A very warm welcome to all of you. I am Rajan Chaudhary, a Professor in the Department of Civil Engineering at the Indian Institute of Technology, Guwahati, and the instructor for the NPTEL MOOC course, Payment Construction and Technology, funded by the Ministry of Education, Government of India. Today's lecture, which will be on the mix design of bituminous-bound courses, will be a part of our Module 4. And at the very beginning, I acknowledge the use of text, information, graphs, and images sourced from various textbooks, codal standards, journal articles, reports, newsletters, and public domain searches. Beginning with the design of bituminous mixes, as we discussed in the previous lectures where we also talked about the unbound courses, there is a requirement to achieve a combination of materials, and that combination is targeted to achieve some desired characteristics in terms of strength or in terms of any specific performance, which can be said. The maximum load it can take; there we discussed the unconfined compressive strength, we discussed the CBR, the requirements were in terms of the CBR, and it can also be in terms of the density.

So, when it comes to bituminous-bound mixes, as the term suggests, you have aggregate and bitumen with us. So, you have to work out the combination to get your bituminous mix; this is the water design of the bituminous mix. So, you need to first work out what combination of aggregates is suitable for a particular layer, and that means you have to ensure every layer performs well when the traffic load comes under different environmental conditions. So, this is what combination of aggregates can be there in terms of different sizes, and once that particular combination is decided, what amount of water is to be added to those aggregates, and finally, to get a mix.

At all stages, we need to ensure that we discussed in previous lectures how we can ensure the quality of the aggregates. We discussed how we can ensure the quality of the binder; here, we will discuss how we can get an idea about the properties of the bituminous mix that we obtain. So, these are the different steps involved in the bituminous mix design, and ultimately, my design, which I am targeting out of this particular design, with this blend of aggregates and binder that I will decide under this mix design, should result in a good, stable mix. A good stable mix means that when traffic comes over it, it should not show deformations or cracks. These cracks very much resemble the skin of an alligator.

So, you can see an alligator is there, and these cracks are there. So, these cracks you can see, there is some flushing, and the binder has come up on the surface. You can again see that some amount of depression and flushing is present; the cracks are also there. Some amount of depression is present. This is the construction of bituminous mixes going on.

These are laboratory-compacted specimens because I need to work out the different properties of the mixes at a laboratory scale before suggesting that particular combination for construction in the

field. So, my mix design will prepare a mix design and ensure it meets all the desired requirements, and then that will be followed in the field. So, one requirement is stability; second, it says that because I am going to add a binder, I very well know that if that binder is there, it is the one that is holding those aggregates together. Now, this is how much quantity of binder will require more binder, which will add more to my cost, and whether it is by increasing the binder 2000 aggregates volume, whether I am adding some gain in the strength, or in addition to the gain in the cost, because the cost will definitely increase when you are going to increase it, as the binder is the costliest component in your bituminous mixes. Now, I need to work out a bituminous binder volume or quantity that is sufficient to provide good adhesion, because the material must have good cohesion; only if there is good cohesion can it support a significant load.

It should be flexible enough, even if it is very stiff. With a small amount of deflection, it will crack down because we have granular courses. So, there will be some amount of deflection, and if the material is very stiff, it can crack. In addition to that particular one, as we discussed during the binder characterization, the aging of the binder is also important. If the quantity of binder is quite low, then the formation of the film will be very thin over the aggregates, and that thin film will be more prone to aging or oxidation compared to a thicker film.

And, in addition to that particular one, this coating should be good enough so that the aggregate's surface does not get exposed in the presence of water. So, I need to because aggregates in general have a greater affinity towards water compared to bitumen. So, I require a binder content that is optimum, in the sense that it should provide cohesion, stability, flexibility, moisture damage resistance, and ageing resistance. Additionally, if you add a significantly higher amount of binder, it may lead to a reduction in stability as well, because your structural units are your So, there is a specific range or there will be a specific quantity of binder that will be good for a mix. So, that needs to be worked on.

