

Course Name – Pavement Construction Technology
Professor Name – Dr. Rajan Choudhary
Department Name – Civil Engineering
Institute Name – Indian Institute of Technology Guwahati
Week – 05
Lecture – 22

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. The course instructor for the NPTEL MOOC course, Pavement Construction and Technology, is a recipient of funding from the Ministry of Education, Government of India. Today's lecture will cover the field evaluation or field tests, which are required to ensure the subgrade quality in the field. And this will be under Module 5 of the course. At the very beginning, I would like to acknowledge the use of texts, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain resources.

We have discussed in our previous lectures the subgrade, its role, its composition, and how the different materials that need to be used for either embankment construction or subgrade construction must be ensured to meet their quality standards. So, the characterization of the subgrade materials and the materials required for the earthwork in terms of the embankment and subgrade is necessary. Here, we will discuss some aspects in this lecture that are required to ensure the quality of the subgrade during construction in the field. We mentioned earlier that the soil subgrade forms the foundation layer; it is mainly constructed from natural earth on which all pavement layers are built.

So, it is mainly constructed with it. It is essential that at no time the subgrade be overstressed, because ultimately all pavement crust layers will be placed over this particular one. So, we want to ensure that at no time is it overstressed, which means that the pressure transmitted over the top of the subgrade should be within the allowable limits. So, during the pavement design, we also ensure that the compressive strains at the top of the subgrade are well within the permissible limits concerning the design traffic. It is always preferred that a minimum thickness of 50 mm of subgrade soil be thoroughly compacted.

So, this compaction needs to be ensured. How do we ensure that it is thoroughly compacted? So that is part of the checks during construction. It should be thoroughly compacted under carefully controlled conditions. One of the conditions is the moisture content at which it must be compacted. If the proper moisture content is used, we can expect to achieve the desired density, especially at the optimum moisture content and maximum dry density.

This is what we aim to achieve: a stable and durable foundation for the pavement subgrade and the pavement structure. Now, as mentioned earlier, the top 500 mm of the prepared foundation layer located at the bottom of the pavement structure are designated according to our IRC 37 specifications for flexible pavement design. Now, if the field testing is to be done to ensure the subgrade quality, the embankment quality, or, in general, the earthwork quality during a road construction project, then under this particular one, there will be a series of checks that are required so that, especially, the subgrade meets the specified requirements. So, field testing and inspection

of the constructed subgrade are vital components of any road construction project. These checks ensure that the subgrade meets the required specifications laid down by different codal standards, MoRTH, and IRC standards, providing a reliable and uniform foundation upon which the pavement crust is designed and constructed.

Now, there are certain checks that need to be made. Follow to ensure the quality of the subgrade during and after construction as per the MoRTH guidelines, which state that you must ensure control of the alignment. That is the level and slope that should determine the bottom level of the subgrade, how many layers of subgrade you are putting in, and what the compacted thickness of each layer should be, as well as the cross-profile of that particular layer. So, that needs to be ensured through the alignment available to you or through the drawings. The surface regularity of the layer also needs to be ensured; there should not be many undulations present because, ultimately, we try to control it from the subgrade itself so that when it reaches the top, we obtain a very smooth surface.

Rectification of the subgrade, if any, will be done during that time if we are able to identify or locate certain sections that need improvement. We can do it during the construction; we can also do it after construction, before laying the next layer. Compaction control check: this is again a compaction control check on the earthwork for embankment and subgrade construction; especially, this is a compaction control check. What we require here is a compaction control check on the earthwork for embankment and subgrade construction. Now, this shows you will have drawings of whatever project you are going to look after, so in that particular one, you will be able to get certain information; here in this one, I just wanted to show that you have one as the FRL, which is your finished road level, and this is at the centerline, so it gives you the levels of the centerline of your road, and then there is an original ground level again at the centerline.

So, the original ground level may be different; you can see the red line is the finished road level. Once the road construction is over, this will be the profile of the centerline of the road, and earlier, this green line, which is shown in this particular manner, represents the original ground level. And in places, you can see the difference between the levels of these two center lines, the original and the finished one; we can determine what the difference is. So, here we can see that some filling will be required; also, a lot of filling will be needed here, and some cutting will be required at certain levels. You will find that it approximately matches the natural ground.

