Course Name – Pavement Construction Technology
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A very warm welcome to all of you. I am Rajan Chaudhary, 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. 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 sources. Today's lecture will be a continuation of Lecture 5 on bituminous-bound courses and their functions under Module 2. In the previous lecture, we discussed bituminous mixes, which can be used in base courses, binder courses, and wearing courses. We discussed the bituminous macadam used in bituminous base courses.

We discussed the dense bituminous macadam, which can be used as a base course as well as a binder course. Then, we discussed the bituminous concrete mix. which can be used again in a binder course as well as in a wearing course. We also discussed stone matrix asphalt, a special mix designed for carrying heavy traffic, especially in the case of national highways and expressways.

Now, today, we will have a discussion on some other types of mixes; one of them is a gap-graded mix. Now, during the last lecture, we also discussed that most of the time we focus on making our mixes dense, and that is why dense-graded mixes are the most popular in the construction of flexible pavements. Then, there are certain mixes, such as your stone matrix asphalt or gap-graded mix with rubberized bitumen. They have a gap in graduation. Some sizes have been skipped.

We skip those sizes to provide more stone-to-stone contact. And the third category was the open-graded mixes, where you have a relatively high percentage of aggregate to serve a particular purpose. So, the gap-graded mix, especially the one provided by IRC: SP-107, is based on guidelines for a gap-graded wearing course mix with rubberized bitumen or bitumen rubber. Now, this particular mix has undergone good trials in India, along with many other countries such as Sweden, South Africa, and China, and it has been proven to be a mix with good rutting and fatigue resistance. We say that it is a rubberized bitumen because, in this case, the bitumen to be used here will be a bitumen-rubber asphalt, or we will call it an asphalt-rubber binder, which is formulated from rubber discarded from vehicle tires. So, we will have crumbs of them in sizes less than 2 mm, and when blended with hot bitumen, we get rubberized bitumen. So, this is the bitumen

that we are going to use to produce these gap-graded rubberized bitumen mixes. Now, since you have a good amount of these crumb rubber particles introduced into your binder, we will have a high viscosity of this particular binder, and we will be focusing on targeting at least 20 percent rubber by weight of bitumen in this rubberized bitumen. So that they will have a viscosity of a minimum value of around 1,500 centipoise at 177 degrees Celsius.

So, these will form highly viscous binders. These bitumen-rubber mixes possess good resistance to rutting and cracking because they have rubber particles introduced at a significantly higher content. So, it is a modified rubber binder, and even these mixes have been shown to provide good aging resistance, especially because they create a good film of this modified rubberized binder over the aggregates, along with whatever carbon black is present in this rubberized bitumen, offering good protection against UV degradation. So, this also gives these mixes good ultraviolet aging resistance. Now, the grading requirements given by IRC: SP-107 have been reproduced here.

You can see the sizes provided, the different sizes mentioned, and the percentage passing, as well as the cumulative percentage passing for the individual sizes. Now, I would just like to point out that when we discussed the dense-graded mixes, it was mentioned that around 50 percent of the aggregates were coarse. Coarse aggregates, especially in bituminous mixes or in pavement construction, are considered coarse aggregates if they pass through a 2.36 mm sieve. So particles above this sieve are considered coarse aggregate, ranging from 2.36 mm to 75 microns, or I can say the 0.075 mm sieve. Falls under my category of fine aggregates. So, coarse aggregates are those greater than 2.36 mm, while those within 2.36 mm and 75 microns, or what I will refer to as the 0.075 mm sieve, become fine aggregates, and the percentage of the aggregate fraction that mostly passes through 75 microns is the fine aggregate. Now, you can see if you have a conventional dense-graded mix: you have around, say, 50 percent coarse aggregate and around 43 percent fine aggregate. Now, see what is here: this is the range that is passing through 2.36, which is 14 to 22, so here it will be around 18 percent, which will be my mid-value in that case.

Therefore, I will have 82 percent of the aggregate, which is greater than 2.36 mm. So, my coarse aggregate is around 82 percent, and what is my fine aggregate if it is around 18 percent? So, only 17 percent of my fine aggregate and around 1 percent of this one are included. So, this shows the gap gradation, which is created by selecting a particular gradation; we are trying to avoid, especially, the finer parts. And that explains why we are doing it: to produce more contacts between the larger aggregate particles to impart good rutting resistance.

