Hydration, Porosity and Strength of Cementitious Materials
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Lecture – 02
Concrete - A Three Phase System

[FL] and welcome to the second lecture in this course on Hydration, Porosity and Strength of Cementitious Materials.

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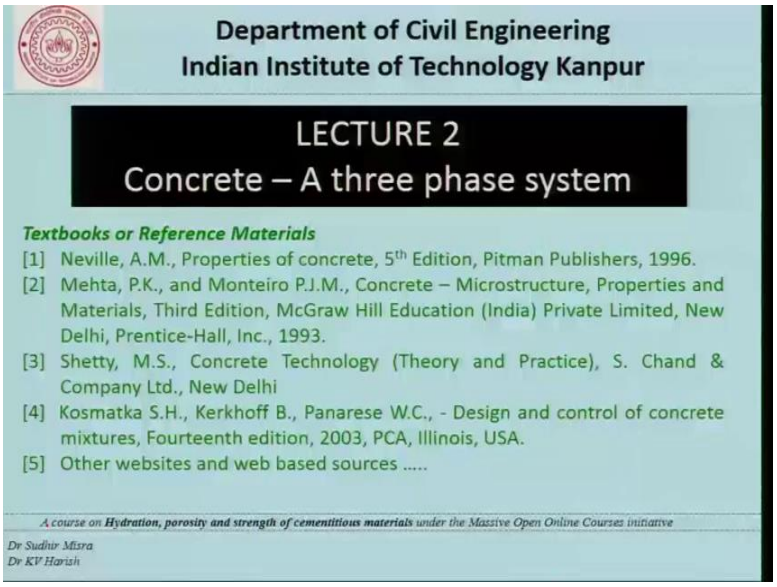

And here in this lecture we will concentrate on talking about a model of concrete as a three phase system, the list of text books send reference materials is included for you to be able to get additional knowledge information and so on relating to some of the subjects that we will talk about.

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This lecture we will help us in better understand a model of concrete based on it is basic constituents and how issues such as strength load transfer and durability can be looked upon in the suggested framework.

Concrete is presented as a three phase system; the aggregate mortar which is also the binder and the interface. The importance of the interfacial transition zone of concrete with an emphasis on the role that it plays in the strength and material transport is what we will seek to discuss today.

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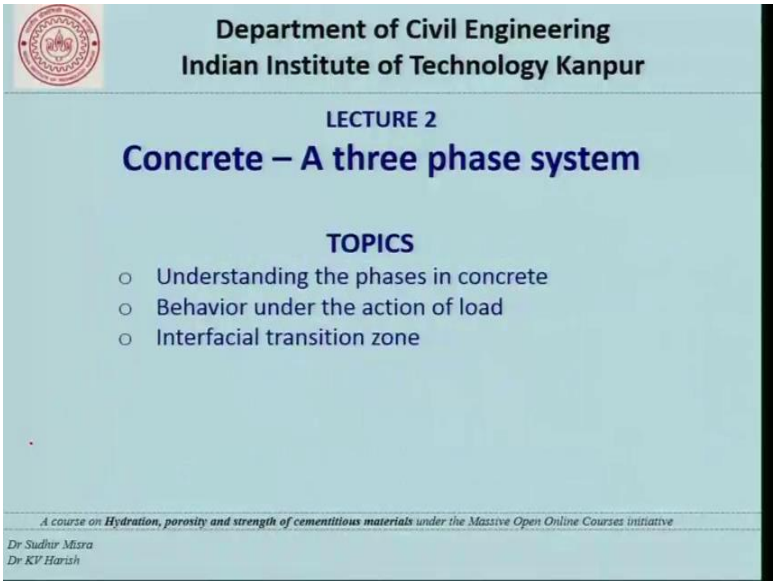

We will talk about understanding the phases in concrete, behavior of these phases under load and the ITZ or the interfacial transition zone.

