Building Materials and Composites
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Lecture - 17
Fine Aggregates

So today we are going to discuss in this lecture 2 of module 4, we are going to discuss on fine aggregates. So in our beginning lecture of this module, we had discussed how concrete is being made. So as it was told that concrete is a mixture or a man-made composite of fine aggregate, coarse aggregate, cement and water mostly.

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Now fine aggregate as we had told mostly refers to sand. So first we will go to the definition of fine aggregate and why sand? So sand as a fine aggregate and the grading of sand and bulking of sand. With these four actually we will try to cover what is the phenomenon or what is the purpose of this particular ingredient in concrete. So let us proceed.

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So any naturally occurring material, which has a dimension in the order of 4.75 millimeter and below (mostly below), that we will term them as fine aggregate. But, at the same time we have to remember that anything below that may even refer to clay or very fine particle of soil. So if we consider those as fine aggregate, we will end up in a lot of problem.

So fineness, this fine particle size should be restricted to the dimension given that is 0.0625 millimeter and beyond that it should be discarded out from the sand. Now sand is one fine aggregate. As you can see in the picture, you can even touch sand and you can feel that it is granular and the granules are fine. And that is why the term comes fine aggregate. But is it only sand? Yes, sand is the mostly used.

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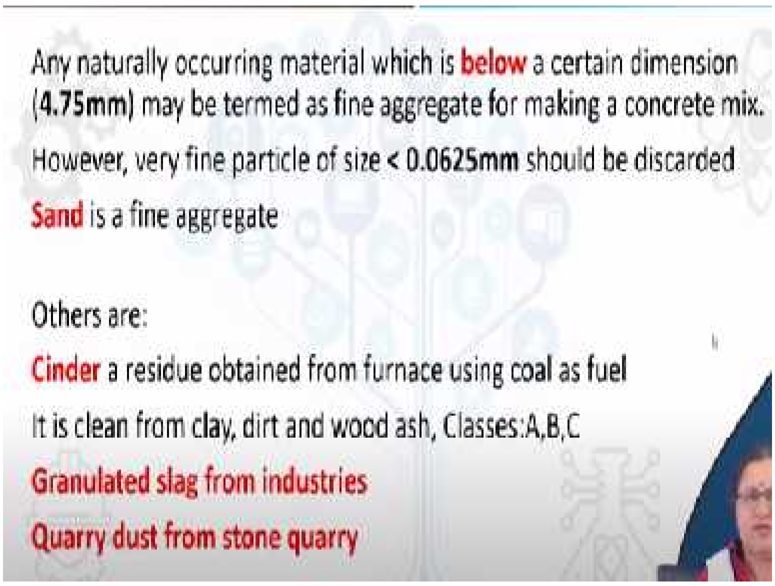

But if we see others are cinder, which is a residue obtained from the furnace or granulated slag which is coming from the industry or even quarry dust coming from the stone quarries. So sand is not always available at all points. So alternatives are there and it is mostly having a very small dimension granules.

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So usually it is sand, which is SiO_2 and refers to the naturally occurring finely divided rock. It is obtained mostly from the river beds and obviously it is free from salt. We all know on seashores you get lot of sand but that is containing high amount of salt. So that is not appropriate for use. So what does sand actually do in a concrete mix? It brings the economy in the mix by reducing the use of cement.

We had seen in the previous chapter that if we have a container of coarse aggregate that is bigger granules, if you pour water in it, it will be consumed. But if you have sand and the granules together the amount of liquid going into it or the solution going into it would be lesser. So obviously, it will bring in economy to the entire thing.

It will also prevent because coarse aggregate have bigger particles which are larger in size and the cement water slurry is very fine. This intermediate layer helps to prevent the shrinkage and prevents the development of the cracks in the structure. So in combination with cement, it adds strength against crushing and it also allows air to enter into the construction and helps in air hardening. So the air can penetrate inside and help in the process of the reactions.

