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Pavement Materials

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Lecture: 19

Aggregate Properties (Part-3)

Hello everyone, welcome back. In the last lecture, we were discussing about the aggregate properties and under the aggregate properties, we have covered our discussion on properties such as impact value of the aggregates or the toughness resistance of the aggregates we have discussed about abrasion resistance of the aggregates.

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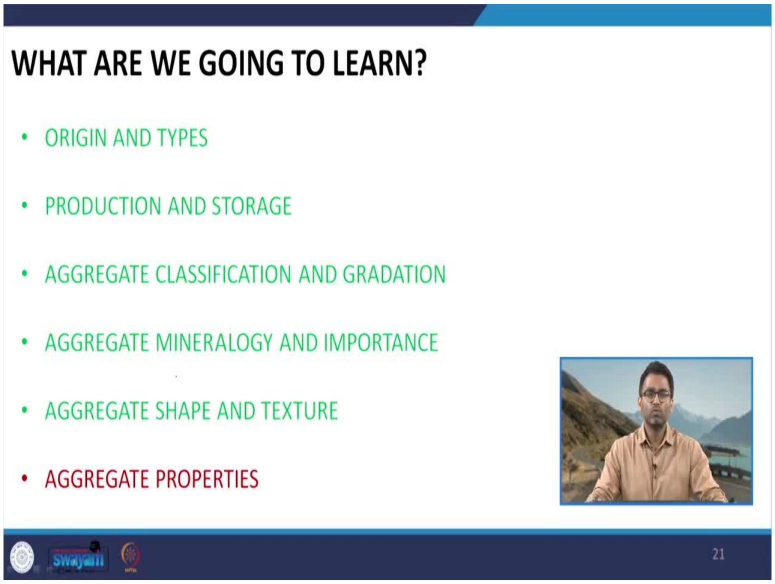

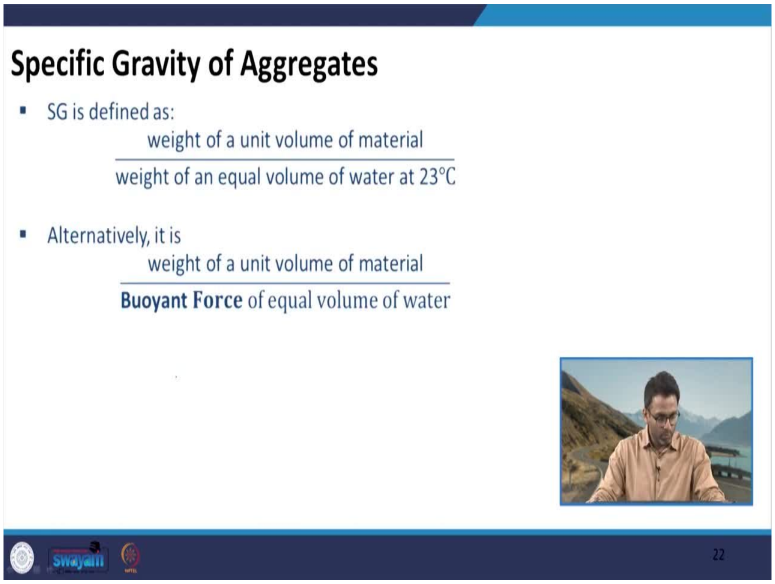

We have also discussed about the properties related to fine aggregates such as amount of clay and the quality of clay by understanding about the sand equivalent value test about we have also looked at the methylene blue value test and also at the Atterberg limits. So, let us continue discussing about the aggregate properties and today we will start with understanding about the specific gravity of the aggregates.

Now, this parameter especially is very critical, because, this is one physical property which is directly used as an input in the mix design of bituminous mixtures as well as mix design of concrete mixtures. Other properties which we have discussed, they are mostly used for the selection of coarse aggregates and fine aggregates.

