Hydration, Porosity and Strength of Cementitious Materials
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Lecture - 32
Demonstration

[FL] and welcome to this lecture 32 in this course on Hydration, Porosity and Strength of Cementitious Materials and this lecture is basically a demonstration. We will show you the constituents of basic concrete and show you how we mix concrete, not really mixing but how we make concrete based on our understanding of paste mortar and so on.

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We will simply give a viewpoint on a concrete made with cement, water fine and coarse aggregate, through a more or less live demonstration of bringing the constituents together.

You will recall that in the outset of this course we had said that one way of looking at concrete is that concrete basically is a mixture of water, cement, fine aggregate and coarse aggregate. Terminology wise cement paste is a combination of water and cement, mortar is the combination of paste and sand, and concrete is equal to mortar plus coarse aggregate. The distinction between coarse and fine aggregate is arbitrary and we use a sieve size of 4.75 mm and so on to differentiate between these two, the coarse and fine aggregates are essentially inert materials. Another view point or another way to understand this is that paste is a suspension of cement particles in water; mortar is a suspension of sand and sand particles basically in paste and coarse aggregate and concrete is a suspension of coarse aggregates in mortar.

Now, therefore, in order to understand the properties of concrete, so far the discursion has been largely on the science of hydration of cement and cement paste, but in order for that to be useful to us we want to extend this discussion to concrete. In order to be able to design a concrete of a certain quality, a certain set of properties the only things we can manipulate or change or vary is the relative quantities of water, cement, sand and coarse aggregate.

We of course, now also have chemical admixtures which help us do the trick a little more easily. We have mineral admixtures which can be used in addition to cement or in place of cement to achieve certain properties. But through the demonstration today we will basically show you how the properties of concrete evolve as we move from water to paste to mortar and then finally, concrete and then discuss those properties a little bit and move on to our discursion with concrete in the subsequent lectures. So, now, take a look at the basic constituents.

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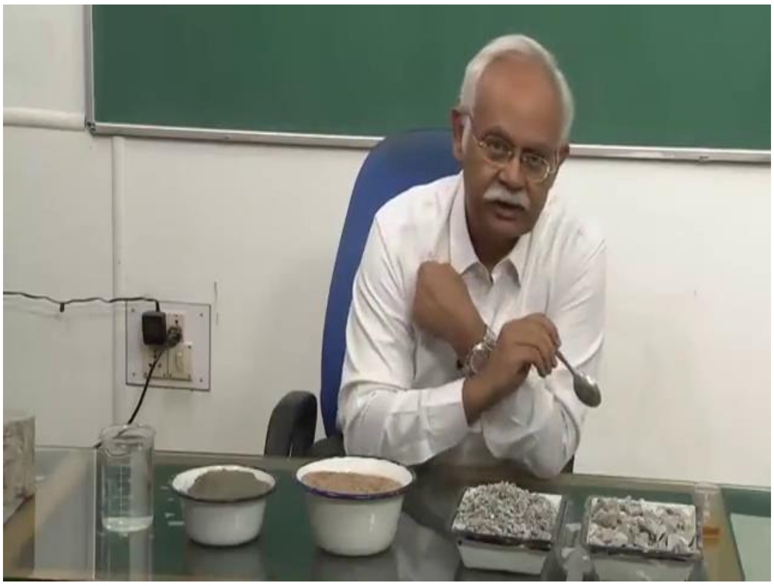

Now, this if from a core taken from a concrete structure we can see that here we have coarse aggregates and mortar. Of course we cannot see sand particles and therefore, we can see as if it is only course aggregate suspended in mortar, but the same discussion can we extended to all kinds of aggregates which are suspended in paste and so on.

So, now, how is this made? This is made using the basic ingredients water, cement which is very fine powder like this, we have sand of fine aggregate which is coarser than cement and then we have what we call coarse aggregates which could be smaller coarse aggregates or larger coarse aggregates. In this case what I am showing you is coarse aggregates drawn from crushed stone. We sometimes also use coarse aggregate which is drawn from rivers and those will be not necessarily so sharp in the edges they will be the rounded coarse aggregate.

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Here is an example of a chemical admixture. So, you can imagine that this is just like a chemical which is added to the concrete to modify its properties. So, now, let us start the process of mixing these ingredients to get paste first, then water and then concrete.

For the mixing of the materials, we will mix a concrete with the following proportions.

