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A very warm welcome to all of you. I am Rajan Choudhary, a Professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati. Instructor for the NPTEL MOOC course, Pavement Construction and Technology, funded by the Ministry of Education, Government of India. Today's lecture will be under module 8, where we will discuss the aspects related to the quality of bituminous-bound courses. At the very beginning, I would like to acknowledge the use of text, information, graphs, and images sourced from various textbooks, code standards, journal articles, reports, newsletters, and public domain searches. Now, as we have already discussed in some of our previous talks, inflexible pavements with bituminous bound courses play a vital role specifically, and they are widely used in the construction of bituminous bound base courses, bituminous bound binder courses, and bituminous bound wearing courses.

So, these are the three typical layers in which these bituminous-bound courses are used. You have a bituminous base course, a bituminous binder course, and a bituminous wearing course, or the surface course. And where you have this one specifically, the binder course is the one that comes in between your surface course and a bituminous bound base course. While discussing these aspects, we will refer to different code standards, test books, and various other methods and sources, including some of the important ones that are specifically followed in India.

You can see we have the specifications for road and bridge works: MoRTH 2012. We have the IRC SP 112 manual for quality control in road and bridge work. Similarly, you have many IRC standards, like this one standard. For standard specifications and code of practice for prime code and tag code, we have IS 73 for paving grade binder and IS 15462 for modified binders. So, a good number of standards exist specifically to examine the quality aspects of bituminous bound courses.

Now, as we discussed in the previous lectures, we need to understand that there is going to be a certain amount of variability that will exist in the various road construction activities. So, it is to be recognized that road construction, like many other manufacturing or construction processes, has a certain amount of variability inherent in the materials and methods involved, and due to testing and sampling as well. So, therefore, prescribing acceptance criteria in absolute terms, the important part is if we are checking a density: if one research fails, then you say no, this lot is to be rejected. So, in absolute terms, that is not recommended. Therefore, prescribing acceptance criteria in absolute terms such that an entire section of a construction or a batch of material is rejected on the basis of a single substandard sample is problematic.

So, one test result should not be considered the only reason behind rejecting an entire lot of work. So, this is important and would be both impractical if we are doing it; it will be impractical, and it will also be prohibitively expensive, so it may not be accepted either. So, because of the inherent variability, the aim of quality control is to limit that variability; yes, what you can do wherever the sources of variability are present is to limit them. So, first of all, one needs to figure out what the sources are during a bituminous mix production. Where some variability may possibly take place, where the chances of any variability existing are high, certain measures can then be taken to reduce that variability, so that the final product is what you desire or what you want to obtain.

So, a philosophy mentioned by William Edwards is that if you improve quality, it helps decrease costs because of less rework, fewer mistakes and delays, and improved productivity. So, for this particular one, the quality checks are very important for any course, and when it comes to bituminous bound courses, since these are the courses that are going to take the maximum loads, these are the courses that are the main structural components of your flexible pavements. The checks and controls have to be much better for specifically these courses. Now, as we mentioned in the earlier lectures, here we will discuss one particular aspect related to quality control charts: what it says is that the analysis and evaluation of test results should be carried out continuously; it should not happen that once the work is completed in one day, some checks have started. No, it should be a continuous process.

So, it should be carried out continuously during the progress of a bituminous work so as to achieve a desired acceptable final outcome and construction. Only then can you expect a product as per your requirements. So, during the entire process, there should be continuous monitoring or a check that is required. An effective method for monitoring quality during construction is the use of control charts. Now this is one effective method that is widely used specifically in bituminous bound courses, and what are these? What does a control chart give you? Control charts provide a simple and efficient means of graphically representing the quality control data, which may be of particular characteristics.

So quality control data for a particular bituminous mix characteristics facilitates its further analysis. So that helps us analyze that particular data and understand if there is some variability and what that variability is, as well as the reasons it is happening, which can be figured out so we can take measures to reduce that variability. So, control charts may preferably be prepared in the form of plots where we can say these are the plots of individual test results, or it can be a running average; we can also average the previous 4 readings, and then this can be. So, this can also be a running average of test results. Now, here you can see that I am putting up an upper specification limit and I am putting up a lower specification limit.

