Pavement Materials
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Lecture 39
Volumetrics in Mix Design (Part-5)

Hello everyone, welcome back. In the last presentation, we have solved a problem related to the volumetrics of mix design, and it was a detailed problem, and I am sure that by now you are confident with the approach that is basically required to solve any volumetric-related problem involved in the mixed design of bituminous mixtures.

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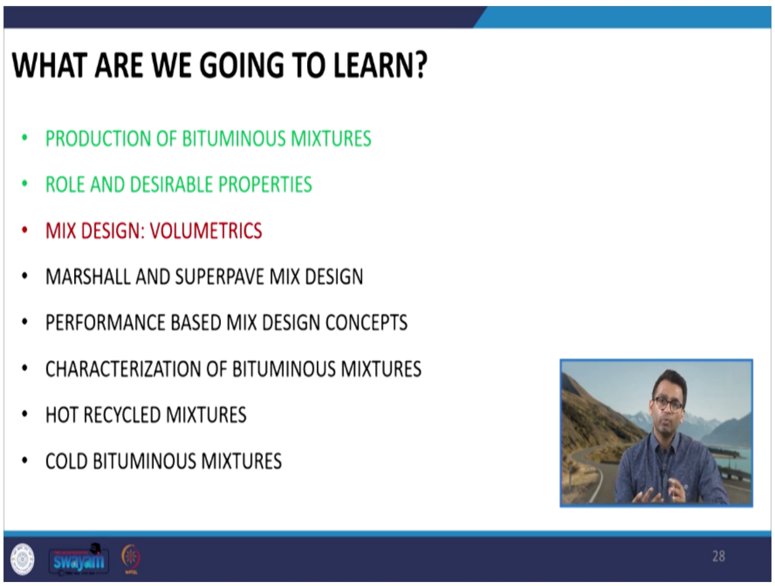

So, today basically will be the last presentation on the volumetrics concept, and then further we will start talking about the 2 different mix design process that is Marshall mix design, and super pav mix design, and further we will also look at different concepts related to the performance-based mix design which is presently becoming popular and is being adopted by various highway agencies.

Then we will talk about the various characterization tests of bituminous mixtures, and then in this module finally we have to discuss about the mixed design concepts related to hot recycled mixtures, and also cold bituminous mixtures. So, let us move forward today and let us understand the importance and few of the critical points related to some of the critical volumetric parameters.

So, we will be discussing about the three main volumetric parameters or important you can say volumetric parameters today, that is voids and mineral aggregates, we will be discussing further about air voids and voids filled with bitumen, we will try to understand them.

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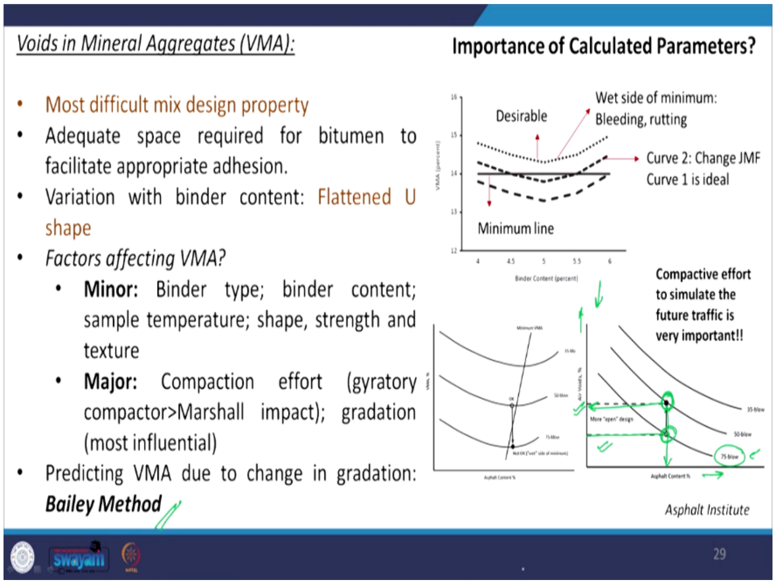

That what do they actually mean in relation to the mix design problem, in relation to the volumetric concept, and we will try to visualize how they vary with change in something what are the factors affecting these parameters, and what is the actual importance of each of these parameters in relation to the mix design problem.

Talking about VMA, VMA is one of the most difficult mixed design property. When I say difficult mix design property, it means difficult to predict, because it is dependent on various properties of individual materials and in fact the bulk properties like aggregate gradation in the bituminous mixture.