So, what you need to see is the asphalt content that is appropriate for a mix; you need to ensure that it achieves good strength, as well as the air void content. When you prepare these bituminous mixes in the lab and field, there will be some air entrapped in this particular one. They will not be completely voidless mixes. There will be voids, and these voids, but a general conception is that if a mix is dense, the denser it is, the stronger it will be. Yes, with the increase in density, the strength and load-carrying capacity can increase, but there are also certain challenges that need to be understood.

Challenges arise when you have this particular mix at a higher density; if, during the aggregate blending process, you create a very dense aggregate packing, then there will be no space for the binder to enter it. The durability will be a concern because the aggregates will not get a good coating of binder over them. So, you also need a good amount of air void content in your aggregate blend. In addition to this particular one, once the mix is compacted during the initial years, there is some amount of secondary compaction that occurs due to the traffic that usually happens in the initial periods of 2 to 3 years of life. So, some densification occurs because of the reorientation of the particles due to the movement of traffic; some secondary compaction takes place, and a little bit of binder expansion can also occur, especially in hot summers.

So, that is why we require a specific range of air void content as well. So, this is also a part of your mix design, and whatever mix you are preparing should be workable enough because ultimately it has to be laid in the fields by your conventional pavers and compacted with your rollers as well. So that mix should be workable for laying and compaction in the field, and if you are using that mix as a wearing course, then it should give you good skid resistance as well. So, these are certain requirements that you expect from a bituminous mix; some of these we will try to address at the design stage itself. So, first, aggregate gradation, as in the case of granular courses, is also very important here, as I mentioned; the general conception is that if I have the gradation yielding the densest aggregate particle.

It will be the most desirable one. Why is this conception there? Because such gradations typically enhance mix stability by maximizing inter-particle contact, when they come close together, their inter-particle contact is greater, their load transfer is better, and it minimizes voids within the mineral aggregate. So, this is a normal conception. While maximum density gradations improve stability, specifically the load, they may not allow adequate space for the bitumen to ensure long-term durability. So, then those mixes are needed because the void in that aggregate gradation is quite low.

So, there is no space for the binder to form a good film over the aggregates. Insufficient air voids can lead to issues such as bleeding or rutting because when secondary compaction takes place, reorientation of aggregates occurs, and expansion of binder occurs; if there are no air voids available, that may specifically lead to rutting, flushing, or bleeding in that case. Flushing is when the binder comes over the surface, filling all the air voids with bitumen from the mix, and you can see dark patches of binder, specifically along the wheel paths. And rutting is when deformation along the pavement surface occurs, mainly along the common wheel paths. We will always have dense gradations, but we will try to ensure that this gradation has an adequate amount of air voids to accommodate the required quantity of binder as well.

So, these dense gradations tend to be, and even if the gradations are denser, we can say they are highly sensitive to the variations in the binder content as well. So, the content of this binder can vary specifically when you are doing the productions at the hot mix plant; there may be a slight variation, and we provide an allowable range. Whatever we do at the laboratory scale cannot be exactly simulated in the field. So, we need to allow some variation in the fields. So, with that, if the densest gradations are there, they are more vulnerable or sensitive to changes in the binder content.

So, in order to have a balance between stability, durability, and workability, we normally try to deviate from the densest packing that we can have. So that we get the required amount of air void content in our gradation to accommodate your binder and to look after the aspects related to secondary compaction. Now, certain parameters need to be worked out for this bituminous mix design. One is required to know the specific gravity of the aggregates and binder. So, for aggregates, the specific gravity that is required is bulk specific gravity.

We also discussed earlier what bulk specific gravity is, and here is an exaggerated view: when all the surface pores of an aggregate that are water permeable get filled with water, there is no surface water. So, this is a saturated surface dry condition. So, for this particular case, the specific gravity, which is determined over the dry weight volume of aggregates plus the surface voids filled with

water, gives you the bulk specific gravity. The other one, if there is no water absorption considered, then what we have is the apparent specific gravity. So, this is already given in our IS 2386 Part 4, which is also there for the determination.

Similarly, you need to work out the specific gravity of your bituminous. So, this one considers the surface voids that get filled with water as a part of the aggregate, which is known as bulk specific gravity, and this is used during the mix design exercises. This is just for comparison to show the difference between apparent specific gravity and GSB. Now, if you have, I will blend one; I may have stockpiles of A, B, C, and D; four aggregates may be there. So, I need to blend these aggregates to achieve my desired gradation.

