

Course Name – Pavement Construction Technology
Professor Name – Dr. Rajan Choudhary
Department Name – Civil Engineering
Institute Name – Indian Institute of Technology Guwahati
Week – 06
Lecture – 25

A very warm welcome to all of you. I am Rajan Chaudhary, Professor in the Department of Civil Engineering at the Indian Institute of Technology, and instructor for the NPTEL MOOC course on Payment Construction and Technology funded by the Ministry of Education, Government of India. Today's lecture will be part of module 6, where we will discuss the tests done after the construction of the granular courses. Now, 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. Now, after the construction and the assurance of the subgrade, the next layer usually comes: your granular subbase courses or the granular base course, followed by granular base courses. So, we have already discussed the composition-related aspects and the construction-related aspects of the granular courses.

Today we will discuss what continuous evaluations need to be carried out once those are constructed, to ensure that we achieve what we expect or have thought about. So, the quality control exercise that is to be done is a very critical aspect of highway construction because we do a good design, we do a good proportioning, and we have good construction equipment, but the entire process has to be monitored very closely and carefully to ensure product quality. So, quality control is a critical aspect of highway construction essential for ensuring structural integrity and the long-term durability of our road infrastructure. So, this forms a very important aspect.

In recent years, you will see there have been a lot of revisions that have taken place in the codal standards given by MoRTH under the flagship of the Indian Roads Congress. We will see that the standards or the requirements are becoming more and more stagnant with year-by-year revisions. So whatever revisions have taken place, the quality standards have become more stagnant, specifically because there has been a tremendous increase in the traffic volume. And then we have an increasing demand for long, durable roads that provide a good riding surface with a very good design speed as well. So, in recent years, the need for stringent quality control has grown significantly, driven by rising traffic volumes and the increasing demands for higher levels of service from the highway facilities.

So, you can see under this particular discussion, today's talk will also refer to various codes of specifications given by the Indian Roads Congress. The one is the IRC-19 standard specification and code of practice for water-bound macadam. This is again used as water-borne macadam, a granular course used as a sub-base or a base course, which we discussed in previous lectures. Then IRC 109 is there, which is a guideline for wet mix macadam. This is the first revision.

Then we have the orange book specifications for road and bridge works, MoRTH 2013. Then, we have the manual for the design, construction, and maintenance of gravel roads IRC SP 77, the pocketbook for road construction equipment IRC, which is the 2018 publication, and the handbook of quality control for the construction of roads and runways. Many others in addition to this will be

referred to during this discussion. Now, the first aspect whenever a layer is being constructed is to ensure whether it is following the horizontal alignment specified in the project requirements. We have the drawings which show the horizontal alignment of the road.

We discussed it when we discussed the subgrade part as well. So, here you can see again that this is an alignment which has been shown; we can very well see that this is a curve which has been shown. What critical information or important information can we draw out of it? We have fixed road level, the finished road level, and the original ground level. We have the difference between these two from which we can figure it out. You can see here that the original ground level is low compared to your finished road level.

So, you need to do some filling in here. Here, some filling is also required. Here in this particular instance, some continuous filling is required, along with a small portion where some cutting may be necessary. So, we will get an idea of where the horizontal curves are. You can see this is the horizontal curve with a radius of 250 meters.

So, we have the information, and we can get the center line of the road; we will get the levels corresponding to the center line because here you can say this is the level of the finished road. So, these are the things I want to have in one particular section; if I want to work out, I am doing the construction of this section. So, I need to work out. So, this I will be able to see what it has to be projected down, and then I will be able to see with that particular chainage, okay, what my finished road level has to be. And then, with respect to this particular one, using the cross-sectional details.

This is again a typical cross-section where you can see there is a layer of GSB, granular sub-base course, a WMM course, a DBM course, and a bituminous concrete layer. There is a carriageway, a paved shoulder, a cycle track, and utility corridors or covered drains. So, we need to have the composition, or the crust composition, or the typical cross section of the pavement, which gives further detailed information. So, here we can see that this cross section gives us information about how much thickness of your subgrade is there. Subgrade is typically constructed with a thickness of 50 centimeters, followed by a granular sub-base course of 200 mm thickness, followed by a water-bound macadam 250 mm thick, followed by a DBM 68 mm thick.

