Admixtures And Special Concretes

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Lecture -69

Special concretes - Lightweight concrete - Foamed concrete, lightweight aggregates,

Lightweight concrete:

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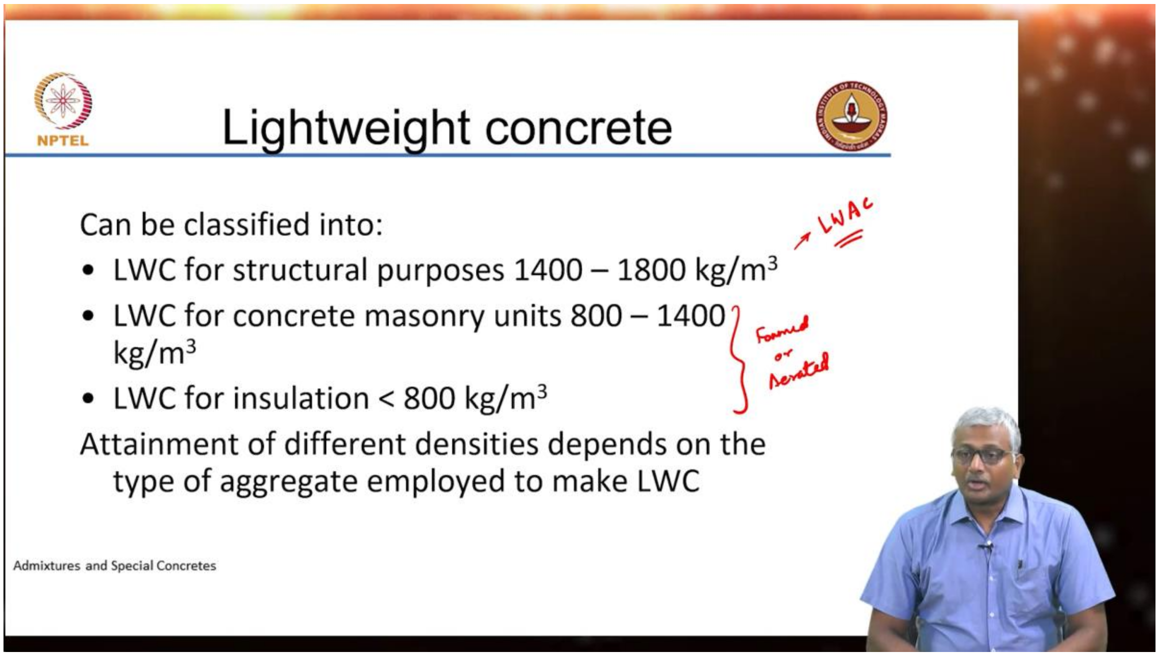

We will resume our discussion on lightweight concrete. So, we are talking about the fact that you can make concrete have different densities for specific applications. When you are dealing with structural purposes, you need a higher density because generally the higher the density, the higher will be the strength capacity of the concrete. For intermediate and low values of density, your application primarily leads to insulation and perhaps uses partition walls where you do not need too much of load-carrying ability. So, in such instances, when you prepare concrete masonry units, you can work with much lower density.

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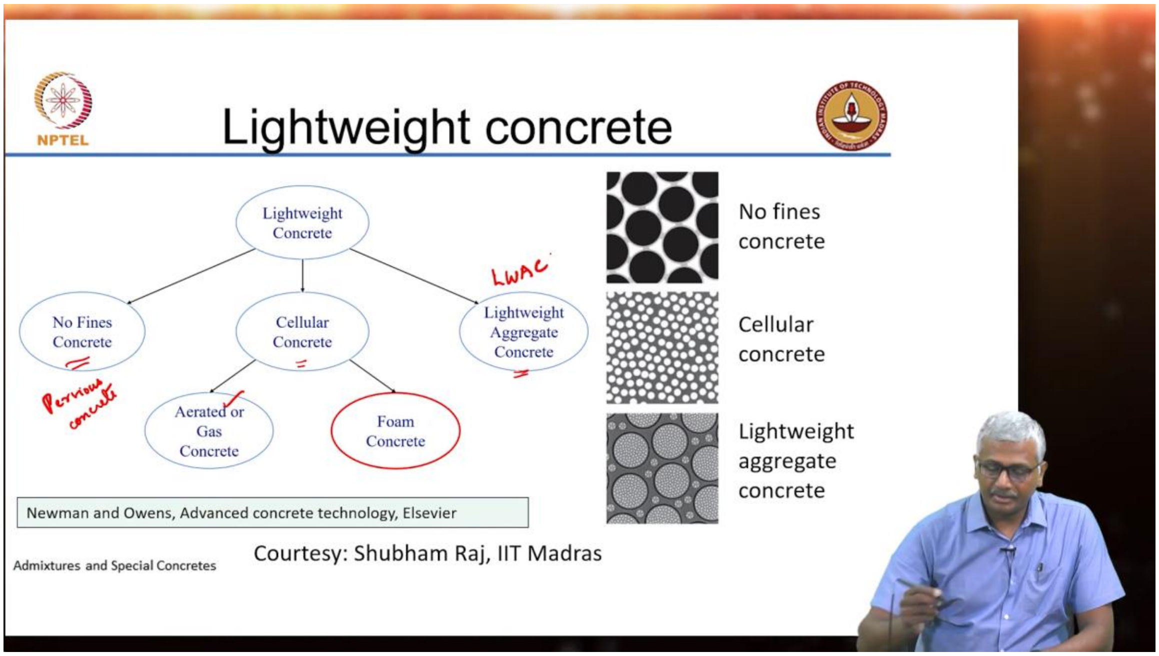

In general, lightweight concrete can be classified into no fines concrete. Why is no fines concrete lightweight? Because we are not adding any sand. So obviously there will be a lot of void spaces present in the system. No fines concrete is also christened as pervious concrete in certain literature.