It also depends on external factors like compaction which we are applying, so with change in compaction VMA again changes, so that is why it is one of the most difficult mix design property to understand, because different aggregate sources different types of binder, in fact the mixing temperature or compaction temperature changes the value of VMA in the mixture.

One important point here is that, that what VMA does that it provides space in the bituminous mixture, so if you remember we have discussed about the maximum density line, we say that we can have aggregate gradation in a very closely packed form such that the air voids between the aggregate particles is not actually 0 but very-very less, so we will have a very dense gradation.

But we have also discussed that in bituminous mixture we require space, and this space is actually required to incorporate binder and to incorporate some air voids. So, therefore this space, this total space which is available is basically defined as the voids in mineral aggregates, voids between the mineral aggregate particles.

So, let me just draw here this space let us say this is the available space, so this entire space I have to fill with some volume of bitumen and then other part will be the air voids, and this sufficient quantity of this bitumen is required, so that we can coat the aggregate particles properly and then we can provide adhesion in the bituminous mixture.

So this additional space allows the binder to come in, and this binder finally facilitate the appropriate adhesion by keeping all the aggregate particles together. If we see that how binder content is affecting values of VMA, so you will see a flattened u shape, flattened u shape means that with, so this is the binder content this is the value of VMA, so you can see you can see any of the 3 curves which are shown here.

So the VMA first decreases and then it increases, so let us try to understand this, let us say we have a fixed aggregate gradation. So, when binders come in this facilitates or this provides some lubrication with within the mixture and the aggregate particles can slide past each other with some which means the friction between them reduces and they can slide past each other and then occupy new space in a more dense configuration.

So, therefore with increase in binder content since we are reducing the individual voids between the aggregate particles by allowing them to move or allowing them to occupy a more dense space, therefore the VMA will reduce because the voids between them is reducing. Well, if you keep on increasing the air voids, so beyond a particular value, beyond a particular value, this binder which is now filling the voids.

It will become so large that this binder will now start separating the aggregate particles rather than allowing them to position themselves in a dense space. So, therefore beyond a particular binder content the VMA curve increases, but you see this is a flattened u shape, so flattened u shape means that VMA is not very sensitive to the change in binder content, so though binder content is affecting VMA but it is not highly sensitive.

Usually, the minimum VMA that is required it is a function of the nominal maximum aggregate size, and we have already discussed previously that there is some requirement of minimum VMA, and I am just repeating it again that why the minimum VMA is required, because we can have sufficient bitumen which can be incorporated.

And then, finally we should have some additional space for the air voids in the mixture and this also depends on the surface area of the individual particles and therefore basically VMA is a function of the nominal maximum aggregate size in the mix. If you see this particular figure, I am just removing all the markings here, if you see this figure here, you see a horizontal line.

So this horizontal line in this figure it is indicating the minimum VMA that is required. So, ideally our mix should be above this line. Let us say you have a VMA curve like the second one here, so this is the minimum VMA line.

So, you see in some portion of the VMA curve is above the VML line and some portion of the VMA curve is below the minimum VMA line. So if you get this curve, this means that you have to change the job mix formula, so you change the job mix formula. The most ideal curve is the first curve that is this is the most ideal curve.

So this is the desirable curve you should not have a curve which is below the minimum VMA line, you should not have a curve which is you know which is like curve 2 that some portion is below and some portion is above, ideally you should have a curve who's minimum VMA is like this.

But this variation is seldom given importance when we actually doing the mixed design in the lab, but we have to understand that this is one of the critical part which I will just explain why this is critical part and why I am stressing, so much on VMA, I will just explain because you know the change in VMA or the control over VMA can actually control the performance of the mixture.

So, even though I say that curve one is the most desirable curve, we should choose the optimum binder content on the dry side of the minimum, so we have a dry side of the minimum means, let us say this is the minimum value, so we should choose our optimum binder content on the dry side of the minimum.

The reason being, that if you choose the binder content on the wet side of the minimum, this means you are putting in more binder you see the VMA is increasing there, which means the binder has increased so much that it is now separating the aggregate particles, so the such type of mixture which will actually be prone to distresses like bleeding and rutting, so wet side of the minimum should be avoided.

And I just said that this curve is seldom paid much attention, because the present mix design concept which we are adopting it uses a air void as the criteria to decide the optimum binder content and at the optimum binder content we only check whether the value of VMA is more than the minimum or not.