But, these physical properties they are not used as an input during the mix design process, but specific gravity is one such physical property, which is also a fundamental property of the material and not an empirical test and is used directly in the mix design calculations for concrete mixtures as well as for asphalt mixtures.

And in fact, specific gravity is one such concept, which is generally not very well understood, because, there are different types of specific gravity which as a pavement engineer, we should know and this is where the confusion starts that how to differentiate between different specific gravities and how to understand the importance of each specific gravity when it is used in the mix design process. Let us first define what is a specific gravity? So, specific gravity it can be defined as the ratio of weight of unit volume of material to the weight of an equal volume of water at 23 degrees Celsius.

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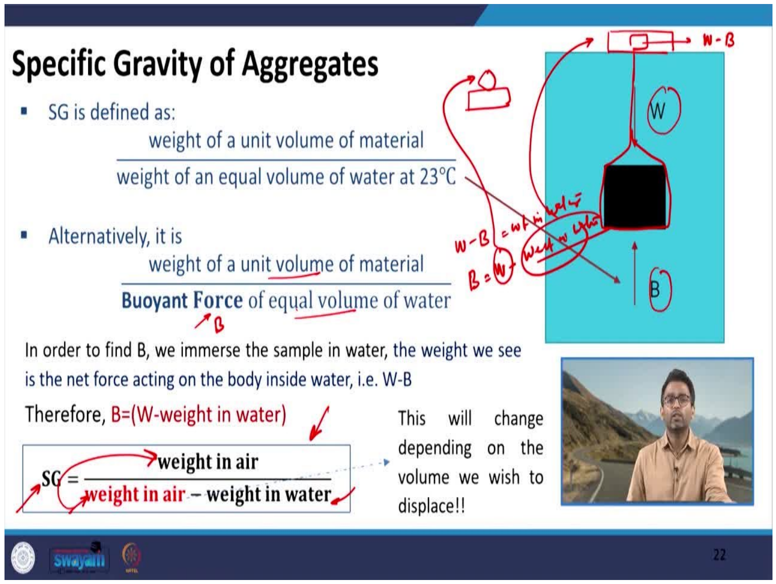

This is a picture showing that a body or a material is emerged in the water this is a static water. So, two forces will be acting on this body one will be the self-weight which is acting downwards here which you can see and the other is the buoyant force. So, what is actually buoyant force? Buoyant force is equal to the weight of the equal volume of this material, which is written in the denominator in our definition of specific gravity is not it and that means, we can also define specific gravity as the weight of the unit volume of material to the buoyant force of equal volume of water is not it.

So, this equal volume is equal to this unit volume. So, what will be the buoyant force of equal volume of water? So, this is how the definition goes and for any given aggregates, I am interested to find out this ratio, when the weight of the material is simple, I can take a weighing pan, I can just put the material on the weighing pan and the weighing pan will display me the weight.

But when you talk about the denominator, which is the buoyant force, it is not very straightforward, what we typically do in the laboratory, we will take the material and we will immerse the material in the water, when I immerse the material in the water and try to take the weight, try to take the weight, this weighing pan will display me a number what is this number? This number is equal to the net force which is acting on the body inside the water.

So, this whatever is being displayed is actually equal to W-B this is the number which we see on the weighing pan is not it. So, this is W-B. Therefore, B because I am interested in the denominator, this denominator is actually B. So, in order to find B I have W-B which is equal to weight in water which is being displayed.

So, B is actually equal to (W-weight in water) is not it. This weight in water I have from this display. This W I have because I have also measured the weight of the aggregate particle in the air. Therefore, specific gravity is $\frac{\text{weight in air}}{\text{buoyant force}} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$.

Now, this weight in air which I have marked in red, this will depend on the volume I am trying to displace. So, depending on the volume which I am trying to displace this weight in air we will change this will not necessarily be the same weight. And this is what we are going to talk in the next slide, but I hope that this fundamental definition of specific gravity is clear to you and it is clear that why we are interested in this calculation which we typically perform in the specific gravity test. So, we have to fundamentally understand that the denominator is nothing but the buoyant force.