These are some typical random values that have been picked up to show this particular cross section. This is for explanation, not for any design-related problem. Now, if I know what the level is at a particular chainage along the alignment, and that at this particular chainage this is the finished road level, then considering how much depth is there, 40108 plus 450 will give you 558. So, there is a thickness of 558 mm. So whatever levels you have here, you will bring them down, so that will give you the bottom of your granular sub-base course.

So now, if you have constructed a layer that is 200 mm thick. So, it might have been constructed in one go if that one layer was constructed, as this entire thickness is constructed in one go. Then, after the construction of the layer, I will try to ensure what the levels are at the centerline, and then I will form grid points, which will help me ensure how the cross slope is maintained. So, first I will transfer the finished road level to the level that is at the bottom of my granular sub-base course; then, using whatever you can see here, the cross slope is already mentioned as 2.5 percent. So, I will work out what the level will be at this point, given the width. So, my grid points will be placed

accordingly, and then I will ensure the levels at those grid points. So, this will ensure that I am following the correct profile and providing the correct thickness of the layer. Otherwise, it may happen that I put up a layer of granular sub-base course that may be of a higher thickness, say 225 mm. So, in that case, when it is reached, it has to get to the final finished road level.

So, in that particular case later on what one may do since there it has been increased by 25 mm. So, to have the same level as the top finished road level, one may try to compensate with the thickness. WBM, which is not accepted at all. So, this will hamper the performance of your payment. So, we will not look into it.

So, whatever tolerances are allowed, only those will be accepted. So, this needs to be ensured by doing the exercise of taking the levels at various points. So, this is the first exercise that is required under the quality control part: to ensure the road alignment levels and surface regularity. So, all construction work performed shall conform to the requirements because, in this typical example, only the granular subbase course was shown as constructed in one layer. There may also be two layers of granular sub-base courses.

So, in that case, you will ensure the levels at the first layer and then at the second layer as well. Once all the requirements we will discuss today are checked for a particular layer, only then, when the engineer is satisfied with that particular one, is permission given for the construction of the next layer. So, all construction work performed shall conform to the lines, grades, cross-sections, and dimensions shown on the drawing as I have shown. So, the drawings have to be referred to; they have to be critically reviewed to ensure each layer's construction. And you will come to know what the existing nearby features are; as in the previous drawing, we have seen that there are also drains on the sides.

So, utility culverts are also to be included. So, that information will be available from all your design drawings and for your section. So, as directed by the engineer, it is subject to the permitted tolerances described hereinafter. So, most of the time, we go with the tolerances prescribed by either MoRTH or the specific code related to that work. So, the horizontal alignment is to be ensured with respect to the centerline of the carriageway, as shown in the drawings.

We have seen that we get the levels for the centerline of the carriageway, and then we bring them down to layers, and using the camber, we can extend it to the edges. Here, one important aspect is the edges; the edges at the top, where the carriageway is, are the top over which the traffic actually moves. So, it needs to be correct within a tolerance of plus or minus 10 mm. So, it is a very small tolerance of plus or minus 10 mm; the edges should be either plus, but this is on the top of the carriageway. When you are working with the lower layers, it states that the corresponding tolerance for the edges of the lower layers of the payments is plus or minus 25, and I will always prefer that you go for some extra because that helps ensure better control later on.

You can have a good gentle slope for your side slopes, and you can achieve better compaction at the edges as well. So, preferably because this is not a significant quantity, you can extend specifically to ensure that the edges are not reduced, as they can be well kept beyond whatever the minimum requirements are. So, we can have it on the positive side. I limit the positive side because if you go beyond that, it definitely incurs more costs as more materials need to be put there. The

levels of the constructed granular sub-base cores or the granular cores shall not vary from those calculated with reference to the longitudinal and cross profile, which I mentioned; once you have the central line levels, you bring them down to these individual layers: first layer, second layer of granular sub-base course, first layer of WMM, and first layer of the second layer of WMM accordingly, and then, using the camber, you extend it to the edges.

