Building Materials and Composites
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Lecture - 20
Water, Plasticizer Admixture and Tests

So we are in the last lecture of this module, module 4 and this was on concrete. We had extensively discussed the making of concrete and from there we have got into the individual constituents of concrete. So we had seen fine aggregate, mostly sand and then we also exposed you to the other items.

The other was coarse aggregate, which was mostly stone and also the other items as alternatives and finally, it was cement where we ended our previous lecture. And when we discussed cement, we had discussed the water cement ratio at some point. It was mostly used for the hydration process. The water is used for the hydration process. So we have not touched upon water. We have not touched upon plasticizers and admixtures, which may be used as and when required.

And also we need to know as architects about some very simple or basic tests that can be carried out on site to get some idea about the water cement ratio as we had talked or to check the strength every architect has to carry out cube test or the compressive strength test of the concrete which they will be casting or they are using (with or without reinforcement).

Mostly we have a dense reinforcement through which this concrete mix has to pass.
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And water is the helper in it that gives the movement to the entire item. So if we mix more of water, the entire thing will pass very easy. But the question is how much water has to be added so that the cement will get enough of water to get hydrated? The answer is we have to stick to a particular water cement ratio and we will answer it later. And we will also see the tests of concrete, go to plasticizers and admixtures and finish this module.

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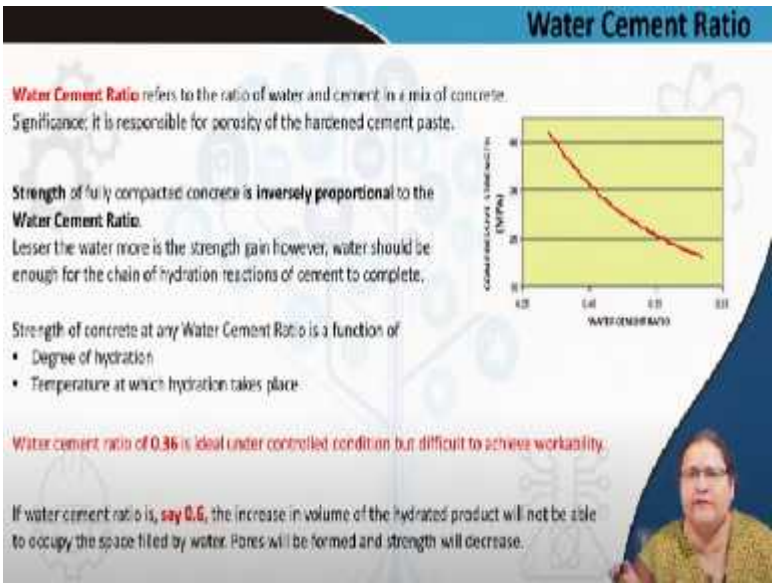

So what is water cement ratio? To put it simply, it is the ratio of the water and the cement in a mix of concrete. The significance is that it is responsible for the porosity of the hardened cement paste. If you remember the gel space ratio, it will increase if you add more of water. So water will affect the strength of concrete because the intrinsic strength of concrete is within the gel.

So some values are also there, which I am not elaborating. But actually this gel gives the strength to the cement and obviously, that is reflected on the strength of concrete. So strength of fully compacted concrete is inversely proportional to the water cement ratio. So should we go for very low water? Can we target very low amount of water?

Yes, ideally, if we can go to a water cement ratio of 0.36 as you can see in this picture. This red line can go and meet the y-axis somewhere at around almost 100 MPa. MPa is Newton per millimeter square (N/mm^2). You can actually extend this graph. But practically what will happen, the concrete will become very hard.

Hard means it cannot move through the reinforcement as I have told and also you can only work in a controlled environment. Ideally you can mix it, but what will happen, complete hydration of cement may not be possible. So ideally it is possible to get complete hydration with 0.36 as water cement ratio and you can gain a good amount of strength.

But, mostly it is seen that we are getting our concrete in this range. So strength is between 30 MPa to 20 MPa and water cement ratio is in the range of 0.45 to 0.55. So we are why are we taking this range? This is because at this point, the workability is very easy. Workability means the movement of the item, no segregation of the items, because those are very important. There is a limit up-to which you can add water. Beyond a certain level, you cannot add water.