So, you will find that the differences are very few. So, this is another aspect. So, with this particular one, we can see that there is a horizontal curve. So, you will figure out what the radius of the horizontal curves is; many other parameters can be extracted. So, this deals with the geometric design of any project that you have.

Now, from this, you can know what the finished road level of my centerline is. Now, with respect to the centerline, there will be side slopes, or there will be superelevation. So, I will be able to know what the levels are at the edges of my pavement. So, I can figure it out based on my crush's physique. So, I can see this is an example here: this is a carriageway, which is shown as a 7-meter carriageway with a camber of 2.5 percent. I am just trying to give you a glimpse of it: the composition includes a bituminous concrete layer, a dense bituminous macadam layer, a wet mix macadam layer, and at the bottom, there will be the subgrade. They have provided a paved shoulder,

a cycle track, and a footpath. Now you can see that the ground level is mentioned here, too. So, the ground level with this particular lot of embankment will rise, a layer of embankment will be added, and then the construction of the subgrade will start. So that you can achieve a finished road level.

So, when you are compacting each layer, you know the finish from your drawings; you know the finished road level, especially at the center line. With the use of these side slopes and cross slopes, I can determine what the levels will be at these locations. Then, by calculating the pavement crust thickness, I can determine the levels at those points. Then, considering how much fill is required, I already have these natural ground levels and the original ground level. So, I will do the construction layer by layer, and I will fix this particular centerline for the first layer of the embankment; this will establish the levels for the top of the first layer of the embankment.

Similarly, what will the levels be at the bottom of my subgrade? So, with this one, I can figure out what the levels that need to be achieved are when I do the construction. So, a good surveying team will help you carry out this particular exercise. You can see again that there is a composition. This is a detailed cross-section that shows what is present. Here, you can see that this is the original ground level, and this is your subgrade.

So, I will come to know what this subgrade bottom is. And the subgrade bottom must be constructed according to the cross slope. So, this is for each layer I will work on; then I will work on the subgrade top, and I will ensure it is maintained during construction. Also, for the granular subbase course, the camber must be maintained. Otherwise, where you are constructing the drainage layers, water should flow through those layers.

So, this is possible when you provide adequate camber in the initial construction of the subgrade. Now, what are the codal guidelines that suggest when you should look into this particular one? So, as I mentioned, this is a survey team. So, in charge, you will look at the exercises where the survey team is doing the proper check on the individual layer preparation and, after compaction, also at what levels are coming up, what the cross is, and what the crossfall or camber we are able to maintain. So, all earthworks performed shall conform to the lines, grades, cross sections, and dimensions shown on the drawing because the widths of these layers will be different, as I mentioned in earlier lectures. When we construct drainage layers, they are to be exposed at the ends.

So, they are constructed to full width. So that needs to be ensured. Now, what does MoRTH say about it? When you look at the horizontal alignment, as I have shown in the previous slide, it should be determined with reference to the centerline. As mentioned, the centerline levels of the carriageway are given as indicated in the approved drawings, and you should verify them against those drawings. There are drawings that need to be approved by the respective agencies.

So, the constructed edges—now, when it comes to the edges of individual layers: the edge of your subgrade, the edge of your granular subbase course, the edge of your base course, the edge of your binder course, and the edge of your wearing course. So, all the edges and their ends have to be checked. So, it states that the constructed edges of the carriageway shall conform to this alignment within a tolerance of plus or minus 10 mm. It is always important; otherwise, the effective width will be reduced. If it is reduced, you will not receive proper support.

So, this tolerance of the edges is in the range of plus or minus 10 mm, specifically for the carriageway part that we are mentioning. The corresponding tolerance for the edges of the roadway and lower layers of the pavement shall be plus or minus 25 millimeters. So, if you can see when you go to the top, the tolerances will be much smaller compared to the tolerances allowed in the bottom layer. So, when you are constructing your lower layers, you give a tolerance of around plus or minus 25 mm.

So, 2.5 centimeters may be present. The constructed levels of the subgrade shall not deviate by more than 20 mm, plus or minus 20 mm, as I mentioned; if I calculate, say, the level with respect to the centerline, it is the bottom of my subgrade with respect to the finished level; this is my finished road level at the centerline. And it says that if I keep this particular one, I will mention it at 1.2 meters. This is with respect to the mean sea level, or I will have my temporary benchmarks, and this reduced level will come up.

