Pavement Materials
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Lecture 37
Volumetrics in Mix Design (Part 3)

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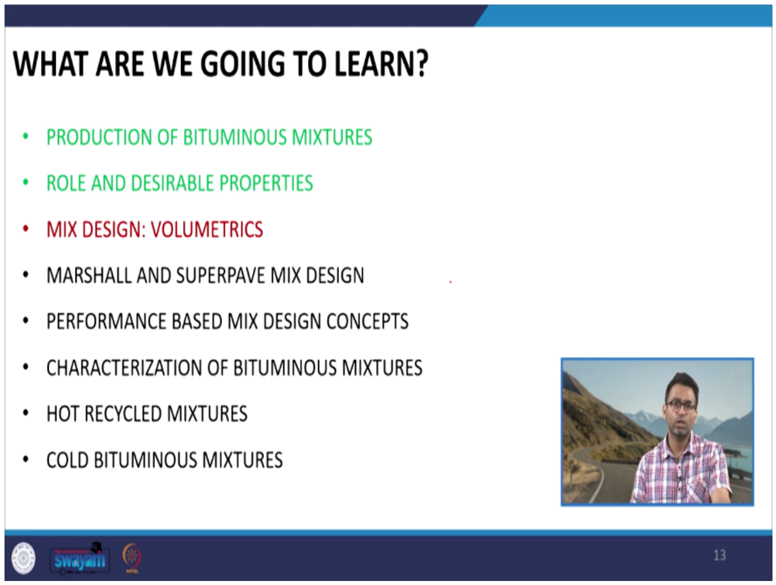

Hello friends, welcome back. If you remember, we were discussing about the volumetrics of mix design and in the last presentation, we tried to derive the expression for voids in mineral aggregates based on the fundamental definition with respect to volume. So, we converted or we derived the expression with volume as the parameter to an expression which included measurable parameters are calculated parameters such as specific gravity and weight or percentage of binder.

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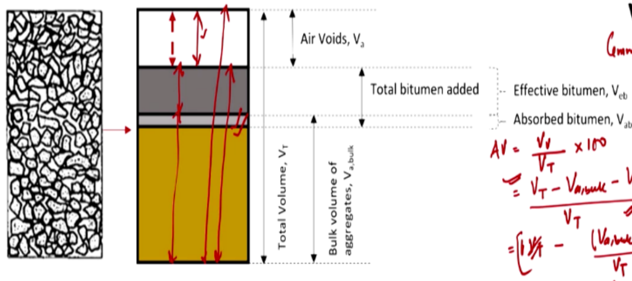
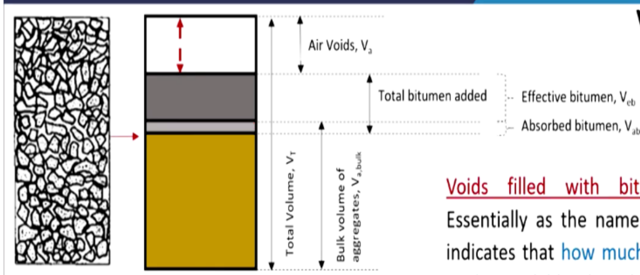
Volumetrics



Air Voids (AV): Very simply it just indicates the total "air voids" available in the total mix. Expressed as percentage of total volume.

$$AV = \left(\frac{V_V}{V_T}\right) \times 100 \qquad AV = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

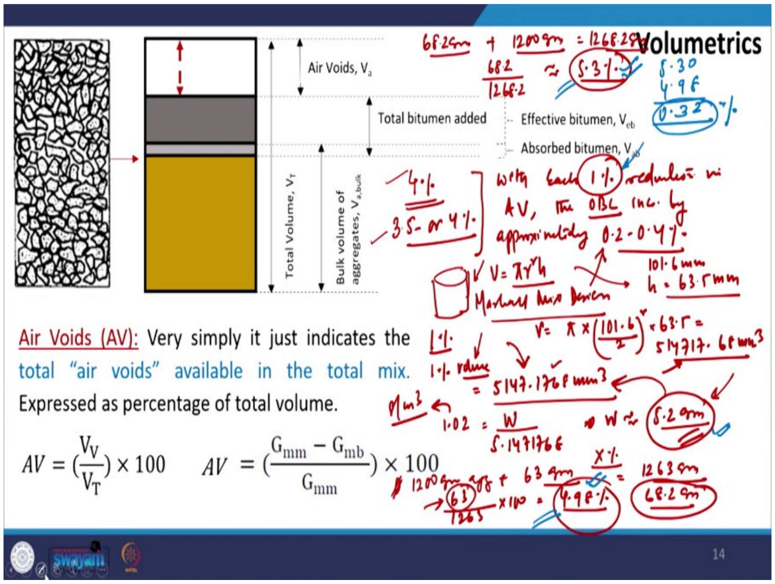
Volumetrics



Voids filled with bitumen (VFB): Essentially as the name suggests this indicates that how much space in the voids available (VMA) is filled by bitumen.

Air Voids (AV): Very simply it just indicates the total "air voids" available in the total mix. Expressed as percentage of total volume.

$$AV = \left(\frac{V_V}{V_T}\right) \times 100 \qquad AV = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$



So, we were talking about this particular phase diagram, where we have already discussed what are the different components, we have also understood the importance and the meaning of these individual components. So, today we will proceed from where we left in the last class and we will try to look at other volumetric parameters we will define it.

And then we will try to see the fundamental expression and then we will try to see how to calculate it based on the values of specific gravity weights or percentage of different proportions. The next parameter of interest is air voids and if you try to define air voids we can say that it just indicates the total air voids that are available in the total mix which is represented by this vertical arrow this space which is available.

And, just like VMA, air void is also expressed as a percentage of total volume of the mix. So, the fundamental definition of air void where we talk about volumetric expression is it is the ratio of $\frac{V_V}{V_T} \times 100$. But as by now, we have understood that volume cannot be measured in the laboratory, we can only measure specific gravities, we can only measure weight and we can know percentages of different fraction mostly by weight.