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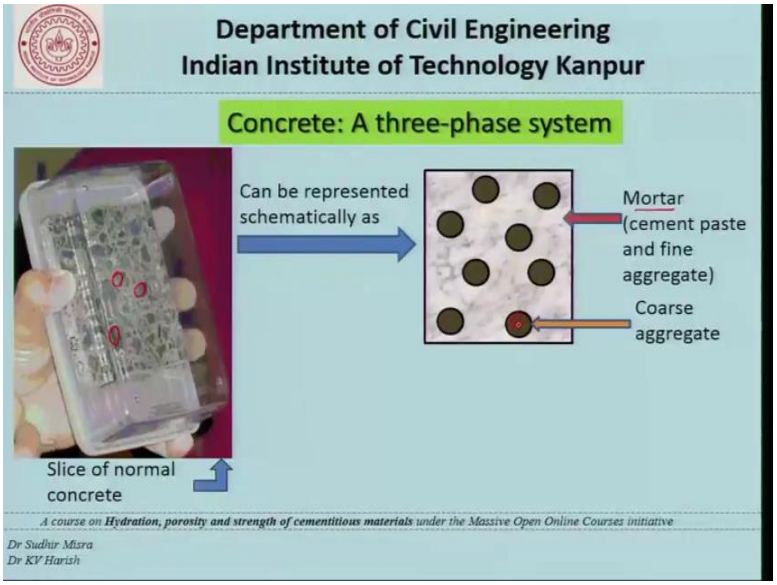

So, let us take a look at this picture which we solve the first lecture, as well which is basically a photograph of what concrete looks like on the inside. We can schematically represent this as coarse aggregates and mortar in a manner that the coarse aggregates here, which is this coarse aggregate particle or suspended in mortar or cement paste and fine aggregate.

We must remember that even in the fresh state, this must be the configuration or this must have been the configuration even though we have taken the picture in the heart and state. Now if you what to understand this model level.

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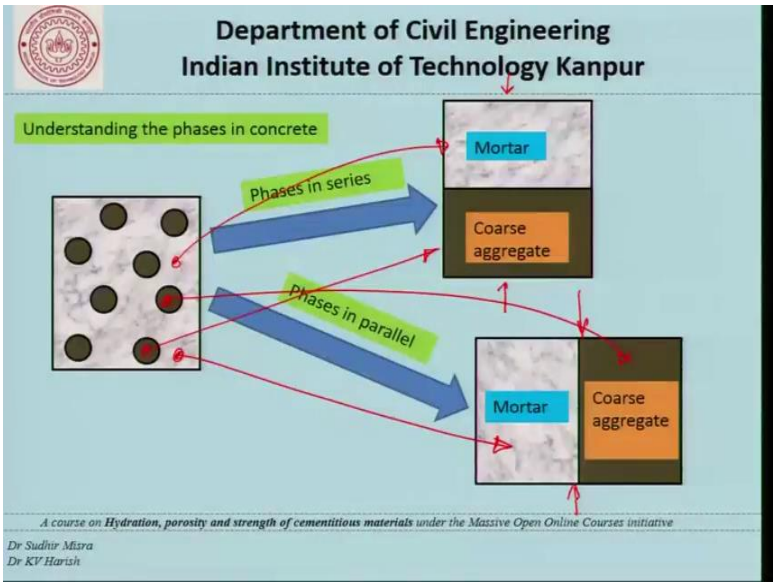

Now, if we what to look at this modeled more closely, we can model at as series representation where we will say that from a load application point of you if the load is being applied like this. All this mortar here is lumped at one place shown here and all this coarse aggregate here is lumped at one place that is shown here. And these 2 phases are a series as for as the load application is concerned. Another representation could be when the phases are in parallel.

Now, what that these is that we have a situation like this, where the same note of mortar and the same mortar is placed here and the coarse aggregates a placed here and the load is applied this way.

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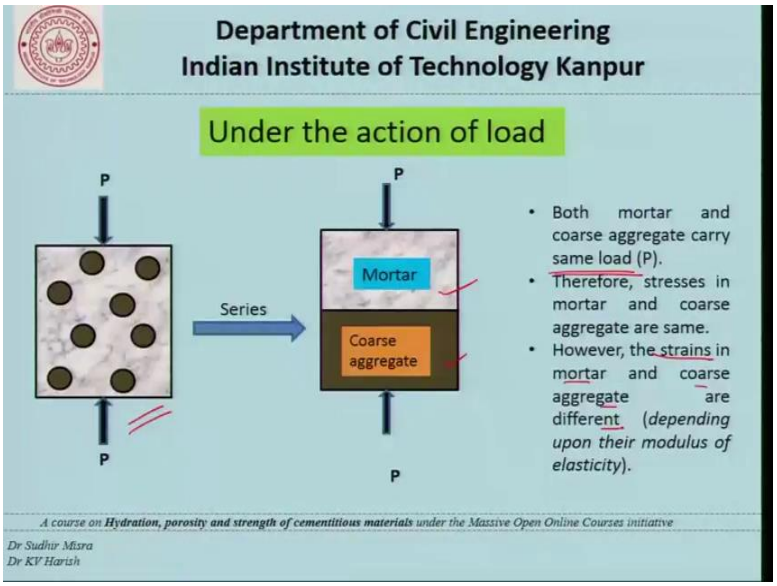

Now, if you look at the action of this concrete which is the real concrete, under the action of load when the phases are in series what we will have is a system like this. Now basic physics tells us that in this case both the mortar and the coarse aggregate will carry the same note, having said that the stresses in the mortar and the coarse aggregate will be the same.