I am just mentioning that, with respect to any benchmark I have fixed as a reference point, this particular point is my central line level, which will be given in relation to any benchmark. And so it may be said, and that may be with respect to the mean sea level; so it is with respect to the mean sea level, say 101.2 meters. Now, when it comes down to this, I can say that I have a crest of around 1 meter, so this will amount to 100.2 meters. So, this will be my subgrade top, and when it comes up, it will be a subgrade with a thickness of half a meter. So, this will come up in that case: 99.7. So, this will be just at the bottom of my centerline; the level of the subgrade bottom will be 99.57 if I am constructing a thickness of half a meter.

Now, with respect to this one, you will have this camber again. So, you will come to know what this width is that will be constructed. So, you will know that with, say, 2.5 percent camber, what the slope is.

Then I will put on a layer. So, there may be a layer of 25 centimeters and a second layer of 25 centimeters. So, for each layer, I will now be able to say that when one layer is constructed with a camber and you are checking with your surveying team either at the bottom or on the top of the first layer or on the subgrade top, you need to ensure that the levels do not deviate by more than plus or minus 20 mm, which is 2 centimeters. So, if your layer is 20 centimeters, it can be either 18 centimeters or 22 centimeters. So, this needs to be ensured once. So, once one layer is constructed, you will look into this particular check regarding the longitudinal and cross-sectional profiles.

Cross-sectional profiles are required because you need to know what the cross slope will be; with that, you can work out the slopes that will be at the edges. And now, while doing this, once you have prepared a layer, whether it is your first layer of subgrade, the bottom of your subgrade that also needs to be prepared, or the top of the subgrade, you need to ensure the surface levels. For this, how many points can be taken? So, we can form a grid. So, it says it can be on a grid with points spaced 6.25 meters longitudinally and 3.5 meters transversely. So, this is not shown to scale, but just as an example, I can work out these grid points from the edges and then ensure the levels at these grid points and check whether they are within the tolerance of plus or minus 20 mm based on what I derive from my standard drawings. And if I am able to see that there are certain deviations that are within plus or minus 20 mm, but certain ones that are going outside of it, then it states that in any series of 10 consecutive measurements taken in either direction, no more than one

measurement shall be allowed to exceed the specified tolerance of plus or minus 20 mm, especially in cases where this tolerance is different for different layers. If I go for sub-base courses, base courses, and binder courses, it is because I cannot give a tolerance of 2 centimeters plus or minus 20 mm, which means plus or minus 2 centimeters when I am constructing a bearing course of 5 centimeters. So, I can make it neither 3 centimeters nor 7 centimeters. So, this tolerance will continue to decrease as you go to the top of your pavement crust.

So, it states that if 10 consecutive readings are taken, no more than one measurement is allowed to exceed the specified tolerance, and that single deviation shall not exceed the tolerance by more than 5 mm. So, it should not exceed 25 mm in the case of your subgrade. So, this needs to be ensured when the individual layers are being constructed. In addition to this particular one, for surface irregularities and small undulations that can occur, which are very important, we need to have a very smooth surface on the top, and for this particular one, it states that the longitudinal profile shall be checked with a 3-meter-long straightedge. This is a straightedge, and this is a wedge that can be inserted.

So, if a surface is perfectly smooth or perfectly straight, there will be no undulations beneath it. So, this wedge, when inserted, will show you how much undulation there is. So, if the height of this particular gap is, say, more than 4 centimeters and less than 4 centimeters, we show that some amount of undulation is present. With this straightedge, we are going to check the surface regularity, and this will start again with the subgrade construction. So, we can use these longitudinal profile measurements with a 3-meter-long straightedge.

We call it a moving strategy as directed by the engineer, especially since the engineer in charge is the one who ultimately looks for construction sites. So, he makes many decisions on his own, depending on how much variability there is; site-specific challenges, regional challenges, material challenges, and construction challenges exist. So, he makes the decision because the limitations and variability are present. Preferably, it should be done in the middle of each traffic lane and parallel to the centerline of the road. So, we have, if this is the one, this is your center line, which can be there on the one; then, if there are three lanes, it can be done in the middle of each lane, and it will go parallel to your center line; it will go in this particular direction.