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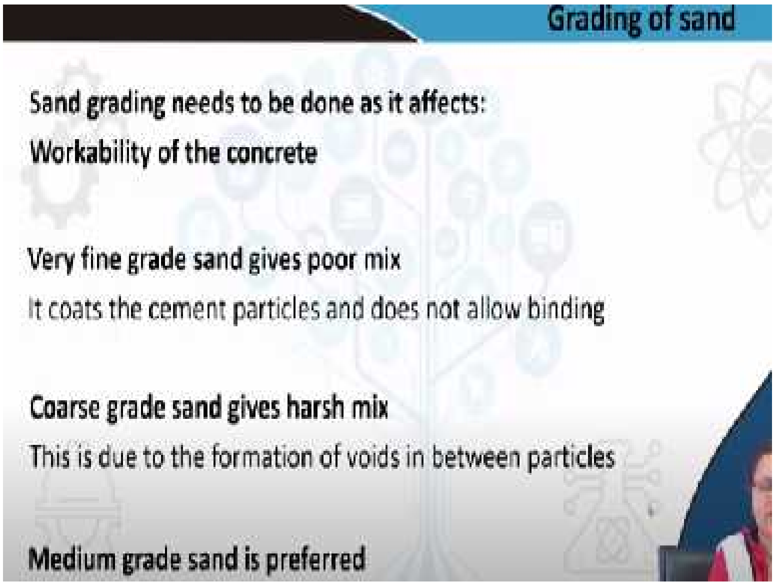

So if we move further, we will see that if you touch sand as I told you, you will understand the grain size. So sand is not always the same in feel. Some may be coarse, some maybe not so coarse. So you need to know how to grade sand and why grading is important. Grading of sand is important because it affects the workability of concrete. So in a concrete mix, when you are adding the sand the mixing process becomes easier.

So workability is how you need to work with it. And very fine grade sand makes a poor mix. What it does?

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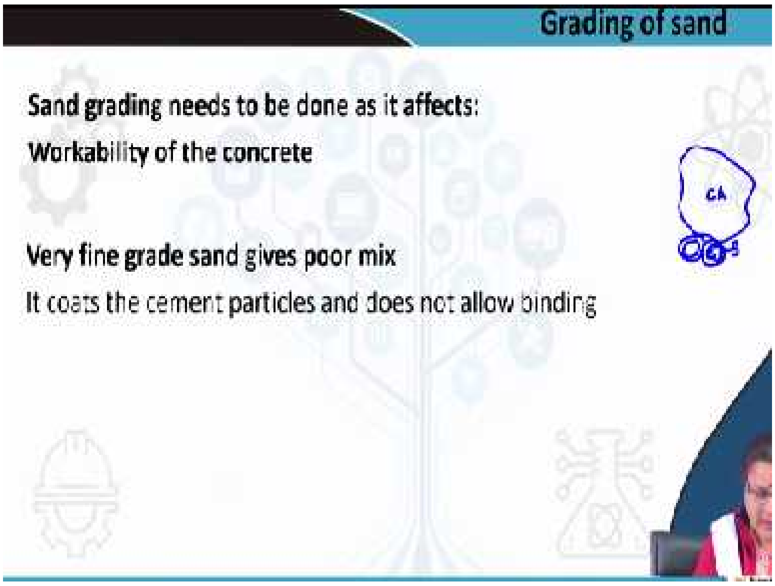

It actually coats with the cement particle and does not allow the cement to actually get associated to the larger aggregate. So if this is the coarse aggregate and this is the sediment particle, this sand that actually coats it becomes clay like. It actually coats the cement particles and stops adherence of the cement particle with the coarse aggregate. So the binding becomes difficult.

Similarly, we have coarse grade sand that is the other end. It gives a very harsh mix. It leaves voids. As I told you, in compaction process you try to get rid of the voids, but if there are coarse particles of sand used, then voids may remain in the mix. So best is the medium grade sand for construction purposes. Now is it possible from a very large heap of sand to find out which sand is of what type?

