete cracks to relieve the stress that develops because of thermal and shrinkage effects. So concrete will automatically crack, you do not need to do anything to make it crack. So this tendency to provide joints results in what we call as plain concrete pavements which are jointed. So we call them jointed concrete pavements or JCP's.

In some cases, between the joints that we have, we usually put a rod called the dowel rod and that is called DCP or doweled concrete payment. And in some cases you may have the payment completely reinforced. So you just put a single layer of mesh like reinforcement in the center of the pavement and that is called continuously reinforced concrete payment or CRCP.

So as I said you need to have joints unless of course you are going to be continuously reinforcing. If you do not have joints, it will lead to cracking. Now reinforced concrete pavements or continuously reinforced concrete payments have enough steel to distribute the stresses so that it does not result in any cracking, otherwise even that will crack. The steel has to be calculated appropriately to ensure that the stresses get distributed.

And the cracks are minimized or at least cracks have a width that is not easy to be seen by the naked eye or the cracks have a width which water cannot easily penetrate into. Now just similar to the case of the flexible pavement, you need to provide a base course which is meant not just for stability of the pavement but also for drainage. You need to provide that drainage course.

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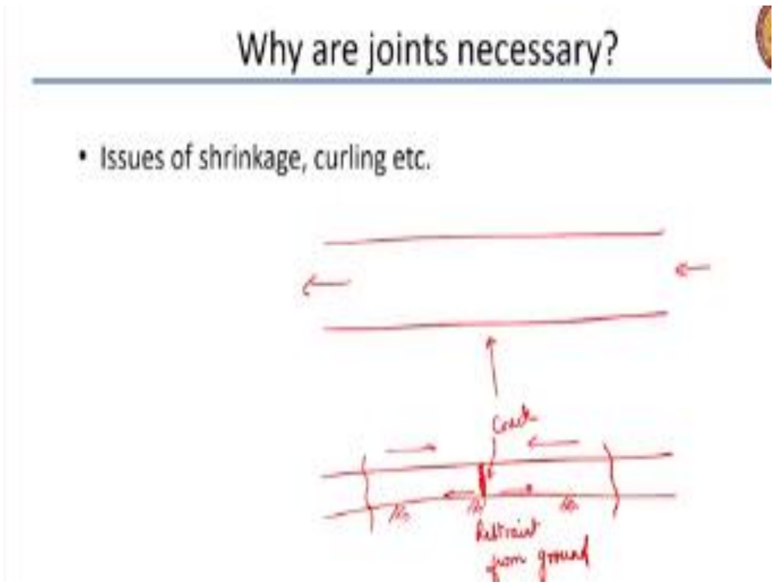

Now of course, we talked briefly about why joints are necessary but there can be other aspects also which may necessitate the use of joints. So let me draw a pavement with concrete, let us say this is a continuous strip of concrete and your vehicles are moving in that direction. If I draw the front view of the pavement, it will be basically a concrete slab like this. So what will happen?

If you consider let us say any small section of this concrete slab because of temperature and shrinkage effects, concrete shrinks. Please remember we had this discussion previously as excess water in the concrete which starts drying out so there will be a volumetric contraction in the concrete. So whenever that contraction is met with a restraint, if the contraction does not get permitted to happen, you will start getting cracking in the concrete.

So this slab is resting on the ground. It is not hanging freely in air; it is resting on the ground. So, if the slab wants to contract because of shrinkage effects, the ground, what is it going to do? It is going to provide a restraint and prevent it from contracting. So because of this restraint what is going to happen is that there will be a tensile stress generated in the pavement slab.

And because of tension, as concrete does not withstand tension easily like most human beings as we also do not withstand tension, we crack under tension and concrete also does the same. So there is a cracking in concrete that happens as a result of the tension. So in jointed contract pavements, what are we doing? We want to make sure that cracks do not appear in any location. In other words we are predetermining the location of cracking. What do we do in that case?