So, a gap-graded mix with rubberized bitumen is preferably used as a single-layer wearing surface. It is used mainly for wearing courses of thicknesses of 40 to 50 mm. As

I mentioned, this will be with respect to your NMAS, and the NMAS is the sieve size where some percentage of the material is retained. So, here it will probably be 13.2 mm, and we normally go for 2.5 to 3 times the NMAS as the layer thickness, which results in around 40 to 50 mm of layer thickness. And even this particular one, if there is an existing surface with some minor cracks, exists. So, in that particular case, we also prefer to give it as a wearing course. So, it prevents the cracks from coming up in any underlying cracks that do not reappear in the top course. So, it also acts as a reflective crack-resistant overlay.

So, finally, this helps to enhance the pavement's performance and longevity. So, this is a specific type of stone matrix, as it is a specific gap-graded mix that is gap-graded and contains rubberized bitumen. Now, the other categories we discussed are dense-graded, gap-graded, and open-graded. One peculiar mix in this particular category is open-graded friction courses. Now, the term itself says it is open-graded, and friction means it has some qualities that impart additional frictional resistance to the surface.

An open-graded friction course is a thin surface layer; typically, it is constructed with a thickness of 1 to 2 inches and is not considered a structural layer. So, my pavement design will not be part of my pavement crush because the thickness is usually around 1 inch. So, the thickness is quite low; that is why it is not considered a structural component. And they are known by different names: it is referred to as permeable asphalt, porous asphalt, friction asphalt, or friction courses in different parts of the globe. And so it is usually placed over an existing dense-graded or impermeable layer.

So, there should already be an impermeable layer where you place this particular mix, and what is the specific purpose for which these kinds of open-graded mixes are used? You can see whether I have an existing road surface layer that is impermeable. So, it may be any dense-graded mix I am constructing, or if I put a layer of this kind, which has high permeability or a high amount of voids; that is why it is open-graded. So, whatever water comes from the rain goes into the layer. Now, what is the purpose of how it is designed so that any rainwater enters this particular layer, and with the help of camber and cross slope, moves out to the sides? So, the sides are to be opened, and the water is to be properly collected from these layers. So, this way, there will be no movement of water over the surface; otherwise, conventionally, what happens is that whatever dense gradients we use in bituminous pavement construction, the rainwater falls onto the surface, and with the help of the camber, it moves across the pavement surface to the side drains.

Here, it will move to the sides, but it will also move within the layers. So, I will show you how it's done. Now, as you can see, there are two surfaces: one is a conventional dense-graded surface, and the other is an open-graded surface. Here, on this conventional

surface, water is moving to the sides with the help of camber. So, you will find some presence of a water film in this particular area.

Whereas in this other one, these are your open-graded friction courses; in this one, water immediately enters the layer and then flows within it. So, you will not find any water on the surface. Similarly, this has been shown by preparing some specimens at the laboratory scale. So, if water falls over this dense kind of surface, it moves over the surface only; it does not go inside the layer, and if it is open-graded, it moves within the layer because it is highly permeable. Now, we have the Indian Codal Guidelines IRC 129, which provides recommendations regarding the construction, aggregates, and binder components of OGFC mixes.

This is the aggregate gradation; you can see that the nominal thickness mentioned is approximately 25 mm. So, typically they are constructed for 1-inch thicknesses, and here they are not considered, as I mentioned; that is why they are not considered a structural layer, and it allows for quick removal of surface water. Thus, the surface is able to provide, and since no water film is present, if water is on the surface, the chances of skidding are present because your tire may lose contact with the surface; this probability is reduced. This phenomenon, where a tire skids because of the presence of a water film on the surface, is known as hydroplaning. And this phenomenon is significantly reduced in the case of these types of mixtures.

And here, you can also see that I mentioned that for the dense-graded one, there was around 50% coarse aggregate and around 45% fine aggregate. Here, you will again see that this has a 7.5, which is considered midrange. So, about 92.5% of your coarse aggregates is a very high percentage, and the other percentage is also very low compared to what we had in the gap-graded.