So, here the converted expression is this 1 where air void is written equal to $1 - \frac{G_{mb}}{G_{mm}} \times 100$, where Gmb is the bulk specific gravity of the mix. Now, the question is, how does, how do we derive this expression? So, let us start looking at this derivation from the point of view of its fundamental expression that is starting from the fundamental expression that is air void is $\frac{V_V}{V_T} \times 100$.

So, $\frac{V_V}{V_T} = \frac{V_T - V_{a,bulk} - V_{eb}}{V_T} \times 100$, so I can write this as VT, I am just separating it $[1 - \frac{(V_{a,bulk} + V_{eb})}{V_T}] \times 100$. I hope you understand this part in the numerator, let me try to explain you using the phase diagram that this is the volume we are trying to write.

So, I am writing that $[1 - \frac{(V_{a,bulk} + V_{eb})}{V_T}] \times 100$. So, here now what I will do, I will just try to divide the numerator and denominator here, I will just use the weight of the total mix and I will divide it in the numerator and the denominator.

So, I am just writing it as $[1 - \frac{\frac{(V_{a,bulk} + V_{eb})}{W_T}}{\frac{V_T}{W_T}}] \times 100$ So, I hope you can understand that this is nothing, weight of the total mix by volume of the total mix $(\frac{V_T}{W_T})$ is nothing but $\frac{1}{Gmb}$, because the bulk specific gravity of the mix is equal to weight of the total mix divided by volume of the total mix. $[1 - \frac{\frac{(V_{a,bulk} + V_{eb})}{W_T}}{\frac{1}{Gmb}}]$

And what about this expression? So if you remember, the theoretical maximum specific gravity Gmm is equal to $Gmm = \frac{W_T}{(V_{a,bulk} + V_{eb})}$. And what does void less volume includes? It includes the volume of the aggregate plus the volume of the bitumen, without air voids.

So this expression which you see in the numerator, the expression which is written, $[1 - \frac{\frac{(V_{a,bulk} + V_{eb})}{W_T}}{\frac{1}{Gmb}}] \times 100$. So this is nothing but $\frac{1}{Gmm}$. $\left[1 - \frac{\frac{1}{Gmm}}{\frac{1}{Gmb}}\right] \times 100$.

So, I am just, solving this or rearranging this expression, so this is $\left(1 - \frac{Gmb}{Gmm}\right) \times$and finally, we arrive at this expression that this is equal to $\frac{Gmm - Gmb}{Gmm} \times 100$. So, I hope again, this this derivation is clear to you that how we use the definition of the volumetric the fundamental definition and then we arrive at the converted expression which includes specific gravity as the parameter with this expression.

I hope it is clear that how we derive for air voids. Before again we see the next parameter air void, let me just, tell you few additional things about air voids in a conventional mix design process. So, typically, if we look at the mix design, which again we will be discussing about the steps later in this module. So, typically the air void which is taken is on an average 4 percent, so we design our mix to have 4 percent air void content.

However, some of the agencies they also use lower air void or target air void content such as 3.5 or let us say 4 percent, it is thumb rule because we are dealing with binder content here and then the air void has to change with the binder content because our given the solid the volume of the aggregate, total aggregate in the mixture is fixed, we can only play with the binder content and change the binder content to change the volume of the effective bitumen if you look at the phase diagram.

So, some, as I said some agency use 4 percent target air voids some agencies use even lower air voids. Therefore, it is important to understand what is the rate of change of air void with rate of change of binder content on an average. So, the thumb rule here is that with each 1 percent reduction in your voids the optimum binder content or the binder content you can say here to achieve this particular level of error void. So, the optimum binder content increases by approximately 0.2 to 4, 0.4 percent.

Now, of course, it is not very easy to just write a statement and believe that it is true until and unless we really fundamentally understand why we say this. So, in order to understand this thumb rule, we can actually try to think about a typical bituminous mixture. So, let us say we have a typical bituminous mixture and we are talking approximately here.

So, if I assume that this is an absolute cylindrical volume, then the volume will be pi r squared h without any surface deformations, so I am assuming that it is a smooth surface. So, the volume exactly is equal to $\pi r^2 h$ So, for a normal martial sample, let us say if you look at the martial mix design, of course, we have not discussed about the details, but I am just trying to explain it from some perspective to just understand about this statement.

So, in a normal martial sample, the data is equal to 101.6 mm and the height is equal to approximately 63.5 mm the standard height of the sample so the volume then becomes equal to πr^2. So, $\frac{101.6}{2}$. So, 101.6 is the dia $\times$ 63.5. So, this is a, this if you solve this this will come equal to 514717.68 mm^3. So, this is what you will get using a calculator. So, now, I am saying that each 1 percent reduction in air voids.

So, if by volume, what is that 1 percent by volume of this total volume because this is a total bulk volume and air void is a part of this volume. So, if I am trying to look at 1 percent volume in this mixture, so this 1 percent volume becomes equal to 5147.1768 mm cube. So, this is the volume 1 percent volume of the total mix.

Now, the question is, how much binder will be required to occupy or to fill this volume? So, let us say that the specific gravity of the bitumen is 1.02. So, I am trying to calculate what is the weight required to fill this volume, so I am looking at this volume. So, this is in centimeter cube, this is equal to 5.1471768. Because this is expressed as grams per centimeter cube.

So, the weight if you calculate it will be approximately equal to 5.2 grams. Now, which means 5.2 gram binder will be required to occupy this volume, say I am making this bituminous mixture using 1200 gram aggregates and plus the binder content. So, let us say the first trial was 5 percent or 4.5 percent any percentage and our calculation told it 63 gram is required for some x percent, optimum binder content.

