Pavement Materials
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Lecture 56
Mix Design of DLC- IRC SP 49

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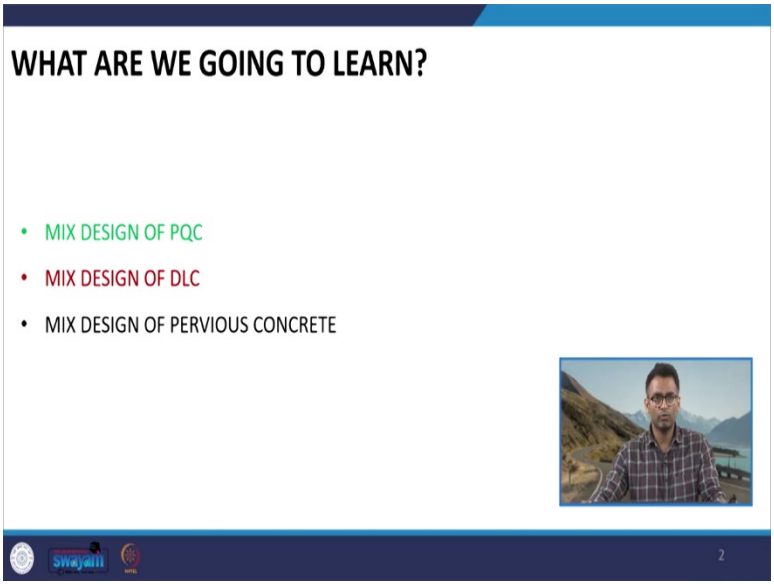

Hello everyone. In the last class, we have completed our discussion on mix design of PQC and today we are going to start discussing about the mix design of DLC. So, what is DLC?

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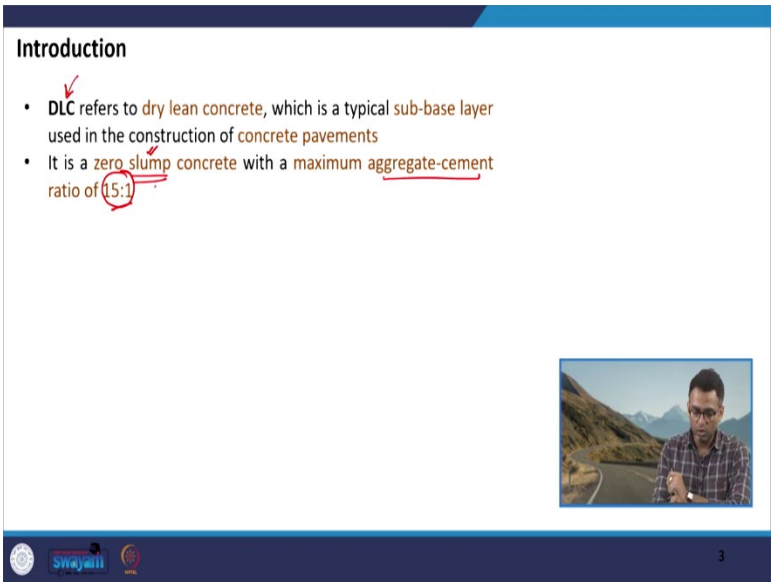

DLC refers to Dry lean concrete, which basically is used as a sub base layer in the construction of concrete pavement. So, Dry lean concrete is also a type of concrete mixture, but, the mix design process is different as well as the proportioning of different ingredients are also different in comparison to PQC. You can say that Dry lean concrete is a low strength concrete mixture in comparison to pavement quality concrete.

So, it is a zero slump concrete a very dry mix with a maximum aggregate cement ratio of 15:1 saying about slump of concrete I mean this topic is something maybe we are discussing about the slump we have discussed about the workability. But, maybe I forgot somehow to explain the process of doing the slump test in the laboratory to assess the workability of the concrete mixture, which I will be covering today.

So, this is a zero slump concrete we will see how the slump of concrete can be measured in the laboratory and the maximum aggregate cement ratio taken for the production of dryland concrete is 15:1 now, this is something which is different from what we have discussed in case of PQC. Because in PQC we were talking about a ratio which is water to cementitious material ratio, but here in the mix design of DLC we talk of the ratio in terms of aggregate to cementitious material ratio.

So, this is something which you have to remember that this is an important ratio for the production of Dry lean concrete.

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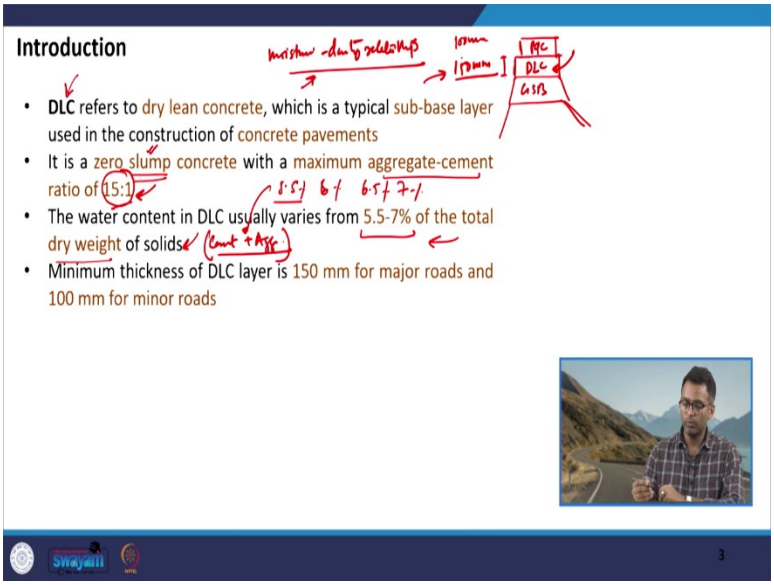

