Admixtures And Special Concretes

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Lecture -46

Mineral Admixtures : Agricultural ashes - Part 1 : Sugarcane bagasse ash

Agricultural ashes:

Let us now move on to other systems that are also in prevalence but these form more what we call as local solutions and not global solutions. As far as silica fume, calcined clay, slag, limestone these are concerned they are more globally available but agricultural ashes are prevalent in certain specific geographies and not all over the place. But wherever they are available they do present a very viable alternative for utilization as blending materials and that is what we are going to look at in this segment of the chapter.

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Now one material about which we have talked about previously when we discussed are methodologies of determining the reactivity of mineral additives is sugarcane bagasse ash. Sugarcane bagasse ash is what you get by burning bagasse. Bagasse is the fibrous material that you get after extracting the juice from sugarcane right all the fibres remaining are called bagasse and when this is burnt in the boilers in sugar-producing factories they burn it because it got very good calorific value and the heat generated can be used to refine the sugar first of all or I mean to produce steam to refine the sugar or it can also the steam could also be used to generate electricity.

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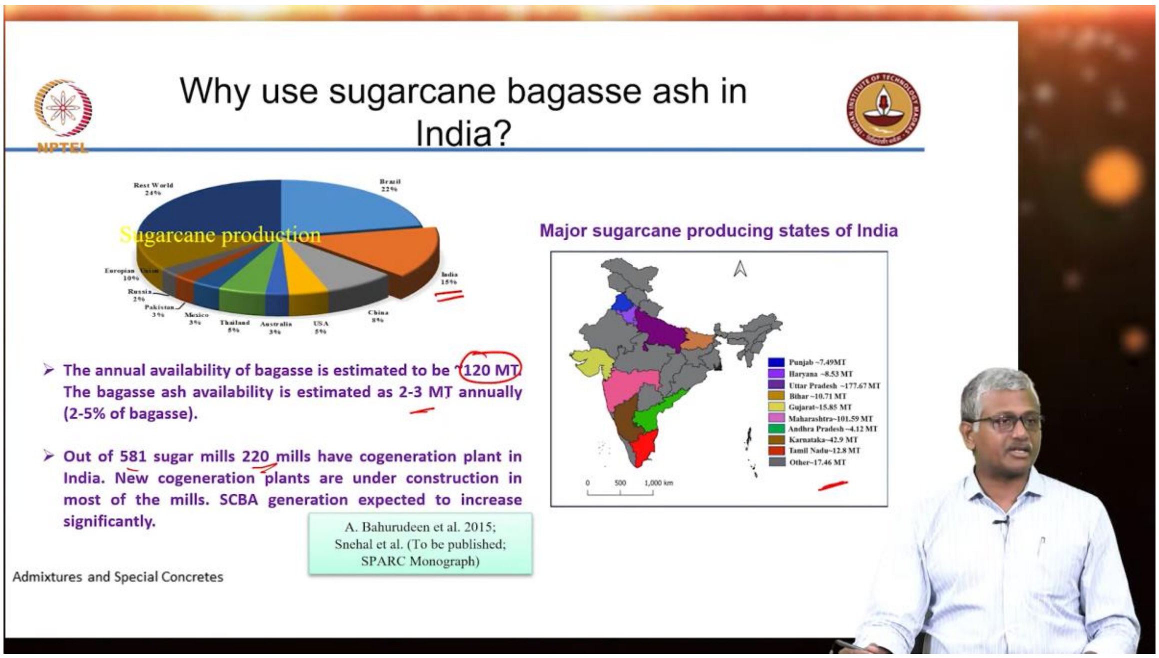

In fact most of these cases the out of the 581 sugar mills that are present in the country about 220 have cogeneration plants. And cogeneration plant means they can also generate electricity and feed it into the state grid and that is what is happening in many of these sugar factories that they are producing more power to be fed back in the grid and for new sugar mills at least in Tamilnadu there is a clear directive that they have to have a cogeneration plant. So, you are going to see increasing production levels of bagasse ash because burning is going to happen and obviously for the benefit of extracting the calorific value of sugarcane bagasse this is going to continue for some time and as you know India produces a significant quantity of sugarcane second only to Brazil in the world right and several states in India are producing significant amounts of sugarcane most of the southern states- Tamilnadu, Karnataka, Andhra then you have Maharashtra and Gujarat and in the northern states from the Indo-Gangetic Plain basically is where lot of sugarcane are actually grown. UP is one of the largest sugarcane manufacturers or producers in the country.

So you can see very clearly that all of these states are leading in terms of production of sugarcane in the country. About 120 million tons of bagasse is available from the processing of the sugarcane. And when it is burnt the quantity of bagasse ash that is available is nearly 2 to 3 million tons. Now this is nothing as compared to fly ash obviously, this fly ash we are talking about 200 million tons right. Here the quantity is only 100 that of fly ash but it starts making sense when we think about the location of the sugar plants in comparison with the location of thermal power plants as seen from the point of view of a ready mix concrete manufacturer or a cement manufacturer. So for a cement manufacturer trucking a large amount of fly ash from a far-off distance may be a difficult proposition may not be an economical proposition but if nearby a sugarcane or sugar processing factory is available where bagasse ash is there that could make a viable alternative for use in blended cement as opposed to bringing in fly ash from far off. So that is something that needs to be looked at in more detail for in order to actually start thinking about use of bagasse ash in a large way.