So, this is an example of the density of a compacted bituminous core. So, I have set a range that I need a density in the range of 92 to 96 percent of our maximum gravity space. Now, I can see how the test results are varying. So, if I see this, the test numbers are shown, and this one. So, I can figure out that the test results are in this particular range; they are consistent, but there was some variability that affected them.

So, this is because this check of density, if done in the field, allows me to analyze that there is a continuous fall and that the density is approaching the lower specification limits during this period. Then I can give some information or instructions there at the paving site that you need to take care of in terms of your rolling or compaction efforts or the paving operation from the paver because some initial compaction is also done by paving pavers. So, I can see that some improvement has happened again. After a certain period, there has been another particular one. So, I can figure out that at the site something is happening that needs control to reduce this variability, and I will always aim to have it in the middle of this particular range that is given to me.

So, this is how I can get a good idea about how this compaction, this variation in compaction, may not be only because of rolling, but there may be some variability in the mix that is coming up. So, there may be some segregation in the mix, and when there is segregation, the density will be lower in that case. So, we can then, in that particular case, do this check for the density with respect to the other control charts, which may be regarding the aggregate gradation. So, I can have a control chart where I am looking for the variation in the aggregate gradation when it is being produced at the mix. So, from there, if there is some change in the aggregate gradation, then for the same rolling pattern and the same number of passes, the density achieved may be different.

So, it may not be so; by seeing the control charts for other parameters, I can see where the variation is happening, and then I can figure it out. The measure has to be taken for this particular activity to reduce this variability and bring it toward my target specifications. The inclusion of control charts in the quality control plan is recommended for effective process control. As I mentioned, an effective process control can be done by using these control charts. As measurements of various attributes of bituminous mixes are recorded and the results are plotted on the control charts along with the upper and lower tolerance limits, this can be considered.

So, this gives you, as I mentioned, any particular characteristics in this particular one. I can see, okay, here this is going along the central line; the target once there in this particular one. So, I can figure it out with respect to the control charts of other characteristics that have been there, and then I can pass an instruction and some measure has to be given up so that it can be brought back to our center line. So, this is what is important. So, this is continuous information; this continuous progress has to be checked so that we can rectify it during the course of construction itself.

So, these charts provide a clear visual representation of the process's performance and its conformity to the specified requirements. Some of the key benefits of using control charts include early detection of potential problems, because in the field at the hot mix plant itself, I can look for this particular one at the gradation of the stockpile. Also, if the source of the stockpile has changed, then this gradation may change when it goes to the cold field bins and from there through the gathering conveyor to the production plant. So, there may be some changes; some segregation may be happening at the cold bins. Then, when it goes to the plant in the case of a batch mix plant, if it goes to the hot screens and those screens are not working properly, there may also be chances that some aggregate gradation is changed.

So, I need to figure out at different stages how to control the charge for different materials, specifically what we have in bituminous mixes, which include aggregates and binder. So, aggregate gradation is the one that is important. So, if I have to control the aggregate gradation, I need to control it at various points; then I need to look into my binder—specifically, my binder content is important, as it determines how much binder content is being incorporated. Then, finally, when it goes into the field and is laid there, the paving operation is there, and the rolling operation is there. So, at the paving operation, some segregation is happening at the screeds of the paver, or the rolling pattern is not good enough to have a uniform density.

So, from my earlier findings, if I am finding that the gradation is good enough and the binder content is adequate, there are certain challenges or issues that arise while it is being transported or laid and compacted. So, accordingly, measures have to be taken. So, some of the key benefits of using control charts include early detection of potential problems, reduced variability, and lower inspection frequency, which is very important. Once you have lower variability, you can easily determine that you will get a uniform mix and minimize the risk of rejection or price adjustment by the owner. We will discuss later the pay factors that are there if there is any reduction in the quality or performance of the final product; if some price adjustment has to be made, that can also be figured out.