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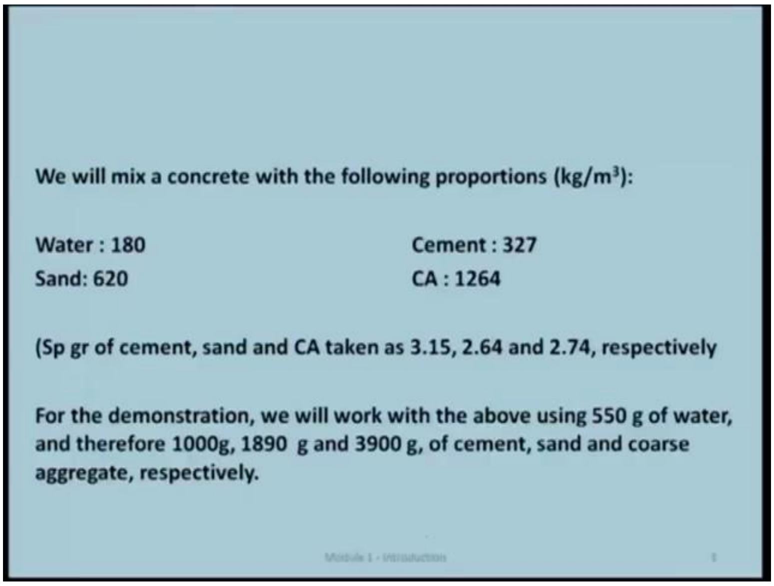

In kgs per cubic meter or the unit contents water is a 180 kgs per cubic meter, cement with 327 kg the cubic meter, sand is about 620 kgs a cubic meter and coarse aggregate is 1264 kgs per cubic meter. Now this is the kgs per cubic meter composition and for this demonstration we will work with the above using 550 grams of water and therefore, a 1000 grams of cement, 1890 grams of sand and 3900 grams of coarse aggregate.

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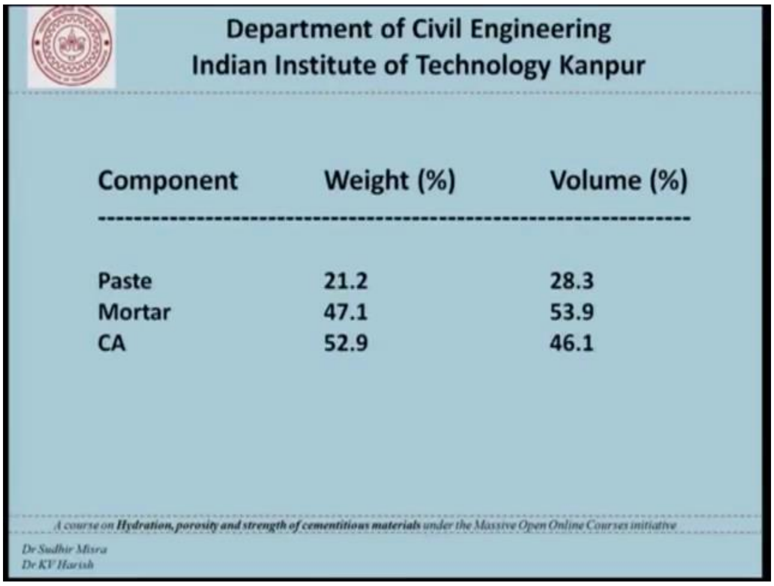

Now taking a special gravity of these constituents to be 3.15, 2.64 and 2.74, what it turns out is that if we calculate the paste that is the water and cement alone that will be 21.2

percent by weight and above 28 percent by volume. Mortar similarly which is paste plus the sand will be 47.1 percent by weight and 53.9 percent by volume. Coarse aggregate will be above 52.9 percent by weight and 46 percent by volume.

