

Course Name – Pavement Construction Technology
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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, Guwahati, and the instructor for the NPTEL MOOC course, Payment Construction and Technology, funded by the Ministry of Education, Government of India. Today's lecture will be part of Lecture 9, continuing from our previous lecture on Lecture 9 under Module 4. 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. In the previous lecture, we discussed that one important aspect of the mixed design of granular courses at the very beginning is to achieve the target gradation. Now, different gradations are given for different courses, considering various applications.

So, there were six gradations that we saw specifically mentioned under the granular sub-base courses as per MoRTH requirements. Now, similarly, there is a gradation for the granular sub-base unbound course that is wet mix macadam. So, when you have different stockpiles of aggregates in the field that you need to proportion, you need to blend them, and that blend should finally give you a gradation that is within the gradation range, with your target being the mid value of the gradation range that is recommended for that particular mix. So, that particular exercise we discussed in the previous lecture is important.

Now, once that is known to you, once you are able to understand, okay, you have the aggregate stockpiles and you have the required gradation range given for that particular mix, you can attempt that blending and reach the gradation. Now, in addition to that, what else is required specifically? So, when it comes to granular subbase courses, especially the unbound granular subbase courses, the materials we have already discussed in some of the previous lectures will consist of natural sand, crushed gravel, crushed stone, crushed slag, or a combination of these materials. So, under the granular courses, the following materials can be used. Now, so simultaneously, while proportioning that attempting that proportioning. Before that, you should also ensure their physical characteristics because if one particular source is not suitable according to the physical requirements, it should not be considered for the proportioning part either.

In some cases, there may be certain challenges related to a specific property. So then you have to look at what alternative source of material can be there. So, as it is mentioned, a combination of materials can be arrived at in that case. So, there may be, if you are using some soil stabilization, which we will discuss in this particular case; if the soil is clay, then you can look for some stabilization through lime. Similarly, so that the requirements of the materials are met.

So, here it says the selected materials have to be checked through characteristics; what are the important characteristics for a material to be used in the sub-base courses? Aggregate impact value,

liquid limit, plasticity index; it says that the liquid limit should be less than 25, the plasticity index should be less than 6, and the aggregate impact value we discussed. If certain aggregates are more susceptible to saturation with water or have a higher water absorption, then we can also go for the wet aggregate impact value. Now, as I mentioned, there are 6 gradations specified by MoRTH for granular sub-base courses. So, in that case, whatever aggregate gradation you have targeted—say you have targeted gradation 5.

Now that you have attempted the physical characterizations, the aggregates are found suitable; you attempted the proportioning, and you got a gradation that is within this particular gradation range. Then the next exercise that starts under this particular one is to evaluate the relationship between water content and density. So you will do the proctor test that we discussed in previous lectures, where you will vary the water content and try to determine the density, the dry density. And from the relationship between moisture content and dry density, you try to figure out the optimum moisture content and maximum dry density. So, because this is important for the construction of that mix in the field.

Now, in addition to this one, you need to evaluate the strength of that material, which is most commonly done in terms of your California Bearing Ratio, as we also discussed. Now, while preparing the specimens for the determination of the California bearing ratio. The specimens should be prepared at a density of 98 percent of what has been achieved at maximum dry density so as to replicate the field situation. So we will go for a determination of 98 percent, and then, as I mentioned, the CBR can be determined under soaked conditions and under unsoaked conditions also. When you do soaking, you keep the sample submerged in water for 4 days before determining the CBR value.

So that gives you the strength that will be retained in the material once it gets indented under the water. And as the MoRTH specifications recommend that the minimum CBR for an unbound material used in a granular sub-base course should be 30. So if that is also not meeting out, you may have to change the aggregate source; a particular source you have to change, or otherwise you have to go for some stabilization techniques. So, this is what is required when you use an unbound granular sub-base course. In addition to this, there is another popular mix, which is water-bound macadam.