But the important thing is to reduce the variability during the production process itself. Now, testing asphalt mixtures during production is essential and ensures a durable and satisfactory product because this is very important. For hot mix asphalt construction, key properties and test results evaluated and monitored through control charts during manufacturing and placement may include what can be monitored through control charts; one is aggregate gradation. Now, in aggregate gradation, you have a different number of sieves; there may be 7, 8, or 9 sieves, so certain sieves are always considered as critical.

The 3/8-inch sieve, which corresponds to the number 200, that is, 75-micron sieve size, is always considered as a critical one.

Additionally, 2.36 mm is considered as a critical one, which bifurcates coarse aggregates and fine aggregates. So, you can select some of the critical sieves and then look at what the percentage was, what the percentage derived in your job mix formula was, and what you are actually getting at different parts of placement or at different places during the production process. The second important thing is binder content because it plays a significant role in the performance of bituminous mixes. Then, we can determine the volumetric properties simultaneously once this is there on the compacted mixes, because as the bituminous sling is applied, the mix is getting compacted simultaneously, and you can observe the compaction of it. You can similarly prepare the samples at the laboratory setup at the plant as well.

So, from there, you will also work out the volumetric properties, especially which volumetric properties are considered: this includes voids in mineral aggregates, air void content, and theoretical maximum specific gravity. Now, strength, along with that in compacted samples, strength, and flow are the other characteristics. The density of laboratory and field compacted samples is measured in the field, and we can also determine it in the lab. Monitoring these properties with control charts helps ensure consistency, reduce variability, and maintain the quality of asphalt mixtures throughout production and placement. Now, we will discuss some of the aspects related to aggregate gradation.

See, although several aggregate properties are important, we have discussed various properties in terms of shape, impact, strength, polishing characteristics, and adhesion characteristics. But one important thing is the gradation. So, if all those physical characteristics are ensured, then that particular source, because we look into the specifics, what the gradation is there. So, for quality control and assurance, samples may be collected. Now, where do we collect the samples from? This is, again, an important part.

So, this aggregate gradation can vary by source, depending on the location from which we are collecting the samples. So, where can we collect during the production from the key points such as the stockpiles at the hot mix plant and the cold feeder belt? So, your gathering conveyor is there, which collects the material from all the cold bins; from there, you can collect it. Hot bins in the case of a batch mix plant since the screens are there, hot is elevated; screens are there. So, there are those screens separated out. So, from there we can collect this particular one, or once it has been loaded in a tipper, we can collect it from behind the paver, or specifically when it is dumped in the hopper.

So, from various places, we can collect the bituminous mixes or specifically the aggregates alone to determine the gradation. One can always say I will prefer to check when it is finally there going towards the laying purposes, but yes, that is true. Before that, if you find that the final mix has a different gradation compared to your job mix, you need to know where it is happening. Whether this is happening because of some changes in the stockpile gradation, because of the inadequate or improper functioning of your cold bins, or because some of the screens of the hot elevator screens and hot bins are not working properly, you need to determine where this particular issue is occurring, or if the dust collection system or the introduction of dust is not proper enough.

So, those things need to be looked into. Evaluating gradation at multiple stages helps identify where variability occurs; this is why it is required, enabling quick troubleshooting. So, we can quickly say this is the place where it is happening. So, what measures have to be taken? If it is happening at the cold bins, we look at what rectifications are required at the cold bins level. So, the aggregate gradation in the asphalt mixture is most critical because it represents the final product. However, controlling gradation at earlier stages is essential to ensure the final image is accurate.

So, this is what happens during the production process itself. We can look into it. Now, as I mentioned what can be at the stockpiles, these different stockpiles are present. So, once the initial stockpile gradation is established, while doing the geomix determination and the combination proportioning, we look into the stockpile gradation; this can change, specifically if some new materials are added to it. So, the stockpile gradation is definitely going to be changed.

