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A very warm welcome to all of you. I am Rajen Chaudhary, a Professor in the Department of Civil Engineering at the Indian Institute of Technology, and the instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Now, today's lecture will be under module 6, and it will be a continuation of our talk, where we discussed the construction aspects related to different granular courses. We discussed the construction aspects of the granular sub-base course, then we discussed the construction aspects of the water-bound macadam course. So, we will continue our discussion on granular base courses in today's lecture. At the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches.

So, the other very popular granular course is the wet mix mechanism, which is preferably used as a base course in the construction of road pavements. It is quite popular because it provides a very durable granular base course in pavements when compared to water-bound macadam. The preference is given more to wet mix macadam, especially when it is to be used as a granular base course or, in some cases, as a granular sub-base course, and the reason behind this particular choice is that the wet mix mechanism offers advantages, including superior aggregate gradation. The gradation is superior in terms of the density it is going to provide.

Faster construction rates are present with this kind of material, as you have seen in the case of the waterborne mechanism; the coarse aggregates have to be laid and compacted first. Then thereafter, the screenings have to be applied along with the sprinkling of water, and it has to be compacted. Then, thereafter, the binding material must be applied. So, a lot of care has to be taken during that process. So, that delays or, we can say, reduces the construction quantity specifically.

So, the construction rates are much higher specifically in the wet mix mechanism when compared to the water bond mechanism. Higher standards of compaction; the requirement is higher specifically. Reduced water consumption, as we have seen, occurs during the application of screenings, during the application of your binding material, and during quality control, because most of the time, the production of this mix is done through a wet mix plant. So, a better control is there, and then it is laid in the field with the help of a paver as well. So, in both cases, you get better quality control with this wet mix macadam when compared to water bound macadam.

So, the key steps involved in the construction of a wet mix macadam are the preparation of the base, as we did for the preparation of the base even in the case of granular sub-base courses, and even in the case of water-bound macadam. So, every time whatever layer has to come up, the existing layer has to be made ready in terms of the upcoming layer that is to be constructed. Lateral confinement of aggregates, specifically the material that has to be there, preparation of the mix, which is in this particular case most commonly done through a wet mix plant, spreading of the mix,

which can be done with a motor grader or with the help of a compaction, has to be carried out, and the setting must be examined for any undulations or depressions. So, that needs to be done, checked, ensured, and then it has to be left for 24 hours before finally opening to traffic. So, in addition to our MoRTH guidelines, which are with us and provide information about the wet mix macadam. We also have IRC 109-2015, which is a guideline for the wet mix mechanism.

Along with that, we have IRC 126-2017, which is a guideline on wet mix plants. So, these are additional guidelines available from the Indian Roads Congress. Now, coming to the construction operations, one climatic-related challenge or seasonal-related challenge is that this construction should not be carried out when there is a rainfall event. So, we will avoid this kind of event because it will disturb the foundation and the construction in terms of composition due to the increase in water content. So, during a rainfall event, the laying of wet mix macadam is avoided.

Now, as the preparation of the sub-base or the preparation of the underlying course is important whenever you are doing new construction, you need to ensure that the existing surface is to the specified lines and camber because that will help us maintain the camber and the levels for the layer of wet mix macadam as well. And if it is thoroughly cleaned of dust and other extraneous materials, then it needs to be cleaned. And since most of the time you will have granular sub-base courses over which you follow with the construction of a granular base course, if you find that any movement of the construction vehicles may occur over that particular one, it is always advisable to allow the movement of the construction vehicles over these layers that are being constructed. So, any ruts, but if unfortunately, this happens, any moving traffic gets shifted over it, because of which any ruts or soft spots are created; they need to be rectified and compacted. That can be done specifically by opening up the surface, adding and sprinkling water, and again doing the compaction so as to get a firm surface.