Sugarcane bagasse Ash- Physical and chemical characteristics:

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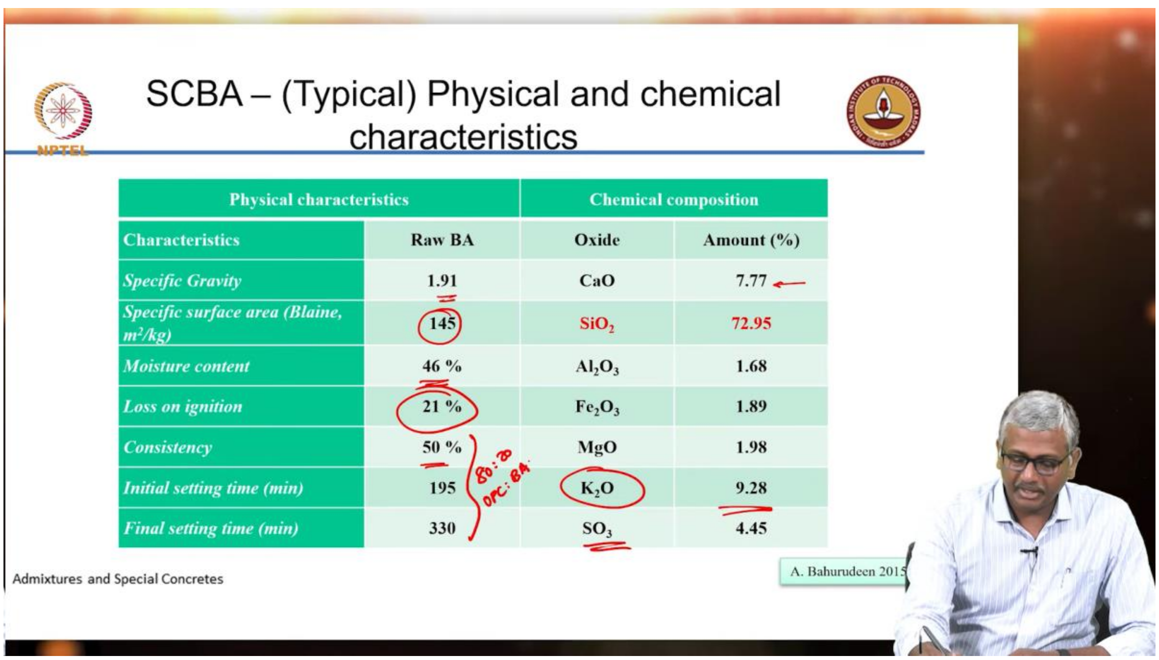

So what does bagasse ash contain? Again it is a silica-rich material so as the plants absorb the nutrients from the soil they absorb a lot of silica also and the silica is basically what strengthens the plant structure but it is not organic so all the organic components get removed by processing. The inorganic components are mainly consisting of silica. Some amount of calcium may be present but not always necessary. Generally, they will have a lot of alkali present. Alkali content of such materials or agricultural ashes is going to be significantly high.

Alkalis and sulphates are possibly coming from your fertilizers, imbibed from fertilizers and also from soil. So there will be some exceeding quantities of alkalis present but we have discussed this before that in mineral additives the presence of alkalis does not really signify anything wrong with the concrete system that you make with such additives because this alkali is going to be held within the glassy or pozzolanic structure of the silica and not available to react with the aggregate which produces the alkali-aggregate reactivity. In terms of the physical characteristics the specific gravity of bagasse ash is again close to 2 quite low. The specific surface area as compared to cement is only one-half and this is because of the unique structure of the bagasse ash which we will see in just a little bit. Generally, when you collect bagasse ash from the sites where it is dumped it will be very moist because to avoid this material from flying off they mix it with water and then dump it.

So that is why moisture content is very high needs to be removed obviously. So bagasse ash that you collect from dumping sites will be full of moisture you need to remove that moisture. If we will have lot of unburned carbon. In this sample that we collected from interior Tamil Nadu we had more than 20% loss in ignition. That is obviously unacceptable as far as a material to be used in concrete is concerned because too much carbon is going to create problems with the setting and hardening and air entrainment and all those kinds of things. And because of this interesting structure which we will talk about the consistency or water requirement for a cement bagasse ash mixture of 80 to 20 is significantly higher than what you have for cement.

What is the typical normal consistency level for cement? Close to about 30%, bagasse ash has 50%. So you can imagine water demand is getting increased in spite of the fineness being so low. Fineness measured by Blaine being so low. So that means there is something else to the structure which is quite interesting to look at. Initial and final setting times okay, not much different.

All these are for 80 to 20 mixtures of OPC to bagasse ash.

SCBA- Mineralogical characteristics:

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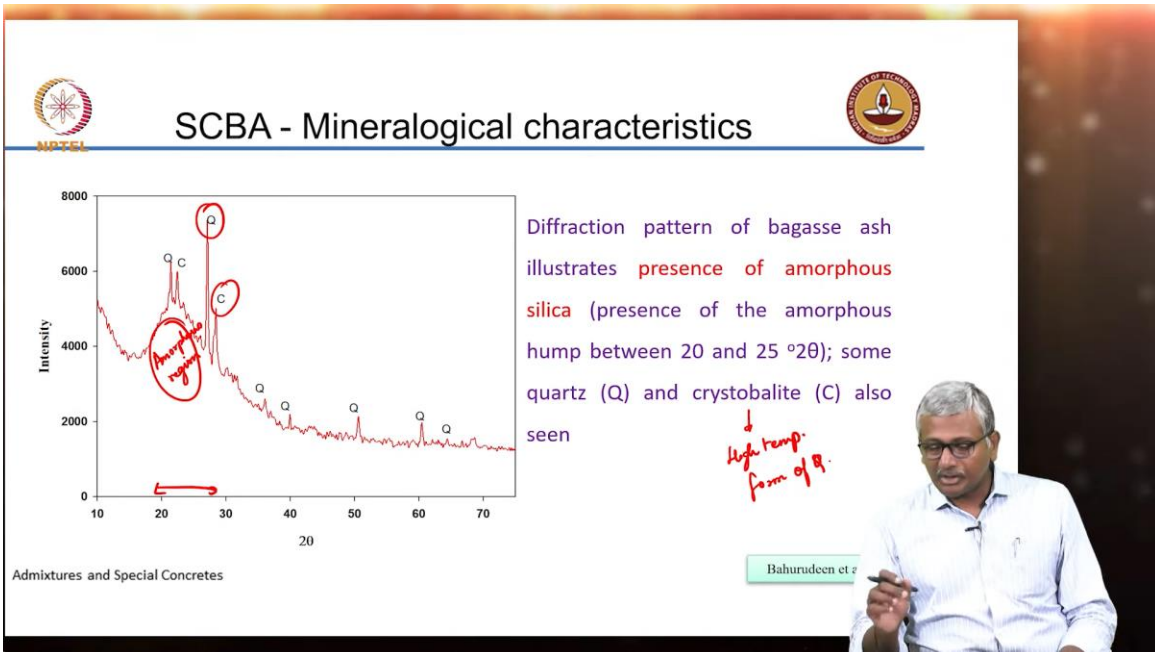

All these are for 80 to 20 mixtures of OPC to bagasse ash. And mineralogically again if you do an X-ray diffraction experiment on bagasse ash you will again see that there is very few crystalline components present. There will be a large amorphous hump as we discussed earlier and you can see that the region in which this amorphous hump is present is again similar to that of fly ash. But you do see some peaks of quartz and possibly also crystobalite. What is crystobalite? It is nothing but a high-temperature form of quartz.

It is a high-temperature form of quartz. Essentially because you are burning this bagasse in a boiler, although your burning temperature may be around 5 to 600 degrees but some parts of the boiler may have a very high temperature. So when you heat quartz up to about 900 to 1000 degrees Celsius you transform into this phase called crystobalite. So you could form some crystobalite also. Now interestingly one thing that happens in nature is when metamorphism takes place of igneous rocks and sedimentary rocks into metamorphic.

How does that metamorphism happen? Because of temperature and pressure. Because of temperature and pressure metamorphism happens and often such crystalline alterations are seen in metamorphic rocks. So when quartz is transformed to crystobalite you now have a situation in which a relatively inert material like quartz is getting transformed into something which may be active in the case of alkali-silica reactivity. Not just that even the fact that the structure of quartz is altered because of temperature and pressure can lead it to become more reactive than it already is. That is why if you keep on grinding quartz a lot, if you grind it too much, if you grind it very fine not only do you make it finer you also alter the crystal structure because of all the pressure that you give while grinding.

And that can also activate quartz to some extent. Same thing happens in metamorphism when you transform quartz to crystobalite some activity may get induced and you may actually end up having alkali-silica reactivity tendencies from crystobalite-bearing rocks. So again that is something you need to be careful about. Nevertheless, what you see is a very high degree of amorphous nature is observed with the case of sugarcane bagasse ash.

SCBA- Barriers to use:

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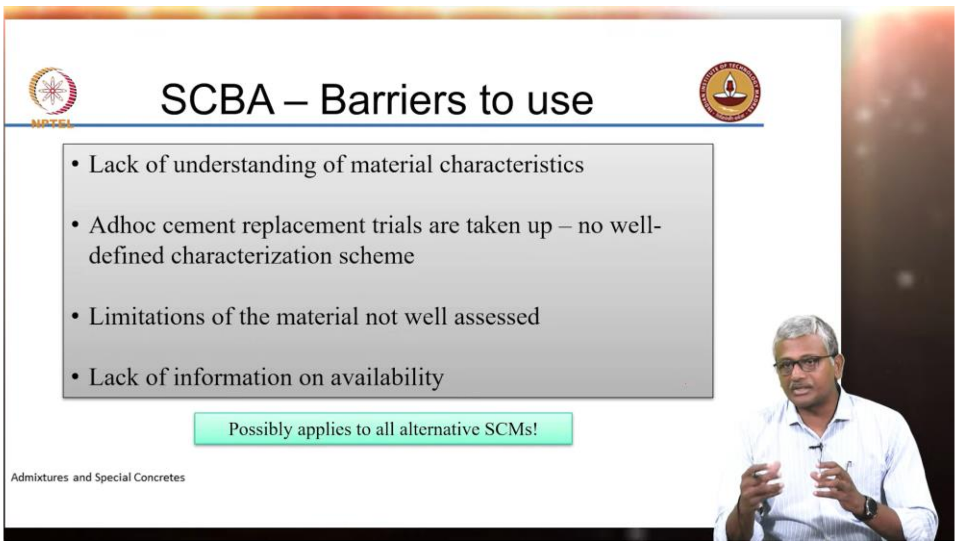

Again people are not using this because obviously they do not know very well about it. Many of the research studies that was done prior to about 2010 where people still had a knowledge of this material for many years but there was no significant scientific systematic effort to really look at how this material can be taken forward. Limitations are there which are not very well addressed and availability information also was not clearly known at that particular time. So the thesis that was done by one of my previous students Dr. Bahurudeen looked at these characteristics and looked at the availability also in a very close way. We also have a current project which has been undertaken with the help of sponsoring agency where our students are looking at mapping the ash locations across the country so that we have a clear idea about availability.