Otherwise, what variations could be possible? It is due to some changes in the aggregate source. The source of the natural rock that was used is different. Segregation during the handling or stockpiling refers to how you are putting up the aggregates. How it is coming up from the crusher's conveyor belt and falling out. So, there is some particular segregation that takes place, and also how do you sample it? If I sample, whether I collect a sample from the bottom of my stockpile only or if I collect only from the top of my stockpile, I will get segregated aggregate particles.

So, this is yet another concern. At the cold feeder, now when it comes to the cold bins and through that particular one, we have the gathering conveyor that is there. So, since combined aggregates are fed into the HMA plant from the cold feeder conveyor or the slinger conveyor after the screening of the bigger size particles. Checking gradation at this point can be quite useful because then I can collect from this gathering conveyor, as this is what is finally entering into the plant. So, if that is entering according to my requirement, it is good enough. So, variations may arise from inconsistent stockpile gradation, and the control chart may show whether the stockpile gradation is going out or not, or from aggregate segregation that may be present in the cold bins themselves.

Improper loading or incorrect settings can lead to overfilling of these cold bins, and the openings and settings of the auxiliary conveyor, from which the material comes from the individual code base, need to be adjusted along with the sampling and testing errors. Similarly, when it comes to the hot base that is specifically present in the case of a batch mix plant. So, what may be the possible reasons for this particular improper cold field gradation and feed gradation? If the gradation coming from the cold beans is improper, then definitely the hot beans we will have will also be improper. Inconsistent dust collector feed is important because it concerns how the dust collected from your primary and secondary collection systems is being fed back to these aggregates. Production rate changes normally because this happens if the production increases or there is a change in the production rate; then the screening efficiency gets changed.

So, this is another aspect. Screen defects arise if some of the defects are found in some of the screens; this may also include sampling and testing errors. So, when it comes to the loose mixes, once the mix is produced in a batch mix plant from the pug mill or through continuous production from a drum mix plant, all earlier steps will have a contributing factor as we move ahead. So, it may be at the mix level, it may be because of cold feed bins, or it may be due to incorrect hot bin proportions, which will be there in the case of batch mix plants; inconsistent dust collector feed, which is there; aggregate segregation within the plant; within the dryer in that particular one in the case of drum mix plants; segregation during storage; and yes, thereafter it may be stored in storage silos before finally. So, if we are collecting after that particular one, there may be some segregation happening at your storage silos, as well as transport, laying, and sampling errors. So, I can work it out with the control charts to identify where my variability is happening, and then you have these standard tables that have been specified by our Indian Roads Congress guidelines as well as the MoRTH specifications to compile the information.

Now, after the aggregate gradation, another important parameter is your binder content, which plays a very important role, specifically in the performance of a bituminous mix. If there is a mix with a lower binder content, then it may have some durability concerns because this is specifically required to provide resistance to moisture-induced damage, giving you the desired resistance to cracking fatigue. So, if the binder content is inadequate, there will be concerns related to durability, and if the binder content is also in excess, it may also result in challenges associated with rutting, as well as deformation and bleeding when the binder comes to the top. So, these kinds of concerns may arise if the binder content is more than what is designed. The binder content significantly affects the mixture properties, and since these are related to performance, the performance will also be affected.

Additionally, in terms of volumetrics, it will play a significant role; lesser binder content will result in a thinner asphalt film over the aggregates. Volumetric properties, specifically voids in mineral aggregates and air void content, are also affected, along with stability. So, it is very important to monitor asphalt content during the production of bituminous mixes. Now at HMA plants, what can be the causes of this variability in the asphalt content specifically at a hot mix plant due to inaccurate aggregate or asphalt content scales, as in a pug mill? Where their wave hopper was, how much content, how much weight of individual sizes of aggregate has to come up, and how much content of binder has to come up. So, if those scales are not working properly, you will get some inadequate asphalt content.