So we are just only checking whether the value is more than the minimum, irrespective of whether my actual VMA curve at the optimum binder content or the minimum VMA at the actual VMA at the optimum binder content is on the wet side or on the dry side. But as I just explained, that in case if it is on the wet side, it can be prone to bleeding and rotting, so understanding this variation for a particular mix design problem is very important.

Now, if you see the various factors that are affecting VMA, there are several minor factors, and there are several major factors, for example the minor factors include the binder type, binder content, which we have already discussed. Sample temperature, because we are if we increase the temperature the viscosity of the binder will reduce, the workability will increase and you can densify the mix to some higher degree.

But of course, we cannot increase the temperature of the bitumen or the sample beyond a particular value which may further lead to aging and loss and durability of the mixture, so that aspect also is important here. The shape of the aggregate is very important, because if you have rounded particles they will have lower air voids, because they can slide past each other and then occupy a much dense space.

On the other hand, if you have angular particles, they will have better interlocking, but the voids between them will be higher, because the friction between them is higher, so they will have higher value of VMA, so the shape of the curve is important when you talk about the value of VMA in a particular aggregate gradation.

And of course, the strength and texture in the sense that when you are compacting it if your aggregate tends to break the VMA will again change. When I say texture, this is more related to again workability, that if you have rough texture it will have more friction between the aggregate particles, so the compaction which is achieved will be lower or the densification which is achieved, because more resistance to compaction will be given by that particular mixture.

So, out of these factors the role of the aggregate gradation and competitive effort is the main, the gradation and the competitive effort is the main. So, you have to understand that the competitive effort which is chosen it is to represent the traffic after several years. So, whatever competitive effort we are giving in the lab it should replicate the density due to the predicted traffic in the field.

What I mean by this, you have some bitumen quoted aggregates here, so this is in loose state now and you are applying some compaction, so you have applied some form of impact compaction you have given 10 blows, so once you give 10 blows, aggregate particles will try to move and then orient itself and the density will increase, so that the new loose height was this, and the first height is this h1.

Now, if you increase the compactive effort to 20, let us consider that the ultimate densification has not taken place, so further the mix will get compact and you can have more reduction in height and let us say this is h2. So, you see when you apply a compactive effort you are actually preparing a bituminous mixture here, so I mean you are having a particular bituminous mixture here.

For example, in the first case your bituminous mixture will look like this, is not it, in the second case your bituminous mixture will look something like this. So, by changing the compactive effort we are getting two different types of mixture having different heights but the aggregate gradation is same.

Finally, we are evaluating these mixtures considering whether it is from the first level of compaction or the second level of compaction, we are finally analyzing this mixture in the laboratory, we are evaluating the performance strength and volumetric parameters of these mixtures. And, you can understand that both these mixtures will have different properties, and therefore they will indicate different performance.

So, the question is, what is that density which we need? and as we have discussed the density at which we have to compact the mixture, it should represent a mixture which we will get in the field after several years of traffic, that is after final densification, and therefore the compactive effort which we are given in the lab, should replicate the density due to the predicted traffic in the field.

It may happen that you have a traffic which is only corresponding to 10 blows in that case you should have the mixture shown using the red line here. In case you have very high traffic that the mixture will be finally compacted to h2, then you should have a mixture corresponding to the green line for laboratory evaluation.

So, the compactive effort in fact should be chosen according to the traffic. Now, if you choose a wrong compactive effort, this can lead to incorrect mixed design and failure of the mix. Now, to understand this let us see these figures which are shown here, these 2 figures. Please see the first figure, so say we have designed our mix using 50 blows, so we let us say we have a criteria that went to apply 50 blows, so maybe corresponding to the traffic which we have, the specification says that you apply 50 blows to prepare the bituminous mixture.

Now, here we are assuming that the traffic will not be very high in the actual field, so we are at we are using 50 blows of compaction, and the binder was chosen on the dry side of the minimum, you can see that for different competitive effort 35 blows, 50 blows, 70 blows, this is the variation of VMA with binder content, and this is the minimum VMA line, joining the minimum points of individual curve.

So, we are talking about the second curve now which we have used anticipating a lower level of traffic and we have correctly chosen our binder content on the dry side of the minimum. But say that our traffic calculation was not correct what we anticipated, and the actual traffic becomes very high. So, though we designed with respect to the second curve, we are actually in the first curve.