What I also have to tell you which I will again emphasize towards the end of this segment is that often times when ash is getting dumped it is not from a single agricultural source. Sometimes you get mixed ashes wheat straw, rice straw, sugarcane bagasse, rice husk all of these can actually lead to mixed ashes and very often what you get is not a single-sourced ash. So, you have to really do a good job of characterizing these materials and try to understand their reactivity and then use it in concrete.

Scope of IITM Project:

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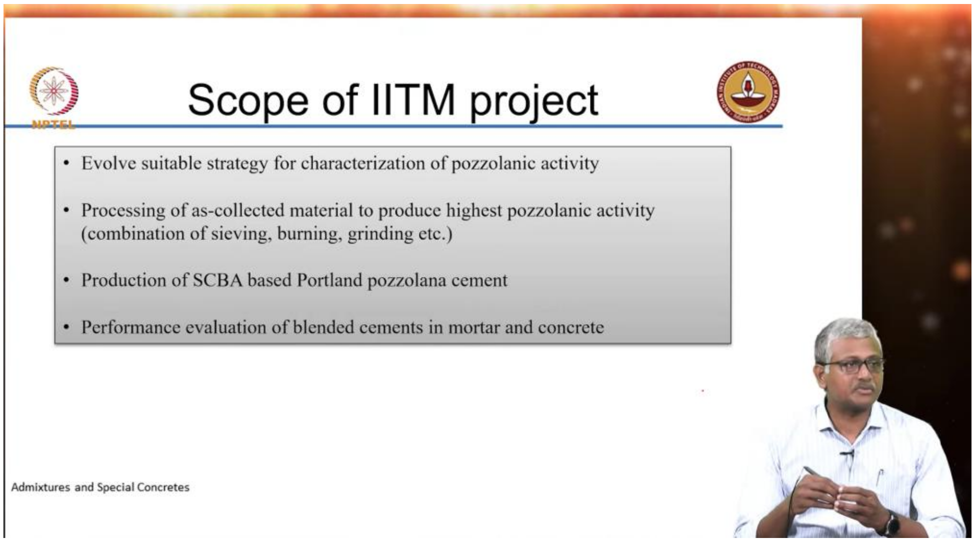

So what we wanted to do at IITM was to evolve a suitable strategy for characterization, process the as collected material to produce highest pozzolanic activity and produce SCA waste or sugarcane bagasse ash based Portland pozzolan cement and then evaluate these blended cements in mortar and concrete.

SCBA-based PPC- Oxide composition:

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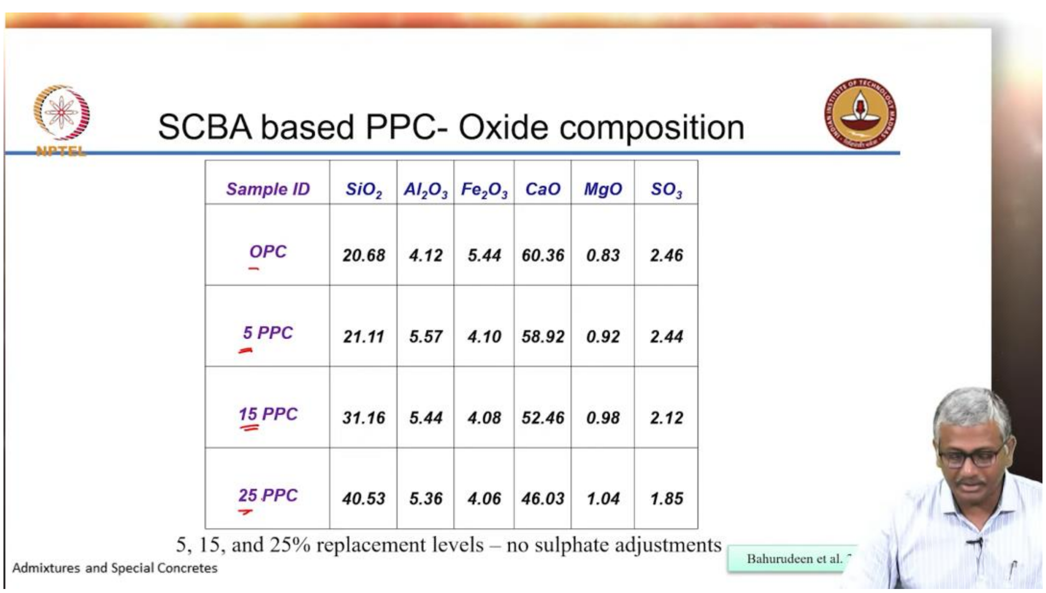

So, here what I am presenting here is basically the oxide composition of OPC replaced by 5%, 15% and 25% bagasse ash without adjusting for the sulphate contents that is the kind of chemical composition that you have for the cements that have been tested in this study.

SCBA-based PPC- Physical characteristics:

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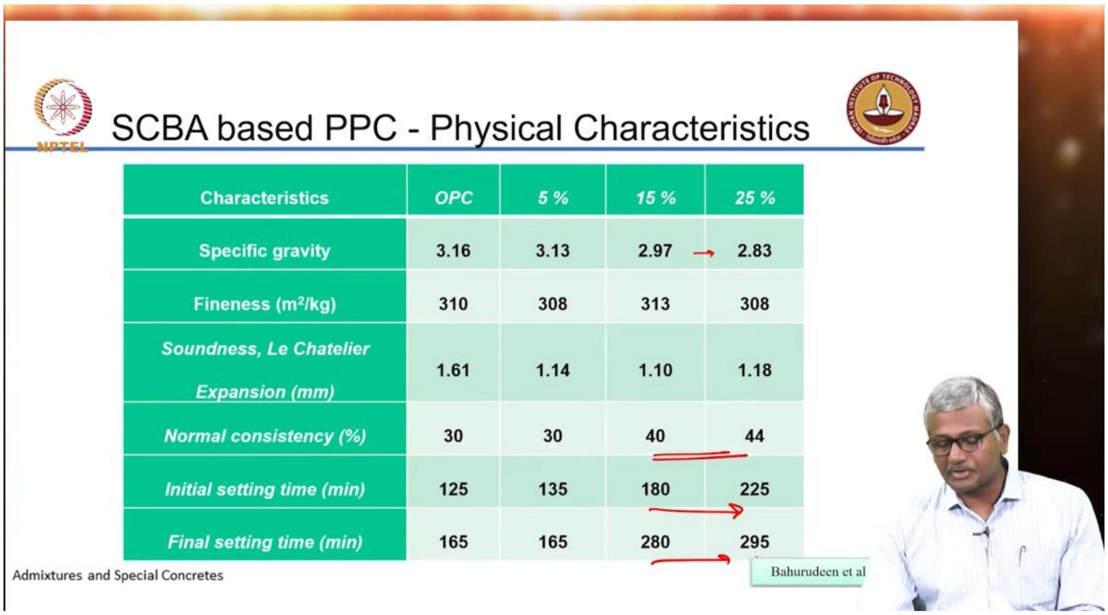

And physical characteristics you can see as you increase the replacement of the bagasse ash the specific gravity of the cement comes down because you are replacing a denser component with a lighter component.

The fineness, the processing of this material was done in such a way that the fineness could be controlled to the same level so you can see that all the fineness are nearly the same. The soundness in terms of Le Chatelier expansion is within the controlled limits. Normal consistency as you increase to 15 and 20%, 15 and 25% you see that the normal consistency are going up significantly that means the water demand of bagasse ash is significantly more. Initial setting time again is getting increased, final setting time is also getting increased primarily because your pozzolanic activity is going to be slower as compared to your cement reaction. This is again for 15 and 25% for 5% you do not really see much of a distinction.

Microstructure of raw SCBA:

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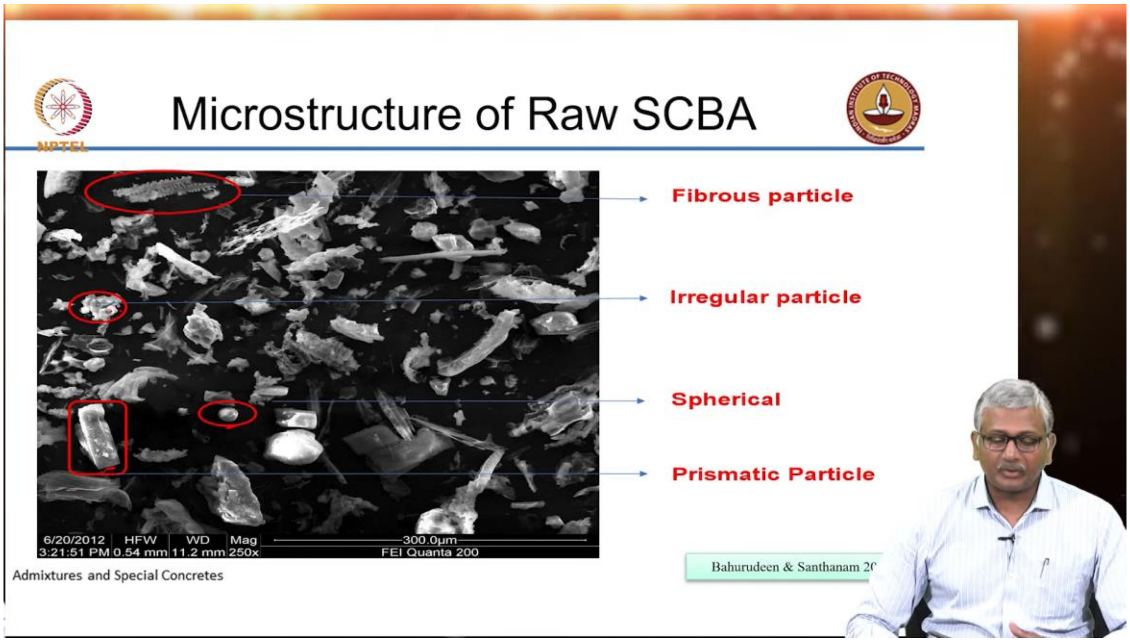

Now in trying to assess how to produce those cements first we had to do an understanding of what this bagasse ash is. So looking under the scanning electron microscope it is almost as if we have taken some garbage from the ground look at all the kind of things that are there in that. It almost looks like some random pieces of garbage that have been thrown together but if you really look at it closely and do some X-ray analysis to identify what these phases are there are some distinct fibrous particles which could be remnants of the original bagasse which are there which have not gotten burnt. There are some irregular particles, there are nicely defined spherical and prismatic particles that are clearly visible. Whenever something has a good shape it obviously means that it has taken some time to get crystallized. But whenever something is irregular it is an indication of some sort of amorphous phase present in the system.

Particles in sugarcane bagasse ash:

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So what we had to do next was look at what these individual phases are like. So again this is something I showed you previously that when we took raw sugarcane bagasse ash after drying obviously we sieved it through various sizes and we saw that it had these coarse fibrous units and fine fibrous units which were present in the system and they were also fine burnt particles which had no similarity in appearance to the fibrous materials. And I showed you during our reactivity discussions that when we use these fine burnt particles we were able to produce more than 75% activity index which indicated that those could be suitable for cement manufacture whereas the fibrous materials, did not have any pozzolanic activity at all.