You can achieve ideally at 0.35 the entire hydration and you can go for higher side also. But segregation will occur and it may lead to reduction of strength. So you can see the curve gradually falls when it is actually crossing a limit. So the value of the water cement ratio is a vital point that needs to be remembered and followed when we are going for any kind of concrete structure.

So any amount of water cannot be poured into the mix, when the concrete is being mixed, whether the concrete is ready mix or it is coming in or it is manually mixed or it is mixed in a rotator. Strength of concrete at any water cement ratio is a function of

the degree of hydration as I have told you. So if it is not completely hydrated, it means there is not enough water. Then the strength gain is not happening.

It is also dependent on the temperature at which the hydration is taking place. The temperature is important because the heat is liberated out during the process of hydration. So strength is being affected by these two. Water cement ratio of 0.36 under controlled condition can be achieved, but it is difficult to achieve workability.

And if water cement ratio is 0.6, the increase in volume of the hydrated product will not be able to occupy the space filled by water. Pores will be formed. Strength will gradually decrease. So for any kind of construction, it is always preferred to have a value from 0.40 to 0.55. Here 0.6 is maximum ratio that you can desire, but not beyond that and remember higher the amount of water lesser is the strength, you are reducing the strength.

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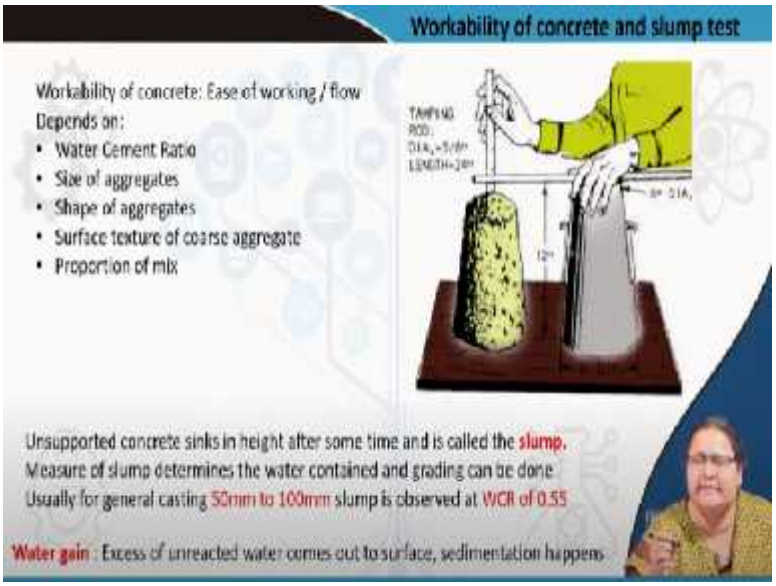

Now let us come to the concept of workability. Workability as I told you, the entire mass of concrete has to move through the dense network of reinforcements. It may be dense at some places like the beams or the columns. It may not be that dense in the slab areas, but yes it has to move through it. So the ease of working or the flow of concrete will depend on the water cement ratio, size of the aggregates.

That was also mentioned when we talked of the clear cover. And size will also be affected by the shape of the aggregate. Surface texture that is the shape with the

number of surfaces it has and also the proportion in which the basic three ingredients that is the cement, sand and coarse aggregate are being mixed is also affecting the workability.

But first of all it is the water cement ratio. So it is the test how to check the workability of concrete. Here you see there is a supporting jar.