We also discussed certain aspects of that particular one in the previous lecture. Here, we will focus more on what the important considerations are regarding its construction. So, one important aspect is that the materials to be used under this particular one need to be ensured for their physical characteristics. So, it says that this is as per the guidelines mentioned regarding water bond mechadorm in MoRTH 2013, and this is a specific code, IRC 19, providing information about water bond mechadorm. Now, here it says that if a water-bound macadam course or a mix is used as a sub-base course, then the requirements for Los Angeles abrasion value or aggregate impact value, one of these can be conducted, and if a choice is given to us.

Preferably, go for the Los Angeles abrasion value. In addition to this, if it is to be used as a base course on top of which a bituminous course will be placed, then the requirements are here. Here, you can see the requirements are becoming stricter. When you are using it in the upper course, and when I am using it in a sub-base course, the requirement for the Los Angeles abrasion maximum

value can be up to 50 percent, but here it is reduced to 40 percent, and in certain cases where you are not going to use any bituminous treatment over it and will use it directly as a surface course, the Los Angeles abrasion value is again 40 percent; in addition to that, there is also a requirement for shape. The flakiness index also needs to be determined when this particular one is to be used.

And this is specifically when some crushed slag is used; this flakiness index is important. Again, there are different gradations that can be adopted for the construction, depending on the layer thickness, and different size ranges are recommended. Here you can see that this is again a table which has been picked up from IRC 19-2005. It says that if the aggregates are in the range of 90 to 45 mm, the thickness should be at least 100 mm for that particular one. Otherwise, for this particular range, the thickness of the waterborne macadam can typically be 75 mm.

So, 75 mm is quite a popular thickness of waterborne macadam that is constructed. Here it says that when it is used as a base course, the layer thickness of 100 mm with coarser sizes of aggregates is specifically for when the water-bound macadam is used as a sub-base course. 90 to 45 mm aggregate size is given for this particular one, and there is a complete gradation range. This is 90; as I mentioned, this is the range of aggregate particles that should be there if a 100 mm thickness is to be constructed. You need to blend the different aggregates available to meet this requirement.

Now, in the construction of this particular one, once the coarse aggregates are laid and compacted, screening materials are to be put over that particular coarse aggregate and then compacted again. So for this particular screening, two sizes of screenings are also recommended: grading A and grading B, where this is 13.2. Now, for this 13.2 specifically, it refers to the NMAAS.

So here it says that this mentions the gradation range for a material that will be classified as 13.2, or the important part is grading A. Therefore, this should be the range of materials that should be present if grading A is used, and this should be the case if this is used. In addition to this particular one, there is a table that gives approximately how much you are going to put in that aggregate; it states how much aggregate is also applied. So, this is a sort of design of how much quantity of different materials is required.

So, this is what we did when the granular sub-base course was there to determine the amount of water that had to be used and then the density that could be achieved here. Already, it is the table based on the research and field experience gained. It says that when you are going for coarse aggregates in the size range of 90 to 45 mm, the loose quantity of aggregate should be in this particular range. This is for 10 square meters of area. So, approximate quantities of coarse aggregates and screenings are required for a 100 mm compacted thickness of WBM.

So, this is as we have seen in the previous slide; for this particular range, the thickness should be at least 100 mm, and it is preferably used as a sub-base course. For this one, the loose quantity of coarse aggregate will be this. And then it says which type of screening can be used; it mentions that if you are using type A screening, which is 13.2, the loose quantity should be 0.27 to 0.3 cubic meters per 10 square meters of area. And if this is stone screenings, there may be certain screenings that may come from mooram or gravel, which are more susceptible to crushing during compaction. So, there they fix up certain criteria properties and size; it says that the liquid limit for those kinds of screenings that are susceptible to crushing should be less than 20, the plasticity index less than

6, and the percentage passing 75 microns should be less than 10. In addition to that, the quantity of the screenings in loose quantity is also mentioned. So, the binding material quantity depends on the type of screenings and the function of WBM, whether you are using it as a sub-base course, base course, or as a surface course.

Now, as mentioned, if this was mentioned for 100 mm thickness, if it is for 75 mm thickness, the quantity that may be required will be here; it is mentioned as 0.07 to 0.09 cubic meters per 10 square meters when it is used as sub-base and base courses. So, this is what is mentioned again: determining which type of grading it is, depending on the grading that is to be used. In addition to the screenings, binding material is also applied, and that particular binding material's specific criteria are that the binding material should have a PI of 4 to 6, and preferably, when it is used on the top, the PI should be, or otherwise, if you have this particular binding material, it is not required where the PI of crushable type screening is less than 4, especially.