So, this becomes equal to how much 1263 grams total weight of the mix. So, the 63 grams for this 1263 grams into 100, if you do? This is equal to 4.98 percent. So, which means that the binder content is 4.98 percent here and I am saying that if I add 5 gram more to this mixture, then it will occupy 1 percent additional volume.

So, if I am just trying to add 5 gram extra to this 63 gram which means it becomes equal to 68.2 grams, now I increase the binder content by 5.2 grams it becomes 68.2 grams. So, if it is 68.2 grams, my aggregate is 1200 gram anyway. So, the total weight of the mixture becomes equal to 1268.2 grams, if you do the calculation in percentage, so this is 68.2 divided by 1268.2 this will be approximately equal to 5.3 percent which means this is the binder content.

So, how much increase in binder content we have seen. So, you have to compare these two numbers I am just using a different color here to explain. So, you have to see what is the difference in these two. So, 5.30 minus 4.98 is equal to almost 0.3 percentage. So, therefore, the statement, the thumb rule is approximately correct that 1 percent reduction in your void which we have done by adding 5 gram, 5.2 gram binder approximately increases the optimum binder content.

So, now, the optimum binder content is 5.3 percent earlier it was 4.9 percent in the range of 0.2 to 0.4 percent. So, this range we are getting is correct. So, again this will depend of course on the type of make shape of the aggregates and so many other things but, but and compaction level but right now, we are just looking at an approximate expression. So, I hope this is correct when I say about the relationship between air voids and the binder content.

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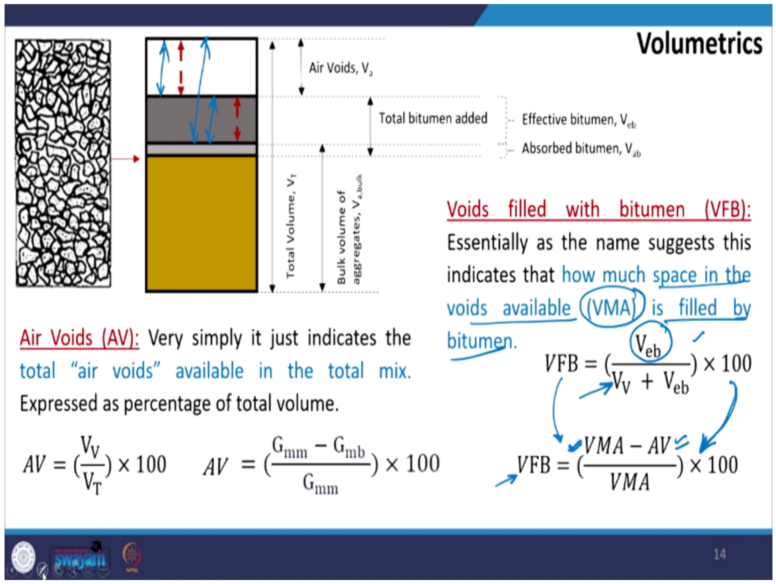

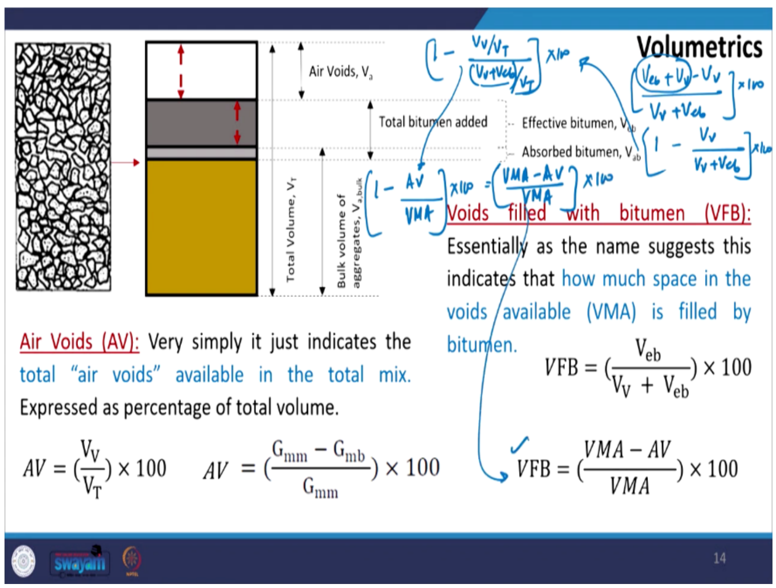

With this let us move to the next parameter which is voids filled with bitumen. Now essentially as the name suggests, this indicates how much space in the voids and what is a total actual void. This is the total void out of which this is the void filled with bitumen and this is the air void which is left so how much space in the void is available which is VMA is filled with bitumen, so I am trying to look at this particular the one which is now highlighted using a red arrow.

I am look trying to look at this volume, the volume of the effective bitumen. So, again the fundamental expression if you see with respect to volume it is it is the volume of effective bitumen divided by the total space available which is volume of voids plus volume of effective bitumen multiplied by 100.

So, again, I hope that this is clear to you look at this expression, and then try to derive the converted expression in terms of already calculated parameters or measurable parameters. So, with, if you see the formula for VFB, it includes VMA and air voids, and we already have an expression for VMA and air voids. So, if we can convert VFB in terms of VMA in air voids, we can actually do the calculation based on various specific gravities rates and percentages.

Here also we will try to derive this before we move forward. So, this derivation is in fact, a little simple, because I will tell you how. So, this is what you are looking at. So, the numerator here, I am just writing here at the top. So, the numerator $\frac{V_{eb}}{(V_V+V_{eb})} = \frac{V_{eb}+V_V-V_V}{(V_V+V_{eb})} \times 100.$, so I am just rearranging this and then adding and subtracting the same thing in the numerator.