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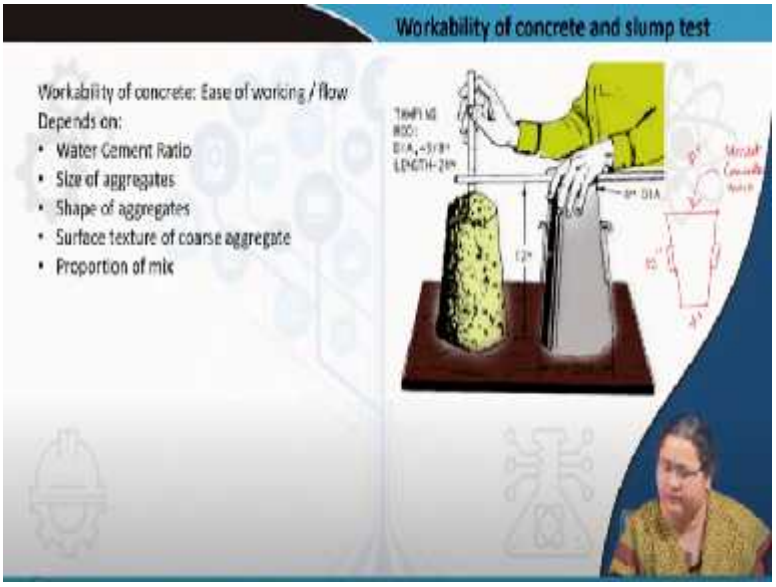

You can see this jar which is initially in its standing position. One side is open where actually you will have to pour this concrete. It has two supports here and it has a fixed dimension. The open end is of 8 inch, the base is of 4 inch and the total height is of 12 inch, that is one feet in height. Now you have to fill it with the unset concrete mix.

And then you have to invert the entire jar (as it can be seen in the picture). So this is now lifted out. So with these two supports, you can actually take out the container. Since the specific height of the container is known, you allow the mix to stand for some time. So it is unsupported concrete which is standing for some time. After some time it gradually tries to go down.

So once it is allowed to go down, you can take a measure of the unsupported height after some time. So you will see a gap here between the original container height and the mix that has gradually tried to settle. So this is how we measure the slump that is the gap between the height of the actual container and how much it has gone down on

its own. That has happened actually or mostly because of the water in it or the proportion of water in it.

It yes, it is not only the water, but all other ingredients are playing the role, but however, it is mostly responsible for water and if we go for general casting, we have to look into the value which is 2 inch to 4 inch (50 mm to 100 mm) of slump where the water cement ratio will be within 0.55, which was our desired value.

So this unsupported concrete sinks in height, which is known as the slump, which is a measure of the water cement ratio. This is a site check. You can check what quality of concrete is going for the construction. This is very important because if you are having more amount of water, whatever be the quality of other ingredients, the strength gain would not be happening and also there is a fear of segregation.

Now if you have excess of un-reacted water which is known as water gain. Sometimes this excess water comes out and sedimentation of the materials do happen, if you have more amount of water. The hydration process will take its required amount of water. It is not an immediate process, but after some time, you can observe that water is coming out and that is called water gain or bleeding of concrete.

Unset concrete is also sometimes called as green concrete. So this slump test gives you a clue of the water cement ratio and which also gives you an indication that yes the strength would be of this order.

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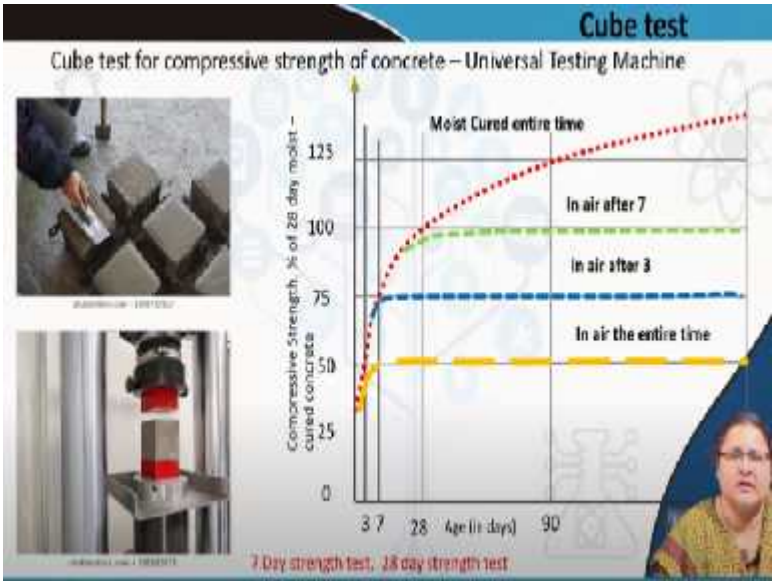

Next is the cube test. This is always done on site before the day of casting. You can see some cubes here where actually with the help of a tamping rod, they have been compacted and the items are left with the material which is being cast on the day, which is a large scale casting. So you have taken samples for testing. Now what to do? On the next day you can remove from the mould.