So, you need to check it with reference to the longitudinal and cross-sectional profiles of the road. And the tolerances are defined; these are the common tolerances specifically defined for the sub-base course, which show that the surface level should be plus or minus 10 mm. Now, when it comes to the base courses, it says the base courses; we will always prefer, nowadays, to use the construction. As we discussed during the construction of wet mix macadam, there is a wet mix plant, and we lay the wet mix using a paver. But otherwise, if it is machine-laid, the tolerance has to be within plus or minus 10 mm for base courses as well.

In special cases where the site does not permit and if you have to go for some manual laying of these courses, then a tolerance of a slightly higher level is allowed. Now, this for verifying this particular one we can will be using the straight edge. So, to verify this particular one, we will take the levels with the help of a dumpy level or a total station, and a leveling exercise has to be carried out. So, normally we have a team of surveyors who do this exercise, and we will verify and ensure we can do some cross-checks simultaneously wherever we feel it is necessary. So, to verify compliance with the above requirements for granular surface-based courses, surface-level measurements are typically taken at grid points; this has to be done before you start this exercise.

So, grid points are marked on whichever stretch you have ready. And they are typically spaced 6.25 meters longitudinally and 3.5 meters transversely. So, we mark the grid points with chalk, chalk powder, or lime powder, and then we do this exercise of taking the levels.

Once you have ensured it and figured it out, the levels are within these tolerances for the sub-base course granular if it is within plus or minus 10 mm; fine. If you are at some locations, you may find that some points are going beyond these tolerances; either the thickness is too much or the thickness is too little in that case. What could be the problem if I am constructing a subbase course with a thickness that is less than what is prescribed? So, in the earlier example where I mentioned that 200 mm of GSB was to be present. Now, if instead of this plus or minus 10 mm, I am off because I did it manually. So, I was unable to have better control over the thickness.

So, the thickness, when compacted, arrived at only 180 mm. So, it is 20 mm down; it is beyond the accepted limit. Now, the problem that arises is that you have the next layer to come over it. So, if you have, say, 200 mm of W mm that is to be constructed over your 200 mm of GSB, which is now constructed as 180 mm. So, when you go for the next layer, the problem is that you have this one as it is, so you have a first layer of 180.

Now, you want to maintain the levels at the top of your W mm. So, then you have to balance this at 20. So, this will be 220 mm. So, at certain locations, you might be constructing a WMM layer with a thickness of 220 mm. Now, when you prepared a trial stretch, you considered only 200 mm of wet-mix macadam.

Now, at the field, the thickness came out to be at certain locations because this will not happen throughout the entire stretch; there may be certain portions where, due to some challenges or lack of control, the thickness has been reduced. So, the overall thickness of the WMM will become 220 mm. Now, this will not be compacted with the same compactive effort that was decided based on a trial stretch of 200 mm thickness. So, at this point, you will have a layer with a lower density because the same compactive effort cannot provide you with a uniform density throughout the depth of 220 mm. So, it is always important that not only should the layer have a thickness greater than the given tolerance, but it should also be ensured that it is not more than the positive side of the tolerance, as well as not less than the negative side of the tolerance, because the compaction may become a challenging concern thereafter.

And it says that among any set of 10 consecutive measurements done to ensure this level, there are results. Either taken longitudinally or transversely, usually, no more than one measurement is allowed. And that one measurement, which is also allowed, should not exceed 5 mm. If that is there, then rectification has to be done. So, you have to figure out the sections where rectifications are required.

So, once you get the level sheet, you have worked it out, and then you have to figure out the points where the tolerances have gone beyond the stated limits, and then you can visit that particular section, see what is actually happening, what the problem may be, and then you need to rectify that section or localized part of that particular section. Once this is done, once we are able to check the surface levels, we will look for surface irregularities or check for the evenness of the surface. So, the longitudinal profile has to be checked, and this surface regularity is checked using a straightedge. So, this is how it looks: you can see this is usually a standard 3-meter edge that we use to measure the surface regularity. And finally, the purpose at the top is not only the levels that are maintained but also that you get a very smooth or even surface.