Maximum pozzolanic activity of SCBA with minimum processing:

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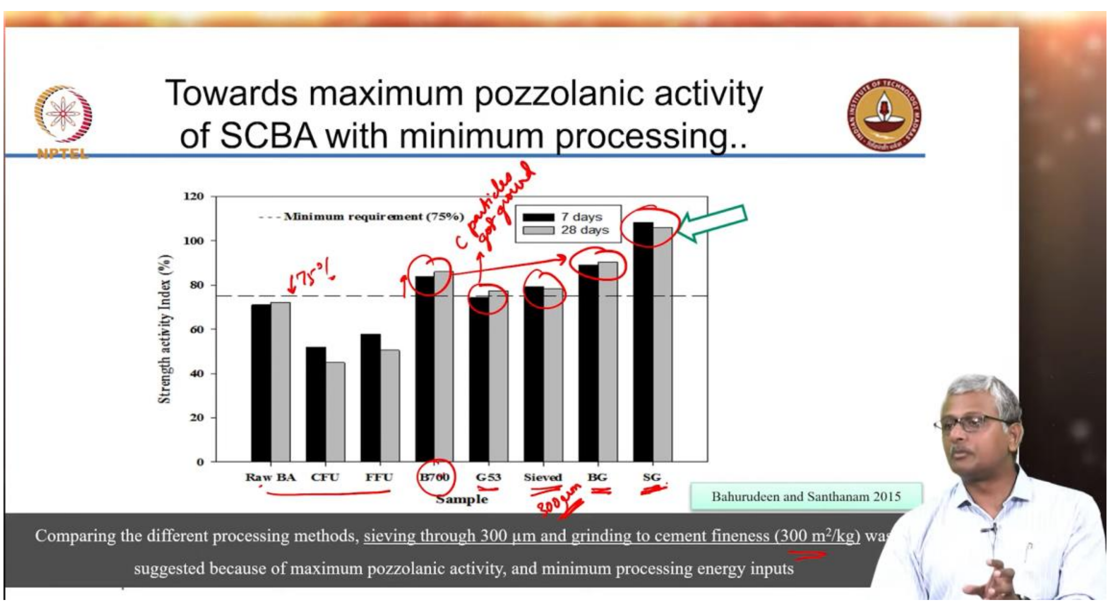

So to make a long story short we tried all other methods also to make the system as reactive as possible.

So as collected material we subjected to different types of processing. The first one was of course this is something which I have shown you before the raw bagasse ash the fibrous materials were individually taken and assessed for pozzolanic activity you see that they are falling well short of the 75% mark. But when you take the same material the raw bagasse ash and burn it at 700 degree Celsius it seems to cross this level. That means if you give more energy in terms of thermal processing you are able to get this material to cross the 75% mark. Why? Why is that? Why is it crossing 75% now? Why is the burning itself able to do that? Yeah, you are removing some of the carbon that is present unburned carbon is getting burnt off to carbon dioxide and that possibly enhances the extent of reactive particles in your system that may be pushing up your the reactivity of the overall bagasse ash.

Now we also ground the material to 53 micron size or below 53 micron that is sieve that is available 53 micron. So we ground the material all the way down to below 53 micron and that just about met this level. This is a very interesting result because we believe that okay when we grind material finer we should produce a much more reactive material. But when we did a microstructural studies of the system we saw that the carbon particles were actually getting grown and the silica particles were not really getting ground because carbon particles were softer this grinding basically ground the carbon particles to be much finer. The silica did not get ground much at all.

But just sieving this through a 300 micron sieve resulted in a better performance achieved a required level of pozzolanicity just sieving the material was enough. Sieving and grinding to cement size to 300 square meters per kilogram increase the reactivity to a level which is even beyond the cement. So it is more than 100 percent indicating that sieving and grinding was able to produce a material that can replace cement pound for pound or kilogram for kilogram without any drop in strength. Burning and grinding it produced a good result that means this burnt sample was ground further and it marginally increase the pozzolanic reactivity. But sieving and grinding which involves possibly the least energy out of all these things because grinding is anyway done together inside the ball mill and sieving is an industrial process that probably involves much lesser energy than burning.

So all of these factors give you an understanding that you could then define a processing strategy that can get maximum pozzolanic activity out of this material. So sieving and grinding was chosen to produce these blends.

Material processing and production of SCBA based PPC:

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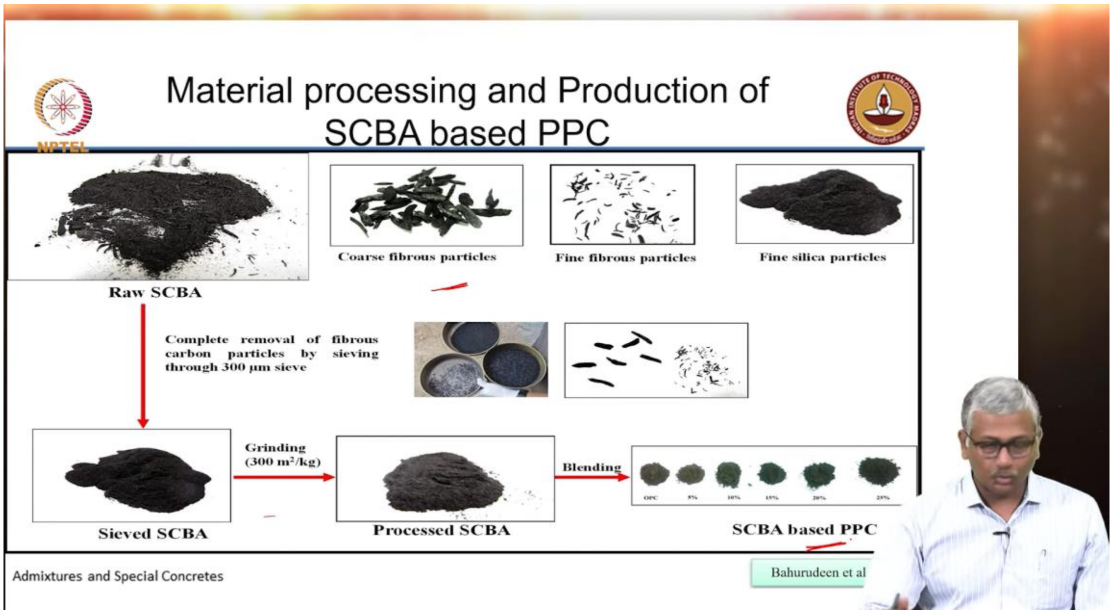