Now, if the stresses are the same and the modulus of elasticity of these 2 phases is different, the streams in the mortar and coarse aggregates will be different. So, this is how the situation will pan out, if the mortar phase and the coarse aggregate phase was taken to be in series.

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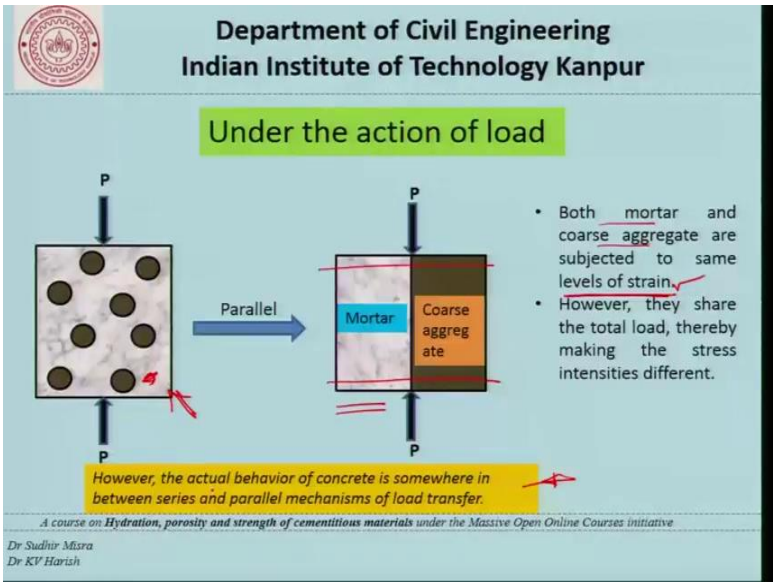

If we take the situation now when the 2 phases are in parallel, then the load carrying mechanism suggests that both the mortar and the coarse aggregate will be subjected to the same level of strain. That is, they have to deform to the same level. And now if the level of deformation which is the strain is the same then the load that they carry which is related to the stress will be different.

But concrete in the real cells which is this picture is neither a truly parallel system nor is it a truly series system. We have an actual behavior which is somewhere in between the series and parallel mechanisms of load transfer. So, this we must remember at the back of a mind when we are trying to understand the action of concrete under looked.

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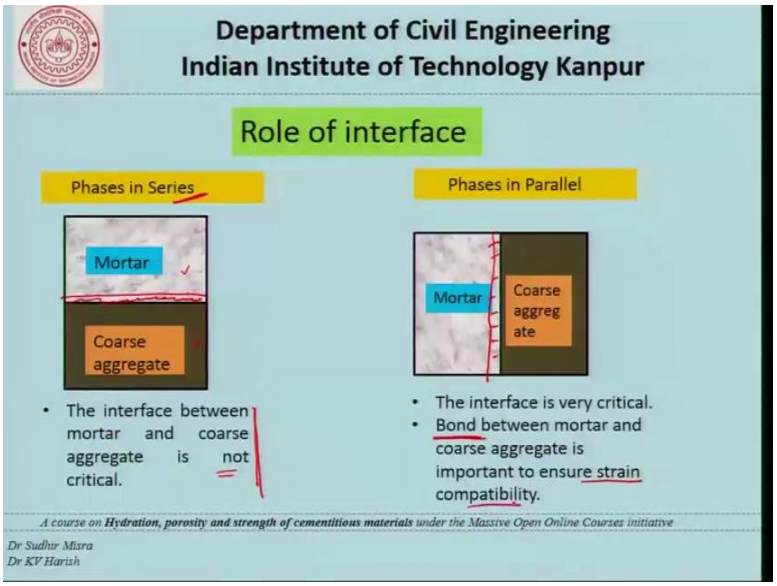

Now, let us talk about the interface, at the end of it the mortar and the coarse aggregate are not necessarily monolithic. The coarse aggregate particles are only suspended in mortar and if we look at the role of this interface, when the phases are in series if we say that well there is an interface in between what is the importance of that interface.