It is very difficult. Yes, maybe a very trained person can touch and feel and say okay, this is good. This is okay for the construction. Yes, but there should be some technical method to find that out.

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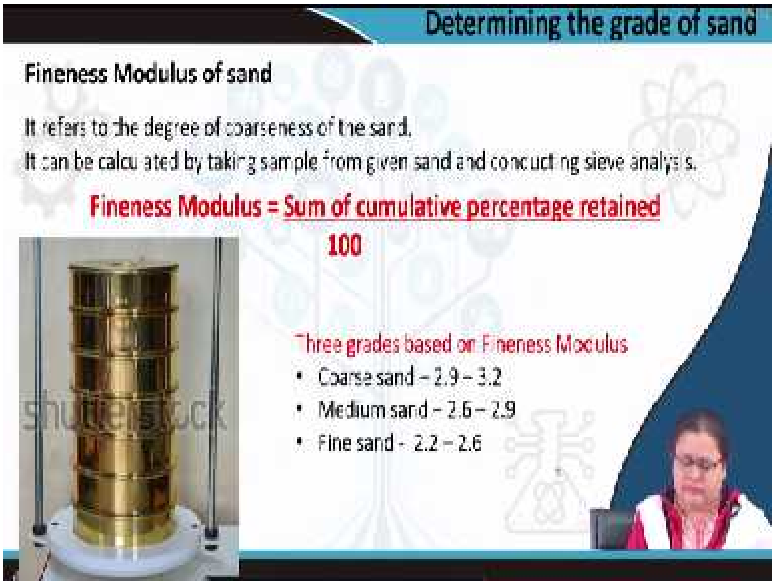

So we have a sieve test, which gives helps us to calculate the fineness modulus of sand. It is not possible the way which we had learned in case of brick to find out whether it is a first class brick or a second class brick. In case of fineness modulus of sand you cannot separate out individual granules and go for testing. You cannot go and measure each and every particle. We can take help of a sieve.

So sieves are of different dimensions. You must have seen a sieve. Whenever you are pouring tea, the tea leaves remain and the tea goes out of the sieve. Even you shift flour, you keep the husk, keep the larger parts up and the flour of desired size will go below. So you must have all seen these at domestic level. Here you see there is a stand which has a number of trays 1, 2, 3, 4, 5, 6 trays, where actually you can put the sample mix and you can move it or shake it.

Now how will it help you? You can pass the sand from the topmost till the bottom by shaking and what will happen? If the sieve sizes are different starting with 4.75 millimeter as we have told, it will gradually come down, the larger particles beyond that size will be remaining on the top and at the bottom it will be strained down. So each of the sieve will retain the dimension which is above that sieve size.

So this method is called sieve analysis. So it can be calculated by taking sample from given sand and conducting sieve analysis. As for brick it was thousand of bricks and you can take a sample of six to eight bricks and you could have done the testing. Here you need to take maybe one kilogram of sand or two kilograms of sand and pour it inside, pour it in this first top tray.

So the entire sand is received on this top tray and then it is shaken. So gradually it trickles down, further trickles down, further trickles down and whatever is retained you can actually collect the mass. Once you collect the mass, you can create a table and find out the fineness modulus, which is defined as

$$F \qquad M \qquad = \frac{\sum ci \qquad p \qquad r}{100}$$

If the value is within 2.9 to 3.2, we will call that as coarse sand. If that value is between 2.6 to 2.9 we will call that as medium sand and fine sand when it is going below 2.6 to 2.2. What do you understand by these figures? If you have more on the top tray that means if you have larger particles, top tray means they are having larger dimensions.

The cumulative will try to grow from this point and it will end up with a higher value of say up to 320 you can see which when divided by 100 will give you the value of 3.2. So the fineness modulus will be higher if more number of the aggregates will be retained by the top part of the sieves. We will see through an example. So more amount on the top tray, the cumulative is the summation every time that values are getting added.