So that evenness, smoothness, and surface regularity have to be maintained from your bottom layers. And it should become stricter and stricter as you go to the top so that finally you get a very smooth surface when the wearing course or your carriageway comes. So, the longitudinal profile is to be checked with a 3-meter-long straight edge, usually a moving straight edge, because it is a long exercise; you keep moving and ensuring the surface regularity. Preferably, we do this particular one at the center of a lane that is parallel to the centerline. So, we do it in the middle of each lane along a line parallel to the center line of the road.

So, if there is, say, a four-lane carriageway, this is your center line, and these are two lanes on this side; these are two lanes. So, we will do this in the center of this lane; this is the center of this lane, and this is what your center line is. So, we will do this exercise of measuring the surface regularity using straight edges along the middle of these particular lines, and we will do it longitudinally; it can also be done transversely. So, the 3-meter straight edge, which is typically made of steel or a box-type aluminum alloy bar with sectional dimensions, has dimensions that may vary slightly, measuring 75 mm by 125 mm. Its edges have to be perfectly straight and free of dust and other defects.

And then a wedge is used; that wedge typically has a length of around 60 centimeters. So, the width of that particular wedge you can see needs to be inserted below this straight edge. So, the wedge

usually has a length of 60 centimeters, a width of 3 centimeters, and a height of 3 centimeters on one end, which is around 30 mm, and a height of 1 mm on the other end. So, you are going to insert this under this straight edge, and there are markings that will be on this particular side as well as on the top. So, then you are going to insert it, and you will see where the maximum variation is.

So, it is said that with this particular one, since one end thickness is 1 mm and the other end thickness of this wedge is 30 mm, you can usually go up to depressions of, say, 25 mm. So, maximum depressions are present when there are lowering points. So, you are going to insert it, and you are going to check that there is no difference of more than 8 mm. So, it states the maximum allowable difference between the road surface and the underside of a 3-meter straightedge, which you are going to check by inserting the wedge under it when placed parallel to or at right angles to the centerline. So, as I mentioned, it can be done at right angles to the center line, but preferably it is done parallel to the center line in the middle of the lane, and the reference point shall be 8 mm.

So, this is the maximum allowable difference, which states that it should be no more than 8 mm for both the granular subbase and base courses. So, an important aspect is that this difference should not be greater than 8 mm. So, this helps us ensure that when we reach the top, we can obtain a very smooth surface. Now, in addition to what I said, the requirements are becoming stricter with the various revisions happening in the IRC codes. So again, IRC 19, which is there for water-bound macadam, states additional requirements for it.

It states that we have used coarse aggregates in water-bound macadam. If you recall, in the construction of the water bound macadam, first a layer of coarse aggregates was laid and compacted, followed by the placing of screenings and water compaction, and thereafter by the application of the binding material and its compaction. So, here it says in the IRC 19 that when you are using coarse aggregates of different sizes, two sizes are mentioned here; typically, we go for a thickness of 75 mm for waterborne macadam, and in certain cases, a thickness of 100 mm is laid. Now what it says is that if you are using coarse aggregates of this size, then the longitudinal profile measured with a straight 3-meter straightedge indicates the maximum permissible surface unevenness. It also mentions that if you are able to find that the surface unevenness is 15 mm in one place, this is allowable, and it states what the maximum number of undulations permitted in any 3-meter length exceeding 12 mm is.

So, along with this, the maximum in addition to this one puts a requirement on how many of this kind of unevenness of 12 mm can be allowed. So, it says that no more than 30 in 300-meter lengths are allowed for these particular coarse aggregate sizes. Similarly, when it is there for this one, the maximum permissible surface unevenness is 12, the sizes of aggregates are lower, so it becomes stricter, and it states for 10 mm, not for 12, that the maximum number of undulations permitted in any 300-meter length is what you are measuring with respect to your straightedge. When you do these measurements, if you are able to find that there are certain accumulations of 10 mm, then that should not be more than 30 in a 300-meter length. So, you have to reject that particular section; it needs to be rectified before the construction of the next layer.