So, I may be using 100 percent of my aggregate blend, with 20 percent from A, 30 percent from B, 30 percent from C, and 20 percent from D. These are the individual percentages. So, my small a will be 0.2, 0.3. This is what we discussed about C point infractions.

Now, I have to work out this combination. Now, if I work out the specific gravity of this aggregate stockpile, I will work out the specific gravity for this one and the specific gravity for this one. There are measures for working out this specific gravity test procedure, as I mentioned; IS 2386 Part 4 gives the test procedures for determining the specific gravity of aggregates of different sizes. So, in for A, you will have a range of particles, and you will determine the specific gravity of that particular blend of A, which can be referred to as Gsb-1, or I can write it as G1. I am referring here to bulk specific gravity, so I will always prefer to write it as Gsb; you can write it as G1 because we do not use apparent specific gravities in the computations, and then here it is G2, G3, G4.

Now, if I blend them in this 20, 30, 30, and 20 percent, what will be the specific gravity of this blend? So, this is how we get it. So, if you have, say, 3 aggregates used, P1, P2, or more than that. So, then you will write this; it will be your 100 because all that needs to be combined to become your 100 percent. And this is your individual shear; P1 is the percentage of the first particle or the first stockpile in the total. So, here, if it is A, it is 20 percent.

So, P1 is the share within that aggregate blend, and P2 is the second share. So, P1 individual percentages of each aggregate fraction by total weight of the aggregate, and the G1 and G2 are individual bulk-specific gravities. So once this is there, you work out the individual bulk-specific gravities of stockpiles and then determine the combined bulk-specific gravity of that blend. There is another thing; this is when I am using water and observing the water absorption, so I obtained my bulk-specific gravity. But when I prepare the bituminous mix, there will be no water; there will be an aggregate and binder.

So, can the water, can the bitumen get absorbed in a similar quantity as water is getting absorbed? It may or may not be, but in general, I will fill because the binder may not go up to the same depth or may not get filled to the same level to which the water will go. Therefore, some of the surface voids may remain unfilled if bitumen is added to the aggregates. So, you can see the same aggregate parts; certain void portions are there. This shows the surface voids. This is an exaggerated view to explain and give an idea that a certain amount of binder may get absorbed in the surface voids of your aggregate.

But that absorption will not be at the same level as water is being absorbed. So, Gsb, there is another specific gravity that needs to come into the picture when we are working with bituminous mixes, because the aggregates will not be submerged in water; they will be coated with the binder. So, this comes out as your effective specific gravity; this is neither your apparent specific gravity nor your bulk specific gravity. And what it says is that it is the oven dry weight divided by the volume of the air. Your solids plus the volume of the voids that are not filled with the bitumen.

So, it says this when we look for the weight of overdrive of your aggregates, and this is the volume of solids plus the volume of voids that are impermeable to bitumen. So, I will use this one. So, this is why it is important to determine this particular one; otherwise, these surface voids will be filled with bitumen. So, some amount of bitumen goes into the surface voids that you need to work out because this bitumen will not be available for coating the aggregates. If a larger amount of binder goes into a certain type of aggregate, then even if I put the same quantity of binder for a particular weight or volume, the larger amount of binder gets absorbed in that type of aggregate, and less binder is available for coating.

So, I need to know what the amount of binder that gets absorbed can be. So, for this particular one, there is an expression given for which you need to determine the maximum specific gravity of the mix. As you can see, there are two parameters that are mentioned. The specific gravity of the loose mix cannot be directly tested on aggregates to get the Gse value; you have to prepare a loose mix where aggregates are mixed with the binder, and then you determine your effective specific gravity. So, for this particular one, what you require here is your maximum specific gravity of the mix.