Laying WMM over an existing bituminous surface is usually not permitted; the same was the case when we discussed the water bound macadam as well. Lateral confinement of the wet mix layer, whenever these layers are to be laid, as you can see on this particular side, if we are laying it and if this side is at a lower level compared to the level of your wet mix macadam, then while compacting at the edges, the mix will slide down. This will lead to a reduced thickness as well as a lower density at the edges. So, for that particular reason, we need to confine those edges, and the easiest way to do that is by simultaneously constructing the material that is to be in the subgrade. So, it says that during the construction of wet mix macadam, appropriate arrangements are made to ensure lateral confinement of the wet mix, mainly achieved by simultaneously laying the material for the adjoining shoulders.

So, when we do this particular exercise, especially for wet mix macadam, it is important to pay attention to the details. So, in the case of granular sub-base courses or drainage courses, they are extended to the open edges, but when it comes to your granular base courses, you start with the construction of the shoulders by putting down some specified material, mainly for shoulders; for southern shoulders, we go for subgrade soil. The soil that meets the requirements of the subgrade construction is preferably used for your earthen shoulder construction purposes as well. So, we will go for simultaneously laying the material for adjoining shoulders along with the WMM layer; it says it is to be ensured that the construction of the shoulder is carried out in layers, and it should

not happen that there may be two layers of WMM, each of which may be 100 mm or 150 mm in thickness. So, the total WMM thickness is 300 mm.

So, the entire 300 mm thickness of the subgrade adjacent to the WMM should not be constructed in one go. You should prefer to go for the construction that is in line with the layer you are constructing. So, if the WMM layer is 200 mm thick, you will prefer to go for the subgrade with a thickness of 200 mm. So, it is carried out in layers, each corresponding in thickness to the adjoining pavement layer. So, that will give you the confinement that is required for compacting that particular layer.

The next layer of the pavement and shoulder shall only be removed. After the previous layer or both have been properly placed and compacted, this is always there. In actual construction practices, we normally put up a request for inspection. So, the abbreviated form is RFI. So, we put in a request for inspection that we have constructed a layer.

Now, the agency can come and inspect it, and if that is found okay, permission is given for the construction of the next layer. So, once the existing layer has been ensured for whatever the parameters in terms of density, strength, gradation, and levels, it needs to be checked and ensured; thereafter, it gets permission for the construction of the next layer over it. Now, the production of this particular wet mix macadam is preferably made in a wet mix plant. So, now here, because we need good control in terms of aggregate proportioning, we need good control in terms of the water content, we need to avoid any segregation, we need to have uniform mixing, we want to achieve a high production rate, and along with that, we prefer to bring down the cost per unit of production as well. So, for those purposes, the wet mix mechanism is mainly produced with the help of a wet mix plant.

It says it is, and we have caudal guidelines that give you the information about the wet mix plant. This wet mix plant can also be used specifically for the production of granular sub-base courses and can even be used for the production of cold bituminous mixes, and sometimes it is also used for the production of soil-stabilized courses. So it can be put to multiple uses. For wet mix macadam, which is used mainly as a base course, we prefer using a wet mix plant. Now the wet mix plant must have a system for a controlled addition of water and should have a forced mixing method similar to a pug mill.

So, we will show how a pug mill looks or a pen-type mixer, which is normally used for a concrete batching plant. So, a forced mixing is present to achieve a uniform mixture and to avoid any sort of segregation. So, the WMM plant should have features for feeding the aggregates. Now, I will show you this on the next slide. Also, you can see here that the features will include these cold feed bins; the bins are there, and I will show a more detailed one in the next slide.

So, what are the arrangements that are required because there may be 3 or 4 different sizes of aggregates that you may be proportioning for use in wet mix macadam? So, you need bins where these different sizes can be stored, and from these different sizes of the bins, it has to be taken up in the required proportion. We normally have a screening deck to separate out the oversize aggregates, which are then taken to a pug mill mixer where the right quantity of water is added, mixed, and then taken out. So, we need to have a proper arrangement for feeding aggregates. A

conveyor belt is there to take the aggregates from these bins to your pug-mill mixer. In between, we have a vibrating screen, so unfortunately, some oversize aggregates may have come into the stockpile, which need to be separated out, and all this is done through a control panel.