Now, here water content also we have to determine that what should be the optimum water content and water content is usually determined by looking at the moisture density relationship of the concrete

mixtures which we produce in the laboratory and these mixtures will be produced at of course, because we are interested to see the moisture density relationship we have to produce the Dry lean concrete mixtures at varying moisture content ranging from typically let us say 5.5 to 7 percent.

So, we can have a gap of point 5 percent which means first sample we can make at 5.5 percent moisture content the next sample we can make at 6 percent moisture content then 6.5 and then 7. So, at different moisture content, we have to make the samples and these moisture content are defined by the dry weight of the solid.

So, what are those solid materials we have cement and we have aggregates. So, the by this 5.5 percent is actually by the combined weight of the solid materials we use in the concrete mixture. We will talk about the mix design very soon. So, in the construction as I said it is used as a sub base layer.

So, if this is the embankment we have a granular sub base for drainage purposes and then we have this DLC mix and above this we will place our PQC. So, this is here and the minimum thickness for major road is 150 mm. This is the minimum thickness if it is a minor road or a low volume road and we are having a provision of using a stabilized segmented layer then the thickness of DLC will be 100 mm, but for most of the major road it is 150 mm.

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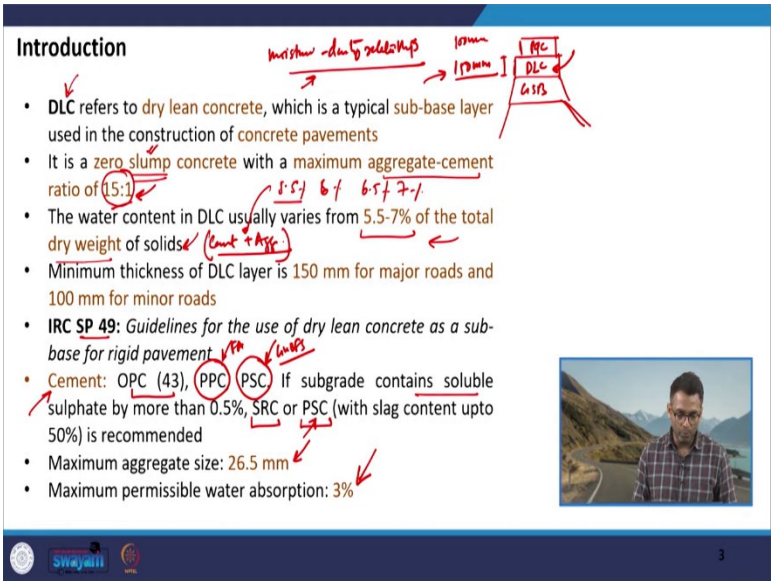

So, the guidelines which we are discussing today is IRC SP 49 which tells us about the process of mixed design of Dry lean concrete to be used in rigid pavement. Now, talking about the ingredients with which the Dry lean concrete is made of we have cement obviously, so, typically we use a OPC 43 cement in case of Dry lean concrete. We also have provision of using Portland Pozzolana cement and also Portland slag cement.

I hope by now, we understand that PPC is will be made up of flyash whereas in slag will have GGBFS. The guideline also tells us that if the sub-grade has soils, which contain more than point 5 percent of soluble sulphate, in that case, we can also use sulphate resisting cement or we can use Portland slag cement, where the slag content or the GGBFS content will be up to 50 percent.

So, this is in case when the sub-grade soil has soluble sulphate content of more than point 5 percent in the Dry lean concrete the maximum aggregate size which we use is 26.5 mm and we have only one gradation here in contrast to multiple gradations corresponding to different nominal maximum aggregate size which we saw in case of PQC.

And for the aggregates, be it coarse aggregate or fine aggregate the maximum permissible water absorption is 3 percent in case of PQC it was 2 percent and in some cases it can go up to 3 percent given that all the other material properties are satisfied, but here the permissible value of water absorption is up to 3 percent.

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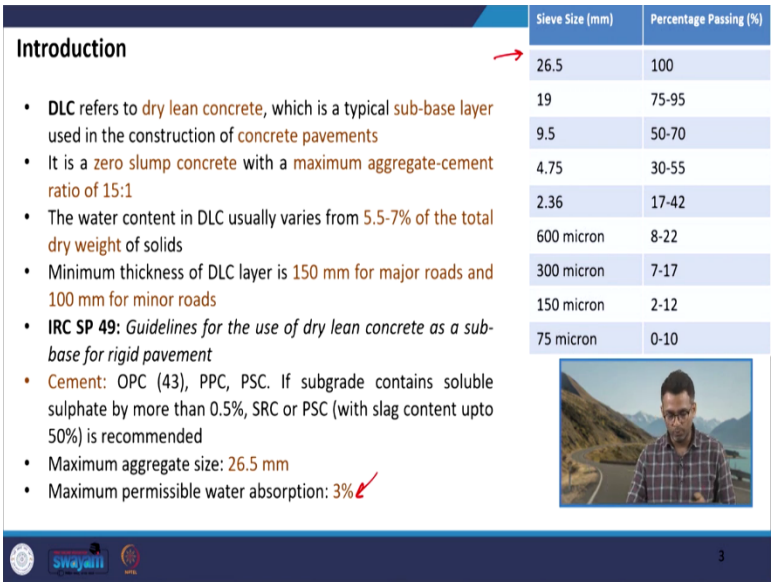