Because, now my actual traffic is corresponding to 75 blows. And here, if you see, that we are on the wet side of the minimum, so what will happen to this mixture in the field? This will lead to occurrence of bleeding and writing. We can also understand this using another example, so say we have designed our mix in the lab, now you see the second figure.

Let us say that we designed our mix in the laboratory considering, that the field traffic will be high, so we chose 75 blows. And here, we are seeing the variation of air voids versus binder content. So, air void will reduce with increase in binder content, so we are at the 75-blow curve because our traffic we have anticipated very high.

And, we have calculated the optimum binder content corresponding to 4 percent air void, so this is the binder content we chose. But if the traffic is less, so that traffic which is going to come will not give the energy to the mix in the field corresponding to what we got you using 75 blows in the laboratory.

So, say the level of traffic is only corresponding to 50 blows of compaction, so though we design for this but we are actually in this position. So, when we are in this position the air void in the mixture artificially you can say increases, because our design mix was here but our actual mix is here in the field.

So, what will happen to this mixture, this will have because of higher voids, more water permeability, more water will be trapped, more oxidation of the bitumen will take place because the void is high, so this will lead to aging, moisture damage, and also occurrence of other distresses in the field. So, therefore the competitive effort should be chosen very judiciously to simulate future traffic.

So, I hope that by now we understand the importance of VMA, and the prediction of VMA actually is a very interesting topic because as I said that this is a difficult thing to do. And, one of the available methods which is also suggested by asphalt institute is the Bayley method which describes the process of optimizing the aggregate gradation and controlling the VMA of the mixture, based on the aggregate gradation. So again, this is one topic which can be looked at, though we are not discussing this during this particular module.

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Design Traffic (20 years)	Number of Blows, Marshall mix design
< 0.01 msa	35 blows
0.01-1 msa	50 blows
>1 msa	75 blows

Given the magnitude of traffic in the current scenario, the mixes in pavement are subjected to much higher energy than anticipated from 75 blows compaction.

Is using 75 blows justified?

So, this table which you are now seeing, it gives the amount of blows for different levels of traffic in case of Marshall mix design, so you see that if the traffic is less than 0.01 msa, you have to prepare a mixture with 35 blows, if the mixture is from 0.01 to 1 msa, we have to prepare mixture giving 50 blows, and in case we have a traffic greater than 1 msa we have to choose 75 blows.

You have to understand that you know this Marshall method which we are dis, which will be discussing was developed in 1900s. So, during that period, the traffic in the highway was, we can expect was not very high than what we have today, and this compaction method actually worked. But today, we can have you know traffic in the pavement of more than 100 million standard axle which is very common, and therefore you can understand that the pavement because of this high level of traffic is subjected to much higher energy.

Using 75 blows of compaction to prepare the asphalt mixture is sometimes questionable, and this is probably one of the reasons that the super pave mix design was being adopted in US by most of the state agencies and they use a super paved geometry compactor. And, one of the difference between super paved gyratory compactor and Marshall compaction or compactor is that super paved geometry compactor gives much higher energy to the mixture in comparison to the bituminous mixture.

And again, some of these studies have shown that the mixture which you get using super paved geometry compactor, the orientation of the aggregates inside the mixture is similarly to what you get when these mixtures are compacted using standard rulers. So, you know with this thought process or with this question related to the compaction, let us now move ahead and let us discuss the next parameter that is air void.

So, air void again is one of the critical parameters which is considered in the mixed design, and in fact we will see later that it is the air voids corresponding to which we determine the optimum binder content in the mix design process.

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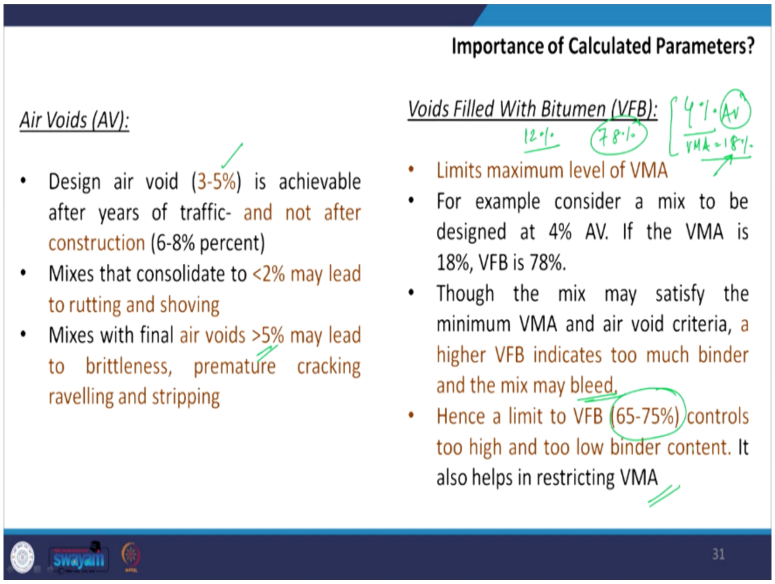