And what it says is that the maximum allowable difference between the road surface and the underside of a 3-meter straight gauge, when placed parallel to or at right angles, can also be checked if I verify it. So, if this is my surface and it goes this way, and if my road goes this way, then I am just showing this to understand that I am going in this direction. So, I can check it. Along this one in the middle of the lane, I can check it perpendicular to my center line. So, this can be done in both directions, and it states that it should be at right angles or parallel to the centerline at points specifically decided by the engineer, and this can be done at multiple points if he feels that the undulations are greater at those particular points.

With experience, we will come to know very well where the surface is being constructed properly through visual inspection, as experience helps in many ways. So, it definitely says that you should not only be doing visual evaluations; you are not conducting the regular tests that need to be done. This has to be used; your levels have to be taken up. So, you have to carry out this exercise, but the

points that can be selected can either be done through random sampling or specified by you. I find it good enough, but it appears that there are some challenges.

So, let us look for this one. And there, with this particular straight edge, it states that the allowable difference between the road surface and the underside of a straight edge should not be more than 15 mm in the case of the subgrade. Because, why finally, when do we reach the top of the surface? Specifically, this is a requirement given by MoRTH Section 900, which states that the surfaces of carriageways, the top surfaces of the carriageways, and the irregularities should be retained within this particular range. And how it is to be retained states a 4 mm irregularity; if it is there over a length of 300 meters, it should not exceed 15 mm. So, for national highways and expressways, there is a 4-mm irregularity. So, if you want to achieve that much smoothness, it needs to be controlled at the subgrade cell level.

So, there we are making a control of 15 mm at the subgrade. Now, it may happen that at certain locations the levels are low, or at other locations they may be higher than what is permitted. So, in that case, we need to rectify it before we proceed with the construction of the next layer. Those deviations are beyond the permissible limits. So, where the surface regularity of the subgrade course falls outside the specified tolerance, the contractor shall be liable to rectify this because it becomes his or her responsibility, and it can be done in various ways. If the surface of any subgrade layer is high, it shall be trimmed; you can use a grader or a dozer, and it should then be suitably compacted.

So, a particular depth that you find to be high enough needs to be trimmed and re-compacted. Where it is low, we will do slight scarification, especially because it is compacted. So, we will do a slight scarification of the existing one, and then we will add some fresh materials. So that it becomes one monolithic layer and then recompacts to the required density. So, at every layer, this check has to be done, and if any rectifications are required, they should be attempted immediately; only then should you proceed with the construction of the next layer.

Now, this is one part of a check where we are examining the surface levels and surface irregularities; then come the checks related to the material aspects. So, the quality of the fill material, especially the quality of the material we are filling and how we are compacting it, is also checked. So, it shall be controlled through the exercise of checks on the borrowed material, as we mentioned in the earlier slides; there may not be a sufficient amount of cutting or soil available. So, you may have to select a borrow area from which you will be nearby, and then you will evaluate whether that soil is suitable; if it is found to be suitable, you can use it for your construction. So, you have to regularly monitor that there is no soil coming from the borrow area that does not meet your requirements according to the standards set for the design of the pavement.

It should not happen that there is a significant difference in the borrow area soil quality that was considered for the design during construction. So, we need to have continuous checks on it. It should meet the construction specifications that are laid out. So, the common tests that are done for gradation requirements are checked, plasticity index checks are performed, we have discussed these tests, the Proctor test for the determination of maximum dry density and optimum moisture content is included, moisture content determination, strength in terms of the California Bearing Ratio, and the free swelling test, and there are various specified guidelines to understand what kinds of quality

control checks are required. So, this is a manual for quality control in road and bridge work: SP-112.

Then we have recommended practices for the construction of our embankments and subgrades for road work. IRC 36 is here. Earlier, this was IRC SP 11, which has now been amalgamated with IRC SP 112. And then we have these individual IS code guidelines: 2720 parts, which are as follows: this is for the grain size distribution; part 5 is for the determination of the liquid limit and plastic limit; part 8 is for the determination of the moisture content and dry density; and part IS 2720, part 16, is for the determination of the CBR. Now, the requirement will arise for how many tests I need to conduct.