There may be leakage in that particular case, and continuous dropping may occur from the binder. Segregation may specifically happen in the case of batch plants if segregation occurs, because if you have coarser aggregate particles, they have lesser surface area, which means the binder content in that particular mix may appear to be more compared to a finer mix if there is some segregation, or due to inaccurate belt scales, particularly miscalibrated asphalt meters, because asphalt meters also need to be calibrated. Incorrect moisture corrections may also be present, especially because, as I mentioned, we normally dry and heat aggregates depending on the capacity of the plant; typically, we are able to address moisture content from 2 percent to 6 percent. So, sampling or testing errors can further contribute to this variation in binder content. Now, finally, the best part is we are able to pick up the mix once it is loaded in the truck.

So, once that is there, we can determine that there are specified methods through which we can determine. One is the centrifuge extraction method, which is very widely used, where a solvent is used to extract the binder from that mix. And second is the ignition oven method, where the binder in the mix is heated to a high temperature so that the binder is completely burned. So, these two are widely used methods, and the advantages of this method are that you are able to get the aggregate, which you can use to determine the gradation as well. So, you have determined the binder content, and you can work it out based on the determination of your aggregate gradation.

This is how an ignition oven looks, which burns off the binder, and the binder content is determined as the weight loss experienced. Whereas, in the other one, when the binder solvent is filtered and the aggregates are separated out, the solvents are normally hazardous. So, nowadays this ignition method is also preferred; non-hazardous solvents also come into the picture. This is how a centrifuge extraction works: this is where you use this binder and solvent to separate the binder, which is dissolved in the solvent, from your aggregate parts. So, how much binder content are you actually getting in a mix? Now, in addition to what you need to know about the volumetric properties, you also need to understand the compacted characteristics, specifically in terms of strength, material stability, flow, and density.

So, for dense-graded materials specifically under volumetric properties, one characteristic that is very important is the air void content, and another that is simultaneously measured is the voids in the mineral aggregates. Coming to air void content, usually dense-graded mixes are designed to have an air void content in the range of 3 to 5 percent or 4 to 6 percent in some cases. So, this is the usual range: 3 to 5 percent. Now you need to understand that here you have an upper specification and a lower specification limit; if air void contents go below 3 percent, then there are chances of rotting and performance-related concerns. If they are above 5 to 6 percent, then it may lead to premature aging because the chances of oxidation are greater, which can lead to raveling, cracking, and stripping.

So, these are again performance-related challenges. We will discuss these distresses in our upcoming lectures. So, we will talk about raveling, cracking, and stripping. So, these are stripping when the binder film is stripped from the aggregate, cracking when cracks are observed on the surface, and raveling when you see that the fines are lost from your bituminous surface. So that is unraveling. Marshall stability and flow should meet mix specifications because, for different mixes and with different binders, the requirements for your Marshall stability may be different.

So, that particular mix should meet those requirements, and specifically, we need to look into it because very low stability and high flow may indicate a mix that is prone to rutting, as that shows the mix is soft enough. And while an over-stiff mix may be prone to cracking, a mix that is very stiff may crack when it is deflected under the traffic load. Now, to compare these volumetric properties of compacted mixes, we need to know the maximum specific gravity, which is the theoretical maximum specific gravity of the loose mix. So, this is normally sampled when we have these trucks in which the loose mix is loaded. So, from here we will work out the theoretical maximum specific gravity, and then we will compare the density obtained in the lab or in the field with the theoretical maximum density; normally, it is said that the density should not be less than 90 to 93 percent of the theoretical maximum density.

So, the mix in the field should be compacted to a density of more than 92 to 93 percent. But there is an upper limit; it says it should not go more than 97 percent in most cases because then the air void content will be reduced to less than 3 percent, and then some concerns related to rutting and bleeding will start. So, this is a particular range we prefer to have the density of a compacted mat in the range of, say, 92 to 97 percent, or specifically 92 to 95 percent. Now, if this density is less than this particular one, then the air void content is more than this particular one. So, in that case, the mixes are more prone specifically to raveling; oxidation of the binder will occur, and that mix will also be prone to stripping.