So as I said sieving to remove the fibrous particles and then grinding to cement size was used to actually produce the Portland pozzolan cement of which the properties I have already shown you previously.

SCBA based PPC- Particle size distribution:

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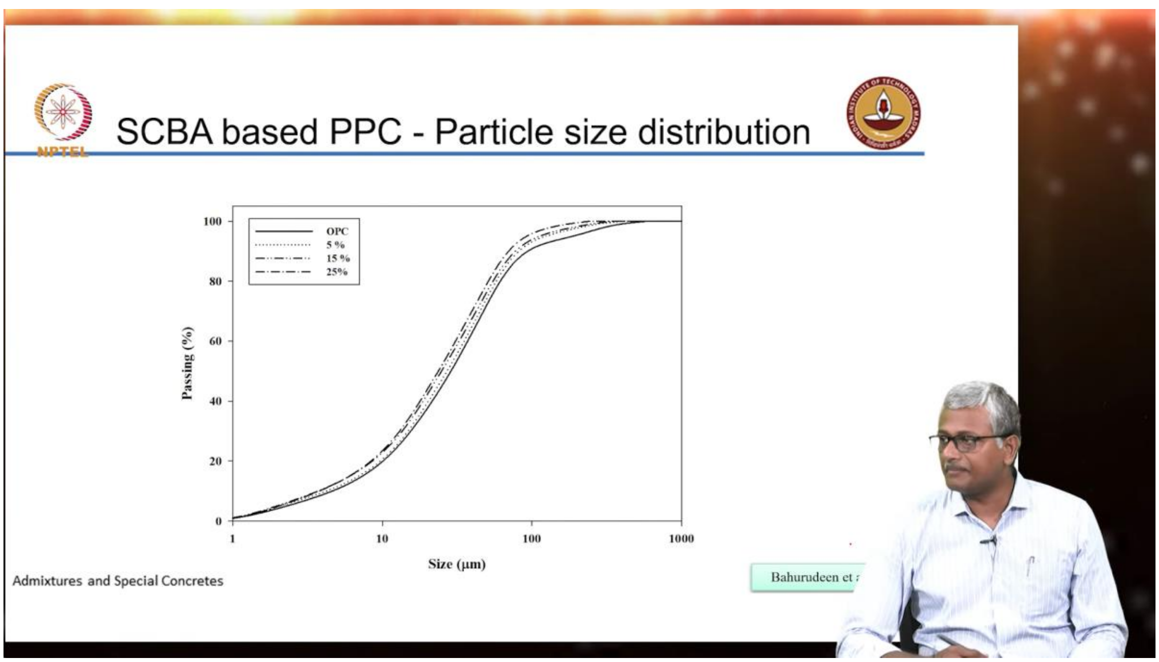

And you can see that all of them are ground to nearly the same particle size distribution. So blends only gives you an approximate average fineness of the particles but you have to do a proper particle size analysis to get this result and you can see that all of these systems have nearly the same particle sizes.

Experimental details:

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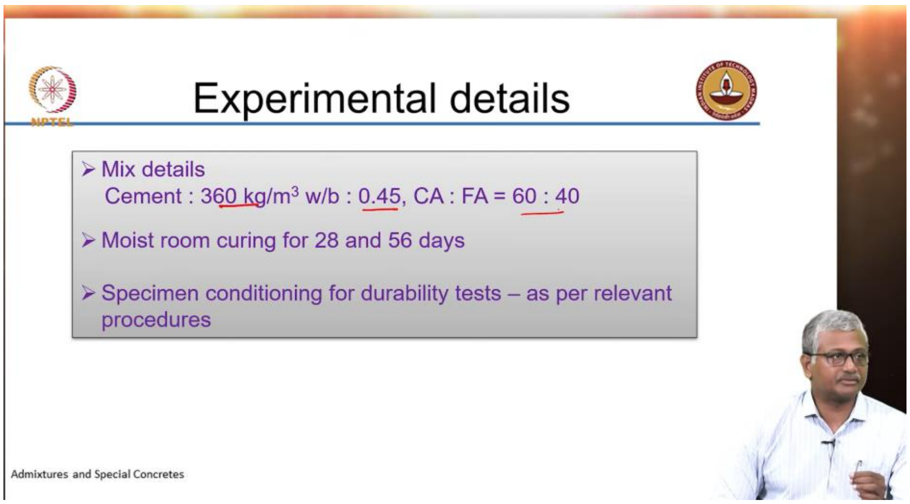

So we made, then concrete with these cements. The concrete had the same cement content and water binder ratio and the same coarse to fine aggregate ratio. Superplasticizer was adjusted in the mixes to compensate for the increase in consistency of the bagasse ash based cements and we went for a constant slump in all the concretes.