Pervious concrete is where you only have coarse aggregate which is graded and then you have cement or cement and water. You do not have any sand in there. The idea is to have a continuous channel of flow of water through the concrete. So, when you are let us say putting down parking lots and you want to conserve the water that falls because of rain and then store it. So pervious concrete is a good methodology for doing that.

People have even experimented use of pervious concrete for roadway pavements where continuously there will be a water recharge into the ground because of the space afforded by the pervious concrete. But for the most part, pervious concrete is taken separately and not treated alongside the other structural lightweight concrete or insulating lightweight concrete that we are going to be talking about. So lightweight concrete includes cellular concrete. Cellular from the point of view of the fact that there are lot of air cavities inside. That is why it is called cellular. The cellular concrete could be either aerated, aerated implying you are putting some sort of gas inside the concrete which leads to the formation of the bubbles or you are entrapping gas inside the concrete or you can also have foam concrete where you are putting foam to create the bubbles inside the concrete.

So, we talked about both also and we will look at more details about how these are done. Then, of course, you have the lightweight aggregate concrete or LWAC, Lightweight Aggregate Concrete.

Foamed concrete:

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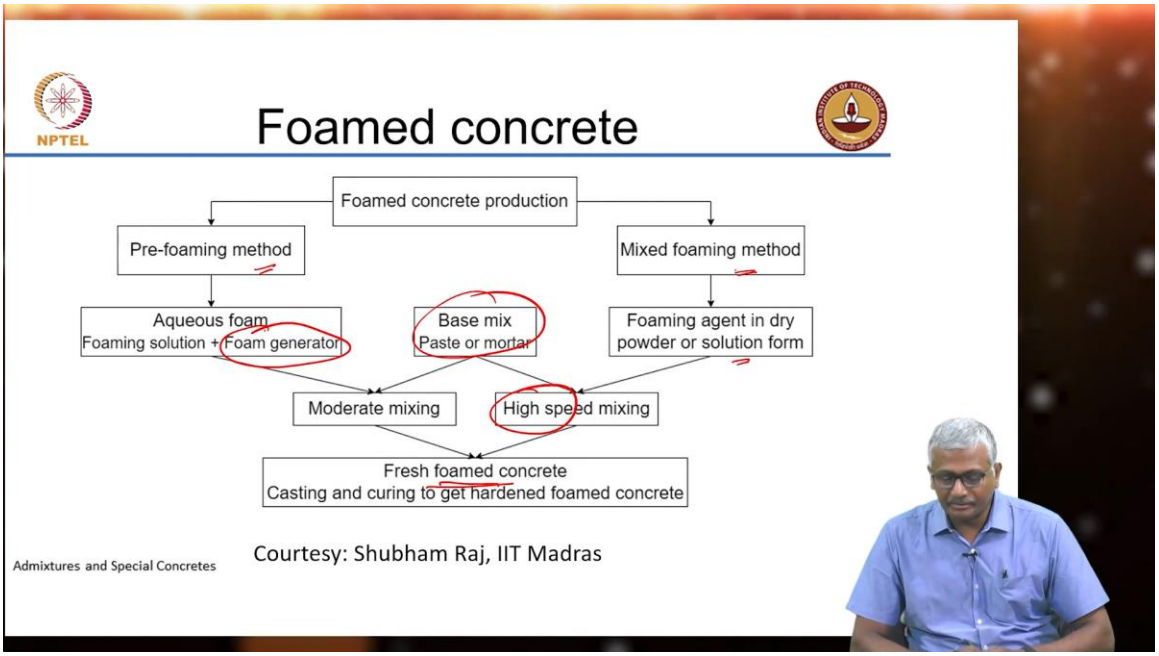

Now let us look first at foam concrete. So, foam is nothing but the kind of stuff that you get when you use shaving foam. The shaving foam or a shampoo when you agitate it with water you get a lot of foam generation and this foam has to get embedded in the structure of the concrete.

And what happens is this foam is not that stable, in general. The foam that we typically think of in terms of the lather from a shaving cream or from a shampoo breaks easily. The bubbles have to be conserved inside the structure of the cement mortar and that is what makes the foam stable and provides a stable air-void system inside the concrete. So, you can produce foam through separate means. One is a pre-foaming method and the other is a mixed-foaming method.

In a pre-foaming method you create the foam, an aqueous foam is created using a foam generator using a foaming solution. You then mix it along with the base mix which is a paste or a mortar. Now problem is, in foam concrete, you cannot employ large-size aggregate because what happens the presence of the aggregates and the angularity associated with it will break down the foam easily. So as far as possible you want to have very fine particles in your system. So even when you are making mortar the sand particles are typically quite fine in terms of lightweight concrete.

So, you do moderate mixing and then get fresh foam concrete out of this. The other way to do this is mixed foaming where a foaming agent is used in a dry powder or solution form and directly mixed along with the base mix at high speeds. Because you need to agitate it at high speeds to regenerate the foam. When you agitate at high speeds only the foam will get generated. Here you do not have to worry about it because you have a foam generator that applies the pressure to sort of agitate and generate the foam.