So, this is the gradation of the DLC as given in the guideline. So, you can see this is a combined gradation of coarse aggregate and fine aggregate and even in the fine aggregate the specification mentions that we can use sand of from different zones zone 1 to zone 4.

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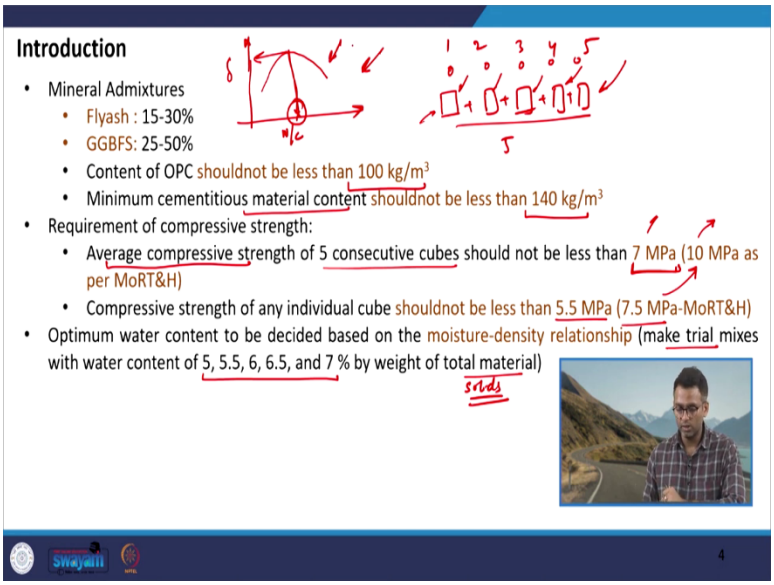

Moving ahead talking about the use of mineral admixtures we can use flyash in DLC we can go up to 30 percent for typical range being 15 to 20 percent GGBFS we can use in somewhere in the range of 25 to 50 percent, OPC content in case we are using a blended segment where we have let us say Pozzolana cement or a slag cement in that case, we have to ensure that the content of OPC is not less than 100 Kg/m^3 and the minimum cementitious material content be it only OPC or a blended cement it should not be less than 140 Kg/m^3.

Now, what are the compressive strength requirement as I mentioned that DLC is a low strength concrete in comparison to PQC. So, the requirement of average compressive strength of 5 consecutive cubes that are being tested it should not be less than 7 MPa, this 7 MPa is as per IRC SP 49 but the ministry of road transport and highways guidelines tells us that the minimum strength should be 10 MPa.

The compressive strength of any individual cube now, this is the average compressive strength which means if we have 5 cubes then you will measure the compressive strength of all the 5 cubes and then you will just do the average. But even if we look at these values, so, as per IRC SP 49 the individual values should in no case be lower than 5 point 5 MPa and as per the ministry of road transport and highways guide book the minimum strength of individual cube should be at least 7.5 MPa where we are taking the average target strength to be average compressive strength to be 10 MPa.

Now, as I mentioned that the optimum water content has to be determined using the moisture density relationship, which means we have to make DLC cubes, DLC samples at varying moisture content and we will be calculating the density of the samples. So, this is similar to what we have learnt in soil about proctor density. So, we expect that similar type of curve here. So, there will be a moisture content where the density is maximum and this moisture content we are going to use as the design moisture content.

So, we have to make trial mixes and the will vary the water content from 5 to 7 percent by weight of the total material which means the by the weight of the solids here and then we will keep on calculating the density of the sample that is being prepared and we will plot a relationship which will look something like this and then we will locate that at what moisture content we are getting the highest density.

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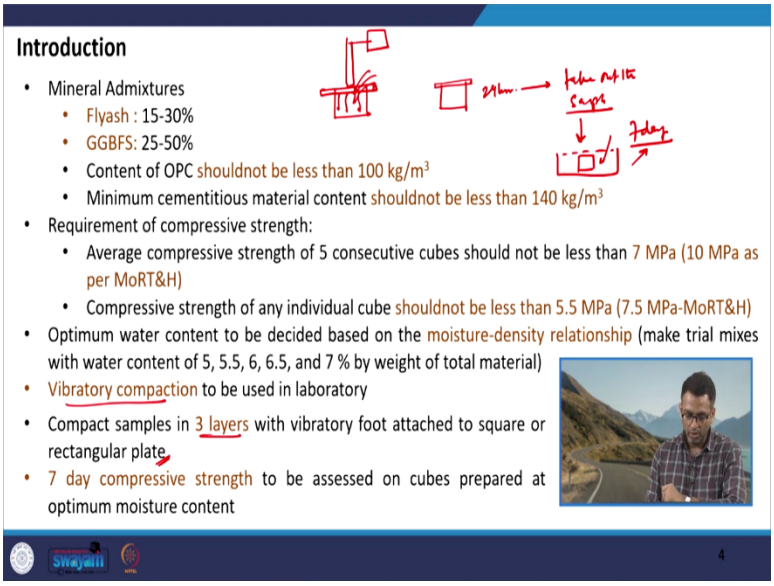