So, in what terms should it be regarding the area, the quantity of soil, and the volume of soil that will be used? So, how many tests need to be done in a given volume of soil, how important is the frequency, and how many times do they have to be conducted? So the type and frequency of tests on borrowed material depend on factors such as the equipment used, the extent of manual labor, applicable specifications, and site conditions. You can see that there is a lot of variability in the sections being constructed. So, if you find that the variability is greater, the frequency of the test can be more than what is specified in the specifications. So, as I mentioned, there can be gradation checks, and one important statement is that the minimum requirement may be increased as needed based on material variability and the compaction methods used. So, if I am using good compaction methods, then I can look for the standard methods of checking for compaction; but if I find that the compaction methods being used do not have good control, specifically that the rollers are not well controlled in terms of their vibrations, I will need to adjust my approach.

So, in that case, I may need to increase the frequency of the tests. So, the gradation test is one test that is done, and it indicates, especially for each kind of soil, whether there is variability; it states that you should normally conduct at least two tests per 3,000 cubic meters of soil. So then, you will check for the gradation and cross-verify it with the limits specified in your project requirements. One is the code specifications requirement, and the second is the project requirements on the basis of which your entire project has been designed. So, there are standard code requirements and specific project requirements that also need to be ensured regarding gradation. So, the test is quite necessary if the specifications call for checks using gradation.

So, there may be some specific requirements mentioned in your project. So, you need to refer to what the specific requirements for gradation are. For example, sand content determinations are conducted at a rate of two tests per 3,000 cubic meters of soil. So, even though these are certain tests that may not be general tests, most of the time, as mentioned, you follow the MoRTH specifications. Otherwise, if there are specific requirements in addition to that particular one, they will include more specific tests, such as the plasticity index test. Normally, one test for each kind of preferred soil is conducted, and then we conduct two tests for every 3,000 cubic meters of soil.

Because we can determine the amount of work that has been done in one particular day, how much of the road has been constructed, what the width is, and what layer has been constructed. So, I can calculate the volume of the soil. So, if a construction of 2,000 cubic meters has been completed in one day, I will conduct at least two tests on the project. So, the proctor test is now again used to determine whether the soil I am using meets my requirements for density. So, I will conduct the

proctor test to ensure that the soil of requisite quality is coming from the borrow areas because certain changes may occur in the quality of the soil in those areas.

And it gives us further information about the optimal moisture content. So, when these tests are done regularly, you receive continuous updates from your laboratory. So, you will have a well-developed laboratory setup at the construction site. These samples will be sent there. You will continuously receive information, and from that information, you will come to know that uniform soil is being used. If you find that certain changes are present in the quality of the soil, whether they are within permissible limits or not, please let us know.

If not, then you have to look into what rectification measures can be taken, or the borrow area must be rejected, and another area must be selected. So, it states that for the proctor test, specifically for density and moisture content determination, there should be two tests per 3,000 cubic meters of soil for deleterious substances that may be present, as we prefer that the soil be free from salts such as sodium sulfate and from organic matter limits that have been specified. So, this test is to be done, and as more organic matter may be present in certain locations, more frequent measurements of deleterious content may be suggested by the engineer in charge. Moisture content, as I said, is important for compaction, even during compaction, because we prepared trial stretches; we worked out that if this is the moisture content, this much compactive effort will give you the required density. So, you need to check during the construction itself, not only after one layer has been constructed or one course has been constructed; during the course of construction, but you can also keep making these checks.

Whoever is there as part of the team, whether it is the engineer from the contractor's side or from the consultant's side, will look into ensuring these matters. So, the natural moisture content, if it is not reaching your optimum moisture content, means that you need to add water; if it is too high, you need to aerate it. So, the natural moisture content of the soil coming out of the borrow pits is to be determined in order to evaluate how far the natural moisture content tallies with the optimum value, which is the optimal moisture content. Whether further addition or reduction of water content would be necessary, and whether we need to aerate it or sprinkle more water to reach the requirements for optimum moisture content, is unclear. And for this particular one, we normally go for at least one test of 250 cubic meters of soil.

And then, in addition to this particular one, the important aspect regarding strength is the CBR. So, we will simultaneously measure the CBR of the particular soil used for your subgrade and embankment construction. So, the CBR test on materials to be incorporated into the subgrade is conducted under soaked and unsaturated conditions.

So, this will be mentioned in your project. A project document indicates whether it must be conducted under saturated or unsaturated conditions. So, it states that the rate of testing is mainly one CBR test for every 3,000 cubic meters of soil. This is average, so this can be done when required; even he can feel that he needs to do two tests. I need to do one test for every 2,000 cubic meters of soil because a lot of variability is observed, and it must be done. Thank you.