So, this imparts a very high amount of air voids, normally in the range of 20 to 25 percent in these types of mixes. So, here is why these kinds of mixes are preferred or used in specific places, especially when there is heavy rainfall. Now, see, this is an example: this is a four-lane divided carriageway; you can see that this is a two-lane road with a paved shoulder alongside it. Now, whenever a rainfall event occurs, water moves with the help of camber, and there may be some minor undulations. So, since the pavement becomes wider, water takes time from these median agents to travel to the site.

So, you will always find some form of water existing on it, and when traffic plies over it, you will find splash and spray occurring when any vehicle tire, especially heavy vehicles, moves at a faster speed; a lot of splash and spray are generated, which specifically reduces your visibility. If, instead of this particular one, you choose a surface that absorbs water into the layer, then you will not immediately find any water films on it. So, the benefit is that it quickly removes the surface water, reduces the chances of hydroplaning

and skidding, because if you apply the brake when a film of water is on the surface, the chances of skidding are very high. Splash and spray because if you are traveling behind any such vehicle, splashes are present, your visibility is reduced, and this becomes more challenging, especially when you are driving at night. So, some other salient advantages that these kinds of mixes normally offer are that you can see here how a heavy vehicle generates a good amount of splash and spray because the water takes time to be removed from the surface; whereas, in the other case, during nighttime, when the water film is present, a lot of glare is also produced.

The presence of a water film and glare even brings challenges in seeing your pavement markings and roadside features. So, visibility is impacted when this water film is present. So, you will have another important advantage with this kind of mixer since it has many voids. So, whenever a vehicle tire moves over it, noise is generated by the interaction between the vehicle tires and the road surface. This noise gets trapped in these air voids.

Otherwise, you might have heard in the newspapers that noise barriers need to be installed. You need to fix the noise limits, especially in residential areas, hospital areas, and educational institutes, because a lot of noise normally occurs. A part of that noise is produced by the interaction of your vehicle's tire and the road surface. So that is significantly reduced because the noise is trapped at the source itself. So, this is because of this feature; it has been quite popular in some countries like Japan and the Netherlands, where it is used especially for noise reduction purposes.

So, we can see it since this glare, the splash, and the spray are reduced. So, you get good nighttime visibility, and with this visibility, glare is reduced, which significantly improves road safety. Especially under rainfall events or wet weather conditions, where skid resistance is significantly affected. So these are some typical features of these open-graded courses. Now these are some of the courses that we prefer to use on different kinds of national highways, state highways, and expressways.

Then there are some typical mixes that are often used for low-volume roads or for urban sections where you do not experience a significantly high amount of traffic in terms of the axle loads. So one of them is your surface dressing. Now, this surface dressing is used as a wearing course for low-volume roads, and it has been popular throughout the globe since the 1920s in different ways; it has been practiced in different parts of the world. Now, this provides the wonderful part: it provides a water-resistant paved surface for the movement of traffic. As we discussed in earlier lectures, the entry of water into your pavement structure can create significant distress and reduce the structural integrity of the pavement significantly.

So, you want that surface to be water-resistant. So, in that case, water is done in this particular one especially, and that requirement is there even if low-volume roads are

present or roads having a lesser amount of traffic are there. So it is known by different names, and in different countries, one common name that has been used for these kinds of mixes is chipseal. Now what is there? It is a combination of a bituminous binder along with an application of chips over the surface we will see. And it has been recommended by the guidelines available from IRC 110, as well as by the rural road manuals, and you can see how the progress has been there, specifically in the enhancement of the understanding of these kinds of mixes.

In 1965, we had the first codal specification, and presently, what we have is IRC 110-2005. So, how has progress been made in the knowledge enhancement over these kinds of mixes? Now, if a single application of this kind of mix is done, first of all, you prepare a surface; if it is a low-volume road or rural road, you will prepare a base course, a granular base course, and then you put a tack prime coat over it. We will discuss the prime coat and tack coat at a later stage; at this moment, you can just say. I will put a thin layer of bitumen over a granular core so as to seal the voids' surface and make that surface ready to take up a bituminous layer. So that is what I am doing; if it is a granular course, I will put a prime coat, and then I will go for the construction of this surface dressing.