So, long as we are talking of a series module, the role of that interface is not very critical because the load had been carried by this and this phase is all the same and it is only the deformations which are different. Whereas if it comes to a module by the phases are in parallel and we have an interface between the coarse aggregate and the mortar phase there this role is very important, because we must ensure that there is proper bond between the coarse aggregate phase and the mortar phase in order to ensure is strain compatibility.

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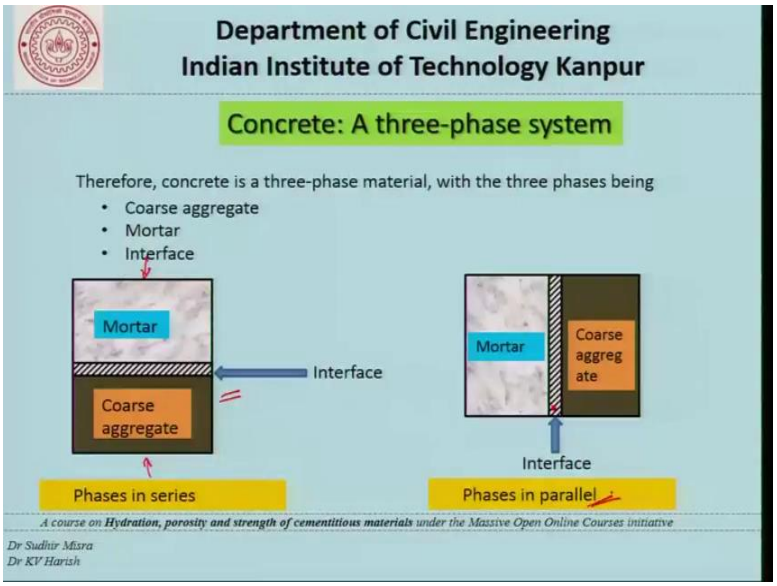

We can therefore, more or less come to a conclusion, that concrete is a three phase material with three phases being coarse aggregate mortar and the interface itself.

Now, this interface is a formal entity which we have introduced between the mortar and the coarse aggregate. And this entity exists in this phone if you are talking of the so, called series system, where if the load is applied like this the interface is the way to shown here and the interface is in this configuration for a system where the phases are in parallel.

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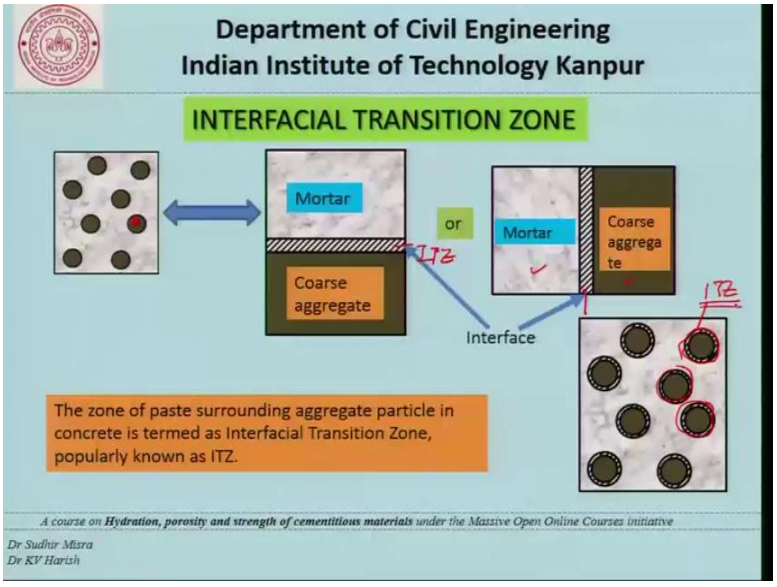

Now, let us look at the interfacial transition zone once again. This is the word model concrete where coarse aggregate particles are suspended in mortar we have this IPZ, which is small zone between the mortar phase and the coarse aggregate phase. In other words, what we have said is that the zone of paste surrounding the aggregate particle in concrete is termed as the interfacial transition zone and is popularly known as the ITZ.

In other words, what it means is that each of these aggregate particles which are showed here is actually surrounded by this ITZ. Now this ITZ actually comes about as a result of bleeding as a result of small amounts of segregation that occur in the neighborhood of an aggregate particle, as some particles try to settle down under the action of gravity resulting in accumulation of water around these aggregate particles; as a result of that effectively.