So, it says the application of binding material may not be necessary where the screening consists of a crushable type because it crushes itself down and serves more or less the purpose that is to be achieved through binding material. So, specifically, when this is to be used as a surface course, varying course, with no bituminous stop on the top over it, where the PI of crushable type screening is less than 4, the application of a small binding material having a PI of 4 to 6 is required on the top. So, these are some specific requirements regarding the design of this water bond mechanism. There is another granular mix, which is a wet mix mechanism preferably used for the construction, or mainly used for the construction, of base courses of flexible pavements. Here again, the requirements in terms of aggregates are related to strength and shape.

It specifies what the value of abrasion loss should be, stating that it should be less than 30 percent for impact and less than 40 percent for Los Angeles abrasion. And here, the requirement is in terms of combined flakiness and elongation index. So, that says that a maximum of 35 percent is allowable for this one. And if you are using crushed gravel, in that case, 90 percent by weight of the crushed gravel or shingle retained on 4.75 shall have at least two fractured faces, which we already discussed; and again, in addition to this particular one, the plasticity index of this material is to be less than 6.

Now, for this material, you are also going to determine the maximum dry density and OMC, and then you will work out the CBR of this particular material. And this CBR of the material should preferably be even for use, and we can estimate, as we have done for the other part, the elastic modulus of the granular materials on the basis of the CBR of these materials, which will be required for attempting the flexible pavement design. Because the input parameter is in terms of the elastic modulus or resilient modulus. Now, this is the gradation that is given; this is the gradation that is given by IRC 109:2015, which is for the Vitamix mechanism. Here it states that the minimum thickness of this layer should be 75 mm, and the maximum it can go up to is 250 mm, but preferably we keep the maximum thickness around 200 mm, which is also stated in the MoRTH 2013 specifications.

One important aspect, even during this gradation or proportioning part, is to see if I will look for two sieves; if I have done a proportioning, I found that the material on this 11.2 sieve was 40 percent passing. So, it was on the lower side. So, 40 percent of the material was passing; my target was 50

percent, but the blend of the different stockpiles gave me a 40 percent passing. Also, since the range is given as 40 to 60.

So, it is within the range. So, it can be accepted. If, when I go for the same blend on the second sieve, it comes out here on the lower side and there on the next consecutive sieve on the upper side, then this can again be 40 percent passing. That is, it is finer compared to what I require; around 32 percent was my mid-value, which I am targeting, and the range is between 25 and 40. So, I will be targeting something around 32 percent passing, but here it is 40 percent passing. Now, what happens is that we should not go for this kind of proportion of blending because, as it stands, 40 percent is retained here.

So, there is no material that is between the 11.2 and 4.75 sieve. So, this creates a gap in grading, and this is not preferable. So, even while doing the proportioning, you should take care to apply your own caution to see what is happening, and this will not be accepted if the final gradation approved within these shall be graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve.

So, this needs to be reconsidered even if they are falling within the ranges, but it should not be the case because it is the engineer in charge who will make the final decision. And then again, as mentioned, we need to go for the determination of OMC, MDD, and finally the CBR, and from that, we get the elastic modulus for use in the flexible pavement design. So, this completes the discussion on the wet mix macadam. In addition to this particular one, nowadays, many materials in certain regions may not be good enough or suitable enough to meet the strength requirements of CBR, or in terms of aggregate individual requirements, specifically, the strength requirements in terms of CBR may not be sufficient, and we require a good quantity of materials for the construction of these unbound granular courses. So, the stabilization of these materials by different cementitious materials is becoming quite popular nowadays, and good information is provided in IRC 37 as well as in MoRTH 2013.