If there is a delay between this particular process of laying a bituminous layer, I may need to put one more layer of bitumen, which is normally known as a tack coat. Otherwise, if it follows the construction of the surface dressing, then over the granular course, you put the prime coat, allow it to set, whatever binder is there, and then you go with your surface dressing course. Here, what is done is that we put a thick film of it; this is important: a thick film of bitumen is first sprayed on a compacted granular WBM or WMM layer using a bitumen distributor fitted with nozzles. So, what I will do is prepare the existing surface by brooming and cleaning it in a good manner, and then I will put a thick layer of bitumen over it. After this particular one, stone chips or aggregates are then spread using a mechanized chip spreader so that there is a uniform distribution of the chips, and in some cases, the chips, or stone chips, may be pre-coated or otherwise uncoated.

So, I will spread these chips over this thick binder film, and then they will be lightly rolled so as to only sit inside that bitumen. Now, what is happening, you can see, and this is how the surface looks. So, you will see there is a lot of this texture; these aggregates are more or less single-size aggregates. So, a lot of textures are created. So, it provides good skid resistance because water gets a path to escape between the surface and the vehicle tire when a vehicle tire comes.

Now, what is happening is that I am putting up a bitumen thick film; this good thick film I have put on the surface. Now, this thick film will make my surface impermeable because if a thick layer of bitumen is applied over any surface, it will make that surface

impermeable. Now, in that particular one, I am putting up these aggregates, and these aggregate sizes, and the binder film is designed or taken in such a manner that around three-fourths of this particular aggregate gets embedded inside this one. So, the aggregates are held in a good manner inside the binder film. Now, this aggregate gives you a good wearing surface, and this binder that is present is going to give you a good impermeable surface.

So, that is why it serves multiple purposes, and again, it is not a structural layer because it has a very small thickness, maybe around 20 mm only. So, why are there several benefits we can derive from this kind? It provides a dust-free wearing course because you seal the surface with a thick film of bitumen, especially whatever grain is normally used in rural roads or low-volume roads, where you use water-bound macadam or wet mix macadam. Then, it enhances the impermeability of the surface because a thick film of binder is applied over it. Offering a rider's riding surface, as I said, the texture looks open, so it provides good skid resistance as well. To arrest minor distress, if there is an existing bituminous surface with some minor loss of aggregates and minor cracks, I can proceed with the application of surface dressing, which will help me address these minor defects in the existing bituminous surface.

To serve as a renewal code for periodic maintenance. So, this can be done for urban sections as well as for rural sections if I need to, because in urban sections, you do not get much damage, severe rutting, or fatigue cracking; minor defects may be present. So, you can put this up as a renewal code. So, because of its waterproofing and skid resistance capabilities, this surface treatment, specifically for low-volume roads to medium-traffic volume roads, is quite popular in India as well as many other countries; as I said, it is known by different names, such as chip seal in Australia and many other European countries. Now, similar to this one, we have another mix, which is premixed carpet that is also used on low-volume roads or rural roads, I can say. Now, this also has a significant feature, and how this mix is constructed, we will discuss.

So, it is a premix carpet, which means I am mixing something and doing some premixing with this particular one, mainly consisting of laying about now again at 20 mm thick. And here it says, "open-graded." Now, this is the thing: what gradation I am picking up is unclear. Actually, I'll be using single-sized aggregate. And when single-sized aggregates are used, they make my gradation open.

So, that's why it is mainly referred to as an open-graded, premixed carpet. Now, when this kind of mix is laid on top of it, we seal the surface. So, we will apply a seal coat to seal the surface of this open-graded mix from the top so that water does not enter it. So, this particular one is explained through our IRC 14-2004, the application of premix carpet with the application of your seal coats, and two types of seal coats are explained under

this particular guideline. So, it consists of constructing an open-graded mix using paving; you know, different types of binders are used.