So, when you add some detergent into a bucket of water you do not see any foam generation. The foam is generated only when you agitate it. That is exactly the function of a foam generator or the use of high-speed mixing along with the cement paste or mortar to generate the foam within the system. So fresh foam concrete is obtained from these two methods and then of course you need to cast in the moulds and then finally curing has to be done to achieve your lightweight blocks.

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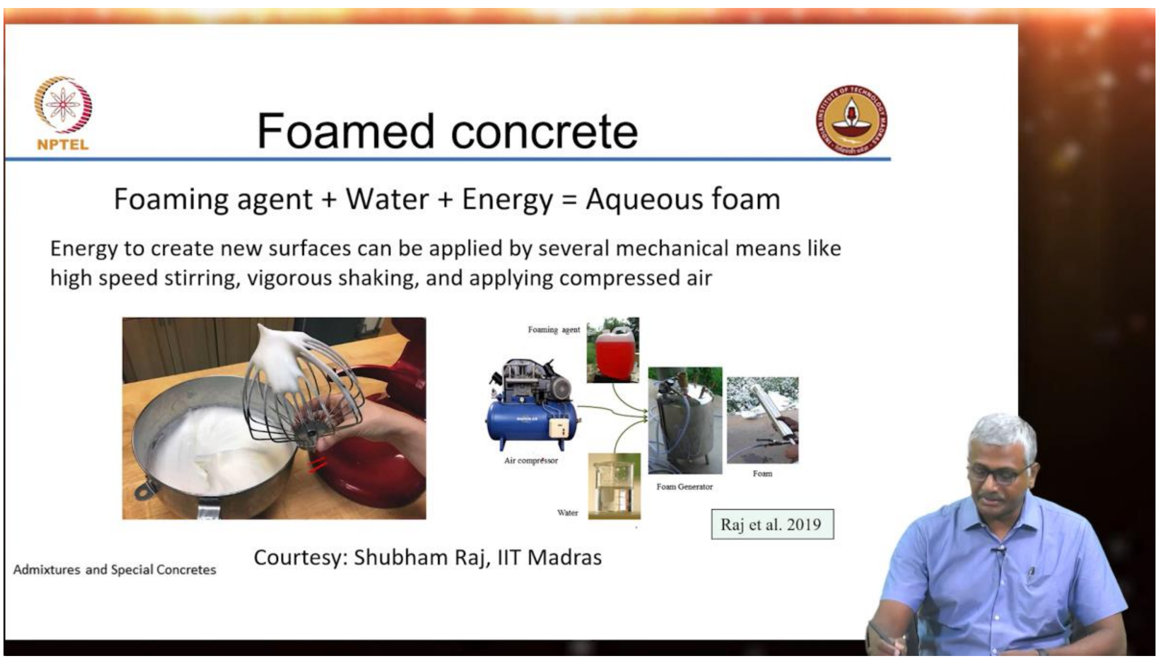

So again, this (refer to the above slide) is an example of the use of a foaming agent. You add a little bit of water and then provide energy here. You can use a cake blender for instance to do the same work in the lab to provide that energy but in most cases, for field applications, you would like to use a foam generator. So, you have an air compressor, you have the foaming agent and water that are added together into the foam generator and then you have a nozzle through which you can extract the foam. So, all you need to do is have the right combination of water and soap.

So, soap is basically the foaming agent and then you apply the right pressure through your air compressor and ensure that you can generate the foam that is required. Foam needs to have a certain density of its own. It has to be very low but you need to control that density by appropriate formation of bubbles. You need to form the right amount of bubbles and you need to then worry whether these bubbles will remain stable when you mix it with the cement paste or cement mortar. Otherwise, if it is not stable it will break down and then it will not get the lightweight nature of the foam concrete.

Surfactants for aqueous foam generation:

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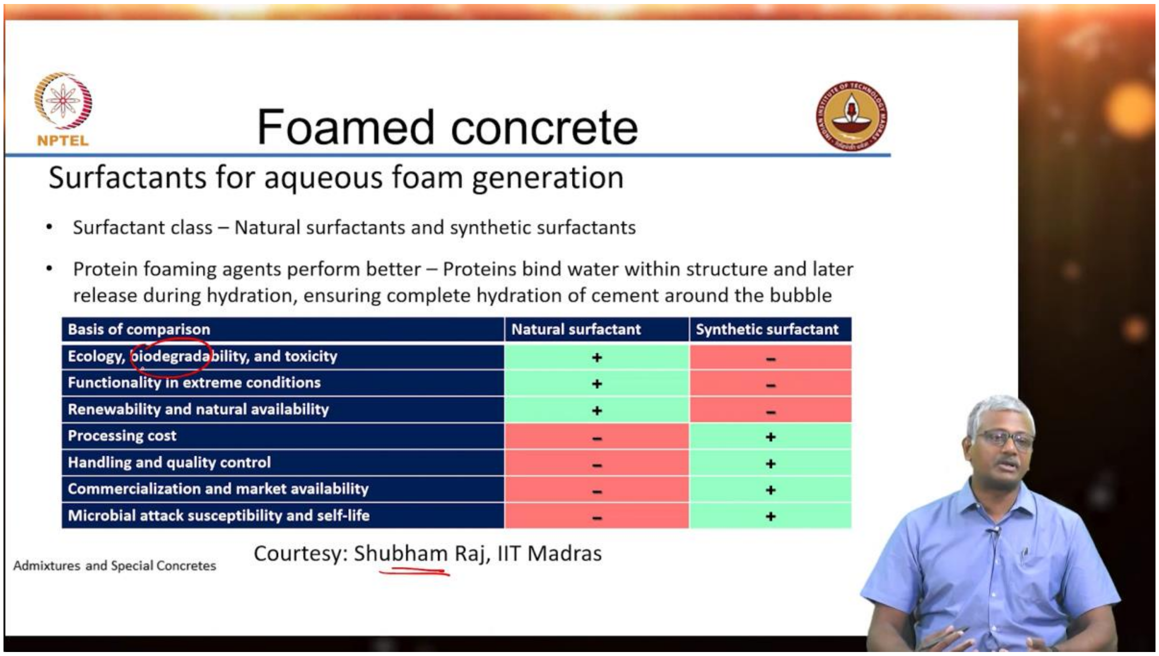