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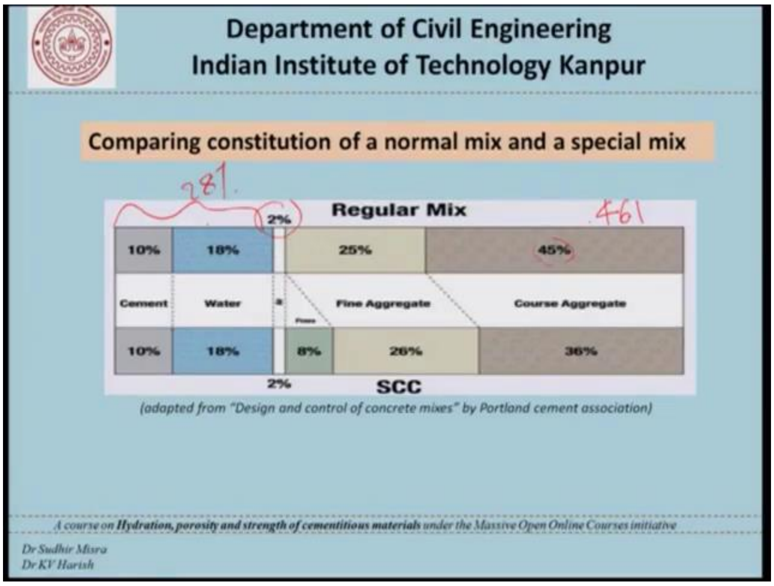

Now comparing these volumes with the volumes of water, cement, sand and coarse aggregate in regular mixes we find that the volumes are very close to those which are normally used. Normally is what 45 percent and we are using what 46 percent, the paste content is about 28 percent by volume and that is what we have while proportioning I have taken 2 percent air, so it is about 20 liters in a cubic meter is air content. What this shows is that the mix we will get today is really representative of a lot of concrete that we see in real life.

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So, in this beaker here I have the paste that is I have mixed the 1000 grams of cement with 550 grams of water. So, this paste has a water cement ratio of 55 percent. So, you can see that it is a fairly flowing mixture except that it is not as flowing as water. So, this is the kind of modification in the flowability that occurs as we add particulate mortar to the fluid. So, if were to model paste as a two face material with water and cement the cement particles are modifying the workability or the fluidity of the water to get the fluidity of the paste and this fluidity; obviously, depends on how much is the water to cement ratio whether we have used any admixtures or not and so on.

So, the same paste has been put in this measuring cylinder and we will see something very interesting happen over a period of time. What we will see is the settlement of cement particles because obviously, cement particles are having a specific gravity of 3.14. So, it is only natural that these cement particles will gradually settle down and we will have a clear layer of water at the top and that is exactly what is segregation. The same kind of segregation does not; obviously, happen in concretes, but that is the principle that operates, at the end of it water is the only fluid medium and all the other constituents are heavier than water and therefore, they settle. One thing we must remember that in a discussion from this stand point we must remember that the movement water is added to the cement hydration has started and therefore, the modification in the properties of the paste has already started because of the formation of hydration products.

Now let us see how the properties of this paste which has 1000 grams of cement and 550 grams of water get modified when sand is added to it and we get the mortar face. Now we could not show you the mixing process itself, but now this is the mortar which has been obtained by adding 1890 grams of sand to the paste that we just saw. So, you will be able to recall I hope that the work ability of that paste has been substantially reduced by the addition of sand.

Intuitively it will be clear to you that the extent of this reduction in fluidity or any change in the properties of that paste would be related to the properties of the sand in terms of its fineness water absorption and so on and also the amount of sand that is added. So, in this case we have added 1890 grams of sand. So, if we add more sand or less sand the extent of modification that occurs to the properties of paste would be different. Now let us see what happens when we add the coarse aggregate to this mortar.

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So, now this is the concrete which is obtained by adding 3.9 kgs of coarse aggregate into this mortar. So, now, you see that there is virtually no flow in characteristics and when we try to evaluate the workability of concrete this is the material that we are dealing with. In this hardened concrete I would only like to draw your attention to these small pockets of air.

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These are the entrapped air pockets which can be seen here, two of them can be seen here another one can be seen here and you can make them out with naked eyes.

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Now, let me show you what happens to the mortar we are not showing it with concrete but let me use mortar. What happens to the mortar when we add a plasticizer? This is the mortar that we had in the beginning 55 percent water cement ratio in about 1890 grams of sand added to this, here is the same mortar with 1 percent of a super plasticizer added to it. So, you can see that the mortar is a lot more fluid it flows much more easily compared to this one here.

Another thing that is very interesting to observe is that this mortar is highly prone to segregation that is the sand very quickly settles in the paste and the paste remains on the top and the sand settles down. So, we have to be careful when we add plasticizers and chemical admixtures that there is no undesirable side effect this is exactly segregation; chemical admixtures making the mortar most susceptible to segregation. Except of course, we must remember that it is mortar when it comes to concrete the kind if segregation or the extent of segregation is much smaller.