So if I separate this by part, I will have 1, I am taking this out here, $\left(1 - \frac{V_V}{(V_V+V_{eb})}\right) \times 100$, so if you see it here, and now what I am trying to do, I am trying to divide the numerator and the denominator by VT.

$$(1 - \frac{\frac{V_V}{V_T}}{\frac{(V_V+V_{eb})}{V_T}}) \times 100.$$

So, what is written here, V, volume of voids by total volume ($\frac{V_V}{V_T}$) is nothing but air voids (A_V) volume of void plus volume of effective bitumen by total volume is nothing but equal to VMA, $\left(1 - \frac{A_V}{VMA}\right) \times 100$. So, this brings us to our final converted expression, this is $\frac{VMA-A_V}{VMA} \times 100$. So, I hope again, this is pretty much clear to all of you. So, now, we will summarizing about the volumetrics, we will discuss the importance of each of the volumetric parameters.

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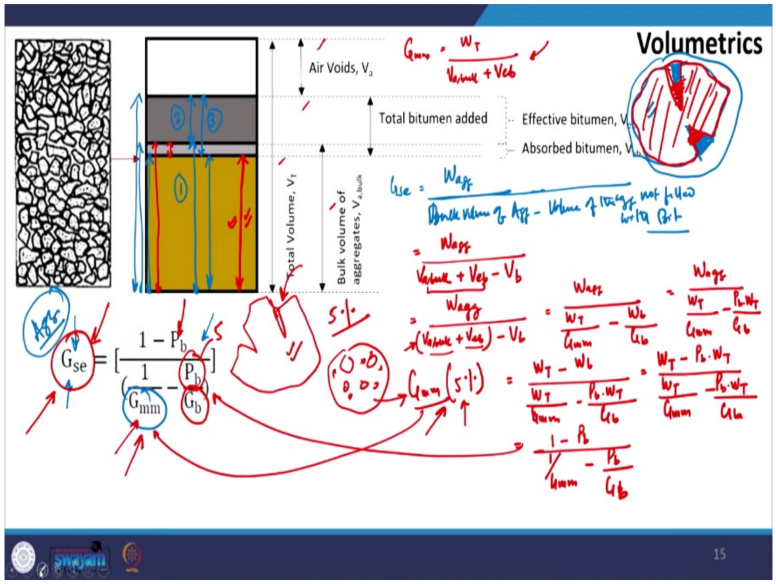

But let us move forward let us try to see other parameters and how to derive them and what is the associated formula for calculation of these parameters. So, now, we come to the most important expression for which we are actually doing so much of calculations previously, because I already told you that Gse is the effective specific gravity of the aggregates.

So, this is an aggregate property and not a mixed property. But since it cannot be measured in the laboratory, unlike Gsb and or appearance specific gravity, we are trying to calculate it using volumetric parameters. So, if you see the expression, the formula, the formula is $G_{se} = (\frac{1-P_b}{\frac{1}{G_{mm}}-\frac{P_b}{G_b}})$.

Now, this is very interesting here, because I am saying that this is an aggregate property does not depend on the property of the mix. But here the formula says that it is a function of G_{mm} which is in fact a function of the mix. So, this appears to be a little confusing at first, but I will tell you in some time, that using this expression, I mean by using this expression, how do we still say that G_{se} is a property of the aggregate is and is not dependent on the actual property of the mixtures.

So, before that, let us first write G_{se} in terms of volumetric parameters and or in terms of volume and then we will first derive that how using the volume we come to this particular expression. So, this is very important and I would like you to understand it properly or try to agree upon this derivation which we will be discussing, because this is one of the very critical and important parameter in the mix design process.

So, Gse we are saying this is equal to weight of the aggregates divided by bulk volume of the aggregate minus volume of the aggregate not filled with bitumen. So, this is the actual verbal definition of effective specific gravity of the aggregate, this is the weight of the aggregate and the volume is equal to the bulk volume minus the volume not filled with bitumen. So, I will just again draw a picture which we have already discussed several times during our discussion.

So, these are the let us see the water permeable voids, but we understand by now that if bitumen is coated over this, the entire void will not be filled with bitumen. So, I am trying to look at the solid volume here, I will try to use a different color again. I am trying to look at the solid volume, the solid volume this part and this part, so this is the volume I am interested in.

So, now, how do I write it in reference to this particular phase diagram, so this is equal to weight of the aggregate divided by the denominator becomes very important and I will request you to pay little attention when I am referring to the phase diagram here. So, you see, this says bulk volume minus volume of aggregate not filled with bitumen.

So, I am basically what I am seeing I want this volume minus volume of bitumen, a volume of aggregate not filled with bitumen, so I am trying to find out this volume, but if you see the vertical arrows here, I do not have any specific definition of volume for this particular arrow here. So, then how do I write it with respect to the phase diagram.

So, I will try to write it in this way that this volume the one in red arrow here, this one is equal to the bulk volume of the aggregate plus the effective volume of the bitumen minus this, total volume of the bitumen and these three arrows I have specific volumetric definition and I hope you see if you take this entire volume and subtract this particular volume you get this volume which is of my interest. And this is what I am doing, I am first writing this.

So this is 1, this is 2, this is 3. So 1+2 - 3 will give me this volume, if you try to see it very closely and this is the most critical part to understand here. So, I am just writing it the same thing here, assuming that you have understood it by now. So, I am writing it this is equal to V of aggregate bulk plus volume of effective bitumen minus volume of bitumen, so this is what I have written here. And I hope that this is pretty much clear by now.

So, what I will do here? Now, I am writing it in this way that this is $\frac{W_{agg}}{(V_{a,bulk}+V_{eb})-V_b}$.

If you remember, this volume pertains to the expression of theoretical maximum specific gravity, where we say that Gmm is equal to $Gmm = \frac{W_T}{(V_{a,bulk}+V_{eb})}$. So, this becomes equal to, weight of aggregate. Volume of aggregate plus volume of effective bitumen from this expression I can write it as $\frac{W_{agg}}{\frac{W_T}{G_{mm}}-V_b}$. Volume of bitumen, I can write as $\frac{W_{agg}}{\frac{W_T}{G_{mm}}-\frac{W_b}{G_b}}$.