So, there are several surfactants you can use for foam generation. I do not know how many of you have seen the shampoo formulations. There are synthetic surfactants that are added to the shampoo. One of the common names is sodium lauryl sulfate or sulfonate which is a common ingredient found in most shampoos and that is a very good surfactant.

We talked about air entraining agents earlier. The idea is that they are also surfactants. They lower the surface tension of water and help the formation of bubbles. So, you can have either natural surfactants or synthetic surfactants. Natural surfactants very often are like the soap nut that you can naturally get and from these, you can easily extract the foaming agent. Even stuff like pulses is sometimes good foaming agents, like toor dal or even moong dal. These are also good foaming agents. When you mix water with the dals you will see a lot of bubbles getting generated and these bubbles are sometimes stable also.

So, protein foaming agents seem to perform better. Proteins have a tendency to bind the water within the structure and release the water later during hydration and this ensures that there is going to be a continuous hydration of the cement. We talked about this briefly earlier with certain types of chemicals you can obtain this. Internal curing of the concrete which traps the water and then releases it when the concrete is hardened so that the internal stresses due to autogenous shrinkage can be relieved.

But here that is not the function. Here of course you do not worry too much about autogenous shrinkage because you have sufficient wetness in the system and low strength overall. So here you are talking primarily about the fact that the proteins that bind water can release it over a certain time. So, this is just a comparison provided between natural and synthetic surfactants. Of course, a lot of the work that I am referring to is from the PhD student Shubham Raj who is currently working on foam concrete. He is about to finish his PhD now.

So in terms of comparison, obviously sustainability-wise a natural surfactant is easier, better, and biodegradable. In terms of toxicity, it is less as compared to a synthetic surfactant. Renewability and natural availability are definite advantage. Processing costs could be high from natural surfactants because you need to extract the material from a plant and then process it to get the foaming agent and so on. Handling and quality control, because you can get variability in natural formations. You cannot control the chemical nature of these materials easily. So that requires a little bit more effort in quality control.

Commercialization is more difficult because market availability depends on what is available in bulk and synthetic chemicals are available in bulk. And then microbial attack. See much of the natural components are subjected to microbial attack. If you store them for too long, they will get degraded by bacteria. This is something you can avoid in chemical formulations by adopting what are called bactericides or fungicides which can kill those bacteria or fungi that are going to be attacking your solutions. So synthetic surfactants have their appeal but at the same time, you can end up being a lot more sustainable by using locally available materials. A lot of the work that the group of Professor Ramamurthy has done at IIT Madras deals with the identification of suitable natural surfactants. They have got a lot of interesting ideas from this and they even have an in-house developed foam generator that is much cheaper as compared to what you can get in the market.

Comparison of stable and unstable foam concrete:

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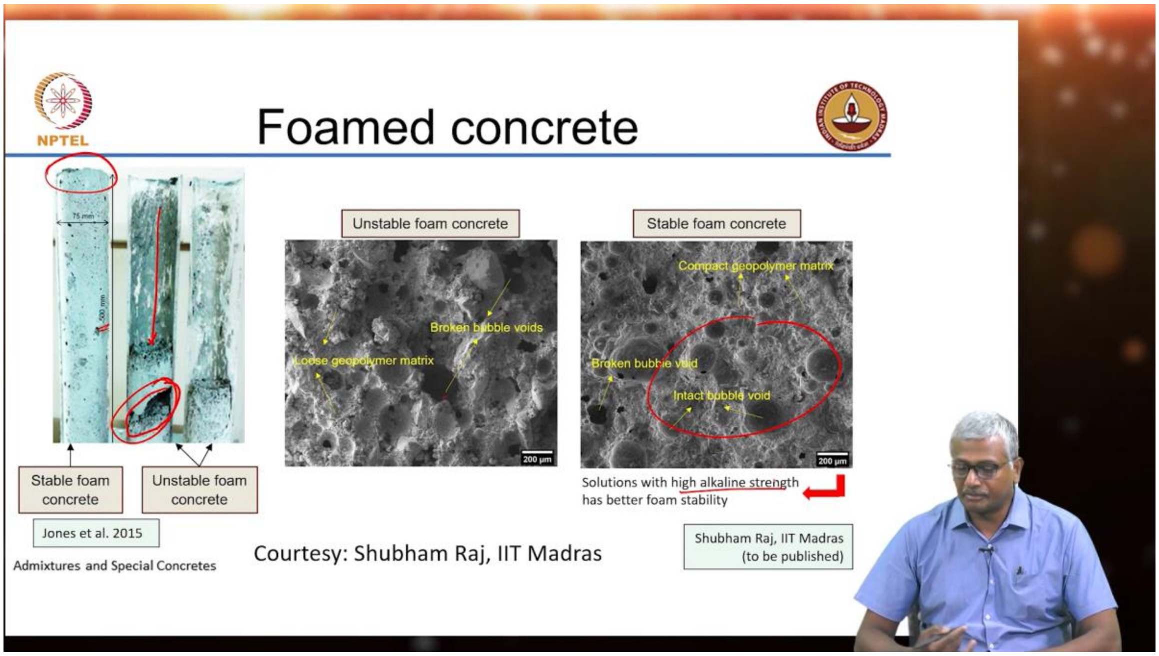