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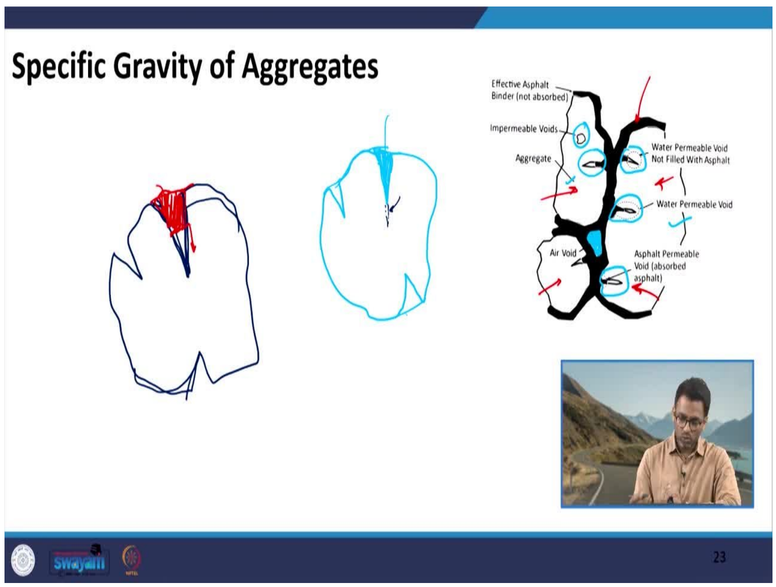

I am taking this example of a bituminous mixture because actually in bituminous mixture, there are different specific gravities which we are interested in this is taken from the Asphalt institute handbook MS2, you can see that there are four aggregates that are shown here from the metrics of the bituminous mixture, then I will try to explain more about this picture.

So, this dark black part which you see that is the film of the bitumen around the aggregate particles because it is a mixture we have aggregates coated with bitumen and they are in a dense mass. When these aggregate particles coated with bitumen are in a dense mass, these different aggregate particles or coated aggregate particles will also have some inter particle voids between them.

So, that is shown here, I will just take a different color here. So, this is shown here this is the inter particle void, this is not void within the aggregate surface this is between the aggregate particles then individual aggregate particles have their surface voids which is shown here you see this is the surface void of this aggregate particle this is one another void for this aggregate particle, this is the surface void for this aggregate particle, this is another void in this aggregate particle another void here. So, individual aggregate particles have also surface voids.

So, if I draw an aggregate particle here let us say something like this, so, you can say aggregate particles have these voids. So, aggregate particles have water permeable voids and water impermeable voids. What do you mean by water permeable voids? When I immerse this aggregate sample in water, water can seep inside and acquire the entire void this is mean by water permeable void.

But there can also be certain other void at further depths. At larger depths there can be more voids where water cannot penetrate. So, this is called as water impermeable voids, I will try to explain it again in another way because I am talking about surface voids here let me draw another aggregate particle similar aggregate particle let us say this is the aggregate particle.

Now, I say that this is water permeable void here. But not necessarily this void is permeable to other types of oils or other types of liquid material if because my discussion is about bituminous mixture, let us say bitumen. So, bitumen is also in a fluid state when it is mixed with the aggregates.

So, because it is in a fluid state, the bitumen will also have a tendency to occupy the surface voids of the aggregate particles, but not necessarily the entire water permeable voids will be accessible to bitumen because the viscosity of bitumen is higher than water. So, there will be more resistance to flow under the voids is not it. So, it may happen that bitumen will be able to move inside these voids it is moving inside but it stops here it is not able to go further. So, which means that only this much void (())(9:32) percentage of voids of the water permeable voids can be occupied with bitumen. So, I hope again this is clear to you.