So, we design our mix usually to have a target air void of 3 to 5 percent, and again we have to remember here that this air void 3 to 5 percent, which we want in our mixture which we prepare in the lab is the air void which is achievable after years of traffic and not after placement. At placement before we open the pavement to the traffic, the air void is typically kept within the range of 6 to 8 percent.

We also have to ensure that our mixes, when traffic starts moving over it, there will be some further compaction in the mixture because of the movement of the traffic, but this compaction should not be, so high that the air void in the mixture drops less than 2 percent, because mixtures having air void less than 2 percent may be prone to rutting as well as shoving.

If we have higher air voids in the mixture, if we have air voids more than 5 percent in the mixture, this as we have already discussed previously will lead to cracking, fatty cracking, will read to a high level of aging, that is finally brittleness, will lead to raveling, and also will lead to moisture related failure, for example stripping, so therefore air void is a very-very important and critical parameter. Now let us talk about VFB.

So, sometimes students always ask that we have discussed about VMA, that is fine, that is an individual property, we have discussed about air void, that is fine that is also an individual property, but why do we actually pay attention to voids filled with vitamin, which is finally again a function of air void and VMA. So, this parameter actually prevents the mix from having too high or too low binder content, and why do I say that how do we accept this.

Let us say that we have a mix which is to be designed at 4 percent year void, so this is a mix which we are trying to design. And once you made the mix, prepare the mixture, you found out the optimum binder content corresponding to 4 percent air void, and for that mixture you found that the VMA is equal to 18 percent.

Let us say and remember, our specification does not tell us about lower bound and upper bound of VMA, it only says that what is the minimum VMA that is required. So, the let us say for this problem which we are discussing corresponding to the nominal maximum aggregate size, the minimum VMA required was 12 percent as per the specification.

So, one may think that, we have achieved 18 percent VMA that is good enough as it satisfies the minimum criteria, but if you calculate the voids filled with bitumen it is 78 percent for this problem. So, 78 percent missed the out of the total voids, almost 78 percent is filled with bitumen. So, this value of VFB is very high, and it indicates that we have too much binder in the mixture, and finally it may happen that this mixture may be prone to bleed.

And therefore, VFB is typically kept in the range of 65 to 75 percent just to put a check to this issue of having too high or too low binder content. And it also helps in you know indirectly restricting higher VMA in the mixture, because we do not have specification related to the upper bound of VMA, we only have the minimum VMA criteria. So, I hope by this we understand the importance of these volumetric parameters and its relation with the occurrence of distresses or you can say with the performance of the bituminous mixture.

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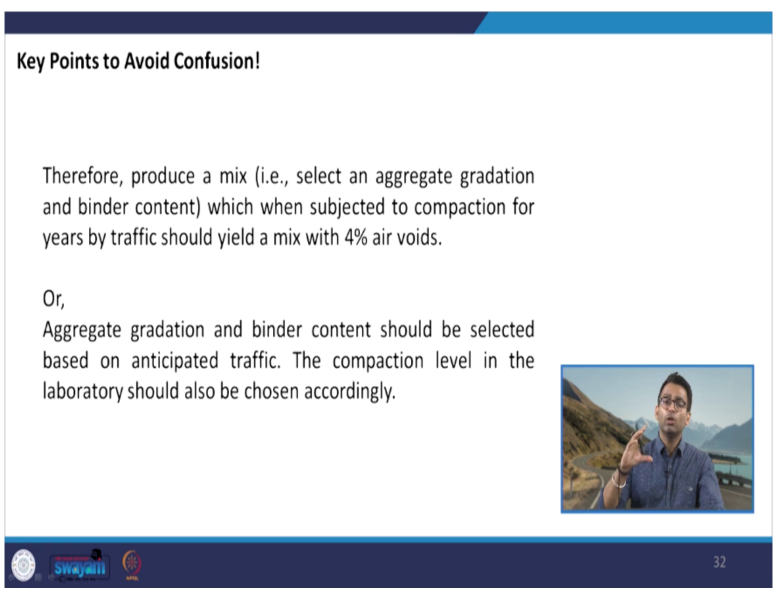

So finally, before we conclude this presentation there are few critical points in the mixed design about which always there is some form of confusion, so these key points we have to remember to avoid this confusion. So, we have to remember that we have to produce a mix, when I say produce a mix, it means that we have to select an aggregate gradation.