So, just a comparison of stable and unstable foam in concrete. As I said when foam is stable the volume of the concrete will always be greater because the air bubbles inside are stable and maintained for a longer period. If it is unstable the air bubbles will break down and your cement paste will start settling. So, you have here a tube of 500 mm height and 75 mm diameter which was filled all the way to the top. So, this is a stable foam concrete you see that there is no lowering of the height of the concrete column whereas here the height is lowered significantly and you also have a gap that is forming inside the system.

There is a separation also happening inside because the foam has completely collapsed. The foaming system is completely collapsed. Again, if you look at that under the microscope you will be able to see where these bubble voids are. So, for instance, you can see here (Refer to the right image on the slide) that the voids that have been generated by the foam are intact they are in place whereas when the foam is not stable the bubbles start collapsing. You will still produce a lightweight material but the problem is the distribution of the bubbles will not be uniform.

You will have weak planes through which failure can happen. Imagine if you have a gap like this (refer to the left image on the slide) inside the concrete it is not a good thing for the overall performance of the concrete system. Now generally it has been noticed that solutions with high alkaline strength have better foam stability. So in terms of alkali content of the solution they will have better foam stability.

Effect on the addition of mineral additive:

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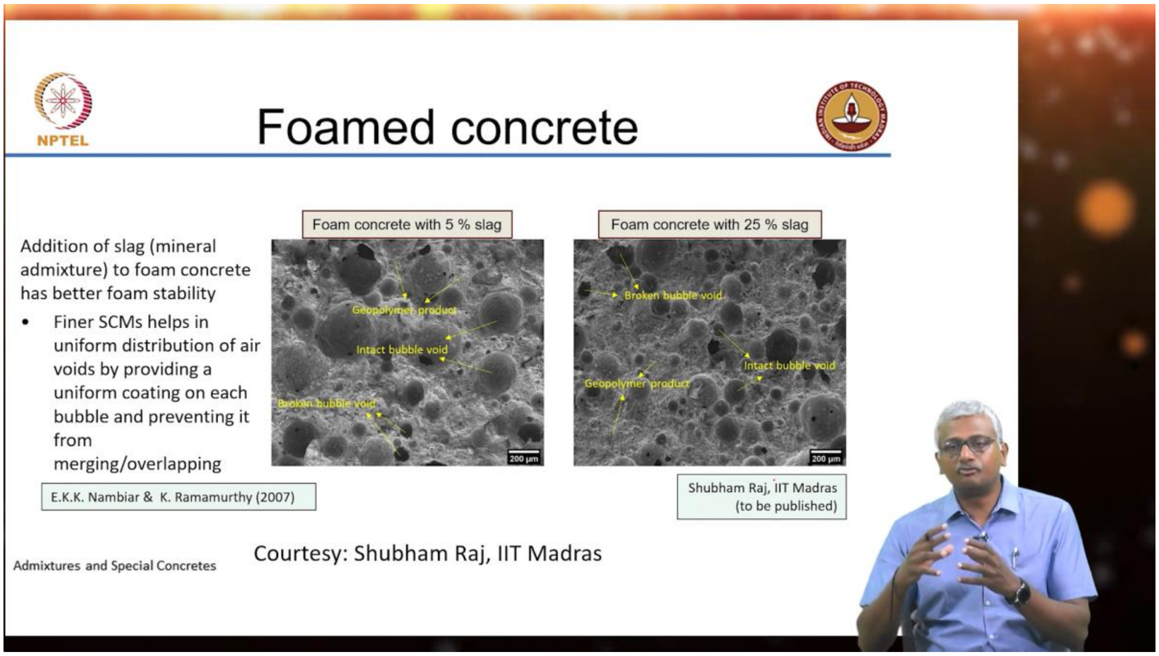

Now again it has also been seen that when you have mineral additives as ingredients for instance slag it seems to help in improving the foam stability. The finer supplementary materials when they are added in the fine foam help in the distribution of the air voids and provide a uniform coating around the bubble. Please remember entirely the system also consists mostly of fines, you do not have any much coarse particles and these fines tend to line the foaming agent around the bubble and that prevents the bubble from collapsing easily. So that is why you see that you get much better foam concrete with higher amounts of fine mineral additives like slag.

3D Foam Structure:

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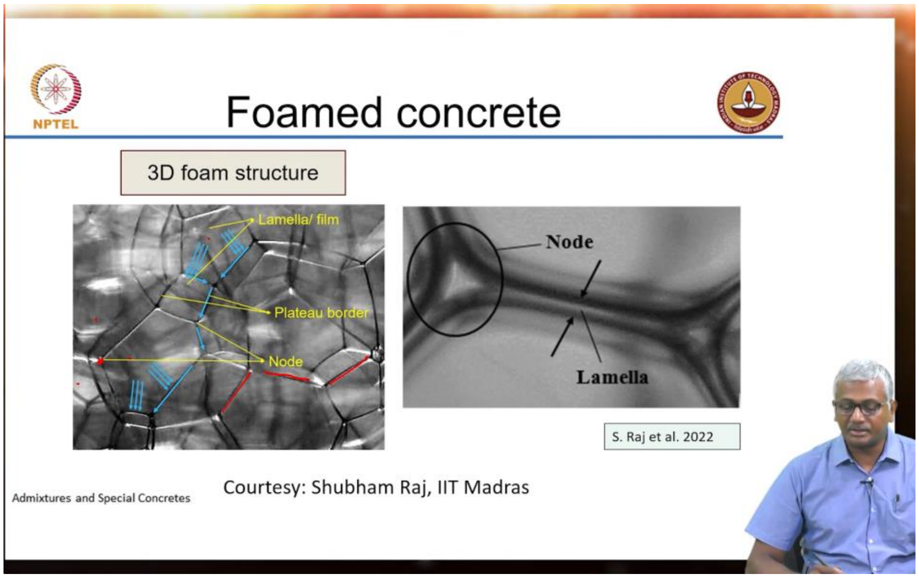