Similarly, it says that if I go transversely with respect to the centerline, then for this particular case, what is the maximum undulation, and especially transversely, we can use camber plate templates to measure the undulations. So, there also for the transverse, it says that for this aggregate size, this

is the maximum permissible variation for aggregate sizes of 90 to 45, and for these two aggregate sizes, it is 8 mm. These requirements outlined on the side will help you achieve a smoother surface from the very beginning, from your subgrade top or subgrade levels to your granular courses, which may include granular sieve base courses and granular base courses. Water-bound macadam, which is preferably used as a base course in some cases, is also used as a base course. So the maximum, here it also says the maximum allowable difference between the road surface and the underside of a 3-meter straight edge shall be 8 mm for the WMM course, which is that it should not be more than 8 mm as per IRC 109-2015.

Now that we have ensured it, we have ensured the surface regularity and the levels. Now, if we find that certain sections are not meeting the standard requirements, what should we do? So, there are certain standard ways of rectification that are already provided in our codal guidelines. What they say is that when the surface regularity of the sub-base course falls outside the specified tolerance of 8 mm, it needs to be rectified. So, what is to be done? It states that if it is high in cases when the subbase or base course is high, it shall be trimmed and suitably compacted.

So, it needs to be trimmed. So, a grader is suitable equipment that can help, or we need to have rippers that will loosen the material, and then it has to be trimmed; again, it may be required that you sprinkle water and recompact it. Where the density is found to be less, it is specifically when there is a challenge regarding the levels where the density is found to be low. Now, this control of density, again in upcoming slides we will see, but at a certain location, if we find that the density is low, then what we can do is that there may be a reason with respect to any, say, gradation; there may be some segregation, or excess water may be present. So, we may have to open up that section; we have to aerate it when we open it, scarify it, and if we find that there is some segregation and that some of the material is not meeting the gradation requirement, we have to replace it with new material or we have to add. Carefully add the material that is lacking, as this is a difficult exercise to perform.

So, we will scarify the affected layer, add the suitable fresh material; this is important: only what is lacking is to be added; otherwise, the complete material has to be removed, new material has to be put in, and recompacting is to be done as per the required density requirements. The density achieved shall be at least 98 percent of the maximum dry density. This is for the granular sub-base course; the density that has to be achieved is 98 percent of the maximum dry density, which we obtained from IS 2720 Part 8. Now, when it comes to the water bound macadam, we discussed that this is a process involving the laying of coarse aggregates, followed by screenings and then by binding material. There, if we see that there are certain irregularities with respect to the surface level, it indicates that in that case the entire thickness has to be removed.

So, the entire thickness, as I mentioned, is normally constructed with a water bound macadam of 75 mm. So, the entire thickness has to be removed from that particular section. So, the entire thickness of the affected area shall be scarified and reshaped with additional material. Now you need to work out what the reasons behind it were; it was the aggregate sizes that had some segregation. The question is whether the adequate water content was not there, the fine screenings were not proper, or the binding material was not appropriate.

Care has to be taken when you are reconstructing it. So that the mistake does not occur again. So, it is important that when you are doing the rectification, the correct materials have to be used. So, with additional material are removed and replaced with fresh material. So, because it will be difficult now, you will have coarse aggregates along with the screenings and your binding materials.

So, reconstruction using the same material will be difficult. So, you have to bring up fresh material specifically for this one, and then, again, the recompaction exercise has to be carried out. Now, for this particular job, you cannot go for a very small section because the compaction has to be taken into account. So, it says that the area where this kind of rectification is required should be at least 10 square meters. So, if any localized spots are formed, you need to scarify it to get an at least an area of 10 square meters.

So, you can proceed with this kind of rectification. Under no circumstances is this usually the big mistake that is normally made in many cases; when we find small surface depressions, we continue using small screenings or binding materials. So, this changes your complete gradation of the layer and this will hamper your performance. So, this should not be permitted. So, it should not happen that whatever depressions exist, because the depressions are small enough, you will be able to put the coarse aggregate in those depressions. So, you have the screenings and the binding materials; you will put up those screenings and binding materials, and you are going to try to match the depressions.