So G_b specific gravity of bitumen weight of aggregate, I am just writing it as as it is right for now. So, this is $\frac{W_{agg}}{\frac{W_T}{G_{mm}}-\frac{P_b W_T}{G_b}}$ because we know that the percentage of bitumen is defined with respect to the weight of the total mix, so this is divided by Gb.

Now the denominator W aggregate I can write as $\frac{W_T-W_b}{\frac{W_T}{G_{mm}}-\frac{P_b W_T}{G_b}}$, the numerator now if you look at the numerator, again, I can write this as the $\frac{W_T-P_b W_T}{\frac{W_T}{G_{mm}}-\frac{P_b W_T}{G_b}}$. So now if you see WT is common in the numerator as well as in the denominator.

So I am just removing it. So, this becomes equal $\frac{1-P_b}{\frac{1}{G_{mm}}-\frac{P_b}{G_b}}$ and this is what you see is the derived expression. So, again, I hope that this is pretty much clear to you that how we calculate the effective specific gravity based on the other volumetric parameters.

Now, let us come to our confusion here, that on one hand, we are saying that the effective specific gravities is a property of the aggregate and should not depend on the mixture property, but in the expression we have parameters that are related to the mixture properties. So, to understand this, you have to understand that let us say we are preparing several samples.

So, first of all, let us understand that why do we call this as the aggregate property because for a given source of binder and given source of aggregate, irrespective of the bitumen content, irrespective of the bitumen content, the amount of binder or amount of that particular binder which we are using for the construction, this aggregate will absorb will remain constant because absorption is the property of the aggregate for a given single binder source and single aggregate source, let us say we are preparing the sample at 5 percent binder content.

So, what we will do here that for 5 percent binder content the mixture which we get, this mixture for this mixture, we will do the Gmm test, which is basically the theoretical maximum specific gravity and when we have already discussed the laboratory test procedure to conduct or to complete this test. So, we will do the theoretical maximum specific gravity test and we will determine the Gmm at 5 percent binder content.

Now, once we have the Gmm at any binder content, we will put this expression here, we know that we have used 5 percent binder content, we also we also know the specific gravity of the bitumen which we have used, you calculate Gse, now Gse by this calculation will become constant. Now, for this mixture, irrespective of any other binder content, maybe you are making the mixture at 4 percent binder content.

4.5 percent binder content, 5.5 percent binder content, any binder content, the amount of absorption which will take place will be same and only the value of Gmm will change. So, what we do typically, that for any one particular binder content, we will measure the Gmm in the lab, which means we need not measure the Gmm again and again a different binder content to calculate air voids or any other volumetric parameters.

So, you will do the measurement only once from this measurement you will find out Gse which will remain constant for this aggregate source and binder source and at any other binder content because at any other Pb, we will calculate Gmm we will not measure it again. So this is another use of Gse that once you get the Gse with one single Gmm, you can calculate Gmm at any given binder content, because the Gse will become fixed.

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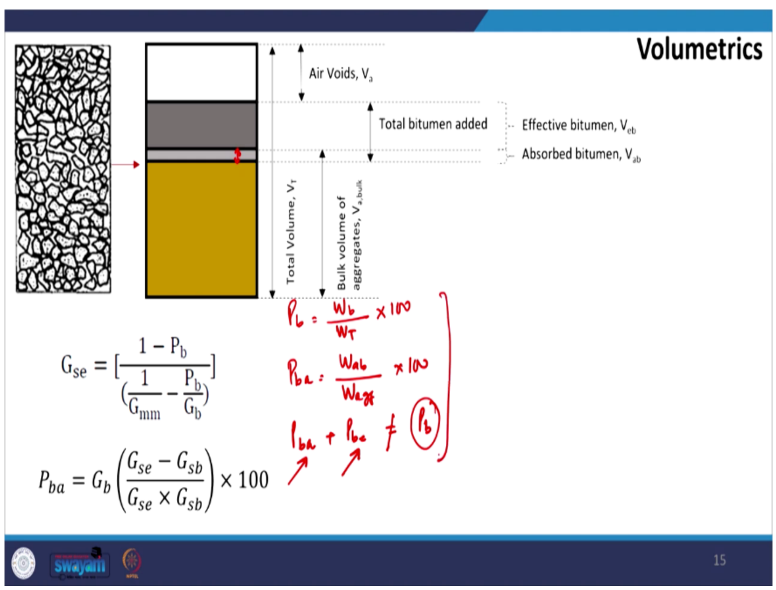