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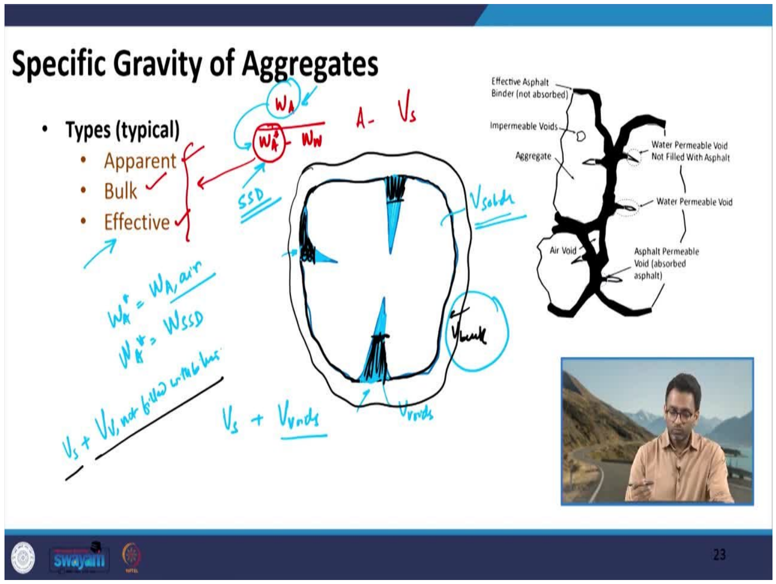

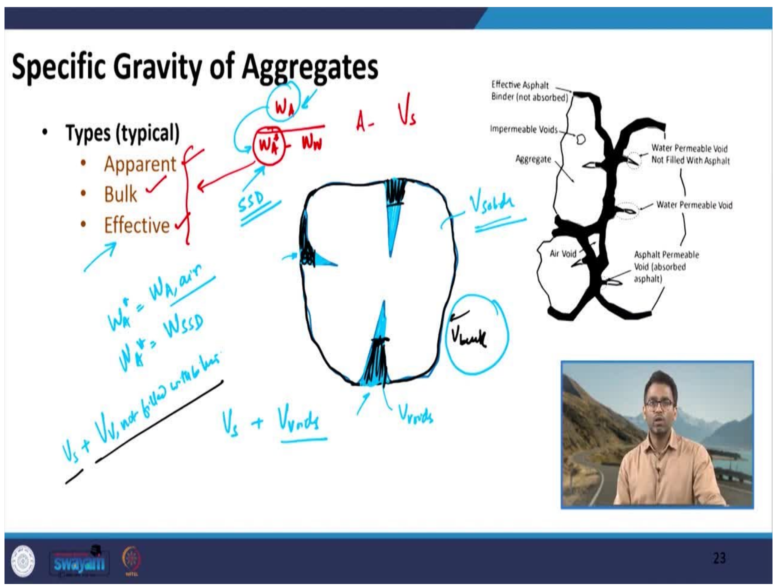

I will discuss further about this after talking about the types of specific gravity. So, the typical types of specific gravity in which we are interested in are the apparent specific gravity, bulk specific gravity and effective specific gravity. Now, the question is how the specific gravities are different from each other. So, if you remember in the previous slide we have discussed that the specific gravity of the aggregate can be calculated as $\frac{W_A}{W_{A*}-W_W}$ this star this depends on the volume I am interested in.

So, this is where these three different types of specific gravity differ from each other. In the apparent specific gravity I am only interested in the volume of solids which means, let us say that this is the aggregate particle, this outer mark which I have drawn this is the bulk volume of the aggregate the total volume including the water permeable and water impermeable voids.

So, this is the bulk volume then we have another volume here which is the volume of water permeable voids. Let us say V voids and then whatever remains in white color which you are seeing that is the volume of solids. In Apparent specific gravity in the denominator the volume corresponding to which I am interested to find the specific gravity is the volume of solids which means that W_A* will be actually equal to W_A because in the air I am not considering the surface voids it does not have any weight.