So, you control all these functions while sitting near the plant, where you can control the speeds of your conveyor belts and look into the openings of these bins. So, all these exercises are done, and normally a wet mix plant with a capacity of around 100 tons per hour to 300 tons per hour is used for producing the wet mix macadam. This plant should work. in a manner, which can give you a controlled mixing in terms of the moisture content. So, optimum moisture content shall be determined, which has already been determined in the laboratory as per our IS 2720 part 8, where we determined the relationship between moisture content and density.

So, that is to be added during the production of the wet mix mechanism in this pug mill, and we need to take care of any allowance that is required for the environmental losses that can occur during this production process. So, you can see here is the dry aggregate that is moving through the conveyor belt; then here we are in the pug mill mixing it with the water, and finally, it is coming out, and the tipper is going to carry the prepared mix to the site. So, this is a clear picture of a wet mix plant where the different components are shown; you can see that these are bins 1, 2, 3, and 4. There will be auxiliary conveyors for each individual bin, and there will be openings to these bins. So, aggregates will come out depending on the required proportion that you have achieved during your design.

So, the gates will be opened, the auxiliary conveyor will put your material over the feeder conveyor, which is there, or the gathering conveyor, which is there. There is a bottom gathering conveyor that will collect material from all these bins. Then, we have a vibrating screen here, so we drop the material over the vibrating screen; it is a single-deck vibrating screen, designed to separate out the oversized material. Then, once that is done, it moves through the slinger conveyor to your pug mill unit. and where the required quantities of water are added to it and then it is mixed in the pug mill.

And then it is taken out; the load-out conveyor is there, and the tipper will come here. The mix will be poured into it. If the rate of production is high compared to the availability of tippers, it can be stored in your storage silos. And this is a control cabin through which all these activities will be controlled. So, a WMM plant has provisions for controlling the feeding of aggregates of different sizes in the required proportion.

So, this is important; whatever proportion you have finalized to achieve the target gradation can be well controlled in this wet mix plant. We will discuss these plants again when we discuss the bituminous mixes because the mixes are commonly produced by using these highly advanced plants, which we also call hot mix plants. So, bituminous plants there again have some features that remain common. So, we will discuss those features again during the discussion about the bituminous mix plants. Some of the features will be discussed there again.

So, the addition of a specified quantity of water in addition to the water, if we are looking for some stabilizing additives, also many times cement may be used or lime may be used; then that controlled addition can be done specifically to the pug mill along with the addition. So, we will have dedicated bins that will be there for what we can call the filler material, which may be your cement, hydrated

lime, or any other stabilizing additive. So, the addition of a specified quantity of any other ingredient or additives, like lime or cement, is also possible. First, mix all the ingredients to produce a consistent mixture. So, this is important: what we get there is a uniform mixing of water, a uniform mixing of any additive that is incorporated, and the produced mix does not have any segregation.

So, this is a benefit when we do it with a wet-mix plant. Now, further, some of the components are shown here and explained, as I mentioned that we, and this is depending upon how many different aggregate sizes you are proportioning; there may be 3 bins, or there may be 4 bins. Typically, it ranges from 3 to 5 bins. So, we have these individual bins. So, from dozers, the materials will be shifted to these bins, and then, as I mentioned, there will be individuals.

We will discuss more about these cold mains in bituminous plants as well. So, there will be an auxiliary conveyor under each one of them so that the gate will be opened for this one and it will fall onto the gathering conveyor. This gathering conveyor will collect material from this bin as well as from the auxiliary conveyor. So, the individual conveyor is also there, and the one at the bottom is the gathering conveyor, which collects the materials from all these conveyors. So, a gathering conveyor collects aggregates of different sizes from the auxiliary conveyors fitted under each bin and discharges them into the slinger conveyor.

But before getting discharged into the slinger conveyor, there is also an oversize removal screen. Once the gathering conveyor is there, it collects material, and the speed of the auxiliary conveyor and the individual gate opening of each of the bins are to be controlled in a manner to achieve the desired proportion of each size. So, if you have A, B, and three aggregates to be used in proportions of 40, 50, and 10 percent. So, this has to be controlled through the opening of this particular one and the auxiliary conveyor speed to achieve a proportion of 40, 50, and 10. Once the gathering conveyor is there, if by mistake some larger materials have entered into the stockpiles, oversized materials can be removed through this particular screen.