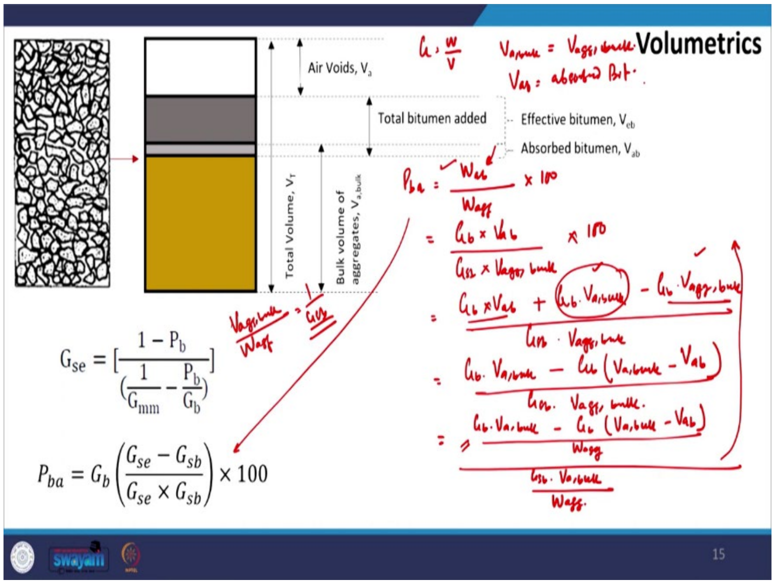

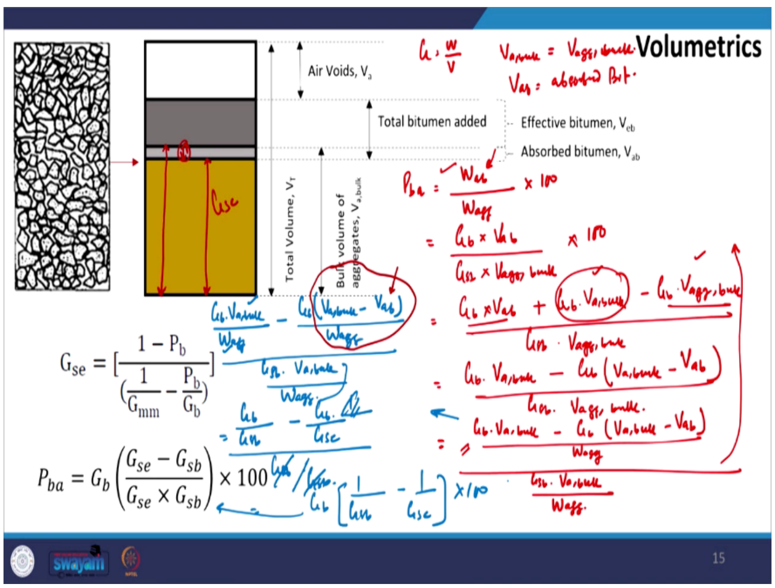

So, I hope this is clear to you. We will now move to the next expression which is P_{ba}, so P_{ba} is the percentage absorbed bitumen. So, this is this is the one which we are talking about and P_{ba} unlike P_b now, this is also one important point here, percentage absorbed bitumen is expressed with respect to the weight of the aggregates because this is an aggregate property again not a mixed property specifically.

So, percentage absorbed bitumen is expressed as by weight of the aggregates and not by the weight of the mixture, so $P_b = \frac{W_b}{W_T} \times 100$ whereas $P_{ba} = \frac{W_{ab}}{W_{agg}} \times 100$. this is the difference therefore, again one important point to note here is that $P_{ba} + P_{be} \neq P_b$.

Because Pbe maybe we are expressing with respect to the weight of the total mixture Pba we are expressing with respect to the aggregates. So, this does not give us the total percentage of binder which we are using. So, again this is something which is very important to note in the mix design process. Anyways, so our definition of $P_{ba} = \frac{W_{ab}}{W_{agg}} \times 100$.

And weight of of the absorbed bitumen I do not have a direct process to measure this weight. So, ultimately I will have to take the help of specific gravities which I have measured or I have already calculated to finally calculate the percentage of absorbed bitumen and you try to understand that these many calculations which we have discussed the derivation of VMA the derivation of air voids the derivation of Gse, all this has been done finally, to calculate the percentage absorbed bitumen, which we cannot measure in the laboratory.

If, if we can develop tomorrow a procedure to measure accurately the percentage of absorb bitumen or the bitumen absorption by the aggregate in the laboratory the mix design calculations or derivations or measurements which we have been doing, it will not be required and the steps of the mix design process especially the volumetric steps or calculations in the mix design process will become very-very simple and easy for us.

However, in the absence of these procedures, we are doing all these calculations and derivations finally, to arrive or to calculate that how much binder will be absorbed in the given source of aggregate. So, finally, we have to convert this expression to this expression. So, let us see the derivation. So, here what I am doing now, weight of absorbed bitumen I can write as specific because $G = \frac{W}{V}$

So, $P_{ba} = \frac{W_{ab}}{W_{agg}} \times 100 = \frac{G_b \times V_{ab}}{G_{sb} \times V_{agg,bulk}} \times 100$, so what I am doing here now is that $\frac{G_b \times V_b + G_b V_{agg,bulk} - G_b V_{agg,bulk}}{G_{sb} \times V_{agg,bulk}} \times 100$. So, I am just adding and subtracting using this.

So, now, what I will do, I am taking this expression and this expression and combining this expression and this expression and the middle 1 I am keeping it separate now. So, this becomes $\frac{G_b V_{agg,bulk} - G_b (V_{agg,bulk} - V_{ab})}{G_{sb} \times V_{agg,bulk}}$ just for my convenience I have done this.

Now, what I will do, that in the numerator and in the denominator I will divide by the weight of the aggregates, I will divide the numerator and the denominator by weight of the aggregate. So, this becomes equal to $\frac{\frac{G_b V_{agg,bulk} - G_b (V_{agg,bulk} - V_{ab})}{W_{agg}}}{\frac{G_{sb} \times V_{agg,bulk}}{W_{agg}}}$.

So, do not get confused that in the derivation, V of a bulk is actually equal to V of agg bulk. So, sometimes I just wrote it V of a bulk and sometimes I wrote it as V of agg bulk and Vab is actually absorbed bitumen. Sometimes it is confusing. So, now, I am just trying to rearrange this expression here So, just again to inform you that $\frac{V_{agg,bulk}}{W_{agg}} = \frac{1}{G_{sb}}$ is not it, this is obvious by now we know this, so this is $\frac{1}{G_{sb}}$.

So, therefore, I am just first in the numerator, I will separate the expression. So, this is this is equal to $\frac{\frac{V_{agg,bulk}}{W_{agg}} - \frac{G_b(V_{agg,bulk} - V_{ab})}{W_{agg}}}{\frac{G_{sb} \times V_{agg,bulk}}{W_{agg}}}$.