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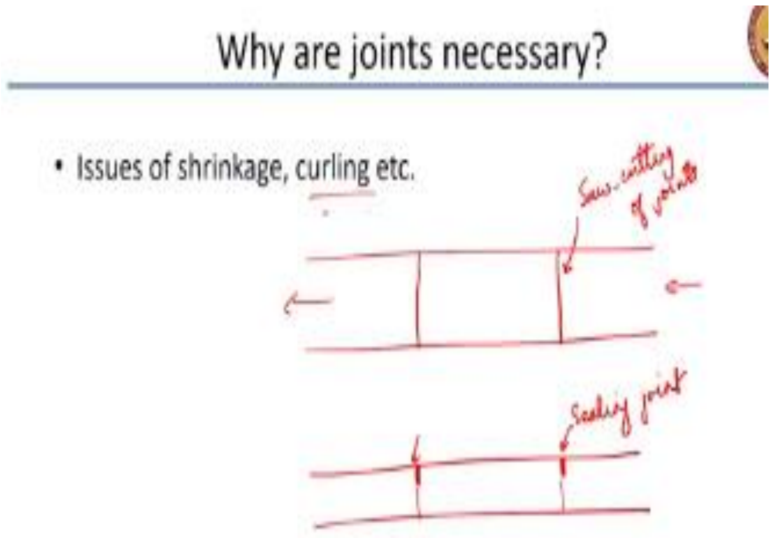

So let us say this is again the strip of concrete. What we are simply doing is cutting joints. We use a concrete saw to cut these joints. This is typically taken up after the concrete has hardened to some extent, not completely hardened because otherwise concrete will become too rigid and brittle and the sawing operation will be met with lot of cracking. So there has to be some degree of hardness in the concrete to take up the sawing and at the same time it should not be very hard.

So we saw cut these joints in the pavement and so now what we are doing is predetermining the location of cracking. So let me just draw the front view of the slab again. So what we are doing is cutting these joints to some depth not to the full depth. Eventually of course because of stress concentration there will be small cracking that will go all the way to the bottom also from the tip of this saw cutting.

Now what will happen is the region in between these joints is not going to crack at all. So that means you have created these joints to pre-determine the location where cracking is happening and what you do next? You are going to be putting a sealing material into the joint. Why do you want to seal the joint? You do not want to permit water to seep into the joint and damage the underside of the pavement.

If water seeps in through the joint, goes to the bottom it will start swelling up the soil and that may cause a failure of your pavement also. So here, the sealing material is put into the joint to ensure that the water does not penetrate easily. So this is the example of why we want to provide joints in the surface. Now this happens because of shrinkage, there is one more aspect that can happen that is called curling of the pavement.

Now curling of course is difficult even with a jointed payment. Now what do you mean by curling? Let us take a look again at a typical cross section.

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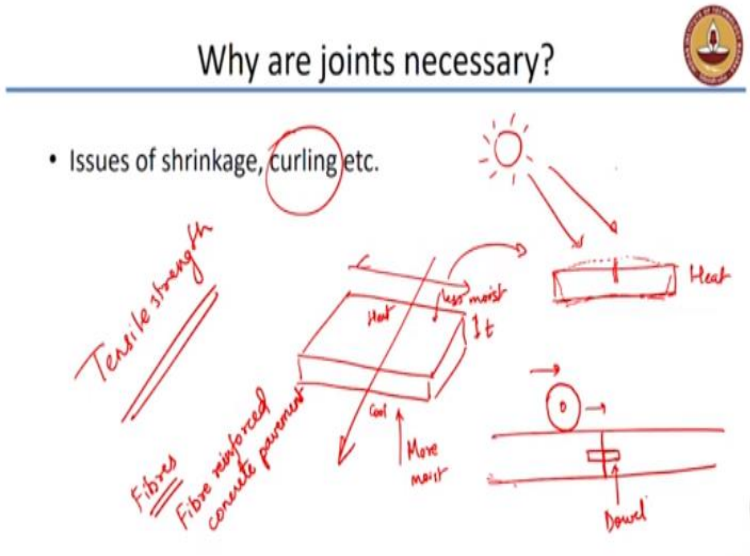