In the lab when we are making the sample for DLC we have to use vibratory compaction if in fact in the field also, we usually use vibratory compactor to compact the DLC layer. So, you have the cubicle mold, let us say you have filled this mold in several layers and then you put a plate here and using a needle vibrator you just vibrate the layer such that all the material settle down into a dense mass. So, this is how typically we will do the vibration.

So, compact the sample in 3 layers with vibratory food attached to the square or the rectangular plate and you give the vibration after you put in individual layers, once you have made the sample so, once we have the sample ready on the first day it is just covered with a red gunny bag the after 24 hours we will just take out the sample we will condition the sample inside a water bath.

So, this will be done for 7 day because (PQ) because DLC is designed for 7 day compressive strength unlike concrete cubes, which are usually designed for 28 day compressive strength. So, we will after 7 days we will take out the sample we will put it under the comprehensive testing machine or the UTM and we will measure the compressive strength of the samples and these samples will obviously be prepared at the optimum moisture content and then we will ensure that the strength is within the desired limits.

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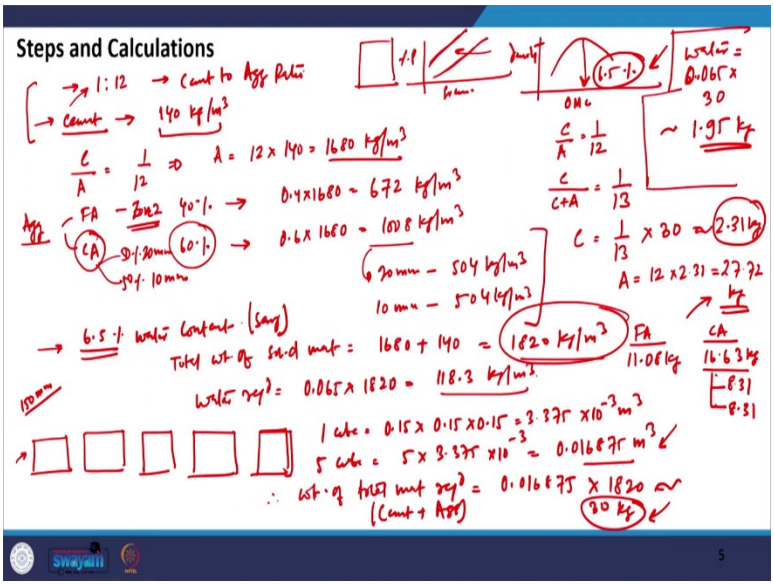

So, let me tell you how typically the calculations can be done for proportioning the material in case of DLC you are using 1 is to 12 as the cement to aggregate ratio you can also use 1:14 because we can go up to 1:15 so, say we have taken 1:12 in our design there is a requirement of cement content. So, the minimum cementitious material content should be at least 140 kg/m^3.

So, let us start with that particular value. So, this example is just to tell you how the proportioning has to be done. Now, we know that cement to aggregate ratio that we have taken is 1:12 and therefore, the aggregate is 12 times of 140 which means this becomes equal to 1680 kg/m^3.

Now, we have the aggregate is composed of fine aggregate as well as coarse aggregate, we are using a zone to sand and after doing the proportioning of fine aggregate and coarse aggregate to meet the desired gradation range which is percent passing by CIF size. So, we have already seen what is the desired gradation.

So, in order to meet these criteria, let us say we are using 40 percent of sand and 60 percent coarse aggregate. So, 40 percent sand means it will be 0.4× 1680 which gives us the value as 672 kg/m^3. Now, coarse aggregate can be a single source aggregate or it can consist of multiple stockpiles in this example, let us say that the 60 percent coarse aggregate comprises of 50 percent of 20 mm aggregate and 50 percent of 10 mm aggregate say.

So, 60 percent means how much total course aggregate will be 0.6 ×1680. So, this becomes equal to 1008 kg/m^{3}out of this 1008, 50 percent is for 20 mm. So, 20 mm becomes equal to 504 kg/m^{3}similarly, 10 mm will be 504 kgs per meter cube, this is what we have got for individual aggregate sizes. Now, we have to make samples at different moisture content.

So, in the first case, let us say that we have already done the we have seen the density versus optimum moisture content relationship and we found that the optimum moisture content is 6.5 percent even if you are not saying that it is the optimum moisture content, we are making trials at different moisture content and the first trial is at 6.5 percent water content say, so, for 6.5 percent water content, how do we do the further calculation.

So, the total weight of solid material becomes equal to how much (1680+cement), which is how much it is 140 is not it, so, this becomes equal to 1820 kg/m^3. So, how much water we need to add, so, water required will be 0.065$\times$ 1820 so, this is 118.3 kg/m^3. Now, this is these proportions we have decided now, we have to calculate that in one mold or let us say in 5 molds because we have to test 5 samples to ensure the minimum strength criteria. So, in 5 molds, how much material will be required to make the mixes.