So, therefore, whatever is done is in the numerator will be used here to find out the apparent specific gravity. In case of bulk specific gravity, I am interested in the bulk volume which means I am interested in the volume of solid + the volume of water permeable voids. Numerator is weighed in air that is different thing, but in the denominator this W_A* should be corresponding to the bulk volume of the aggregate.

So, how do I do that, because now I am interested to also add this particular volume. So, that is why we take saturated surface dry volume what we will do? We will take this aggregate dip it in the water. So, after you dip it in the water what will happen? This water will go inside and occupy the pour the water will also form a film around this aggregate what I will do using a dry cloth I will remove this film, I will remove this film, I will remove this film.

So, finally I will have only the aggregate surface with pores occupied with water and that is what I am trying to replace here. So, that is why $W_A^* = W_{SSD}$ Saturated Surface Dry. And in the effective specific gravity, the volume which I am interested in is the volume of solid +volume of voids not filled with bitumen.

Now, this is critical you see, let us say only this much bitumen was able to go only up to this height here it was able to go up to this height. And here it was able to go up to the height. So, I am interested in the white volume + the blue volume - the black volume, so I am interested in volume of solid + volume of voids which is not filled with bitumen.

Now this becomes very critical. I will talk about it later because you could say that okay that we can do just take a piece of aggregate dip it in hot bitumen take it out again saturated surface dry, but when you dip it in bitumen in addition to the amount of material will which will go inside the voids you will also have a film of bitumen here and this film of bitumen cannot be just removed using a dry cloth. That is why it is not very easy to experimentally assess the effective specific gravity of the aggregates.

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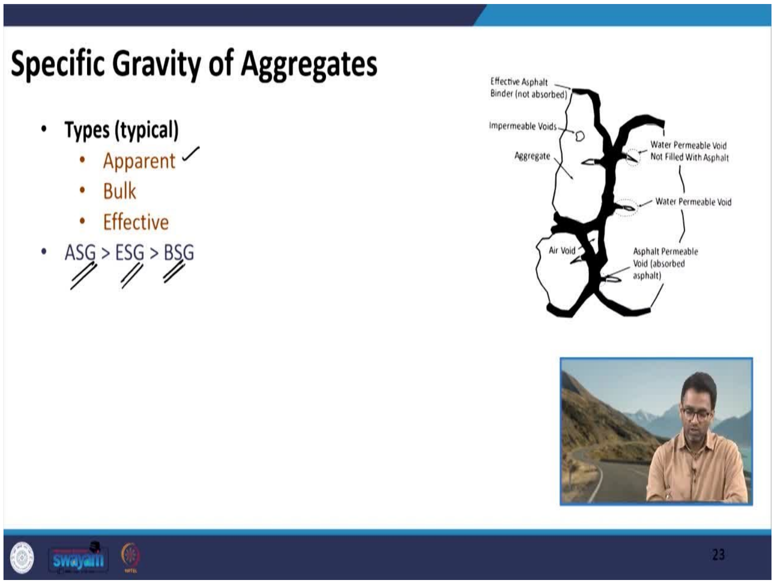