Let us say we have a jointed slab resting on the ground like this. I am just drawing one particular slab which is resting on the ground. Let us say that is the direction of traffic. So in the day time you get lot of solar radiation**.** What is that going to do? It is going to heat up the top surface while the bottom surface will be cooler. Top surface will be hotter because of solar radiation and bottom surface will be cooler.

So what is that going to do? It is going to start bending the slab. If I just draw the slab like this, I am just drawing this dimension here. If I draw the slab like this and solar radiation causes the top to get heated up. So the top is having a higher temperature as compared to the bottom. So because of that what is going to happen? There may be some expansion of the top whereas there will be some contraction of the bottom.

Bottom wants to contract, top wants to expand. So, in other words your entire pavement slab now has started curling, which is why we call his phenomenon as curling. Now what will this do? If the temperature differential is too high, it will start resulting in cracking wherever you have expansion. Because expansion means tension, concrete does not tension then it starts cracking. Now this can happen because of heat caused by solar radiation or it could also happen because of moisture.

So take the case of moisture, obviously there will be more moisture at the bottom and less moisture on the top. So in that case you may get an opposite effect. You may get the bottom that wants to bend or expand and the top that is contracting. So this is heat and this is moisture effect. Note that these are opposite to each other because of the availability of the moisture. So these are aspects that you need to design your concrete against.

And that is why when we talk about cement concrete pavements, it is no longer the compressive strength that is the deciding factor, the tensile strength is also very important. The tensile strength is the property that you will be using to decide upon the suitability of a particular concrete type for use as a pavement slab. It is no longer the compressive strength but the tensile strength. Of course we saw earlier in the concrete chapter that usually tensile strength is related to compressive strength.

The higher the compressive strength, the higher the tensile strength but tensile strength can also be improved or tensile load carrying capacity can also be improved by using fibers. That is why today, people are trying to work out strategies of using fiber reinforced concrete pavements. That reduces the requirement of the thickness; you can reduce this thickness.

If I use fiber instead of plain concrete, I can reduce the thickness of the pavement significantly to take the same extent of loading and also work against the cracking that happens because of curling and shrinkage related issues. Why? Because, fibers will have the tendency to bridge the cracks. So let us say I have a payment like this which is cracking. So if I put fibers inside, they are like sutures, when you have when you have a cut on your face or in your body you put stitches.

The stitches keep the cut from opening up and then there is healing that takes place and then you can remove the stitches. But as far as the payments is concerned when you have fibers, they will bridge the cracks and ensure that the cracks do not open up and that increases the load carrying capacity in tension.

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So again instead of fibers you can imagine that you are using now dowels across the joints. So just to explain this dowels a little bit more let me draw this again here. So let us say I have this pavement here and which has a joint in between. Now what will happen is as the wheel passes on top of the payment, this slab will tend to deflect down. I am just exaggerating obviously; this is this level of deflection for a wheel load will not be seen.

But there will be a deflection of the slab down and as it passes on to this side this other slab also will start deflecting down. At the joint there will be a major deflection of this slab and the next slab. So what will happen is every time that your wheel passes over the joint in the pavement there will be a big depression in the pavement. That means the wheel will bump there and that is not very good for rideability. That means your stress transfer is not happening effectively from one slab to another.

So how do we ensure that the stress transfer happens properly? We put in dowels. What are dowels? This is a joint here and I am putting a steel rod like that. So the dowel ensures that when the wheel moves from one slab to the next, there is effective load transfer. That is what is called a dowel and it is provided at the joint to ensure that there is proper stress transfer between one slab to the next.