This should not be permitted at all. This is a wrong practice that needs to be addressed, and once that has been rectified, your surface will be okay in terms of your levels, density, and density measurements. Also, we will discuss that density measurements and compaction assurance have to be based not on a single measurement; there is a requirement for how many tests we have to do. In one set of tests, there may be 6 to 10 measurements, and the requirement in one set of tests for having 6 depends upon the availability and variability of the material. So, this comes when you are there on the project; if you find that there is a lot of variability in the material under one set, you can take 10 measurements. So, you have to make a decision because it is usually expected to have a measurement of around 5 to 10 in one set of evaluations of compaction.

Similarly, when it is to be done and when any rectification has to be attempted in the wet mix macadam, it again states that the entire thickness of WMM should preferably be constructed at around 100 mm. So, it also says that the entire thickness of the affected area is scarified, reshaped, and that additional material is removed and replaced with fresh material because normally, in the case of WMM, segregation occurs. Even when the paver is laying, there may be times at the end of the day's work when all the material from the hopper of your paver is moved out. So, there may be chances that some segregation may take place, which has to be controlled, but if it has been it is not controlled then you will find some segregation is there. Segregation will lead to a reduced density in that case. So, there may be, as I mentioned, some excess amounts of fines that have entered because of another challenge at the wet mix plant.

So, in that case, either it has to be scarified if there is a lack of fines; if possible, it can be added and mixed with the help of a grader, then it can be attempted, or, otherwise, the entire material has to be removed and fresh material has to be put over it. It also says that we will not have an area less

than 10 square meters. So at least a width of 2 meters by a length of around 5 meters has to be selected if you want to rectify any particular spot in wet mix macadam. It says that if the entire depth is more than that, then there is a requirement mentioned in IRC 109 and MoRTH, which states that the top 75, if not the entire depth, is to be scarified over the affected area, and then whatever deficient material is to be added or the complete material has to be replaced with fresh material. Here also it states that in no case are the depressions to be filled with unmixed and ungraded materials or fines because certain fines may not be available.

So, it is never permitted because this will change the complete gradation and functioning of this particular layer. So, we will not permit this, and this will create concerns later on. So, it will not permit any direct placement of fines or any mixed material to fill up any depressions that are present in the wet mix macadam. Now, there are certain requirements for tests that need to be carried out during the continuous construction process. Say, as per MoRTH, there is a definite section: section 900 states what control tests can be done for this particular one.

For granular materials, such as granular coarse material, it is stated that you need to ensure one test is conducted for every 400 cubic meters of the material. At above limits to ensure your plasticity index do one test per 400 cubic meter area. Moisture content prior to compaction is one test per 400. Definitely, you already have moisture content from your laboratory determination of your mix design during mix design at the laboratory scale, and then from trial stretches as well, but this needs to be continuously monitored on the site at regular intervals.

So, the density of a compacted layer indicates one test per 1,000 square meters of area. So, I am saying I am doing a stretch that may be about 10 meters wide, and this may be around 500 meters long. Of a stretch half a kilometer in length, I have constructed one; you can prepare this much length of bed in half a day's work. So, this is a width of 10 meters and a length of. So, this will amount to me saying 5,000 square meters of area.

Now, with these 5000 square meters of area, it states one test per 1000. So, it already says that in 5000, you are required to have 5 tests. Now, there may be a requirement that for judging the quality, it may only be, say, 300 meters; in that case, there will be 300 or 3,000 square meters of area. So, there will be only three test requirements, but it states that when you do these compaction-related checks, you should have at least 5 to 10 measurements in at least one set. So, whether your area requires only 3 tests, it indicates that you have to do some statistical measurements to ensure the quality of compaction. So, at least for that, some minimum measurements are to be done, and those minimum measurements are usually in the range of 6 to 10 in one set.