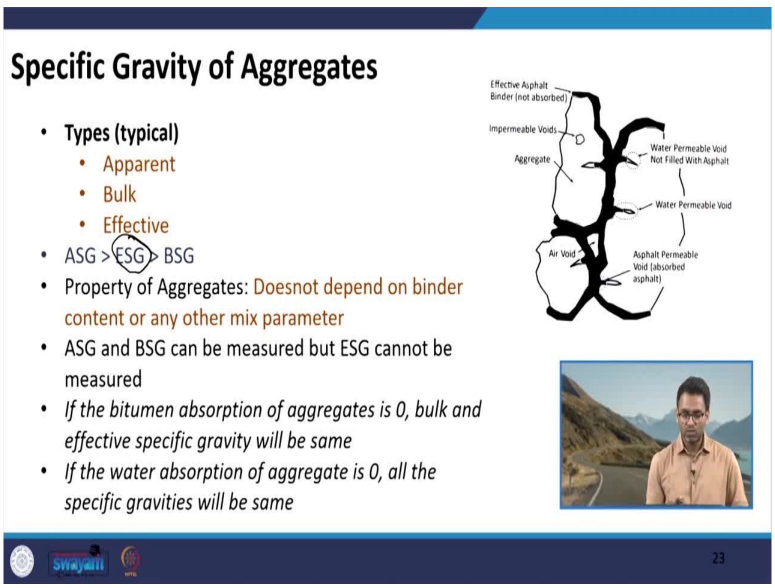

We will talk in detail when we discuss about the mix design, but I hope the concept of apparent, bulk and effective specific gravity is clear to you since the volume of apparent specific gravity is the least here that is why apparent specific gravity is highest followed by effective specific gravity followed by bulk specific gravity.

You have to remember that specific gravity is our properties of aggregate. So, it does not actually depend on the binder content or any other type of mixed parameter, this is again always a confusion especially when we talk about the effective specific gravity, but you have to remember that specific gravity is actually a property of the aggregate.

As I mentioned apparent specific gravity and bulk specific gravity can be measured in the laboratory, but effective specific gravity cannot be measured because in the laboratory we cannot assess the bitumen absorption experimentally. Hypothetical case can be bitumen absorption of aggregate is 0 let us say that the aggregate does not absorb any bitumen then of course, the bulk and effective specific gravity will be equal. Another hypothetical case can be if the water absorption is zero let us say we have an aggregate does not absorb any percentage of water then of course, all the volumes of interest become equal and all these specific gravities will be same. So, these are two extreme conditions.

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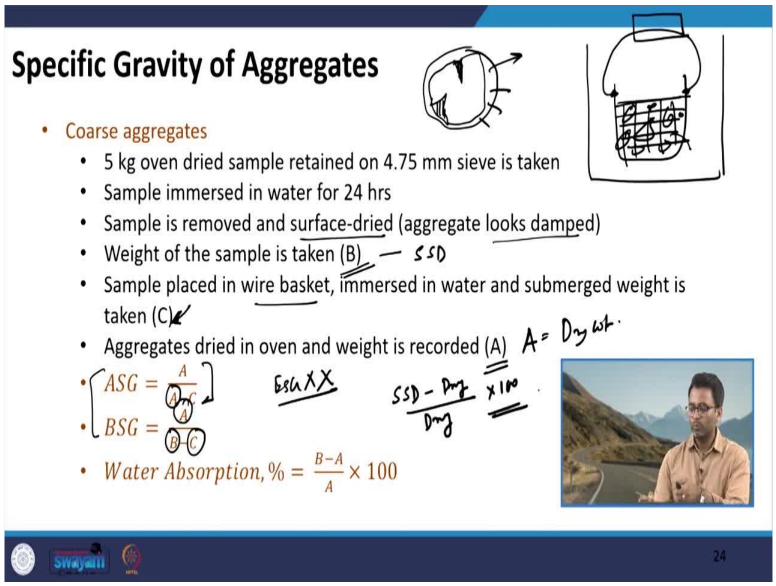

Now, let us talk about the experimental procedure of determining the specific gravity of aggregates in the laboratory, we have different method for coarse aggregate we have different method for fine aggregates. So, let us discuss both what we do for coarse aggregate we will take 5 kg of oven dried sample that is retained on 4.75 mm sieve. It can be of different sizes also greater than 4.75 mm sieve.

So, the sample is immersed in water first for 24 hours. So, you take oven dried sample 5 kg immerse it in the water for 24 hours why we are immersing it. So, that the water gets sufficient time to get absorbed in the pores of the aggregates then what we do we remove the sample and surface dried. So, when we remove what will happen we will have water in the pores and we will have a film of water.

So, I want to remove this film of water. So, what I do? I will surface dried it using dried cloth after drying the aggregates will still look damp, but this will indicate a condition that the pores are filled with water but surface is not having any form of water film over it. Then we take the sample weight which is B so, this B is the saturated surface dry weight then what we will do we will place the saturated surface dry sample in the wire basket.