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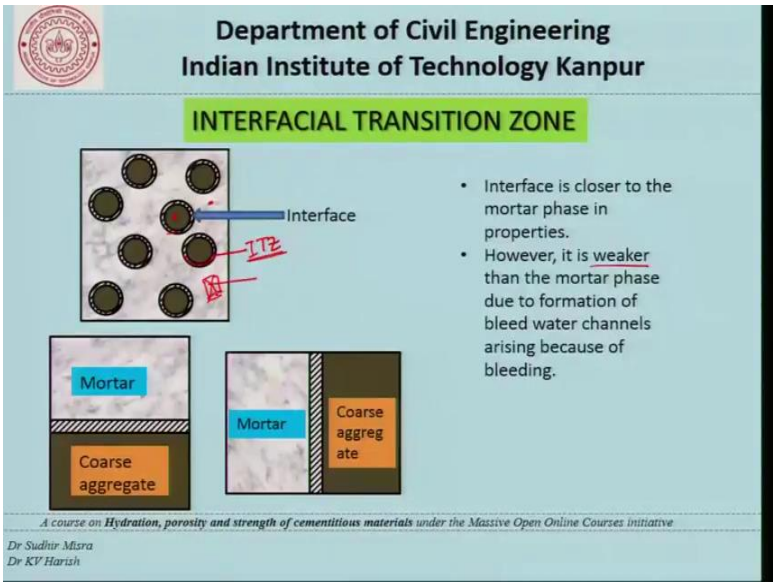

The water cement ratio in the ITZ is slightly higher than that of the main body of the mortar effectively once again the interface is closer to the mortar phase in properties see thus no way that we can argue that this interface between the aggregate particles and the mortar is close to the aggregate, because the aggregate has a very well defined geometry, whereas the mortar is feeling this phase.

And like I said before because of small amounts of segregation that happen around the aggregate we have the formation of this, interfacial transition zone the ITZ. Now this ITZ is close to the mortar phase and it is properties, but is weaker than the main body of

the mortar because of the formation of bleed channels arising out of bleeding. And the effective water cement ratio in that small area or that is small volume around the coarse aggregates be slightly higher.

As for as the mortar phase is concerned we can talk of the properties of the main body of the mortar which is here and the mortar which is existing in the ITZ with the mortar in the ITZ being slightly weaker than the main body mortar. What are the implications of having this weaker ITZ in the neighborhood of the coarse aggregates? One implication is that the ITZ is more prone to micro cracking because of it is weaker strength.

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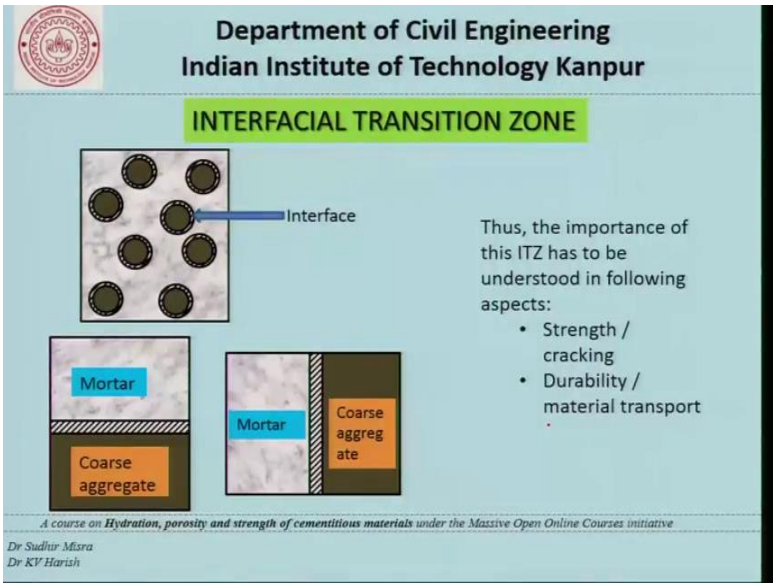

To summarize: the importance of this ITZ can be understood in the following aspects. One is strength and cracking and the second is from the point of view of durability and material transport.