So, the gathering screen drops a material on this oversized removal screen, and what is it? It is a single deck vibratory screen. With an adequate screening area, a bigger screening area, and an appropriate vibrating mechanism, it is there. So, it is a single deck, so we will separate out the top oversized materials, and the bottom-sized materials that are accepted for this particular wet mix mechanism will then move with the help of this slinger conveyor to your pug mill mixer. A single size DAC vibrating screen with adequate screening area and an appropriate vibrating mechanism is installed at the discharge end of the gathering conveyor. So once the gathering conveyor, which collects the material from these bins, discharges the material to this particular oversize removal screen.

To reject any oversized aggregates before they can be fed onto the slinger conveyor. So, once this conveyor is there, it separates out the oversize material, and then the slinger conveyor comes into the picture, which takes your material to the pug mill. A pug mill typically consists of what is there; you can see this is an example of a pug mill. So, it is a twin shaft system; typically, we have a twin shaft system with each shaft equipped with high abrasion resistance; these are pedal arms. These are pedal arms that are present, and the number of pedal arms or tips also depends on the capacity of that particular plant.

And these pedal arms, or in this particular pug mill mixture, help to facilitate effective forced action mixing of aggregates and binder. So, the aggregate and binder here are water and any other additive that is to be added. If there is no additive, then it will be aggregate and water only. So, once this mixed one comes from the pug mill, you will have a good gradation along with a proper mixing of water; this is what is aimed for once it comes out of your pug mill. Now, from the pug mill, you will look into whether it can be directly put into the tipper or if it has to be stored for a period of time before it is finally laid and compacted in the field.

Now, when it comes to the field, once this is produced, we have done it through a wet mix plant for better quality control or for a homogeneous mix with a uniform controlled water content. Now that particular mix is brought to the field, it is preferred that we go for the laying of this wet mix mechanism with the help of a mechanized paver. The different components of pavers we will discuss when we discuss bituminous mixes because pavers are widely used in the construction of bituminous mixes. So, here I will just give you an example. So, whatever mix that has been produced from your wet mix plant that comes here is dropped into this hopper, and then it comes out on this particular end, and you get a uniform thickness of the loose mix.

Now, through your trial stretches, you will work out what the loose thickness should be in order to achieve your final targeted compacted thickness. So that needs to be done through trial stretches where you will decide how the compaction has to be carried out with the available compaction equipment or rollers that you have. So, this will depend on the material composition, your compactive effort, and the type of rollers that you have. So, from your trial stretches, you will work out how much loose thickness needs to come out. So, this paver will help you provide your loose mixes to the required camber as well.

So, the required camber, or I will say the cross slope, can be this screed, which gives you the required camber and slope. So, the loose mix will come up to the required thickness, and this takes good care of your cross slope and levels. So, the paver is very helpful equipment for getting a proper profile and thickness of your loose mix. So immediately after mixing, the material should be uniformly and evenly spread over the prepared subgrade. Normally we do not go over subgrade; we go over a sub-base course or a base course because there may be two layers of WMM there.

Then there may be one layer of WMM1 and WMM2 in the required quantity, preferably using a paver finisher. But in many cases, small projects may not have a paver finisher with you. Then in those particular cases, you may need to use a motor grader, which we saw when we were doing the spreading in the case of granular sub-base courses. So that motor grader may be used; otherwise, for bigger projects, we will always prefer to go for a paver finisher. In specialized cases where it is not possible to utilize the paver, mechanical means like a motor grader may be used, but with prior approval.