So, we will have a wire basket here we will put the aggregate samples here and this entire assembly we will put in water. We will immerse it in water and then we will measure the submerged weight of this particular aggregate and that is taken equal to C this is the immersed weight that is equal to C then what we will do we will take out this wire basket we will take out the aggregate material we will again dry it in oven until a constant weight is reached and we will record the weight as A dry weight.

So, apparent specific gravity is simple it is $\frac{A}{A-C}$ why we are taking A because we are interested in the volume of solids only. Bulk specific gravity $\frac{A}{B_{SSD}-C}$ why B because we are interested in the bulk volume of the aggregate. Here we are not talking about effective specific gravity because we cannot determine it in the laboratory. And then again, we are also interested to find out the water absorption.

So, water absorption will be how much surface dry condition where pore $\frac{\text{water is inside the pores}-\text{dry weight}}{\text{dry weight}} \times 100$. So, $\frac{B-A}{A} \times 100$. Well, the determination of specific gravity of coarse aggregate is relatively simple in the laboratory. But for fine aggregates it is not very straight forward and I will tell you the problem with the determination.

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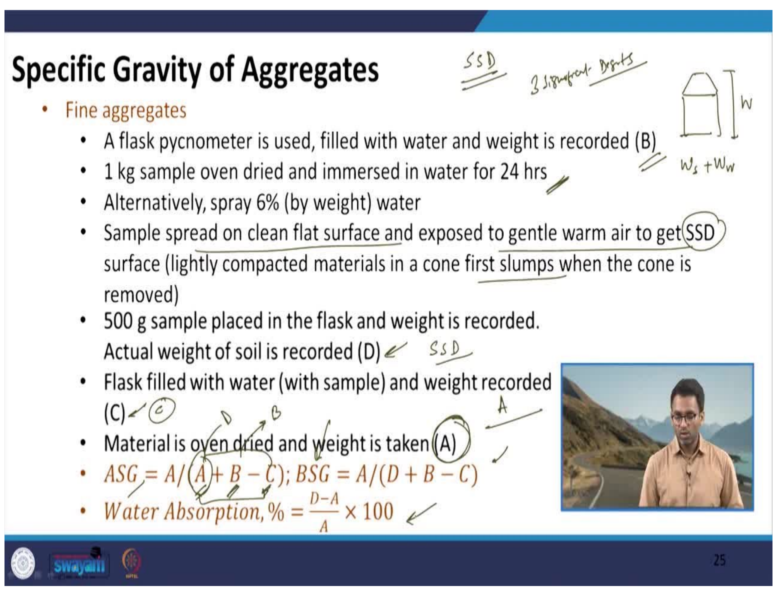

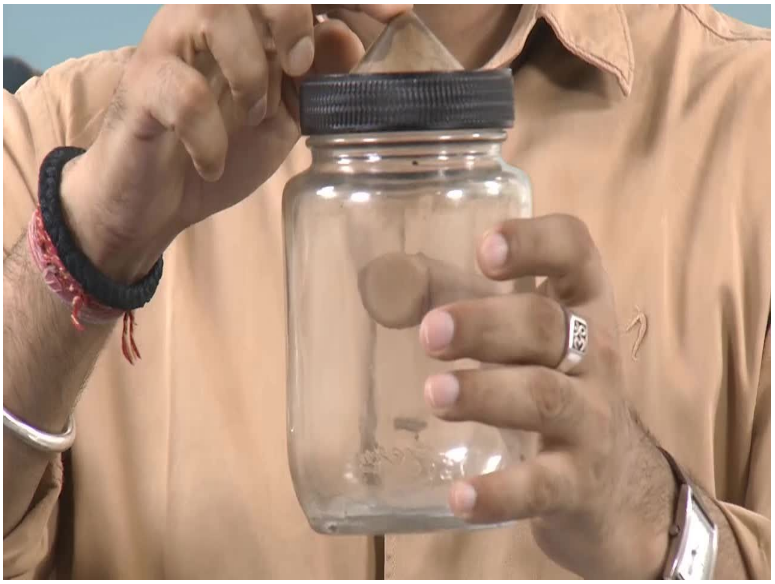

So, the problem actually lies in the determination of the saturated surface dry weight it has been observed that the repeatability of saturated surface drying is not very good. And in fact when we talk about specific gravity, we need accurate results at least up to three significant digits, it becomes critical for correct measurement of specific gravity in the laboratory.