So, this should not exceed an air void content of more than 7 to 8 percent in that particular case. So, the constructed pavement should not exceed a density of either 96 percent or 97 percent of the theoretical because we aim to achieve an air void content of around 3 to 4 percent after 2 to 3 years of service life. This is if it is initially during the laying and compaction only if the density goes below 3 to 4 percent and the air goes below 3 percent; then the chances are that the mix will show certain failures related to the rutting, and you can see a depression shown along the wheel path. So, this can happen in a newly constructed bituminous course. So, this is again a table that shows how the information can be recorded for different parameters, how the results can be plotted, and we can continuously see the percentage of bitumen content, stability, flow value, and VMA; we discussed these once during the bituminous mix design.

So, considering these different parameters, there are usually certain parameters that are widely preferred by pavement technologists specifically to monitor the process, out of which the one that is most commonly preferred is the density and the binder content. Thereafter, it was followed by aggregate gradation, air void contents in compacted material specimens, voids in mineral aggregates, voids filled with asphalt, stability, and flow of compacted material specimens. So, these are the important parameters that are usually considered, and the first two are the most widely referred to. Now here comes this particular aspect we can look into, as we discussed in the previous lecture, that we can examine the distribution of the results of these different parameters. And as we mentioned, a normal distribution curve for different attributes is usually used to compute two parameters: one is the percent within limits, which is PWL (percent within limits), and the other is the percent defective.

These are the two parameters which indicate what percent is within limits if the results are plotted using your standard deviation and mean, and if I see that the limits are shown. So, the percent within limits indicates the percentage of the lot conforming to the specification. So, if this is the plot of my results of, say, 5 to 7 samples, then I can see, and if this is my specification limit, which is a lower specification limit, my test result should be more than this one. Then, this is the area under this particular curve where I am meeting my requirement. So, if I work out this particular area, I will get how much percentage of results is within the limits.

So, this is what the percentage is within the limits, and this is what is below this particular one; my percent defective will be. So, it indicates the percentage of a lot falling outside the specification limits. So, there can be a single limit; as I mentioned, we can have a single limit if it is in terms of some density or in terms of binder content, or we can have a range; we can have a lower limit as well as an upper limit, and then I look to see how much is there within the lower limit and upper limit. So, this will be my percentage within limits, and the sum of this one and this one will be my percent defective. So, this is a criterion for this case of binder content where we allow a variation of plus or minus 0.3 percent; my target is 5 percent. So, then this will become 4.7 percent this will become 5.3 percent. So, I will ensure regarding this one where my results are actually falling. So, once this is there with you, both the percent within limits with respect to the percentage defective of a lower limit and the percentage defective with respect to the upper limit can be established, and there can be certain parameters that may have only one limit; either it may be an upper limit or a lower limit. So, I can work out the percent within limits as if in the case of one limit it can be the percentage defective either lower or upper, and with two limits, it is 100 minus the percent defective up with the upper limit while considering the lower limit as well.

So, this is for. And on the basis of this particular one, we can work out the pay factors. This is generally the percentage of contract cost that can be paid. So, for one day's work, we can work this particular one out on a lot-to-lot basis. It should not be once the entire project; it should be lot to lot because we will do this monitoring continuously. So, for quality allocation, this is a typical example that has been shown here; it is mentioned that the pay factor is the percentage of the contract cost that can be paid.

So, it says 55 plus 0.5 times PWL. So, the percentage is within limits if I can say what the percentage should be within limits. So, if 90 percent is within limits, then in that particular case, this will be 100 percent. So, I can make a 100 percent payment. This is a typical example because I understand; therefore, there will be 5 percent variability. So, I have to recognize and consider this variability while making the payments through the contract.

So, due to inherent variability in materials, production, construction, and testing, some test results may fall outside the specification limits; as I said, 5 percent may fall out of it, or a lesser amount may evolve, but yes, definitely, this is a normal phenomenon that some test results may fall outside your ranges. So, this is expected and not necessarily detrimental, and one or two test results falling outside is not a cause for concern. So, that is what we are checking through these percentages within limits. For example, a 90 percent limit within the limit, as I mentioned, will work out to a pay factor of 100 in that particular case. These pay factors are developed on the basis of experiences we have with our mixes and our conditions of construction.