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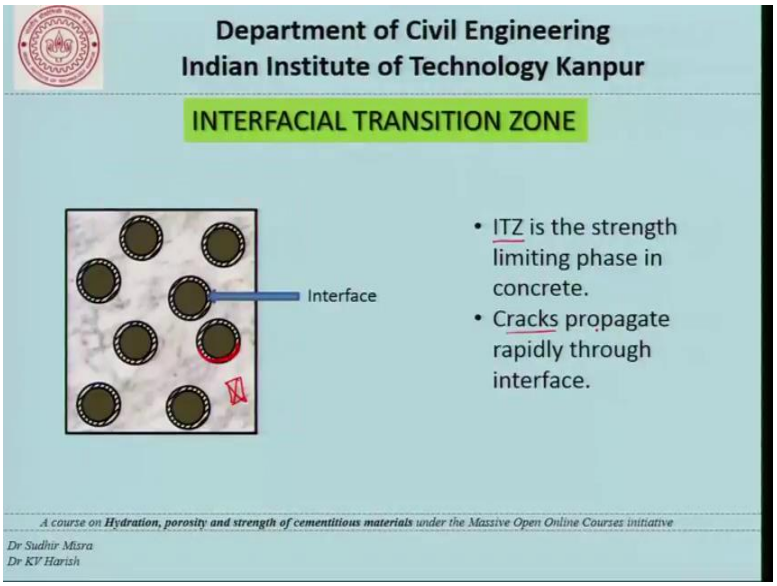

If we read literature, about what governs the strength of the concrete? The traditional wisdom is the water cement ratio and indeed water cement ratio governs these strengths of this mortar, because that is exactly where we are trying to control the extent of porosity and so on. And we can control the strength of this overall matrix through the control on the strength of mortar, but just now we argued that the strength of this ITZ is slightly lower than that of the main body mortar. And therefore, the ITZ becomes the strength limiting phasing concrete. And cracks propagate rapidly through this interface.

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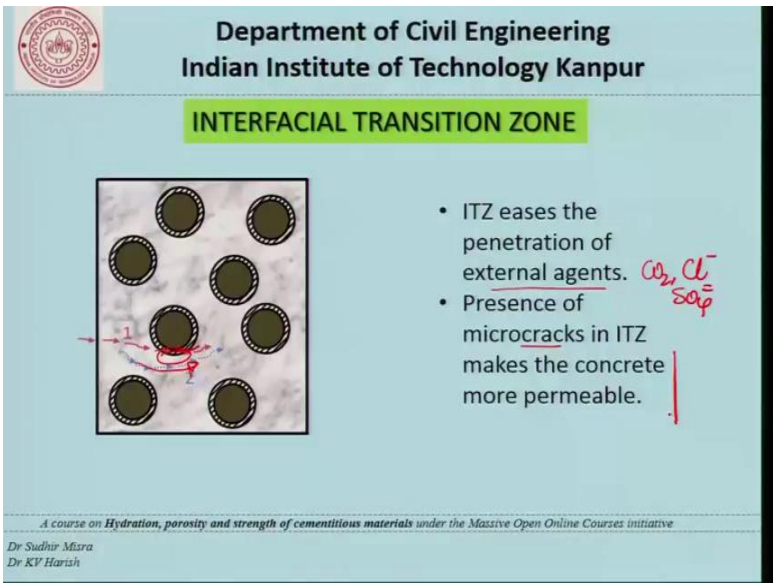

As far as the durability issues are concerned, ITZ eases the penetration of external agents. Basically if the is strength of the ITZ is lower, it is also an indication of the fact that the porosity in the ITZ is higher.

Now, if the porosity of the ITZ is higher the material transport that is the penetration of external agents whether it is carbon dioxide or it is chloride ions or it is sulphate ions. All this would be easier through the ITZ, then through the main body of the mortar. It is the presence of the micro cracks and the fact that there are more course in the ITZ that is what makes the ITZ more vulnerable for penetration is more permeable. So, with this what we did today was try to understand the phases of concrete that is the coarse aggregate mortar and the ITZ. We are try to look at the action of concrete under the load if the 2 phases were taken as series or the 2 phases were taken in parallel and argued that.

So, long as the phase is very serious the ITZ has limited role to play as far as strength is concerned, but it will of course, have the same amount of impact as far as durability and material transport is concerned, what if the phases are in parallel then the ITZ phase in important part in even determining the strength and ensuring strain compatibility between the coarse aggregate phase in the mortar phase and we talked a little bit about the importance of the ITZ from the point of view of strength and durability.

And with this are like to thank you for your attention, and look forward to seeing you again.