And that is why it is recommended that the number of tests number of reputation should be at least 3 to 5. To see whether we get repeatable results, as I mentioned in the coarse aggregate, it is still relatively has higher repeatability because in coarse aggregate, the saturated surface dry weight is more uniform from one sample to the next sample, but in fine aggregates, it is not very simple, because, let us say if you take a cloth to saturate surface dry.

So, because these are very fine materials, there can be loss in materials in the surface of the cloth. So, you will end up having wrong results. So, there are process which can be used to appropriately assess the saturated surface dry weight for fine aggregate. Moreover, in fine aggregate in contrast wire basket we use a flask pycnometer. This is pycnometer which you see in my hand, this is a simple pycnometer which can be used for assessing the specific gravity of fine aggregates flask pycnometer is used first we will fill it with water.

So, what we will do we will fill this with water till this top position and we will take the weight of the pycnometer with completely filled bottle and we will record this weight as B then we will take 1 kg of oven dried sample which is passing 4.75 mm sieve because we are talking about fine aggregate and will immersed it in the water for 24 hours similarly to what we did in case of coarse aggregates. Alternatively, I missed two mentions that we can also if the water absorption is not very high for the coarse aggregate, then instead of immersing it in 24 hours, because here our idea is to obtain a saturated surface dry condition after full absorption.

So, they say alternatively, you can spray 6 percent of water by weight of the aggregate that will give you a similar type of condition, then what we do, we will take out the sample after 24 hours of immersion and then we will spread it on a clean flat surface. And then we will expose we will just spread the material on the surface and we will expose to gentle warm air. So, you can use a blower also with lower speed and we can just the spread fine material to this warm air. And our idea here is to get the SSD surface condition.

So, the question is how you will know that when the SSD condition has been achieved, so, what we can do after visual observation, we know that the material is in the saturated surface dry condition, we can take some material, we can put it in a cone with light compaction, the cone will have a slump when the cone is just removed.

So, this will indicate that the material is in the saturated surface dry condition. Out of this total material you can take 500 gram of sample and place it in the flask and the weight is recorded. So, the actual weight of soil is recorded let us say it is D, D saturated. So, this is the saturated surface dry weight.

Then what we do we will fill the flask with the material and water so we have these 500 grams of material inside and then we will fill it with water the remaining portion we will fill it with water and we will record the weight which is taken a C then we will take out the material dry it in the oven and the oven dry weight is recorded as A.

Using this weight, we can calculate the apparent specific gravity which is obvious you see apparent specific gravity is $\frac{A}{A+B-C}$ where A is weight in air B is the weight of the flask filled completely with water and C is the weight of the soil sample plus weight of water.

We have to do this calculation, because this calculation will finally give us the buoyant force which we are interested in. This is the apparent specific gravity the calculation of bulk specific gravity is the same only in place of A you will use D because we are looking at the saturated surface dry weight. And the calculation of water absorption is similar to what we did in case of coarse aggregates.

So, we will stop here and I hope that this discussion on a specific gravity of aggregate is clear to you. I will repeat again that this specific gravity is a very important test from the perspective of mix design and appropriate determination and accurate determination in fact a specific gravity at least up to three significant digit is very important for successful calculations in mix design.

So, we have to ensure that we are following the correct procedure in the laboratory for the determination of specific gravity specifically for fine aggregates. So, with this we will stop here and we will continue in the next presentation and we will discuss some further calculations related to the specific gravity of aggregate gradation. Thank you.