So, now, what we have this view of aggregate bulk by W of aggregate is equal to Gsb. So, $\frac{\frac{G_b}{G_{sb}} - \frac{G_b(V_{agg,bulk} - V_{ab})}{W_{agg}}}{\frac{G_{sb} \times 1}{G_{sb}}}$, try to understand this expression, this is like inverse of weight of aggregate bulk by volume of aggregate bulk minus volume of absorbed bitumen. So, I think from our previous discussion, we know that, if we subtract this volume by this volume, this gives us the volume corresponding to the expression of Gse ($\frac{(V_{agg,bulk} - V_{ab})}{W_{agg}} = \frac{1}{G_{se}}$.

So, weight of aggregate by this volume is nothing but equal to Gse which means the expression in the numerator becomes equal to $\frac{1}{G_{se}}$. ($\frac{\frac{G_b}{G_{sb}} - \frac{G_b}{G_{se}}}{1}$)So, this is equal to $G_b(\frac{1}{G_{sb}} - \frac{1}{G_{se}})$. So, Gsb because V of aggregate bulk by W of aggregate bulk is equal to Gsb, so this just gets cancelled.

So, now, what we have here, we will just take out a Gb outside which is common and we have $G_b(\frac{1}{G_{sb}} - \frac{1}{G_{se}}) \times 100$ which was always there outside the bracket. So, I again hope that this derivation is clear and I will recommend that you remember or practice or understand this derivation.

Because then only you will be able to connect yourself to the volumetrics in the mix design process the volumetrics of the bituminous mixtures and you will feel more confident when you are executing any order or solving any problem related to the mix design of bituminous mixtures you will never get, you will never get stuck in the process if you understand this derivations, if you understand the phase diagram.

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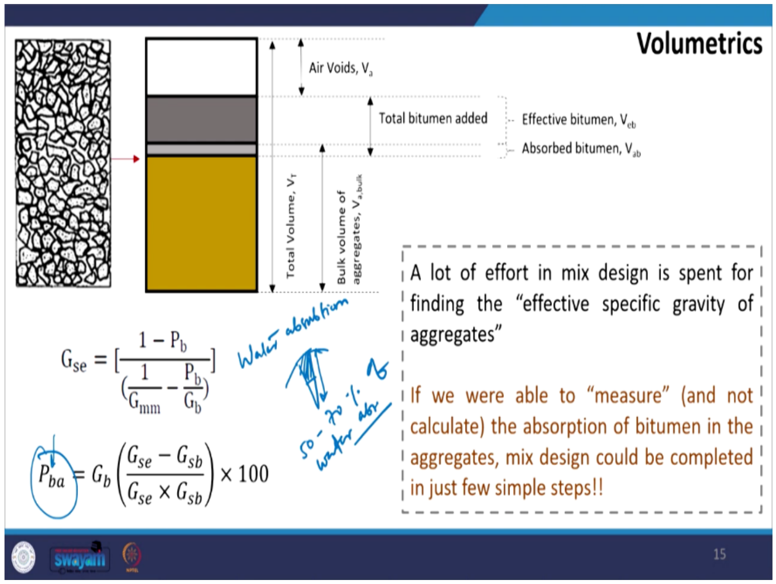

As I was mentioning that most of the efforts which we are doing in the mix design in this calculations understanding this derivation is for finding out the effective specific gravity of the aggregate because ultimately we are interested to know the absorption of bitumen in the aggregate.

And if as I mentioned we can someday find a process of measuring the bitumen absorption using some method the mix design process related to the volumetrics can be completed in just a few simple steps some of the researchers they have also tried to correlate the absorption of bitumen with the water absorption because if as I told you if this is void, which can be completely filled with water, and then we are talking that the bitumen will come which is more viscous.

This void will not be completely filled with water but partly will be filled with water. So, researchers have an explanation that bitumen absorption is nothing but a proportion of water absorption and water absorption is relatively more easier to measure in the lab because we can have a saturated surface dry specimen here.

So, a thumb rule which have been sometimes used sometimes argued is that the bitumen absorption ranges from approximately 50 to 70 percent of water absorption. So, in absence of any equipment for measurement or if there is some repeatability issues in the measurement or a if you want to just have an approximate idea about the volumetrics of the source of the mixture prepared using a specific source.

You just measure the water absorption it thumb rule of 50 to 70 percent of the water absorption can be taken as P_{ba} and once you have P_{ba} you can actually calculate everything in the mix design calculations and you will have the calculation of air void will also become very simple for you, you need not spend much time in measuring the parameters in the lab.

But however, just a word of caution that this is just an approximate idea not an absolute idea of what will happen in the actual case when you are working in the laboratory. So, now, let us discuss about one last volumetric parameter which is also very critical and related to the performance of the bituminous mixture and that is dust to binder ratio.

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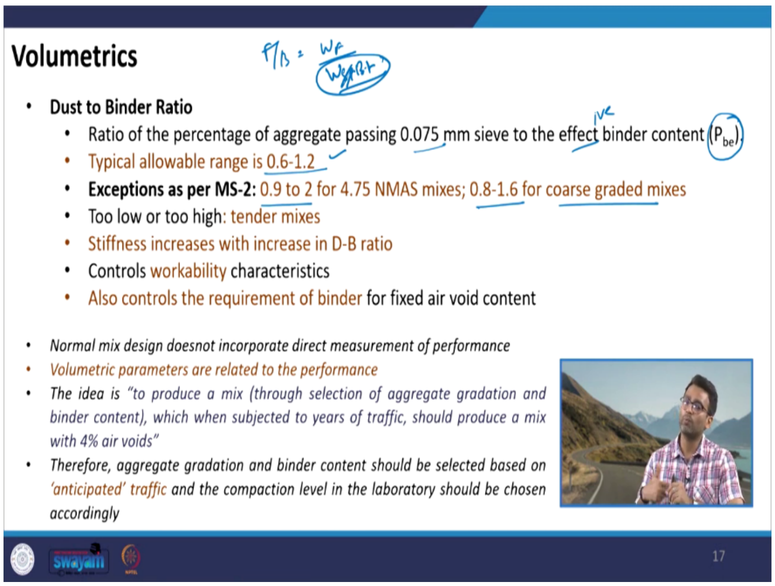

So, dust to binder ratio or we also call it as filler to binder ratio is defined as the ratio of the percentage of aggregate passing the 75 micron sieve because this is the one which we call as filler, 75 micron sieve to the effective binder content, So, this is effective binder content.