So the overall value will become larger. Since it is a mix, it will also get values from the lower trays. So you are restricting the upper limit by 3.2. You are restricting the lower limit by 2.2 so that you do not end up with very small particles only at the lower shelf. So if it is only on the lower shelf, the cumulative starts only in these two shelves or these three shelves and it will give a very low value. So value below that also is not to be entertained.

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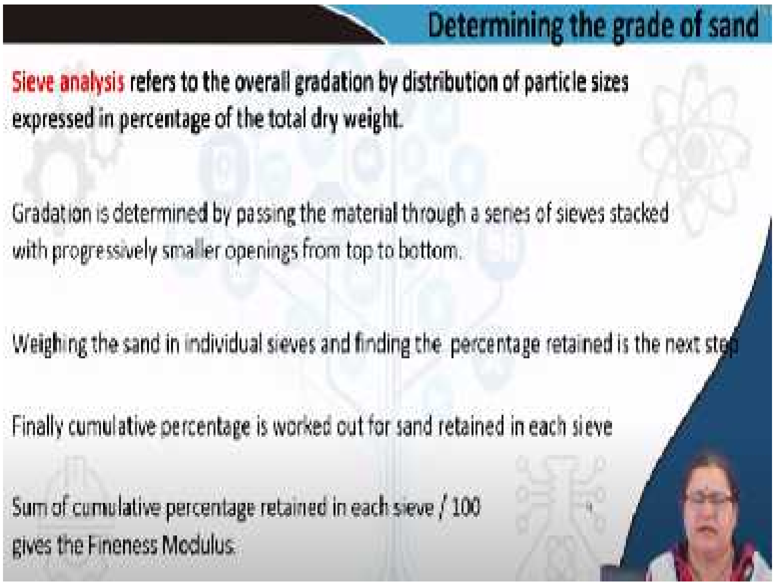

So let us move to this sieve analysis in details, which I tried to explain. So the overall gradation by distribution of particle size expressed in percentage of the total dry weight is the objective. The gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom. Hope you understood in the previous picture I actually discussed these points.

Weighing the sand in individual sieves and finding the percentage retained is the next step. Finally the cumulative percentage is worked out for the sand retained in each sieve. So sum of the cumulative percentage retained in each sieve divided by 100 gives the fineness modulus. So I think a demonstration through an example will make it clear.

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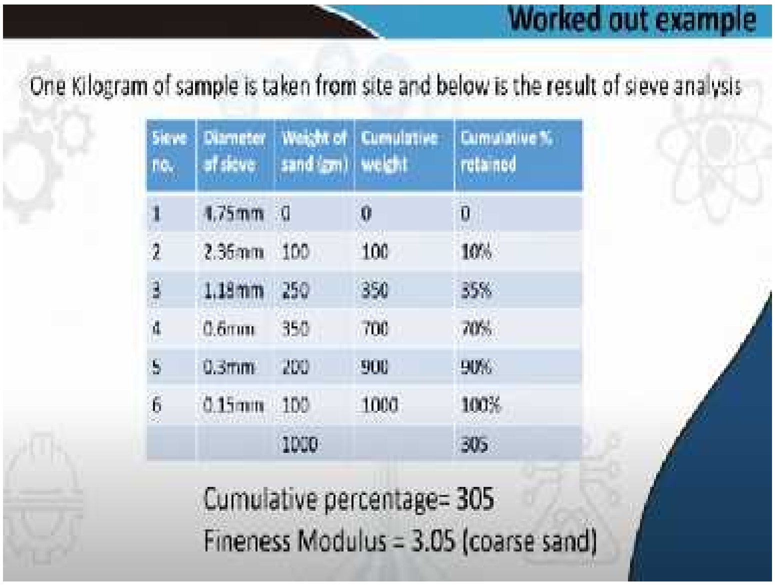

Worked out example

One Kilogram of sample is taken from site and below is the result of sieve analysis