I will discuss this in the upcoming slides, and then we will again discuss this particular Gse part. So, now important here we can understand it says it is the ratio of dry mass per unit volume of aggregates, including impermeable volume, plus water permeable, not filled with bitumen. So, this is the impermeable one plus the ones that are permeable to water but not permeable to bitumen. So, it includes impermeable volume; this is impermeable plus water-permeable, not filled with bitumen. These voids were water-permeable but were not filled with bitumen.

So, this is what this specific gravity is, effective specific gravity. For the binder determination of binder specific gravity, it is as per IS 1202. So, here these pycnometers, small pycnometer bottles, are used; it is a conventional method we use for fine aggregate specific gravity measurements by using pycnometers. Here you have an empty pycnometer bottle, the second one filled with water, and the third one is first half filled with bitumen, approximately half filled, and thereafter the remaining part is filled with water, and I need to work out the specific gravity of bitumen. So, what I need to know first is the weight of the bitumen, which is c minus a, because here it is half-filled, and this is empty water.

Then I need to work out the volume, which is equal to this volume of bitumen. So, what I am doing here is that b minus a is giving me the volume of this water, which is in this particular pycnometer. This is your b minus a; through this water, I will subtract out from d, and I will subtract out c, so that will give me this water. So, from this total water, if I subtract this water, I will get the volume corresponding to my bitumen sample, and this is what goes in the denominator, so you get the specific gravity of the binder. So, this is now you have a specific gravity of aggregates with you, the specific gravity of binder with you, a specific gravity Gsb, the specific gravity of the blend's

aggregates, and for individual aggregates as well, and you have the specific gravity of bitumen, which is the only thing we will further discuss: what is the Gse, effective specific gravity of aggregate.

Once this is there, you need to prepare an aggregate and a binder blend. Now, for this one, the aggregate proportioning has already been done to achieve a particular gradation. Now I need to prepare a mixture. So, for laboratory testing, specimens are prepared, which are cylindrical, and the very common specimens that are prepared have a diameter of 4 inches and a height of around 2 and a half inches. Now, for this particular cylindrical specimen, which is in this particular manner, the height has to be approximate because I need to have this one.

So, this is 2 and a half inches in height and 4 inches in width. Now, for this particular cylindrical specimen, approximately 1200 grams of aggregates are taken for these specimens to be prepared, and these are what we need to do some determinations, especially volumetric measurements, to come to this particular design of bituminous mixes. Now, for this one, we will prepare these cylindrical specimens, which will take around 1200 grams of aggregates. Then we need to start with a trial binder content for different mixes, including the codal specifications, whether it is your IRC 111, which is on dense graded bituminous mixes, or your MoRTH, which states that these mixes should have a binder content that can be more than this one, and they also provide a range. For an example of preparing a blend, we need to understand what volumetric determinations are and how they are done.

So let us go for a binder content of 6 percent by weight of your mixture. Now, for this particular one, what it means is that if I have taken an aggregate of 1200 grams and I want to have a binder which is 6 percent, then what I will do is work out the total mix weight. So, the total mix weight in this particular case will be 1200 divided by 1 minus 0.06. So, you will have your total mix weight as 1 minus Pb by 100. Pb is the percentage of binder. So here I took 6 percent of the binder. So, this particular one became 1.06. So I got the mixed weight as 1266. Now, the aggregate weight is 1200, and my total mix weight is 1276. So, what is my weight of bitumen that I have to incorporate is 76.6 grams. So, if 76.6 grams of binder are in 1276.6 grams of mix, then it makes 6 percent of bitumen. So, I always prefer to have these binder contents with respect to my mix weight. You can have respect to aggregate also, but for mix design computations, you will find it is easy to work out with respect to the total weight of the mix. So, here now, if I need to prepare a mix with 6 percent bitumen content, I will take 1200 grams of aggregates, add 76.6 grams of bitumen, whichever grade of bitumen VG 10, 20, or 30 you have already selected, or any modified bitumen, and mix it with that. There is a standard process, there are standard protocols for mixing it, the temperature at which you should heat your bitumen, the temperature at which you should heat your aggregates, and then it has to be mixed in a laboratory mixer; afterward, you need to transfer it to ovens where conditioning is done.