And even in IRC SP 89, which also addresses the stabilization of soil and granular materials by using different cementitious products, cementitious products can mean one of the following: it can be cement, it can be fly ash, it can be lime, it can be a lime-fly ash combination, or it can be a lime-fly ash-cement combination as well. So, when you are using these materials in this particular case, you need to refer to what the requirements are for these individual cementitious materials, what the requirements are for cement, for fly ash, and for lime. And then what proportion has to be arrived at, as we have seen, even in soil, certain clay soils are highly clayey; they can be stabilized by using lime. When you use this combination of soil with lime and fly ash, you can again attempt stabilization, which is referred to as mechanical stabilization, where you can blend different materials in the same manner in which we attempted, through the graphical method, the blending of the aggregates for these mixes. So, finally, when we blend these aggregates or soil materials of different sizes, it improves the workability and strength of the material.

So, without adding any cementitious product and by combining two or three different products, we can ultimately achieve a significant amount of stabilization or strength for these materials without generating any cementitious product by changing the gradation. So it says that you can have cement-treated sub-bases and cement-treated base courses, both of which are mentioned in

our IRC 37 guidelines for flexible pavements. It says the material used for cement or cement fly ash-treated can be soil, including soil treated with cement, fly ash, lime, or a combination of lime and fly ash. It can be gravel, conkers, brick aggregate, crushed rock, or slag, or any combination of these materials. So, their combination can be attempted and worked out.

Some specific requirements are mentioned. In MoRTH, SP89, and IRC37, they discuss that if you are using aggregates, the aggregate should have an aggregate impact value of no more than 30 percent, a combined flakiness index, a specified shape, and a Los Angeles abrasion value; these are requirements related to the aggregates. And for material passing 425 microns, it says the liquid limit should be less than 45, the plasticity index less than 20 percent, and the uniformity coefficient should not be less than 5. The uniformity coefficient gives you an idea of how much dispersion there is in the aggregate gradation; whether the material is uniform, if uniform, then your coefficient of uniformity will be less. So, you always want this coefficient of uniformity to be greater than. Now, in addition, as I mentioned, different cementitious products can be used, which can be your ordinary Portland cement, Portland slag cement, and Portland pozzolana cement.

When they are tested for physical characteristics, these individual components also need to be evaluated. The cement you are using needs to be tested as per the IS requirements: IS 269, IS 455, and IS 1489; all these are for different cementitious products, and different requirements are there. Now, when we are using this treated sub-base course, cement-treated sub-base course, or cement-treated base, IRC 37 recommends that for a cement-treated sub-base course, the thickness should be at least 200 mm, and for a cement-treated base, the thickness should be at least 100 mm; this is as per IRC 37. So, when you are doing this treatment or stabilizing the material with any cement, the most commonly used is the cement, and you have to work out the strength in terms of unconfined compressive strength; especially, this is done for the granular materials or the stabilized granular materials. Now, when you are using that material as a cementitious sub-base, it says that the unconfined compressive strength at 7 days should be in the range of 1.5 to 3 MPa. So, this is an important requirement that the unconfined compressive strength of any stabilized material to be used as a subbase must meet. Now, once you have this UCS, it gives a preliminary idea of whether this stabilization is good enough to achieve the desired strength. In addition to this particular one, we work out the modulus for ourselves. So, you can say the modulus of the cement-treated sub-base is given as 1000 times your unconfined compressive strength, and this is for 28 days. So, this is the elastic modulus of the cement-treated sub-base, which is as per the expression given in IRC 37:2018.

It says that from the UCS of 28 days, you can get an idea about the elastic modulus of that material. This elastic modulus will be used in the analysis of flexible pavements or the design of flexible pavements. And there it says an important consideration is that whatever UCS is arrived at after 28 days should be at least 1.5 times what is expected in the field because a lot of variability will exist in the field, especially in mixing, quantities, and blending. So that is why when you do a controlled one at laboratory scale, the UCS determined in the laboratory should be at least 1.5 times what you are targeting in the field. Now, once this is established, the elastic modulus or resilient modulus is used in the design of flexible pavements. And this value, it says, should be restricted to a maximum value. So, by default, you can go for a cement-treated sub-base with an elastic modulus of 1600 megapascals. So, here you get the values in MPa; this is again the UCS at 28 days in MPa. Now,