So, under one set, if this is there, I will prefer under the 3,000 square meters of area where only three tests are required, but as per statistical requirements, I need to at least get 6 to 10 measurements. So, that needs to be done. So, deleterious constituents can be carried out at any place as per the site constraints and the variability observed in the field. Similarly, CBR states that, as per your requirement, wherever you want to check that there is no variability in the material, you can do the test at a longer interval; otherwise, you can reduce the interval for the CBR evaluations. So, similarly, it is there for water-bound macadam also; the aggregate impact value is to be ensured, and grading of the aggregate states one test per 250 cubic meters of area.

The shape is to be ensured; it states one test per 500 cubic meters of aggregate is to be conducted. Atterberg limits again; it states 50 cubic meters. Now here it states. One needs to look into it; it is for screening and the binding materials.

So, the Atterberg tests are used to determine the plasticity index of the fine particles. So, the Atterberg limit measurements have to be done, which indicates that for your binding material, the frequency is higher. So, it is 50 cubic meters of your binding material, and for screenings, it is 100 cubic meters. So, this helps ensure that there is consistency in the quality of the material that we are using. Similarly, here we have the frequency of quality control tests for wet mix macadam.

Gradation is present. It is as per IRC 109-2015. It says to do one test per 500 cubic meters, subject to a minimum of two tests per day. So, even if you are going for a construction that takes only one day and you are working with about 300 cubic meters of material, you still have to do at least two tests. So, a minimum of two tests has to be done; this is for the plasticity index. Again, it states one test per 500 cubic meters, subjected to a minimum of two tests per day for moisture content prior to compaction. This is important because rectification is always a challenging task; it disturbs this layer and is more time-consuming.

So, we will prefer that we have better controls during the construction itself, so that we do not need to make some rectifications at a later stage. It is always better to say it in other terms: precaution is better than cure; but yes, if some default has taken place, then you definitely need to rectify it. So, moisture content prior to compaction has to be ensured so that, with the compactive effort, you get the required density. The trial stretch plays a very important role in this regard. So, the density of the compacted layer states one test per 2,000 square meters, subjected to a minimum of four tests per day.

And then, as I said, depending on your statistical requirements and the number of tests you are going to do, the aggregate impact value, or Los Angeles abrasion value, and the shape need to be ensured. So, these are the requirements already. So, there is a continuous exercise that goes on: we have a laboratory setup that will be at the site, and we have the laboratories at our plants. So, the samples will be continuously taken, evaluated in the lab, and the reports will be shared with the field professionals so that they can continuously get information about the uniformity and construction quality. Now, the compaction control, as I said, requires us to follow the frequencies already mentioned, and in addition to this particular one, it states that when we have granular courses, specifically granular subbase courses, there should be at least one set of 10 density measurements for every 3,000 square meters of area.

So, it says one set has 10 density measurements, and this should be done in at least 3,000 square feet. So, it gives an idea of how much the frequency should be, and we can even have it at closer intervals. If you find that the variability in the mix or the aggregate is higher, we can reduce this particular one; we can have more measurements than that, or instead of 3000, we can make it 2000, and that set of 10 measurements in 2000 square meters of area has to be done. This is just a tentative guideline given by the MoRTH. Locations and another important aspect are that this should use a random sampling technique.

I will discuss these random sampling techniques when we discuss the bituminous bond course as well. It should not happen that when a stretch is present, one stretch is ready to be used. I will not do all I say; I prefer to do all my tests on the edges, or I prefer to do all my tests in the middle of the lane. Because the possibility may be there at the edges, the compaction may not be as good compared to what it may be in the middle of the lane. So, if I am only going to take measurements in the middle of the lane, I may get densities that are quite good compared to what may be there at the edges.

So, I will do random sampling to get a complete picture of this particular study. So, I need to do some random sampling in this way. So, this random sampling is very important. It has to be decided, and then the compaction measurements have to be taken. The locations for random sampling have to be decided, and then these density measurements have to be taken.