Sieve no.	Diameter of sieve	Weight of sand (gm)	Cumulative weight	Cumulative % retained
1	4.75mm	0	0	0
2	2.36mm	100	100	10%
3	1.18mm	250	350	35%
4	0.6mm	350	700	70%
5	0.3mm	200	900	90%
6	0.15mm	100	1000	100%
		1000		305

Cumulative percentage= 305

Fineness Modulus = 3.05 (coarse sand)

Say you are given 1 kilogram of a sample that is 1000 grams and this side you see there are sieve numbers 1 to 6, which is starting from 4.75 to 0.15 millimeter and here is the sand, weight of the sand, which you have got after shaking the sieves. So you have allowed that 1 kg of sand to separate out in all these trays of different dimension. So you see in the all the sand has passed the 4.75 millimeter sieve.

100 grams are retained by the 2.36 millimeter sieve. 250 grams are retained by the next layer. 350 grams are retained by the layer next to it. 200 grams are retained by the 0.3 millimeter sieve. And 100 grams are retained by the in the last sieve. And that completes your 1000 grams. So all the sieves excepting the first one, the top one the entire sand is distributed as 100, 250, 350, 200, and 100.

So if you take the cumulative weights it will be 100 for the first tray, next tray will be 100 + 250 i.e. 350. Then 100 + 250 + 350 is 700. Then with 700 another 200 that is 900 and then another 100 that gives 1000. What is the percentage weight? 100 grams is 10% of 1 kg or 1000 grams. 350 grams is 35%. Similarly 700 is 70%. 900 cumulative weight is 90% and 1000 gives you 100%. So this is the cumulative percentage retained. If you add up all these values you get 305.

That is the cumulative percentage is 305. Hence, the fineness modulus is 3.05 which mean it is coarse sand. Sand comes in truckloads. You can take another sample from another side of the entire mass, but you cannot do it for the whole. So you are taking samples and doing such test and giving it a tag, this is medium grade, that is coarse grade and that is fine grade.

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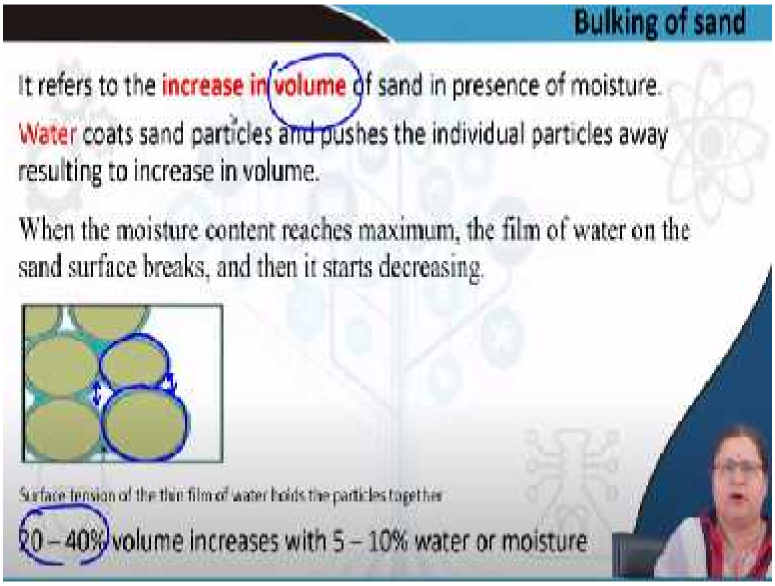

After knowing this, we move to the important phenomenon, which is called bulking of sand. If you remember, in the previous lecture, when we were discussing batching, where we learnt that one is volume batching and the other is weight batching. And in many domestic level works, we go by volume batching because that is easier, rather convenient.

You have a measuring unit and you are using two times, one time, three times whatever is the mix, you are going and using that as the unit. And yes, one bag of cement always comes dry and it is 50 kg. You call it by weight or you call it by volume that is perfect. But in case of sand, if you are doing a construction during the rainy season or in a very humid season part of the year you will understand you will see that your volume of sand will increase.