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Now, I would also like to show you what has happened to the cement paste having a water cement ratio of 55 percent and which was left to stand in this measuring cylinder. So, you can see in the last about 15-20 minutes that this paste has been allowed to stand there is a clear layer of water which has emerged at the top. Now this is exactly the bleeding that is appearance of water on the top. We would get exactly the same kind of bleeding in mortar also and also on concrete and that is the test for bleeding in concrete, we have to make sure that bleeding does not happen.

Now in the case of cement paste that we are seeing in this measuring cylinder what causes the cement particles to settle so quickly - the phenomenon that, that is the phenomenon of flocculation of cement particles, the cement particles when they are mixed in water they tend to form flocks and those flocks are much heavier and they tend to settled down much faster than individual cement particles would if they were to be left in water by themselves. So, this flocculation and the fact that the cement particles are heavier than water is what leads to this kind of appearance of water at the top or the settlement of heavier particles towards the bottom. Its bleeding and segregation which could we promoted by the use of chemical admixtures if we are not careful.

So, in this demonstration we went from found water to paste to mortar and to concrete. We also saw the effect of using super plasticizers at the mortar level and now if we think what can we do to improve the workability of concrete to make it flow more easily than what was apparent in this experiment today one obvious answer would be increase the amount of water. So, water is the only fluid component and if we increase the amount of water the concrete will become more flowing however in order to maintain the water cement ratio in that case we will have to use more cement and that would make the concrete uneconomical.

Another case if instead of the crushed stones we used rounded gravel what would happened to the workability of the concrete? So, what you think that it will become more, the concrete would be more workable if we used rounded gravel than the sharp edged crushed stone that we used and that is indeed true. In other words the water demand for a given level of work ability would be lower if we were to use rounded gravel compare to crushed stone.

Now another case in point could be we reduce the amount of coarse aggregate, so instead of using 3.9 kgs to as we used today we use less than that then the workability would be more and that is exactly what happens for certain concretes when we want greater fluidity we reduce the coarse aggregate content, in other words we increase the mortar content. If we increase the mortar content or if we want increase the mortar content we have the option of increasing the sand or increasing the powder, that is either the cement or use a mineral admixture which will increase the paste content and therefore, the mortar content reduce the coarse aggregate content and we get a higher fluidity. By using chemical admixtures also we change the cohesiveness of the paste or the mortar and that is also very important to understand when we try to understand or study the geology of fresh concrete.

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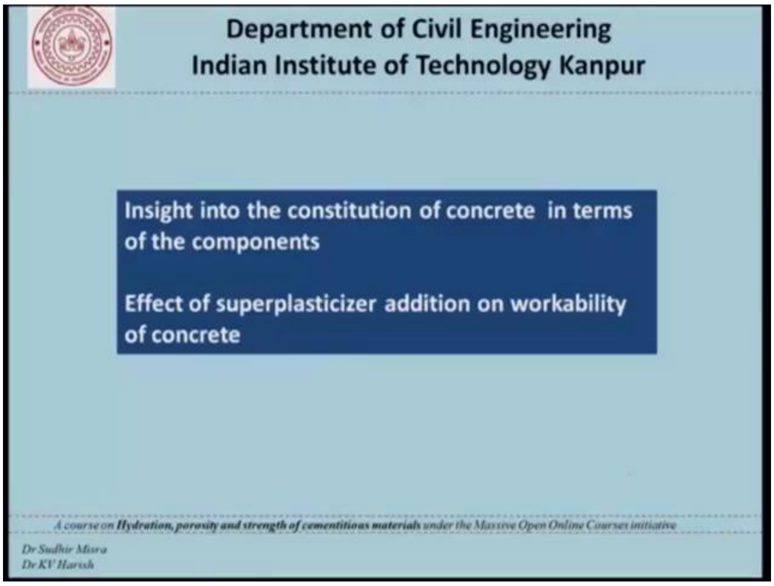

So, with these kind of comments what we have done today is to get an insight into the constitution of concrete in terms of the components used only one mix, but that was an illustrative example of how we move from water to paste to mortar and then to concrete. And we also saw the effect of super plasticizers on the workability of not the concrete, but the mortar, and we also saw the vulnerability of a concrete or a mortar to segregation. We showed it through a demonstration of paste how the water layer a clear layer of water emerges at the top. I hope this demonstration goes at least some distance in improving your understanding of concrete as a construction material.

Thank you.