Most probably, the preferred ones are either paving grade or, when we discuss the characterization of bituminous mixes, we will discuss what the different types of binders are. One is that you can see a binder that needs to be heated up before it is applied. So, that is a paving-grade binder; it does not require heating, which can be your bituminous emulsion. So, it can be applied at ambient temperature. Later on, we will discuss more during the bituminous mix design about what bitumen immersion is, what a paving-grade binder is, and what a modified binder is.

At this moment, this is good enough. So, I can make an application of bitumen immersion at ambient temperatures without heating it. It is because it has a low viscosity at ambient temperatures. If I use a paving binder, I have to heat it. I am able to mix it so that its viscosity is reduced. So, once this open-graded mix is layered, it should be followed by the application of a seal coat.

Two types of seal coats are recommended here: a liquid seal coat and a premixed seal coat. Now, let us see what else there is. So, here you can see that this is an application where you are applying the open-graded premix surface. The premix coat is being applied to a rural road. Now, the aggregates for premix carpet typically consist of a blend of two predominantly sized aggregates: one is 13.2 mm, which means it passes through 22.4 mm and is retained on 11.2 mm. So, you can see that there are more or less uniform sizes, and the other size that is required is 11.2, which means passing through 13.2 and retaining 5. So, these two sizes are required, as mentioned here, and the quantities are specified in terms of the amount required for 10 square meters of area. So, if a 10-square-meter area is to be constructed, then in that particular case, 0.27 cubic meters of aggregate should be used in that 10-square-meter area of premixed carpet lane. And along with it, the aggregate requirement, once that premixed carpet is laid, is the requirement for a seal coat. So, in seal coat type A, which was mentioned as a liquid seal coat, there is again some requirement for aggregate; it states that the coarse aggregates to be used are of 6.7 mm sieve size, passing 11.2 and retained on 2.8, and then there is premixed seal coat where the aggregates are of smaller sizes, passing 2.36 and retained on 180 microns. So, this and its requirements are given again, and they are also provided with respect to the 10 square meter area. So, once this surface is laid on top of it to seal the surface, and because this is an open-graded surface, you need to apply a seal coat.

So that the voids are sealed. Now, as I mentioned, different types of binders can be used. One is the viscosity grade binders, which need to be heated up and modified; however, not very popular binders are not popular. It mentions how much of each quantity is required. Their aggregate was given as 10 square meters of area. What size of aggregate A is required, and what size of aggregate B is required? Then, for that, A was 13.

2 mm NMAS, and this was 11.2 mm. For those, they also provide the required quantities of binder. It states that you require approximately 52 kg of binder per cubic meter. That means we were using the quantities in terms of 0.18 cubic meters and 0.09 cubic meters. So, it says that either in a 10-square-meter area you use 9.5 kg or 5.1 kg. So, you will be using about 14.6 kg of binder in that 10 square meter area to produce that open-graded premix, and once that is laid, then comes the seal coat.

For that liquid seal coat, you make an application of around 9.8 kg of binder in a 10 square meter area. Once the premix carpet laying is done, you spray the binder, which is a quantity of 9.8 kg, on top of it, and you put the chips over it. The chip sizes are already mentioned to be in this range.

So, this quantity of stone chips has been applied. So, this is how you seal the surface. The other says that in the other case of seal coat, this fine aggregate is to be mixed with this quantity of binder and applied over the surface so that it covers it. So, this is how we do the premixed carpeting and seal the surfaces. Now, many times a challenge may arise; specifically, one must be very careful when applying the seal coat. Because if the seal coat application at some point in time and in some places is not properly applied, you can see, "This is my seal coat, this is my premixed carpet, this is my seal coat.

If there is a part where the seal coat application is not very proper or adequate, then the rainwater may enter. And once it enters, because it is an open-graded mix, the water will be present in this particular mix itself. And we have not designed it, considering an open-graded mix for the movement of water to the lateral drains. So, this water will remain in this layer. This will damage the underlying layer if it is a bituminous layer or a granular layer, and the layer itself will be damaged.

So, the application of the seal coat has to be done carefully to ensure that the surface becomes impermeable. So, these are some of the mixes that fall under different categories, and we call them bituminous bond mixes for this particular discussion. Thank you so much.