This shows you the foam structure, the structure of the foam itself under a microscope. So, you can see very clearly each individual bubble and the joining bubble next to it.

So, these are the boundaries between the bubble and that is the actual film. The bubble film is the lamella. These are called plateau borders and where several bubbles meet those locations are called nodes. Just a clearer example of the nodes and lamella at a higher magnification that can show you the details of each bubble meeting the other one.

Strategies for enhancing foam density:

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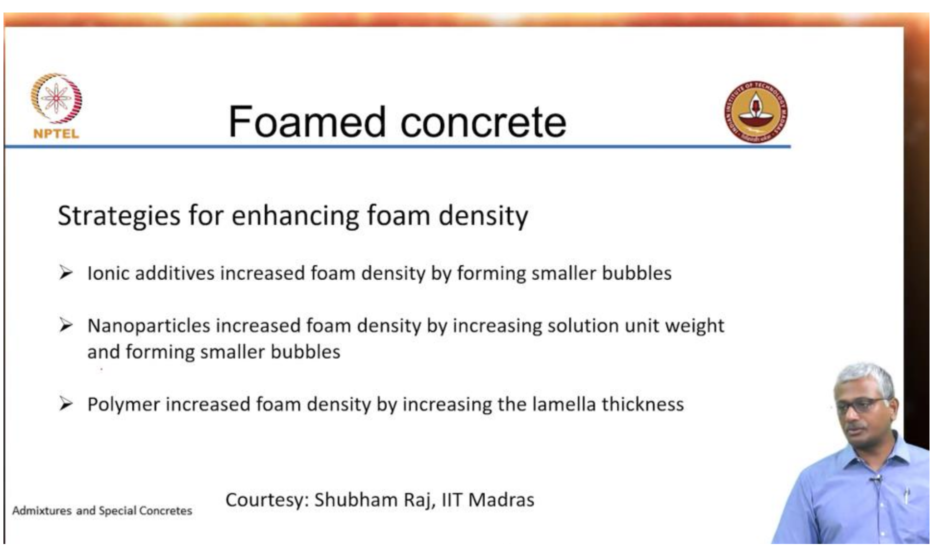

Now foam density, not the concrete density but foam density.

What do you mean by foam density? Enhancing the extent of air that the foam can carry with it in a stable way into the concrete. So that is the foam density. You can enhance that by putting in ionic additives which increase the foam density, and lead to the formation of smaller bubbles. When the bubbles are smaller, they will not collapse easily. Larger bubbles can collapse fast but smaller bubbles will not collapse easily.

Nanoparticles have also been known to enhance foam density. They increase the solution unit weight because again the same strategy applies. They will line the bubbles because they are very small particles. They are not going to have the weight to crack or break open the bubble but they will line the bubbles and keep it stable. Polymers can also increase the foam density because you can make the lamella or the film thicker which will cause the density of the foam to be better.

So, all these are important criteria for deciding how the concrete will become a successful lightweight concrete because if the foam starts collapsing then you will have an internal degradation of the structure which then will not achieve the required insulation or lightweight nature of the concrete as in the case.

Compressive strength vs density of OPC foamed concrete:

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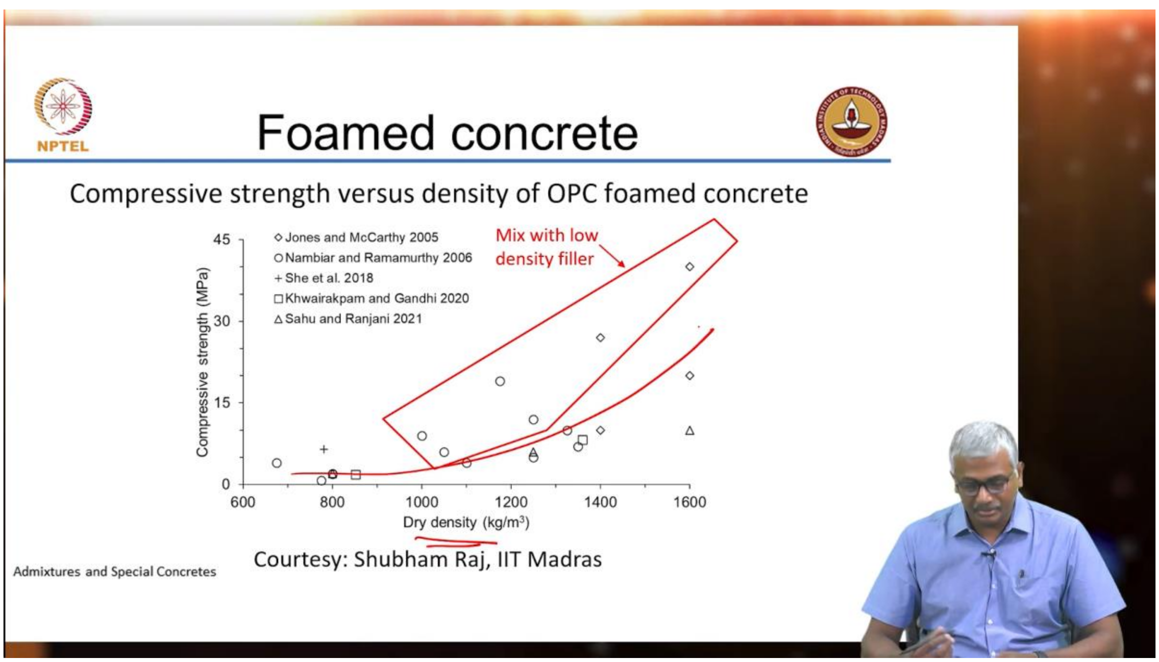