That is called bulking of sand. And that happens due to the presence of moisture and because of the very small fine sand particles. As you see here in the picture, water is actually coating the sand particles and it is not breaking. And they are actually pushing the particles; the water is pushing the particles, one from the other which is giving an effective increase in the volume.

So whatever you see as volume, it is because of the moisture or water encircling it. And that gives an increased volume and that is not a very small amount. You see 20 to 40% volume increases with 5 to 10% of water or moisture. So it is not to be neglected. So if the volume increases in this order 20 to 40% that means, you are doing something wrong when you are taking the sand by volume.

So in that case, maybe weight would have been a better measure and dry sand is the answer. But, you may not have always access to weight batching. So you have to check that whether the sand is dry or not. On the other hand, you are actually adding more of water to the system to the mix, which is also not desired. As I told you water you have to give it in a very measured quantity to achieve the maximum strength out of the same mix.

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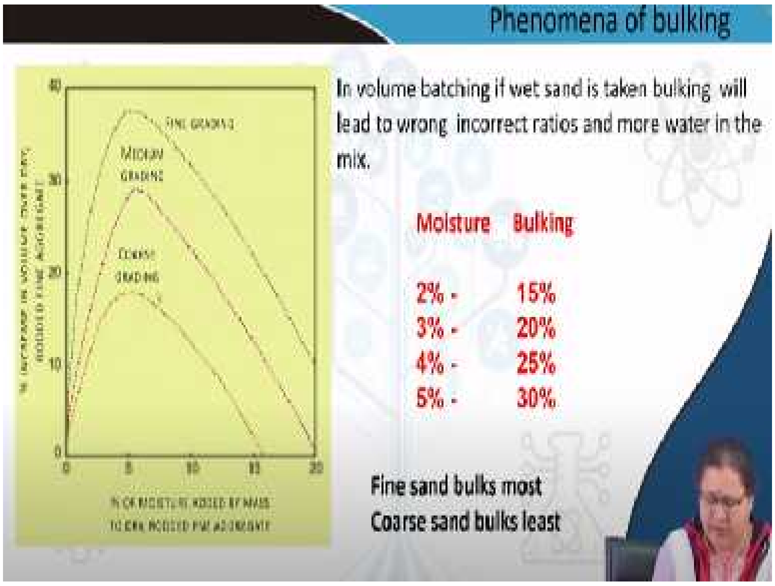

So if we see in this graph, wet sand, which is fine, will have more number of particles, more amount of expansion and it will push the particles more. So if you see this graph, the fine sand is actually growing the maximum and reaching almost 40% when the amount of moisture is almost 5 to 6%. Yes, medium may grow up to 30% and coarse will go up to 20% because the particle sizes are larger.

So fine sand bulks most, coarse sand bulks least. How can you measure this? What happens if more amount of water is added, more amount of moisture the sand is facing, this water coating breaks and the sand reaches saturation. Then the water gradually comes out.

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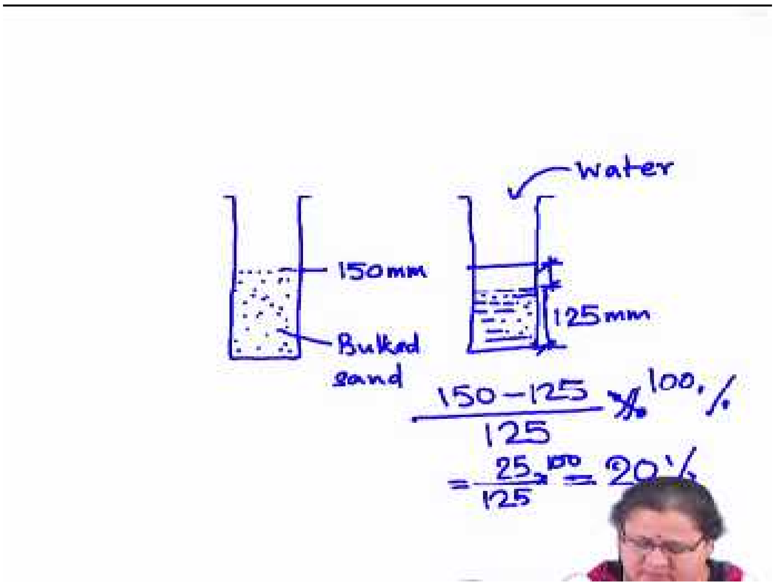