So, the standard mold which we are using is 150 m^3. So, our so, 1 cube will have a volume of 0.15 into 0.15 into 0.15 so, this becomes equal to 3.375 $\times$ 10^{-3} m^3now, 5 cubes will be equal to 5 $\times$ 3.375 $\times$ 10^{-3}.

So, this if you do the calculation you get a 0.016875 m^3so, you can just cross check this value. So, therefore, the weight of total material required when I say total material I am calculating the quantity of cement plus aggregate that is required this will be equal to 0.016875 $\times$ 1820 so, 1820 this is equal to approximately 30 kg if you do the calculation.

So, you have to take 30 kg of the material and in the 30 kg what will be the weight of course aggregate and what will be the weight of cement. So, you see cement by aggregate you are taking as 1:12 so, if I just do C plus A this is $\frac{1}{13}$ so, cement becomes equal to $\frac{1}{13} \times 30$. So, this is equal to 2.31 kg, so, this much of cement will be required therefore, aggregate will be equal to 12×2.31. So, this is equal to 27.72 kgs

So, out of this 27.72 kg fine aggregate is how much 40 percent so, 0.4 of this value 11.08 kg whereas, coarse aggregate is 60 percent of this value which means 16.63 kg in the coarse aggregate we further have 2 divisions that is 20 mm aggregate 50 percent 8.31 kg 10 mm aggregate 8.31 kg.

And Finally, the water content which you will require will be equal to how much 6.5, 0.065 percentage in percentage into 30 kg so, approximately 1.95 kg. So, this much water you will require to prepare these 5 mixtures and then you will have 5 different molds and after the conditioning period is over we can measure the compressive strength.

So I hope that these calculations now you understand and you also will be able to perform the proportioning for producing the Dry lean concrete mixtures in the laboratory. So, now, we are almost done with the concepts related to the mix design of DLC as I mentioned that 2 tests were left which we need to discuss in this lecture related to concrete mixtures.

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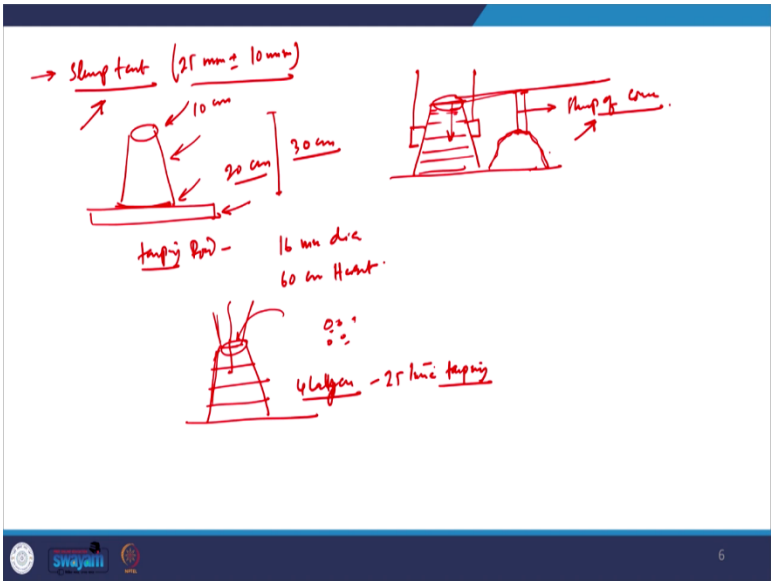

So, one was the slump test, which is a very important test to see the workability because, ultimately, after we have completed making the trial mixes, what we have to do we have to ensure that the the first proportioning which we have completed satisfies the required workability criteria say, the our workability criteria is 25 $\pm$10.

So, we have to ensure that this criteria is satisfied. So, the question is how do we measure the slump of the concrete mixture? So, once we have made the concrete mixture, what are the steps that are involved so, let me just show you the slump cone. So, it is a very simple experiment, we use a slump cone which is placed on a base plate.

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So, if you see that this is a slump cone, the dye at the top is less than the dye at the bottom and then this it has some extended plates here, which will get fixed on the base plate. So, we have a base plate here and we will just fix our cone on the top of this rigid base plate before we start the experiment and there are screw attachments which you can see at the sides, which can be used to clamp these extended arms.

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In this experiment we also need a tamping rod of standard dimension and standard weight which is used to compact the fresh concrete mix which we have prepared inside the slump cone. So, this metallic mold which you have seen it has a bottom dye of about 20 centimeter the top dye is 10 centimeter and the height is 30 centimeter.

And then we have a base plate here the tamping rod again which you have seen is 16 mm in dia and has a height of 60 centimeters so, what we do in this test, we will just place this cone on the base plate, we will prepare our concrete fresh concrete mix then we will start filling this cone with the concrete mix we can put in a funnel arrangement here, so, that we can just put the concrete mix inside.

So, this has to be filled in 4 layers 4 layers and each layer will be timed 25 times using the tamping rod, then once this cone is filled with the concrete material the extra material again we will remove and just will make the surface plane then you see we have handles here. So, we will gradually lift this cone which is now filled with fresh concrete.