And we have to select the appropriate binder content which when subjected to compaction, and again you when I say which one subjected to compaction, it makes the mix itself project dependent that for which project for which anticipated traffic I am going to prepare this mixture. So, which when subjected to compaction for years by traffic should yield a mix with 4 percent year void.

So, you have to first know the anticipated traffic, you have to understand what level of compaction this traffic will impose on my mixture, and corresponding to that then you try to design your mixture, because this becomes very important. In other words, if you have to place, we can say that aggregate gradation and binder content should be selected based on anticipated traffic.

And in the laboratory when you are preparing a mixture, the compaction level also should be chosen accordingly, and then only you will have a mixture which will be actually present in the field after years of traffic which will dictate the performance of the pavement. So, with this let us very quickly recap some of the points we have learnt during the past few presentations, as we are concluding today on the volumetric concept which I said is the backbone of the mix design process.

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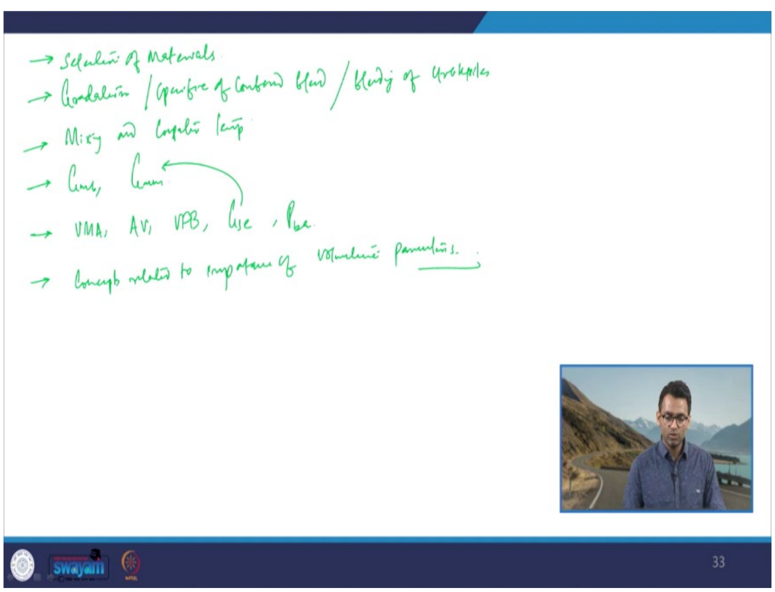

So, if you see very quickly, we have discussed about the selection of materials, when I say selection of materials which means selection of binder and selection of aggregate based on their properties. We have discussed about that once these materials are selected, then we have to decide aggregate gradation and specific gravity of combined blend and also you can say that you know blending of stockpiles.

Then once this step is done, then we know that we have to mix them, then we have discussed about the mixing and compaction temperature, at what temperature you have to mix, at what temperature you have to compact the mixtures. Once the mix is compacted, then we evaluate the volumetric parameters in this direction, we have discussed that you have to find out the value of Gmb, you have to find out the value of Gmm in the laboratory.

And then, we have discussed about various volumetric parameters like VMA air void, VFB, how to calculate Gse, and how Gse is related to Gmm. We have discussed about calculating the percentage of absorbed binder in the mix. And then, we have discussed concepts related to importance of volumetric parameters.

And you know these are some critical or important steps which we have basically discussed during our several presentations in the past few classes. So, with this, I will stop here today, and we will meet in the next class where we will start discussing about the steps involved in the mixed design process of Marshall mix design, and super paper mix design.

We will try to also understand the difference between these 2 mix design, the advantages and disadvantages of the existing mix design principles, and then we will talk about performance based mix design concepts, and further we will discuss about characterization of bituminous mixtures, hot recycled mixtures, and cold asphalt mixtures, thank you.