It states that the test location shall be chosen only through random sampling. If non-destructive tests are carried out, the number of tests will be doubled. This is another concern because, as we have seen, a sand replacement method is available that is a destructive test. If you are doing that measurement, but instead, if you are using some density gauges, whether they are nuclear density gauges or non-nuclear density gauges, we have already discussed that nuclear density gauges have higher accuracy, but certain concerns related to health and the environment are present. Non-nuclear density gauges are also achieving higher accuracies nowadays, but compared to nuclear gauges, their accuracy is slightly lower. Now, when you are measuring these density checks or doing these density measurements with non-destructive methods, especially with the density gauges.

Here you need to do a lot of calibrations, and these calibrations have to be done regularly. If there is any change in the material variability, we have to do more calibrations. So, there is a reason why it is said that in the case of non-destructive testing, you may have to require the test you are doing in the case of destructive testing, such as the replacement method. So, this is another concern that exists. If considerable variations are observed between individual density results, the minimum number of tests in a set can be increased. As I said, it can be 6 to 10, so if I find that 6 is not working out, I will go for 10 measurements in one set for greater variability.

And the acceptance criteria are the same; this is why, because for one stretch, I will take eight density measurements. I will go for some random sampling, and I can proceed in this particular manner. So, if I am going to do in this particular manner, I will get my things. So, I will randomly distribute these compactions check points and if 1, 2, 3, 4, 5, 6, 7, 8. Now, with these 8 points, the density measurements will be taken, and then it needs to be ensured. So, what it says is that the mean density of these 8 points shall not be less than the specified density, and what is the specified density specifically for the granular sub-base course? It is 98 percent of your MDD.

So, it should not be. The mean density should not be less than the specified density plus the number of square roots of your number of samples, 1.65 minus 1.65 times the square root of your samples multiplied by your standard deviation of these 8 measurements for WMM, and during this particular exercise, when you are doing this monitoring in the field of density, you need to ensure the moisture content, because what you will get in the field is the wet density. So, simultaneously, you can either

monitor the water content in the field using these rapid moisture meters or send the sample to the lab.

So, they won't dry; it will retain the water content. Once you have the water content, then you work out the dry density because you have to compare it with your dry density. So, again it says that for WMM, random sampling of 5 to 10 density measurements is also required, and the number of tests in one set of measurements shall be at least 6. So, as I mentioned, from 6 to 10 measurements are usually preferred; if you find more variability in the results, you should go for 10 measurements in one set. So, along with it, it says that if considerable variations, that is, 15 percent, are observed, IRC 109 again states that if you find considerable variations, that is, 15 percent and above, the minimum number of tests in one set of measurements is increased to 10.

So, either you, because many times you have to justify it. So, you can say that according to my code requirements, it states that within individual measurements, if the variation is more than 15 percent, I will go for 10 measurements to ensure whether this particular stretch is okay from the compaction point of view and that the next layer can be allowed. In addition to this, there can also be acceptance criteria for compacted WMM that can be checked to comply with the following requirements. What are the requirements if I need to increase my number of tests? So, I am increasing from 6 tests in a test to 7, 8, 9, or more tests.

So, here it says that, along with its minimum average value, the percentage relative compaction is to be this. 100.5, 100.6, 100.7, and 100.8 indicate the minimum average percentages of relative field compaction. So, this also needs to be ensured simultaneously.

The minimum value of any single test is the percentage relative field compaction. It says: what can be the value for a single test if you are doing 6 tests in a set? What can be there if you are doing 7 tests in a set? And what can be there in 8 and 9? So, you can see that the minimum value when you are increasing the number of tests is due to the fact that you are getting more variability. So, this 98 percent may be the one you desire. So, if the variability is more than 15 percent, as mentioned in the previous slide, you may need to increase the number of tests in one set. So, these checks need to be ensured: we need to check for the levels, we need to check for the surface regularity, we need to check for the material consistency in terms of gradation, the physical characteristics of aggregate, and the plasticity index. During construction, we need to monitor the moisture content, and along with that, we will perform the compaction control checks.

And if things are found to be okay, we will allow the construction of the next layer. If not found acceptable, we will look for what rectification measures can be taken to correct the defects. So, this is all about the field-related evaluations for granular courses. Thank you so much.