Those are inside moulds. These moulds are of various shapes and sizes like 3 inch, 4 inch or 6 inch mould, it can also be circular mould. These are usually cube like, circular is obviously cylindrical. And at least 6 to 12 such cubes are taken. Next day onwards they are immersed in water so that they can get hydrated.

They have to be maintained in the moist condition and after 7 days they are tested under a machine which is called the universal testing machine. You can see one sample put here and it will be subjected to a compressive load and it will actually rupture at a certain point and that is noted down. Some of the cubes are tested for 28 day test strength and it is seen that strength of concrete is achieved up to 50% within 3 to 7 days.

By seven days around 75% strength is gained and up to 28 days it gradually reaches almost 100% of its strength. And if it is still kept in moist condition, it may also gain further strength. However, mostly on 28 days, this moist condition and all are withdrawn. And you will get almost a hundred percent strength gain by 28 days and that is noted down. That is the design strength.

Whether these samples comply the design strength is actually noted through this cube test. So once this cube test is done, you can assure your client that yes your concrete has taken the maximum strength and that is what you had tried to achieve.

So remember when you are making these cubes, proper tamping should be done because voids can lead to reduction in strength you. Hence, these are to be done very carefully and the tests are to be done exactly on the same days.

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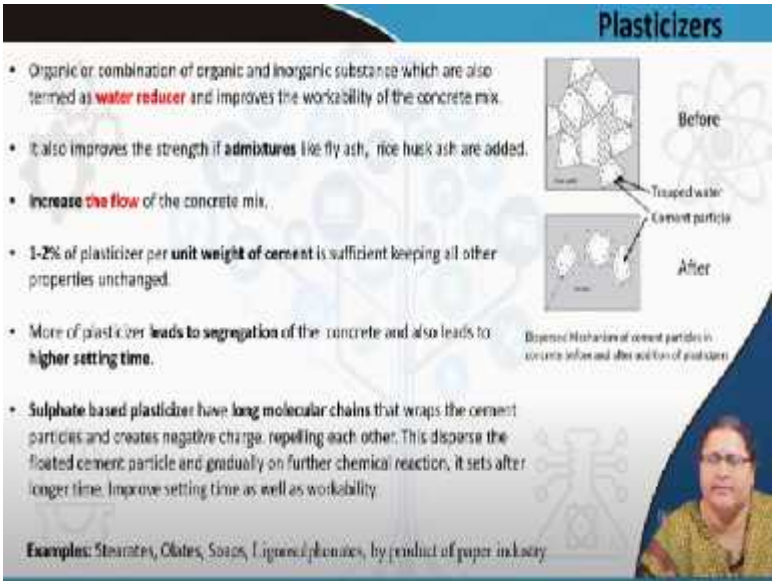


Now once we have learnt all about concrete, we also need to know these were the basic materials discussed. And sometimes as I told you many a time that concrete is always or mostly used with reinforcements. And there you actually have to move these large size particles through the dense network of reinforcement. And at the same time, you have to remember the setting process begins.

You have transported concrete for large scale construction sites, you may have transported concrete from some ready mix agent. So they are already brought to you maybe with a delay. So sometimes you may require your concrete to remain unset for a longer time period. There comes the role of plasticizers. They are also referred to as water reducers.