So if you have a beaker and if you put bulked sand up to a level say this is 150 millimeter measure and in the same sand you now add or pour water. You are pouring water from top. This was bulked sand. Now you are pouring water the sand gets saturated with the water and it separates out and this part is water say and only this part is the sand, say this is 125 millimeter.

So what is happening here? This was bulked sand which was having 150 millimeter. Now it has been saturated with adding some water. You have got the sand separated out. That is showing 125 millimeter. So

$$\frac{150-125}{125} \text{ x } 100$$

is equal to 20% increase. So here you are neglecting the area because they are the same. So you are getting some 20% increase and this is how you can measure. So if you would have used this sand, you would have used 20% less of sand in the mix.

This graph shows fine sand having the maximum bulking, coarse sand having the minimum bulking, but it is in both the cases or in all the three cases it is quite huge. So if we keep these points in mind you will understand that yes sand by the name it is sand but yes it has lots of tasks in a concrete mix.

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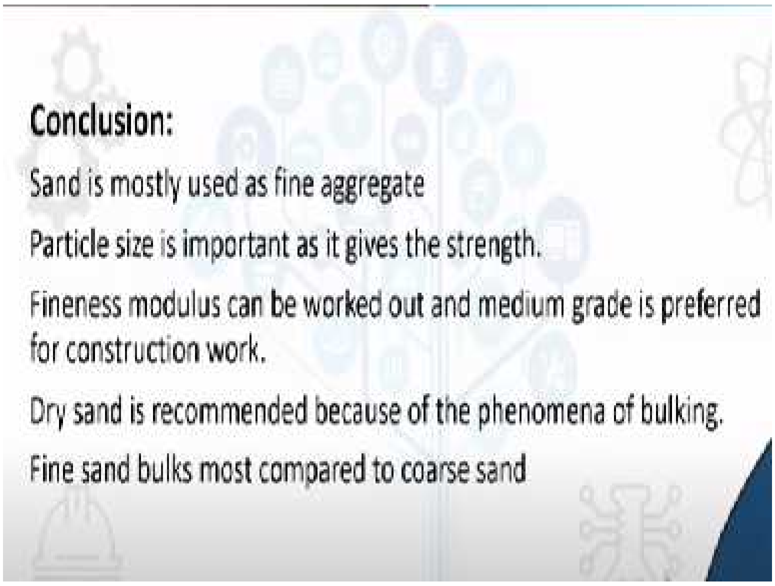

So we can conclude by saying that sand is the mostly used fine aggregate, though we also use other items as fine aggregates. Particle size is important as they give strength. Particle size is important as very fine sand also coats cement and does not allow cement in the binding process. Fineness modulus can be worked out and medium grade sand is preferred for construction work.

Yes coarse grain and fine grain sand have their particular uses. Dry sand is recommended because of the phenomena of bulking. It may not always be possible to get 100 percent dry sand. But if you keep the point of bulking in mind, then some additional portion of sand in a proportionate way maybe increased. Fine sand bulks more than that of coarse sand. However, bulking is a huge process.

It is in quite good percentage. So we just cannot ignore the process of bulking. Once said all these points, I think we are in a position to move to the next item that is coarse aggregate, which we will try to cover in the next lecture. And we will always have to keep in mind that we are targeting to achieve a good mix for the concrete, which we will use it every now and then in our building industry.

So this is a very challenging material and with these few words I end here. Thank you.