similarly, when it comes to your cementitious materials for use in base courses, it says that the strength should be in the range of 4.5 to 7 MPa. Now, here again, as when cement is used, there is an early gain in strength, but in the case of other pozzolanic materials, the gain in strength takes a longer time. So, that is why it mentions that while the conventional cement-stabilized material should attain this strength in 7 days, granular materials and soil-aggregate mixtures stabilized with lime, pozzolanic stabilizers, lime, fly ash, etc., should meet the above strength requirements in 28 days, since the strength gain in such materials is slow. So that is why you need to check for 28-day strength when you are using lime, fly ash, or other pozzolanic materials to ensure that the rate of gain of strength may be slow. And again, once you work out this particular elastic modulus, the one which is as per IRC 37, it is advisable to use this elastic modulus for cement treated as 4000, and for cement-treated base as 5000 megapascals.

This value is used for there. In addition to this particular one, when a cement-treated base is used, the construction of the bituminous course will follow thereafter over the cement-treated base. So there, you need to do a fatigue damage analysis; also, for that, you need to work out the modulus of rupture or the flexural strength of the CTB material, cement-treated base material. And this is an important aspect that needs to be ensured for that material, and it also states that the values of this modulus of rupture can be taken as 20 percent of your 28-day UCS strength, which you used while determining the elastic modulus. And, there again, some maximum values are specified; it states that if it is a cement TCS stabilized, then this modulus of rupture can be considered as a maximum value of 1.4 megapascals, and if it is a lime fly ash soil, it will be 1.05 megapascals; this has to be this one, and if it is a soil cement, it has to be 0.7 megapascals. So, this is again a requirement. In addition to this particular one, when these materials, cement-treated base courses, are used to avoid any reflection or propagation of cracks from these cement-treated base courses to your bituminous courses, a crack relief layer is also provided; this crack relief layer can be in the form of wet mix macadam, and a 100 mm wet mix macadam layer can be provided as a crack relief layer, and we have already discussed the wet mix macadam gradation. So, that particular aggregate interlayer can be provided over; it is preferable to be provided over a cement-treated base, and then over that particular one, and here in this case, it is usually compacted to 100 percent of its density, which is your MDD, laboratory-derived density.

In some cases, instead of this aggregate interlayer, they put a certain stress-absorbing membrane interlayer, where you put a layer of modified binder over the surface of it, followed by some stone chips, and then you proceed with the construction of bituminous mixes. So that stress-absorbing membrane interlayer is only the application of binder with some layer that stress-absorbing membrane interlayer, but these two layers, whether aggregate interlayer or this stress-absorbing membrane interlayer, will be a bituminous layer or modified bituminous layer. This will not be considered a structural layer; it can be considered because this is 100 mm of WMM, which helps to prevent any propagation of cracks or transfer of cracks from the cement-treated base courses to your bituminous courses. In addition to this requirement, one requirement is in terms of durability when you are using these cement-treated base courses, as they may be subjected to different wetting and drying cycles or different freezing and thawing cycles. So it says if this material is subjected to a wetting and drying cycle, the minimum quantity of cementitious material is to be decided based on that in such a way that in a wetting and drying test, which is specified by BIS, the loss of weight,

because when you subject this cement to this wetting and drying, I am not going into the depth of the test procedure.

Here, you can get an idea that the loss of weight is determined through this particular method when a specimen is subjected to wetting and drying cycles. So, it says the specimen has to be subjected to 12 cycles of wetting and drying, and the loss of weight should not be more than 14 percent. So, this is when there are chances that this particular layer is exposed to more water, and subsequent wetting and drying can happen. In addition to that, in colder regions or snowbound regions, it may be preferable to evaluate the durability in terms of freezing and thawing cycles. So, there again 12 cycles are applied as per BIS 4332, and the weight loss is mentioned that it should not be more than 14.

So, this completes our discussion specifically on the different aspects related to your granular courses, material, the blending of aggregates, the determination, and the mix design in terms of the determination of the blend of materials. The amount of water content and the density, the possible density achievable, the determination of the CBR, the requirement of the CBR, and the requirement of strength in terms of the elastic modulus for cement-treated base courses and cement-treated sub-base courses. So with this particular one, we will now complete this discussion here for unbound courses, both the unstabilized one and the stabilized one. Thank you.