They improve the workability of the concrete mix that is it will move easier between the network of reinforcements and these are usually concrete or combination of

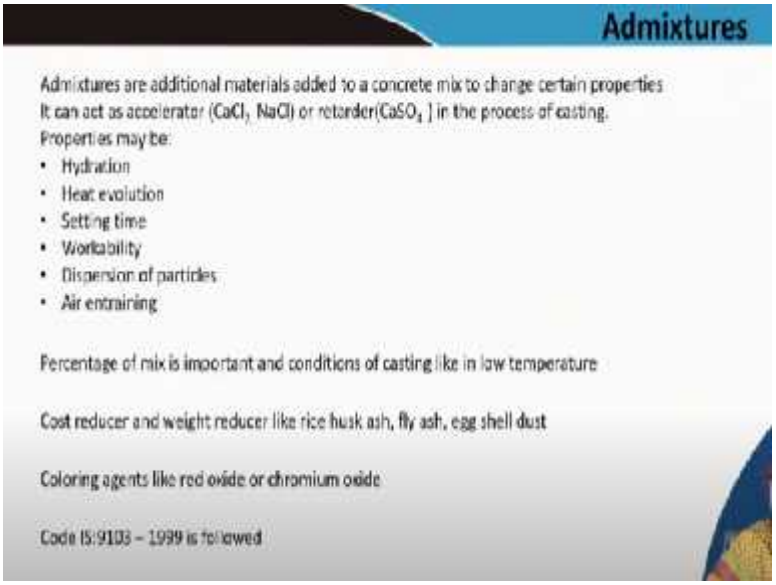
organic and inorganic substances. It improves the strength if admixtures like fly ash or rice husk are added. It increases the flow of the concrete. So plasticizers actually delay the process of setting.

So instead of putting water they are doing the job of water. But remember they are to be added in very small portion, 1 to 2% per unit weight of cement. So with the amount of cement, the amount of plasticizer is determined. So other properties would not change. If you add more of plasticizer it will lead to segregation and delay the setting process.

So adding more amounts of plasticizers in the mix will lead to segregation and higher will be the setting time. Sulfate based plasticizers have long molecular chain. They wrap the cement particles and create a negative charge. You see in the two pictures here. So water was trapped between the cement particles here. With the addition of plasticizers these cement particles are repelling from each other and the water is flowing outside which is helping the other ingredients to move.

So this is the pictorial representation of the dispersed cement particles in concrete. Initially it was closer, water was trapped in between. Now the water is free, the cement particles are repelling each other and it is allowing a free flow. So sulfate based plasticizers are long molecular chains, wrapping the cement particles allowing them to move and delaying the setting process.

Yes the chains break and gradually the setting begins. It improves the setting time and also helps in workability. Examples of plasticizers are stearates, olates, soaps, lignosulphonates coming from the paper industry and there are super plasticizers. So they are added entirely in the mix. And they are improving the workability of the material. **(Refer Slide Time: 21:53)**



Next we come to admixture. Water admixtures they are added additionally to the mix to change certain properties. What properties? It can act as an accelerator, it can act as a retarder, it can be used as a cost reducer, weight reducer that gives insulation properties. But mostly if you see they are accelerators in the process of hydration or heat evolution or the setting time, even the workability and dispersion of particles.

So these admixtures help in the process of concrete formation. They have air entraining property that is they bring air particles inside. They can be coloring agents as you see red oxide, chromium oxide. They can be used as reducers such as cost reducers and weight reducers like fly ash, like rice husk ash, egg shell dust. But what are they? They are all silicates, silicon dioxide. They have 80% to 90%, silicon dioxide. Egg shell dust has calcium oxide.

So all these finally, help in the process of hydration, process of setting and obviously, they are used whenever they are required or recommended.

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So coming to the conclusion of this module, we had tried to learn concrete as a whole. It is a versatile material and it is a monolithic item. You can have a continuous casting of it without any gap, without any joinery. But it is very difficult to reshape it. Once it is set you cannot change it, which could be done in case of a brick work or in the case of a stone work. Here you cannot break it entirely.

Without the coarse aggregates, it can be used as a binder of materials or as mortar that can be used as plastering item. By changing its composition different types of concrete can be formed or made. Codes are to be followed when there is a construction and we are going to try to achieve a particular strength in it.

So codes are always there for us, but as an architect, you need to emphasize on the versatility and you also need to know that what is the type of construction, where it is to be made, are the raw materials available or not, what is the role of each of the ingredients. As architects if you know these, then you can always take up challenges in using concrete as a compressive material and also as a tensile material with reinforcement in it. Thank you.