So, you see depending on the workability characteristic depending on the moisture content and admixtures that are present and of course, various other parameters like the amount the gradation of the aggregates and so on, this fresh concrete it will lose its height it will subside. So, after you just remove it the fresh concrete will maybe look something like this. So, it will subside and it will lose its height.

So, we measure the height from the top that what is this drop in height what is this drop in height and this height is nothing but the slump of concrete. and we have to ensure at the site that before placing the slump of the concrete is within the specified range to ensure proper workability characteristics in the concrete mix which we have prepared.

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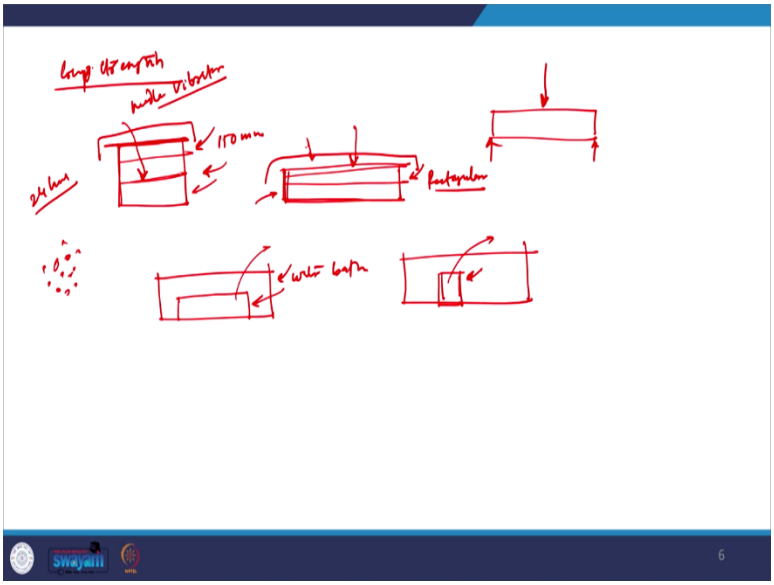

Similarly, let us now talk about the compressive strength test, which is very similar to the cement concrete strength test which we have discussed though the size of the mold was small there, but almost the process of doing the test remains the same. So, here we typically have a 150 mm cube we in case of concrete

payments since our design parameter is flexural strength, we are also interested to make beam specimens to do a 3 point of beam loading to SSD flexural strength of the concrete sample.

So, we can have a mold which is rectangular. We can also have a cubicle mold if we are interested in the compressive strength. So, what we do have to make the sample again we prepare the fresh concrete with the proportion as per our mix design, then we will fill this cube in 3 layers typically and each layer will be vibrated using a needle vibrator. So, we will use a needle vibrator to just compact the mix. And once the top surface is filled and the compaction is done, we will smooth in this top surface using a trowel so that every plane surface we can get.

Similarly, we can do the compaction in the beam also and we will make the surface plane then, before removing it from the mold for 24 hours we will allow it to set and we will place a gunny bag wet gunny bag over these samples after 24 hours we will D mold the cube or the beam whatever is the case and then we will place this sample inside a water bath for the required number of days.

So, we will say we are talking about 28 the compressive or flexural strength. So, we will condition it in the water for 28 days. After the period is complete, we will remove the samples if it is a cube we will do the compressive strength test if it is a beam we will do the flexural strength test and then we will check whether these values are within the specified range.

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Just as an example, I will show you how the finished concrete cube and the finished concrete beam look like this is a finished concrete cube which you see in my hand 150 mm concrete cube, we also have a fresh concrete beam which you can see in my hand. So, this will be required if I want to measure the flexural strength of the beam specimen.

So, we have now completed our discussion on the mix design of PQC as well as DLC. And before we conclude our chapter on the mixed design of the usual concrete materials that we use in the construction of concrete pavement, let us quickly go through some of the pictures which I got just this morning from a friend from industry and I thought that these pictures might be very interesting for the participants to very quickly understand the steps on how the construction of concrete pavement is usually carried out at the site.

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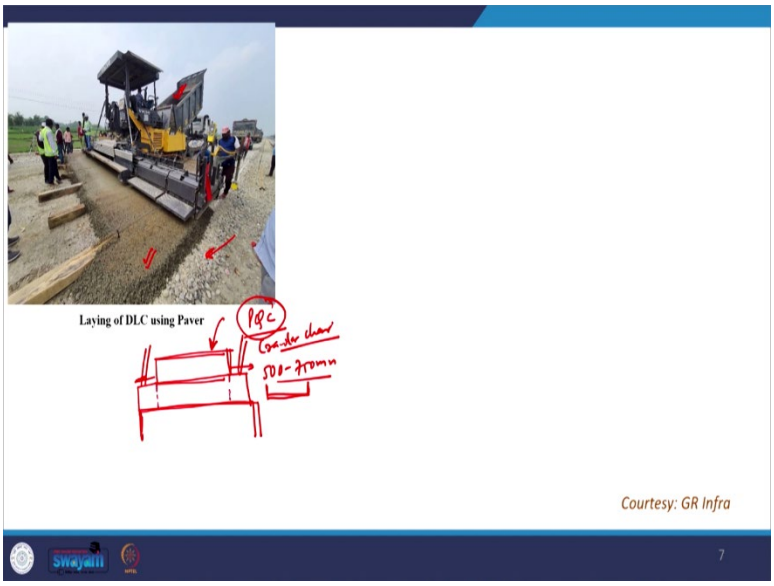

So, these pictures have been taken from GR Infra and I am very thankful to them for sharing these pictures. So, we will be discussing only about the DLC and PQC because these materials we have discussed in this particular module. So, you see, this is the laying of DLC using paver so we have paver here and you see this is the sub base which is prepared and then we have a paver and we have a tipper here that will spread the material beneath and then it will be uniformly compacted.