So, depending on this, here is one example taken from some other countries. So, there can be this particular one. Similarly, we can have pay factors for our particular projects, and this may also depend on the size of the project. So, percent within limits-based payment systems account for both penalties and bonuses; even I can keep a clause that if the variability is less, there should be some bonus awarded to the contractor in that case because he has put in a lot of effort to reduce the variability. However, in general, a percent within limits below 60 percent is normally considered for rejection.

So, in that case, you have to go for a replacement of the lot. So, in that case, here we can see if the percent within limits is more than 95 percent, that means the percent that is defective is less than 4 percent; then, in that case, a bonus has to be given, which is 105 percent of the contract cost; otherwise, in this particular case, it is 90 to 95. So, this is a typical example which has been taken up; this has to be decided based on the projects, and it has to be well decided before the commencement of the project. Now, for the different characteristics, our specifications give the requirements for the number of tests to be done and the frequencies to be followed, as we discussed regarding the prime coat and tack-out application as per IRC 16. So, it says the tests that are to be done in respect to the quality of binder. So, it says one test set for a tanker of lot 10 tons as per IS 217 for cut back bitumen and IS 73 for bitumen, and IS 887 for bitumen immersion.

So, one test for a tanker has to be done of 10 tons; in that particular case, binder temperature can be regularly monitored. There is no specific frequency mentioned. The rate of spread of this prime coat or tack coat needs to be checked for 1000 square meters and not less than 2 tests per day. So, this is already well specified in our code specifications. Similarly, we have different tests that can be carried out for the aggregates, as I mentioned; there can be soundness, plasticity index, water absorption, polished stone values, sand equivalent test, and specifically the shape and strength-related tests.

So, it mentions one test per 350 cubic meters of aggregate for each source and wherever there is a change in the quality of the aggregate. So, if there is a change in the source of aggregate, then this has to be done again. Then the quality of binders will depend on whether we get your neat viscosity grade binders or modified binders. So, when you get the different grades of binders, specifically from the same category and the same manufacturing batch, they are there.

So that is known as one lot specifically that forms a lot. So, a lot is defined by the same category, whether neat binder or modified binder, with the same grade VG 30, and the manufacturing batch is also the same; in that case, it forms a lot, and that lot's tanks determine how many samples you will be taking. So, up to a total of 52 containers. So, the number of containers is there. So, up to 50 containers can be selected for modified binder and for neat binder as per IS 73; this is IS 15462. So, it says how many containers need to be picked up specifically for these binder grades and on these containers, what are the specific tests that need to be done.

We need neat binders for absolute viscosity, penetration, and softening point tests, and for modified binders, the tests mainly done are softening point, elastic recovery, separation, and penetration tests. So, these are some of the tests that are recommended by IS 73 and IS 15462. Then, the type of construction mentioned allows us to work out the binder content, as per MoRTH specifications, which state that the binder content should be determined for at least 400 tons of mix. One set for 400 tons of mix subjected to 12 tests per day per plant.

So, one lot two tests have to be done at least minimum specifically. And temperature should again be monitored regularly for your different types of binds. And along with it, the aggregate, if there are certain aggregates where concerns are related to the fractured faces, then one test per 350 cubic meters of aggregate is required when crushed gravel is used, specifically because we have concerns related to the crushed faces. The other requirement, like the two main parameters, is density. So, the compaction field density states that this is

SP 112, which indicates 3000 square meters, but is limited to a single day's production. So, how many samples are to be taken? Four samples at least, and when voids in mineral aggregates are again 400 million tons, but limited to a single day's production, three tests.

So, the number of tests that are to be conducted on these different components of bituminous mixes is already important. So, the most important thing is that we are able to monitor the variability through control charts, and we should realize that definitely a little amount of variability is going to exist. So, we can work out the percentage within limits, and then based on this, we can judge the quality of these mixes. So, this is all about the aspects related to the quality control of bituminous mixes. Thank you so much.