The motor grader shall be capable of spreading the material uniformly over the surface; then the uniformity of the material must be maintained, and the cross slope must be maintained with the grader. So, it needs to be ensured that you have to be more careful, specifically when this is done with a motor grader compared to the good quality control that you achieve with these pavers. Now, in addition to this particular one, when the mix is transported and spread over the surface, you need to ensure that the hauling of the mix over a freshly compacted stretch is not permitted because that

may disturb or stress the existing course, which is freshly laid; if the construction vehicle moves over it, it gets distressed. So, we will avoid hauling the mix over the freshly prepared surface. To avoid moisture produced from the wet mix plant, which may be 20-30 kilometers away from your actual construction site, there are guidelines for establishing the wet mix plant in terms of environmental regulations.

So, if it is far away when you bring the wet mix to your construction site, there may be a loss of moisture there. So, to avoid that loss of moisture, we may also cover the mix using some tarpaulin. So, when the mix is brought through the use of tippers, it can be covered so that the loss of moisture is minimal. Here you can see again that the spreading is done with this particular one.

This is done with the help of a screed and a paver finisher. We will discuss these components of paver finishers in detail when we discuss the construction of bituminous mixes further. So once this particular part is done, thereafter the compaction starts. Now, here before this one, as I mentioned, the paver can ensure it gives you the loose thickness that is to be there. So once that loose thickness is present, the compaction process starts, and the layer gets compacted. So, we have to pick up the rollers according to the thickness that needs to be compacted so that the entire thickness gets compacted and a uniform density is achieved.

So, it says for a thickness of up to 100 mm. A smooth wheel roller weighing between 80 and 100 kilonewtons may be used specifically for a thickness of up to 100 mm. And when the thickness is up to 200 mm, this is the maximum thickness usually constructed with a wet-mix mechanism. So, a vibratory roller of 80 to 100 kilonewtons is to be used, and this will have, as we have seen, a combination of your frequency, vibration frequency, and amplitude, which we work out. So, we need to see, as we have seen earlier, that initially we can go for higher amplitudes and lower frequencies, and later on, when they may become stiff.

We will prefer to go for lower amplitudes and higher frequencies. So, this is when we are doing the compaction for a thickness of 200 mm; we will prefer to use vibratory rollers. Now, again when we are doing this compaction, we need to ensure that if there is a one-sided cross slope, especially at super elevations, we will prefer to start from the lower edges and go towards the upper edges. If there is a camber there, then we will prefer to start compacting from the edges and move towards the center. So, this needs to be ensured: if this kind of thing is there where a camber is present, then we will prefer to start from the edges; we specifically go for compacting the edges first, with to-and-fro passes over the edges, and then we will move towards your center line or the camber. Now, during this particular part, when these roller passes are present, at least one-third of the previous pass should be overlapped by the next pass.

So, this is to be taken care of. So, this is done when you have a camber if there is a cross slope, specifically in the case of your superelevation; we start from the lower edges and go towards the upper edges, which we also call the inner edges and outer edges. And preferably we go for compaction at roller speeds that are around a maximum speed of about 5 kilometers per hour. Now, in addition to this particular one, it is important to ensure that the moisture content remains in the range of plus or minus 2 percent of OMC. See, this is a dense material where, if additives are present, then it is very important that the amount of water content is as close to your OMC as possible to achieve the required density, because when you prepare the trial stretches, you will also

be preparing them within a given range of your optimum moisture content. So, that compactive effort will be able to achieve density only if the moisture content is within that prescribed range.

So, it is very important while transporting the mix, and it should not be left open. Immediately after the wet mix is laid in the field, we should start with the compaction process. Rolling shall continue until the achieved density is at least 98 percent of the maximum dry density. So, this is again an important requirement that when we, simultaneously in the next lecture, will discuss the checks or the field control tests that are done to ensure the density and the levels of this particular one during the compaction itself continuously. We got an idea from trial stretches as well, but again we can do some monitoring specifically to ensure that the compaction has given us a density that is more than 98 percent of your maximum dry density.

Now, once this particular part is done, it is always advisable that the wet mix macadam course, which is constructed, shall be allowed to dry for 24 hours before the next course is constructed. So, this is again important that once you have constructed a wet mix macadam surface, this is how a compacted surface look. It should be allowed to dry for at least 24 hours before we proceed with the construction of the next layer. So, this is all about the construction aspects of the wet mix method. Thank you so much.