And again sometimes students are confused that filler to binder ratio is actually equal to the weight of the filler by weight of the bitumen, but it is not actually the weight of the bitumen, it is the weight of the effect of bitumen and it is very obvious because the other part of bitumen is inside the bulk of the aggregate which is not active which is not interacting specifically with the fillers.

So, we always have to consider the effective bitumen when we talk about the dust to binder or the filler to binder ratio. So, the definition will just repeat that this is the ratio of the percentage of aggregate passing 75 micron sieve to the effective binder content. Typical allowable range is 0.6 to 1.2. And this has been decided based on studies on various mixtures based on experience and a lot of research work.

So, this and again some of the researchers also suggest that instead of using the filler to binder issue of percentage by weight, it is better to use it as by percentage of volume, because different fillers can have different specific gravities. So, for the same weight, the volume will change. And therefore, they think that since it is an important parameter related to the performance, specifically fatigue response of the mixtures and also related to other parameters.

For example, workability for example, stiffness of the mixture, it is better to describe it by volume, but the present specifications which we have, it describes just to bind a ratio as ratio by percentage of weight of aggregate passing 75 micron sieve and the percentage of effective bitumen. So, as I was mentioning, the typical allowable range is 0.6 to 1.2.

And, as per MS-2 of asphalt institute, there are some exceptions, if we have aggregate gradation with smaller nominal maximum aggregate size for example, if we have aggregates with 4.75, nominal maximum aggregate size the suggested range is 0.9 to 2. Whereas, for coarse graded mixtures, so these are mixtures, which are below the maximum density line is 0.8 to 1.6.

And, as I was mentioning that, this is a critical parameter and it describes the workability in the mixture and if you have too low filler to binder ratio, it can produce tender mixes, which are difficult to compact under rollers. If you have very high again, you will have a tender mix will which will be difficult to compact under the rollers.

Typically with increase in the amount of filler to binder increase in this ratio, the stiffness increases because the amount of dust is increasing, which has very small surface area. So, it acts as an, it goes inside the existing voids of the mixture, it can improve the interlocking properties, so the stiffness of the mixture increases.

And it also controls the workability characteristics as I have already described, it also controls the requirement of binder for a fixed air void content which is very obvious because with increasing surface area more binder will be required considering we have a fixed criteria for air voids, so more binder will be required to coat the surface and therefore, the amount of the optimum binder content will increase.

Well with this I think we have discussed most of the volumetric parameters we have tried to understand them. And with this knowledge, we should be almost ready to undertake the mix design process which we will be discussing subsequently. But before that, we also will understand probably in the next presentation about the importance of at least three critical volumetric parameters that is voids in mineral aggregates, air voids and voids filled with bitumen, the importance of these parameters.

Some of the concluding remarks related to the volumetrics and the mix design is that the normal mix design does not incorporate direct measurement of performance. Now, this is, an early statement right now, but I wanted to make the statement at this point. So, that when we are done with the mix design process, we can actually accept this statement and we can understand that what are the aspects missing in the present guidelines, which needs more attention which needs more research in the future.

So, the normal mix design process it does not incorporate direct measurement of performance. So, historically, we have always used volumetric parameters as indicators of performance. So, engineering or the science in materials related to bituminous mixtures have taken a leap in the recent past you can say and there are so many materials so many binders which have come up.

And then when this was believed that only volumetric parameters are indicators of performance is typically not accepted in the present times when we have so many materials of different varieties with different individual mechanisms of the response to any given loading condition. So, only volumetric parameters are not found to be very good indicators when these materials are used.

But conventionally, if we have unmodified bitumen and normal bituminous mixture, then of course, volumetric parameters have been related to the performance of the bituminous mixtures. So, ultimately the idea in the mix design process is that we have to produce a mix and this the same statement I will repeat at the end of our discussion in the next presentation that the idea is to produce a mix.

And how do we I produce a mix by selection of an aggregate gradation, which again just to recall that we are doing it empirically based on the maximum density line. So, we have to select an appropriate aggregate gradation and an appropriate binder content. So, so that we meet some of the requirements of the volume metrics.

Now, this mix, where which will produce when it will be subjected to years of traffic should produce a mix with 4 percent air voids. So, this will be our mix design criteria that in the laboratory we are giving a compaction level which is actually representing the actual compaction after the years of traffic and when this entire traffic will or this traffic will move on my mixture with a given design life.

The final air void at which it should compact should be 4 percent or should be in a range with an average of 4 percent so that we have certain level of air voids present in the mix. And how do we do that? We do that by selection of an aggregate gradation and binder content, based on the anticipated traffic. And here again is one more critical point that the compaction level which we are giving in the laboratory.

Will again talk in detail when we discuss about the steps of mix design. But this is just to ponder upon food for thought that all these things will change when we talk about volumetrics, volumetrics is dependent on the compaction level compaction level is dependent on the anticipated traffic, anticipated traffic is random because for different locations for different traffic conditions, the anticipated traffic changes.

But the question is for different anticipated traffic do we use the same compaction level in the laboratory? If we are using the same compaction level in the laboratory, does this really hold true when we say that ultimately after years of traffic it should arrive at 4 percent year void why do we say that? So, the idea is to use an or select an aggregate gradation and binder content based on the anticipated traffic and the competition level in the laboratory which we have to use should also be chosen according to the anticipated traffic.

So, we will see that how do we incorporate these aspects in the mix design process, which we will be discussing. With this will end here today and we will meet again in the next lecture, where we will discuss about the importance of three volumetric parameters including voids in mineral aggregates, air voids and voids filled with bitumen and also we will solve a problem incorporating entire knowledge which we have gained till now related to the volumetrics. Thank you.