And you can see how the DLC mixtures look like. So, DLC is usually, constructed to the full width. When I say full width say this is the sub-base, earlier construction equipments that were required to construct PQC layer they typically had a crawler chains on both the sides so, we needed some space for the movement. Because DLC provides a firm base so, the DLC was also constructed let us say that this is the PQC slab which we want to construct, this is the width our design we want to construct.

So, on both the side usually some offset was given and up to date offset the DLC is supposed to be constructed. So, this offset can range from somewhere between 500 to 750 mm, on both the sides. So, we need sufficient say so that the crawler chain can move or the paver can move to construct or to compact the PQC layer here.

Now, the equipments which are presently coming in in the market which are used in the industry, they are actually capable enough they are modified as per the standard as per the requirements and this particular offset requirement is presently no longer required, there are equipments which are capable of laying the PQC, just by resting over the sub-base also, which means that the DLC width of the DLC can can be similar to the width of the PQC. But the conventional equipments, in case of conventional equipment, this is not the case and some offset is required.

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So, this is just for your information. So, and in fact, the laying also can be depends on the width. So, if it is a conventional paver, then the DLC can be laid to a width of 5 to 7 meter at a go. And these legs it can be extended depending on the width of paving, which we desire.

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So, this is a close up of how the DLC layer looks like you can see it is more of a dry concrete layer, this is the picture of compaction going on in the DLC layer using a vibratory roller, this is a finished surface of DLC you can see and in DLC typically we do not have longitudinal and lateral joints so, in contrast to what we have in case of PQC.

Because this is a low strength concrete and we are not expecting huge cracks in these layers, and therefore, the provision of lateral and longitudinal joints are specifically not required. Then in the initial module when we just introduced the two types of pavement I told that in in the just above the DLC, we also have a polyethylene sheet which is placed and this is done to reduce the frictional stresses between PQC and DLC.

So, this is this shows the length of the polyethylene sheet on the DLC layer. After that, you will place dowel bars so, you can see that dowel bars can be placed in this form also using dowel chairs in case the PQC is to be laid using a slip form paver, then we also have automatic dowel inserter so, the paver itself will insert the dowel in the fresh concrete which is being spreaded.

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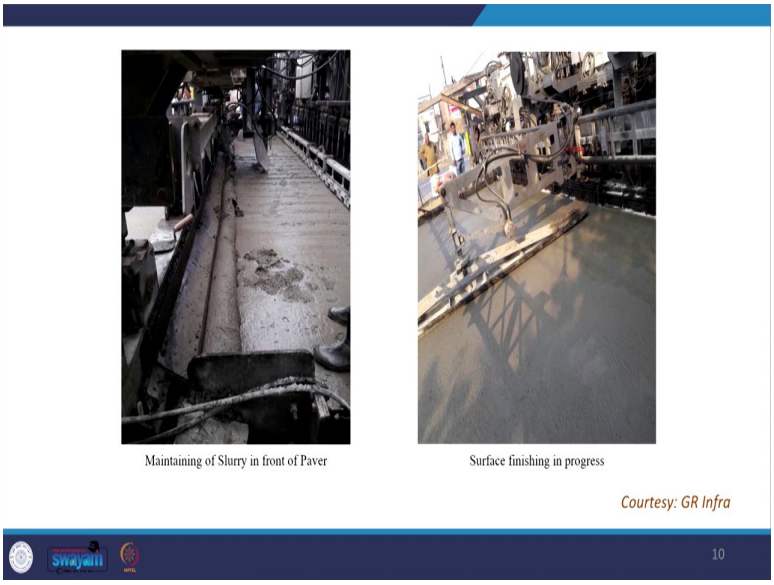

This is picture shows how the concrete mix is spread over the polyethylene sheet you can see both these pictures and this is a close up of how what happens in the paver. So, you can see that the slurry is maintained being maintained in the paver and this is how the finishing is in progress using the slip form paver.

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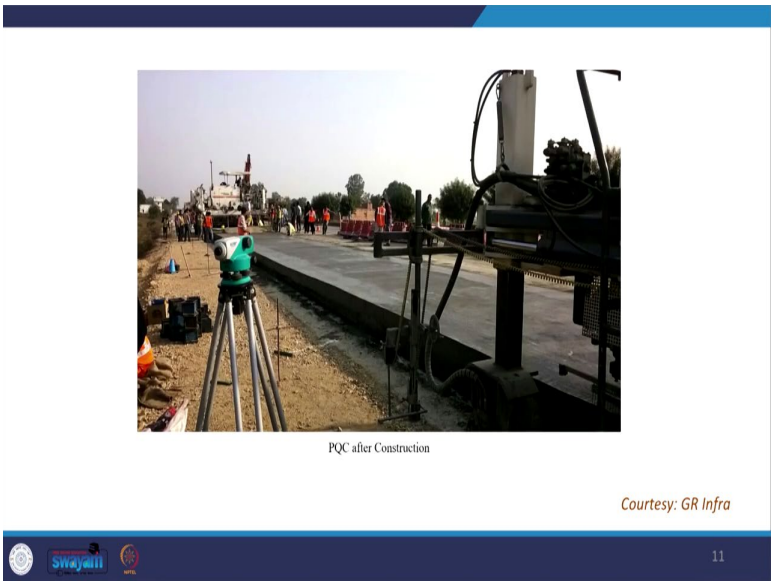