So again, it is obvious to think that compressive strength will go down as the density reduces. The lower the density the lower the compressive strength. So that is what you see mostly here.

The dry density of the system is presented. If you plot the compressive strength with it you see that there is a general increase in strength with an increase in density which you can readily imagine why that happens because you have less air voids in your system and that is the reason why you are getting lower strength with lower density. When you have more air voids you have lesser strength. And these are from several different research papers that have been looked at including several that were done at IIT Madras.

Range of Lightweight Aggregate Concretes (LWAC)

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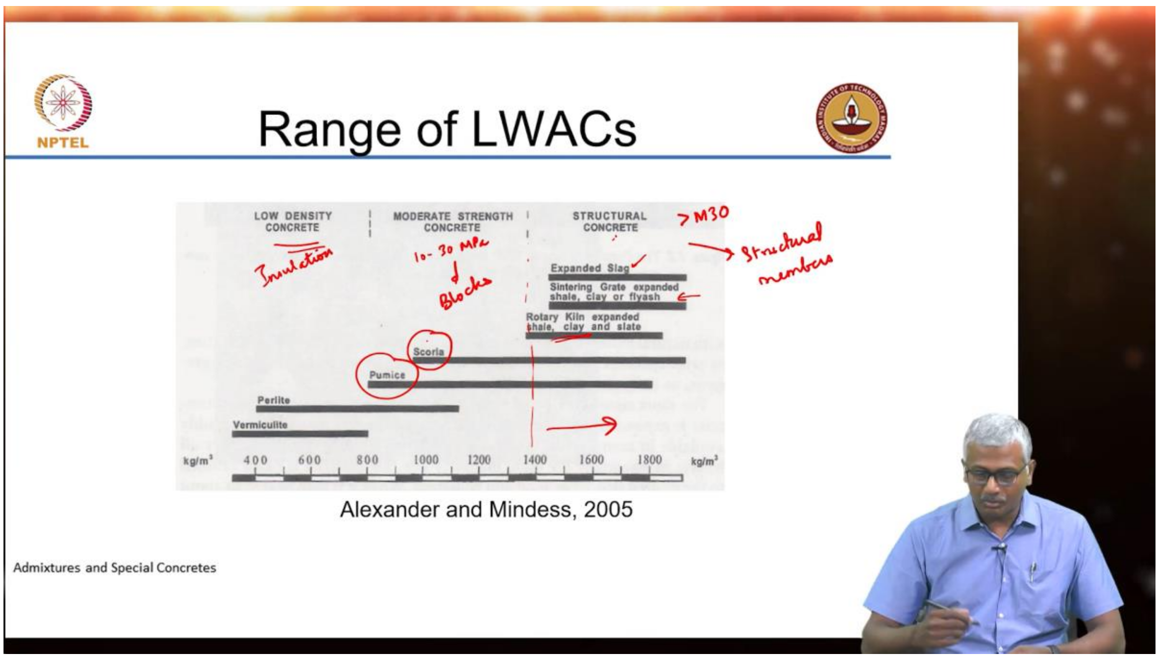

So that is about foam concrete. Now let us shift our attention toward lightweight aggregate concrete.

Lightweight aggregate concrete employs aggregates of a nature which are of low density and these could be either natural low-density aggregates or manufactured low-density aggregates. As I said structural concrete considers densities of more than 1400 kg per cubic meter and we consider light weight until about 1800. More than that can come into the realm of typical air-entrained concrete. So, it is not really considered as major lightweight aggregate concrete. So structural concrete must have a strength let us say of at least greater than M30.

Structurally we will be using strengths of more than M30. Moderate strength concrete is in between when you have 800 to 1400 density. We can look at moderate strength be 10 to 30 MPa. That could be still a stretch of 10 to 30 MPa with a density that is close to water is going to still be a stretch. But of course, low-density concrete here is primarily for insulation purposes we are not going to be able to use it for structural purposes.

So here these are for blocks concrete blocks and these can be for structural members. Yeah, service life is an interesting question. If you need service life, foam concrete is not the solution for providing extended service life. Of course, the air bubble system inside the foam concrete is uniformly distributed. It does not necessarily mean that it is going to enhance permeability significantly.

But yes, there will be some enhancement in permeability because whatever pores are interconnected will also lead to the air bubbles. So definitely there will be some continuity in terms of the travel path of any liquid that forces its way into the concrete. So these are not intended for high service life environments. You are looking at it when the solution demands that you lower the overall weight of the concrete element. For instance, if you are going to higher floors in a high-rise building, the structural walls that you make can be with lightweight concrete because your primary aim there is to reduce the mass of the overall structure because that will reduce the overall load that comes to the ground story columns also.