So, the conditioning here is the drying of aggregate. Similarly, after this particular one, you do the conditioning of this loose mix, and then it is compacted. So, when it is compacted, you apply a compactive effort, and that compactive effort should be the one that can give you a density that will be there after 2 to 3 years of service life. So, this is what you can see now: my loose combination of aggregate and binder, when compactive effort was given, resulted in these cylindrical specimens

being prepared. Now, for this, considering the usual specific gravities we have for aggregate and binder, we will normally get the diameter because it will be prepared in cylindrical molds.

I will show you cylindrical modes later. So, the diameter will be exactly the same; only there may be a small variation in the height of the specimens. Once you have this particular one, this is a prepared compacted bituminous specimen, and the density should be the one that is after the secondary compaction. If this mix is layered and compacted first in the field by rollers and thereafter undergoes some secondary compaction, then the density after 2 to 3 years of life should target achieving the same density in the laboratory. Now, once I try to show in a phase diagram this particular one, where I can, if this is a diagram that shows the different volumes of different components, I may have the volume of the aggregates, which is at the bottom. Then there will be some amount of asphalt volume that is free and some amount of asphalt that has gone inside the aggregates, which I will call absorbed aggregate, sorry, absorbed bitumen or absorbed asphalt, and then definitely some amount of air voids is also there.

So, this is a phase diagram where you show the volumes of the different phases that exist. So, what I am mentioning here is that my Vs is my volume of aggregates; specifically, this is the volume corresponding to the bulk specific gravity. Because, to a certain extent, the binder goes inside it, I will mention that this is my volume corresponding to the bulk specific gravity or volume of my solids, including the surface voids. So, some amount of binder has gone into those surface voids.

So, the volume of asphalt has gone inside the aggregate surface. Some part is free, so if this is my total binder, out of which Vba is the one that got absorbed, and Vbe is the binder that is effective, or I can write it as Vbf binder, which is free, and Vba is the binder that is absorbed inside the aggregates, and what is there on the top is your air. Now, another important parameter here is the voids in mineral aggregates (VMA). This is when the aggregates are packed, which is the space available in that compacted specimen for the free asphalt and the air. This forms voids in the mineral aggregates because there you have free asphalt as well as air.

Now this makes your total volume; this is the bulk volume of your mix. Now, if I put it in terms of weight, this volume of aggregates will correspond to the weight of the aggregates. This volume of bitumen, including the absorbed bitumen, will be my weight of bitumen, and this will be my total weight of the mix. So, these are important. Now, under this particular mix design, I need to determine a few parameters; one is the air void content in that particular compacted mix. How much air void is there, as I discussed in the beginning? For me, it is important to control the air voids because some amount of secondary compaction is also going to happen, and there is also some extent of binder expansion.

So, I want to keep a particular range of air void contents. So for that, I need to know how much air void content there is. I need to work out the voids in the mineral aggregates because this void is important; only my binder is available, and the free binder that is going to coat the aggregates is available, as well as the air voids. So, for me, these voids in mineral aggregates are important. Voids filled with bitumen, because out of these total voids, which include asphalt, I need to know the shear of the asphalt, also, so that I can get an idea about how much coating is possible. I want the shear to be at least a good shear in this VMA from my asphalt, the volume of the asphalt.

And then I may need to know how much binder is being absorbed. So, I may look into the percentage of binder that is being absorbed. I do not prefer aggregates that have a high-water absorption because it will increase the cost of my mix. And then one may ask, okay, considering how much binder has already absorbed, can you tell us the percentage of binder that is free or effective and available for coating the aggregates? Similarly, this shows that these are the three components that have been shown. Now, here we have important voids in mineral aggregates that we already discussed. So, if I remove this from this particular one, if I remove this binder, whatever binder and air part is there will be my VMA.

This will be my VMA-free asphalt plus air. My voids in mineral aggregates are the small air pockets between the coated. Now, if I look for what this air is, then this air is the small air pockets that are trapped between my bitumen-coated aggregates. So, the proportion of voids in mineral aggregates filled with the bituminous materials is referred to as voids filled with bitumen or voids filled with asphalt. As I said, people, these are synonymous: asphalt binder, bitumen, bituminous binders. Now these all need to be worked out, and as I mentioned, when I look into this weight, I will have the weight of aggregates, the weight of water, which will make the total weight of the mix; the weight of air is taken as being 0.