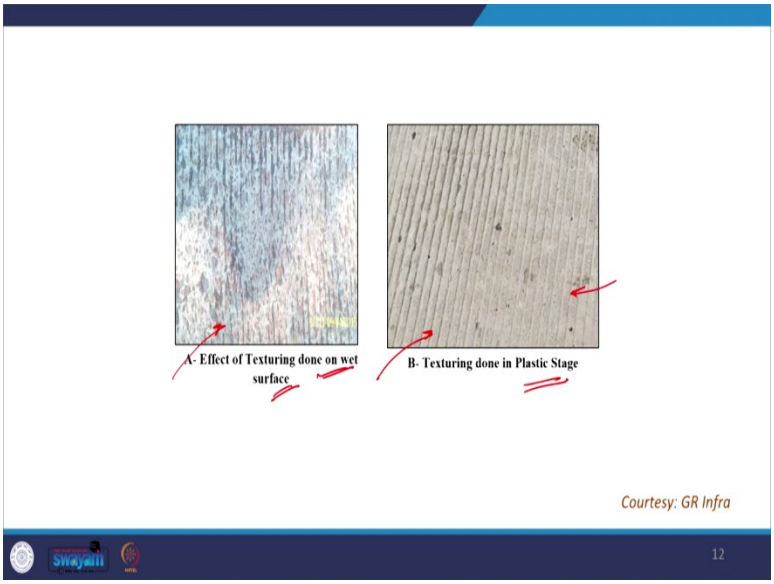

And after finishing the surface will look something like this you can see that this is the PQC layer. After this we have to also do texturing in the layer. So, texturing is very important because it provides frictional characteristics to the surface and the timing of texturing is also very important. So, this pictures it shows that how the texturing can be different in in the first case it is done on the wet surface and in the second case it is done in the plastic stage. So, you can see very clearly that this is a better finished surface in comparison to the first one.

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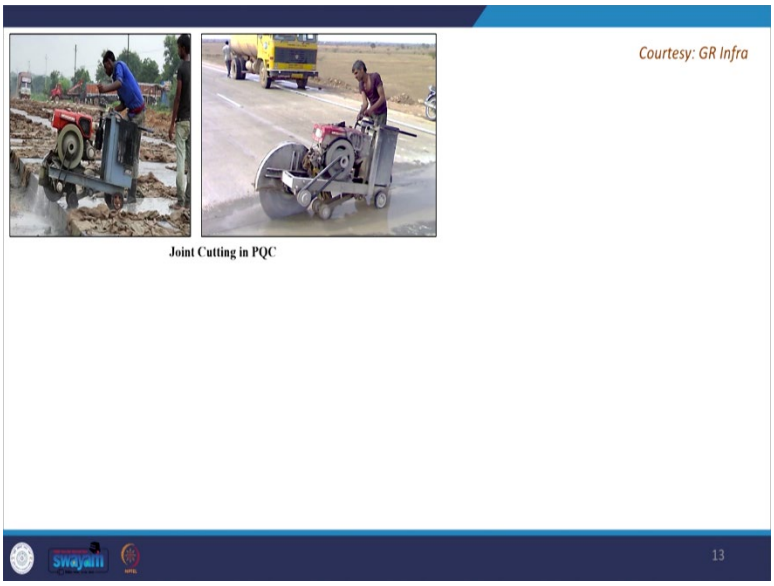

This picture shows how the joint cutting is in progress. So, we have lateral and longitudinal joints I am not going into the detail because it is not within the scope of this particular subject but these pictures just show us how the cutting of the joint is initiated.

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After that we have also to do the smoothing so this picture, I think just came in from somewhere. So, this picture shows the smoothening of DLC prior to laying off PQC, so this should have been placed earlier.

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So, this is a video before we conclude this lecture this video again has been taken from GR Infra which was prepared for the ministry of road transport and highways. And then this picture shows the entire procedure of how the concrete pavement construction is carried out. So, this can be a very interesting short video just to see the get an overview of the construction process so I will just play it for you so you can see the sub-grade soil being laid and compacted here as you can see I think the presence of a sub base layer over the sub-grid.

So, you can see how the sub base material will now be spreaded and it will be further compacted production of concrete mixtures in the plant and then this has been laid by a paver here so, you can see this DLC layer is being compacted now, just over the sub base curing of the DLC layer now, you can see the slip form paver working for the construction of PQC these are the dowel inserters you can see the dowel bars moving here because everything is automated.

So, with this we will stop here today and we have completed our discussion on PQC and DLC which are conventionally used in the construction of concrete pavement. We are yet to complete one last topic, which is the mixed design of pervious concrete which is a very special type of concrete we will be discussing and this we will complete in the next class. Thank you.