On the other hand, when you are using concrete blocks, the idea is to increase productivity by lowering the weight. It is not intended to provide service life. In a service life, we are primarily concerned with reinforced concrete members. Of course, when you are using structural walls, they are going to be reinforced.

So, you must consider some aspects of that also. But the primary load-carrying capacity and the structural capacity are determined more by the frame structure that you have in the system. But again, service life is a concept that you do not typically think about when you apply lightweight aggregate concrete or lightweight concrete in general. So let us look at what type of aggregates lead to these 3 different classes of concrete. If you are going at the structural concrete level, you can have expanded slag which means at the time of actual formation of the slag you remember that slag is formed from a molten state.

It is solidified by quenching. At that point in time if air is introduced into the system, it will encapsulate air and that will become an expanded system that has a lot of porosity inside the slag and that will be a lightweight aggregate. You can also sinter sorry sintering grate expanded shale. Basically, shale has a foliated structure. If you can expand that by pushing in air through the foliations that will lead to a lightweight aggregate or clay or fly ash can also be used in the system.

Clay also can be expanded because of its layered structure. Fly ash on the other hand as I talked about earlier you can fuse particles of fly ash, pelletize it, and then sinter it, and that produces a good lightweight aggregate. Fly ash density is not much, it is only about 2.2. So, if you are pelletizing it, it will encapsulate some air in the system and you will end up producing somewhat of a light low-density material but not very low-density. That is why you are only able to get 1600-1800 kg per cubic meter of concrete with it.

Again, here shale, clay, and slate using a rotary kiln expansion technique. There are different ways of providing expansion within your material either a sintering grate or a rotary kiln. Those are different processes by which you can do the expansion. Expansion simply means entrapment of air in the system. The entrapment of air while forming a material is your expansion.

Pumice and scoria are lightweight volcanic rocks that are formed because of the fusion of the ash particles and then perlite and vermiculite are again systems that are created because of foliated structures and I will talk about that in just a minute.

Natural Lightweight aggregate:

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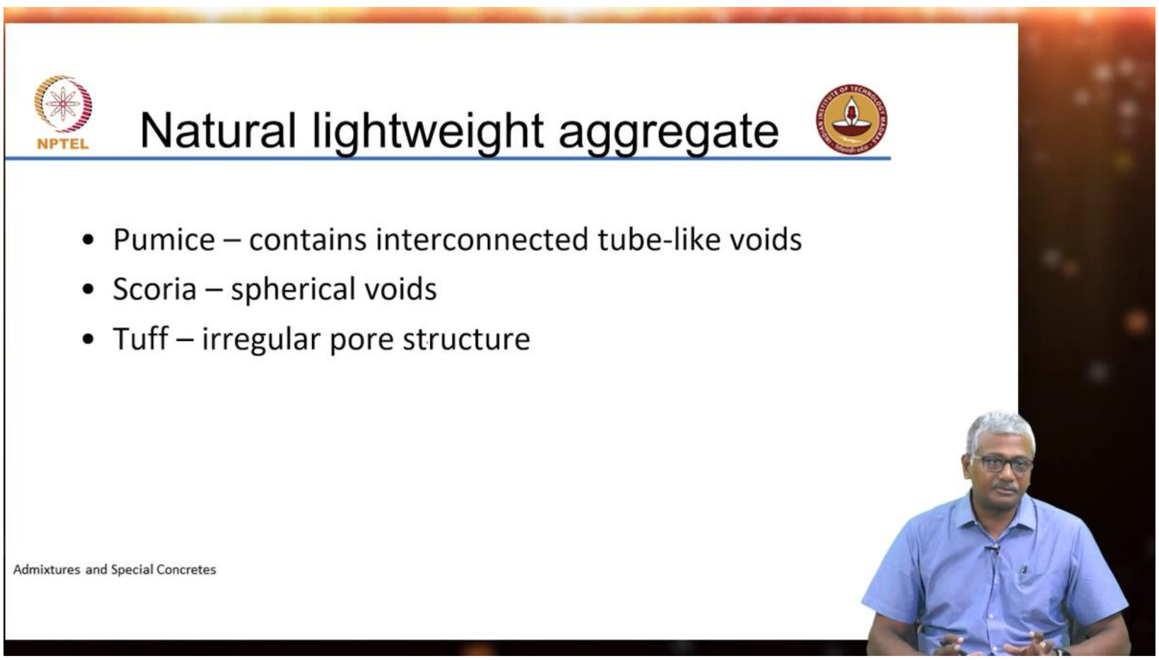

So, as I said natural lightweight aggregate includes pumice, scoria, and tuff and these are fused particles of the volcanic pyroclastic material that comes out. So, pumice can contain interconnected tube-like voids, scoria is known to have spherical voids whereas tuff has an irregular pore structure. Now of course, when you crush these lightweight volcanic-derived aggregates, what kind of a material will you get when you crush? Can you relate it to something we learned during the mineral admixtures section? This is ash, so it will be a pozzolan.

When you crush this material, you will get a pozzolan. That is how the term pozzolana was also derived from the eruption of a volcano in Italy and the subsequent deposition of the ash. That ash was used along with lime mortar and they found that it enhanced the properties of the lime mortar. Again, these ashes will become pozzolans but they are cemented together because of high pressures and that causes the formation of a lightweight rock. So, these will have some alkali reactivity perhaps that you have to still worry about. It is not going to be that straightforward to use them in lightweight concrete.