Now, you have the compacted specimens, so the density of those compacted specimens can be measured, as while preparing, I knew how much of the mix I prepared using a 1276.6. So, when I prepared the mix, I used 1276.6 grams of mix, so I know the mix weight.

Now, here I need to determine the specific gravity of this particular item. There are ways of doing it; one conventional method for solid objects is to measure their height because their diameter is fixed. So, you can get this volume of this specimen, but this is not the correct manner because you will have many surface voids that are there, and they become a part of this particular mix if you are doing it from dimensions. Here I am just measuring the height; this gives you the height, and this gives you the diameter. Then, if I work out the volume as $\pi/4\ d^2\ h$, this will give me the volume of this one, but this volume will be more than what is there because of the surface voids that are already present. Also got to become a part of this specimen, which in actuality is not a part of this specimen.

So, if the volume is more, you will get a specific gravity that will be less because your weight remains the same; the mass of the aggregate and asphalt here for our specimen was 1276.6 grams. Now, the good way of doing it is the water displacement technique, where you measure the weight in the air, and you measure the weight in the water. The loss in weight is equal to the weight of the volume of water that gets displaced, which you might have experienced in your school days with any volume of a substance in water. When you dip any particular object in water, its weight gets reduced, especially because of the buoyant force.

So that particular application is here; here we will see what the loss in weight is, which should be equal to the volume of the weight of the volume of water displaced. So, then I get the volume of that water, which is equivalent to the volume of the specimen, and this will give me the correct result. So, here, this particular one, I will determine the saturated surface dry condition, which exactly gives only those surface voids that are part of the specimen, and then I will dip it in water; I will get the bulk specific gravity of the specimen. So, once this bulk specific gravity of the mix is

determined. So, these specimens will be prepared, and through this water displacement technique, you will get their volume.

So, I will get a Gmb, which will be my weight that was already given to me, and this volume of my mix is the bulk volume of my mix. In addition to this one, this is the compacted mixture. I need to know a mix without any air voids. So, for this particular one, I want to measure the specific gravity of a loose mix when there are no air voids in it.

So before compacting, I can do it. So, for this one, I will prepare some loose specimens. With the same binder content of 6 percent, the total mix weight was 76.6, and there are techniques that are used to determine the specific gravity. We refer to this as maximum specific gravity, not theoretical maximum specific gravity. Maximum specific gravity is determined especially for loose mixes, and here, for the loose mixes, there are different techniques that are used; the most common are the rise specific gravity method and the automatic vacuum sealing method.

Here, the loose mix in the basic concept is submerged in this rise-specific gravity meter; you submerge it in water and apply a vacuum to trap out or take out all the words that can be present inside this particular loose mix as well. And then you get the weight of this loose mix in air and the weight of this loose mix in water without any air bubbles. So that will give you the volume of this particular loose mix. Here, in a vacuum sealing method, the loose mix is taken out, and through the vacuum application, all the air voids are expelled. Then, this loose mix is submerged in water, and you get the weight of the loose mix in water, which gives you the volume of the loose mix.

So, you work out the specific gravity of this particular one, Gmm, in this manner. Now, once this Gmm is known to you from laboratory methods, there are two laboratory methods where you actually prepare a loose mix and determine the maximum specific gravity. So, then you can work out the specific gravity, which takes care only of the words that are not filled with the bitumen, as we discussed earlier. So, if Gmm is known to us from this particular measurement, then this Gse can be determined. Here, the expression for Gmm is given in terms of Gse, but otherwise, I am going to determine Gmm from these laboratory experiments once I am able to obtain it at one binder content; at other binder contents, I can do so without performing this exercise.

So, if I have it, I will show you if I have, say, Gse determined. This Gse will be in terms of the total amount of materials. This is also explained in the coming slide. I will give Pmm minus Gmm, Pb over Gb. So, once you understand what this expression is, here you have the maximum specific gravity, which you determine through laboratory methods; this is the specific gravity of the binder, this is the percentage of the binder, and this is the total percentage of the mix, which is 100. So, 100 minus your percentage of binder, in our case, was 6, and then this is again 100 divided by the denominator, 100 divided by Gmm.

Which you have determined by any of these laboratory methods minus Pb is your 6 and divided by the specific gravity of bitumen. So, with this particular one, your numerator is this, and your denominator is this; you work out your Gse. Now, this is an aggregate characteristic, so the amount of binder an aggregate can absorb should remain more or less constant and not vary significantly. However, with a slightly higher amount of binder available, this particular Gse value may increase

because more binder gets absorbed and goes up to a higher depth. For my ease, because otherwise, for all the different binder contents, I need to work out this Gmm.

So, it is time-consuming; what people normally do is determine the Gmm at one binder content and then determine Gse. Once the Gse is known to you from this expression, you can work it out in reverse, and you can figure out the Gmm at other binder contents. So, this was my 6; now for the contents of the other binder, I can also work out if the GSE is known to me. So, it is done in this particular manner. Now I have my maximum specific gravity, Gmm, of the mix; I have the bulk specific gravity of the mix.

So, how much air void content will be in this particular mix that I will work out? This will give me my air void volume with respect to the volume of the mix, and whatever these air voids are, I am trying to determine the volume of these air voids with respect to my total volume. So, this will be in percentage of it, which I will get; this is important. I need to see how many air voids I have in my mix. Second is VMA. So, for this VMA, voids in mineral aggregates, as I mentioned, the volume of aggregates will be there; when VMA is present, it is that particular portion which will have your free bitumen as well as your air voids.

So, I will need to work out that this VMA will be your 100 minus the bulk specific gravity of the mix, and this is the bulk specific gravity of your aggregates. Then, when we work out the voids filled with the bitumen, VFB will be your Vma minus your Va divided by Vma. This is how much shear of these voids in mineral aggregates is filled with binder. So, I am this VMA—sorry, this VMA, what my VMA was having; my VMA was having this free asphalt with me.

This is my free asphalt, and I was having my air vaults. Now, what I want to ensure is how much percentage of this free asphalt is in this total volume. So, this is what, for this particular one, VFB plus VA is your VMA, and what your VA will make is your volume of free bitumen. So, this is how your volume of free bitumen is determined in terms of percentages. Then, as I mentioned, in certain cases, we need to work out the amount of binder that is absorbed in the aggregates. For this particular one, you need to know the effective specific gravity and the bulk specific gravity already.

Now, since Gmm is determined, you know the bulk specific effective specific gravity. So, from this particular expression, you get the percentage of bitumen absorbed in your mix. Now, once here, Gse is the effective specific gravity, and Gsb is the bulk specific gravity. So, I just want to see on the surface how much binder has been used, and this is with respect to the weight of the total aggregates. Other parameters that I was working on were with respect to the weight of my mix. Here, this is expressed as a percentage by weight of aggregates rather than a percentage of the total weight of the mix.

And then finally, once this PBA is there with us. You can work out how much the effective binder is because the effective amount is free with respect to the total weight of my mix. So, for this particular one, Pb is the actual binder content that you have inserted; for example, we took 6 percent. Ps will be in that particular case, and the remaining will be your aggregate percentage, which is Ps, and then whatever PBA you are going to work out. It will be mentioned here that gives you the percentage of bitumen that is effective or that is free and available for coating the aggregates with respect to the weight of the mix. So, here you see that Pbe is the percentage of effective binder

in the mix, total weight of the binder less the binder absorbed, and this is with respect to the weight of the mix.

So, these are some important parameters. Once you prepare a compacted specimen, you determine the bulk specific gravity of the compacted specimen, and simultaneously, from the loose mix, you obtain the Gmm. So, for the aggregates, you have the GSB with you. Now, once the maximum specific gravity of the mix is there, you work out the effective specific gravity of the aggregates. Then, from those particular ones, we are working out the voids that are present in the manganese aggregates, voids filled with bitumen, the percentage of bitumen absorbed, and the effective bitumen content. So, the remaining part will continue in the next lecture. Thank you.