Compressive strengths:

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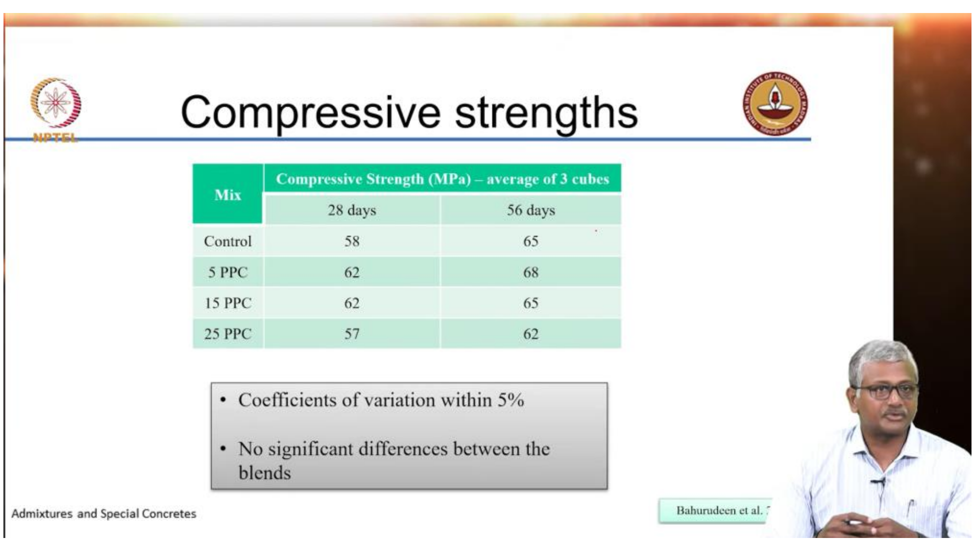

As far as strength is concerned you really do not see any distinction in the performance. Up to 25% there is really no change in the strength as compared to your plain Portland cement mixtures. There is no real cause for worry as far as using it as a pozzolanic cement is concerned.

Durability Test methods:

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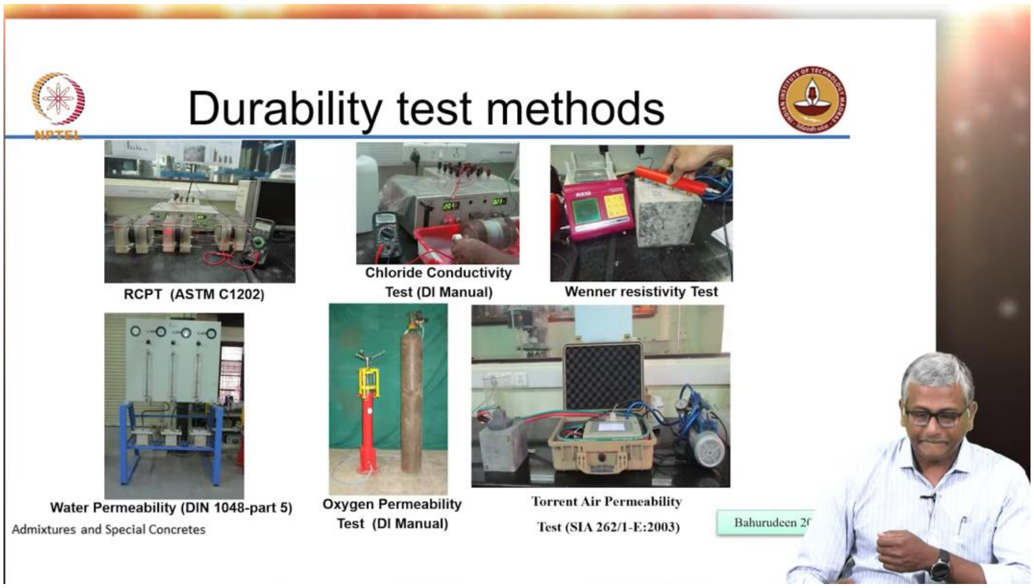

Again durability test methods where as per several different methods as I showed you previously for the fly ash and slag systems also.

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An interesting observation here is that you can see the kind of surface texture this bagasse ash is given to the concrete. It is given at a very dark color and very interesting to note that the perception of people in terms of concrete is very different with respect to the color. If you are in the southern and western parts of India the darker the concrete the better it is supposed to be because they are used to fly ash-based concrete.

So the darker concrete they think that it is right and people have put in sufficient cement in it. In the northeast part people are used to slag and slag produces a whiter concrete. So for them, if the concrete is darker something is wrong with it. Not the right cement is not being used. If you go to northern European countries like England for instance slag is very common there also they do not have much fly ash.

So when they use slag again they get whiter concrete and for them that color distinction can prove to be quite a decisive factor in acceptability of concrete. So here you are producing a concrete that looks so it has probably some geographical advantages in certain regions where you can show that maybe you put more cement in your concrete or whatever. For some reason people believe that more cement you have in concrete the better it is. Anyway, it will be very difficult to overcome that kind of a attitude in people's minds. You cannot really change that very easily and your advertisements on TV do not really help much.

Anyway, so this is just the preparation of specimens for durability testing. Okay. I should also make a note here about durability testing. Increasingly in projects we are doing lot more durability testing but what people on site have to also understand that the rigor with which these tests are done and the rigor involved in specimen conditioning preparation for the concrete durability test methods is much more than what we do for compressive strength. Compressive is simple we put it in water we take it at 28 days and crush it that is it.

Here you need to do a lot more. You need to do a lot more for specimen conditioning before durability and it is very important because it has a direct effect on the result.

Rapid chloride Penetration Tests:

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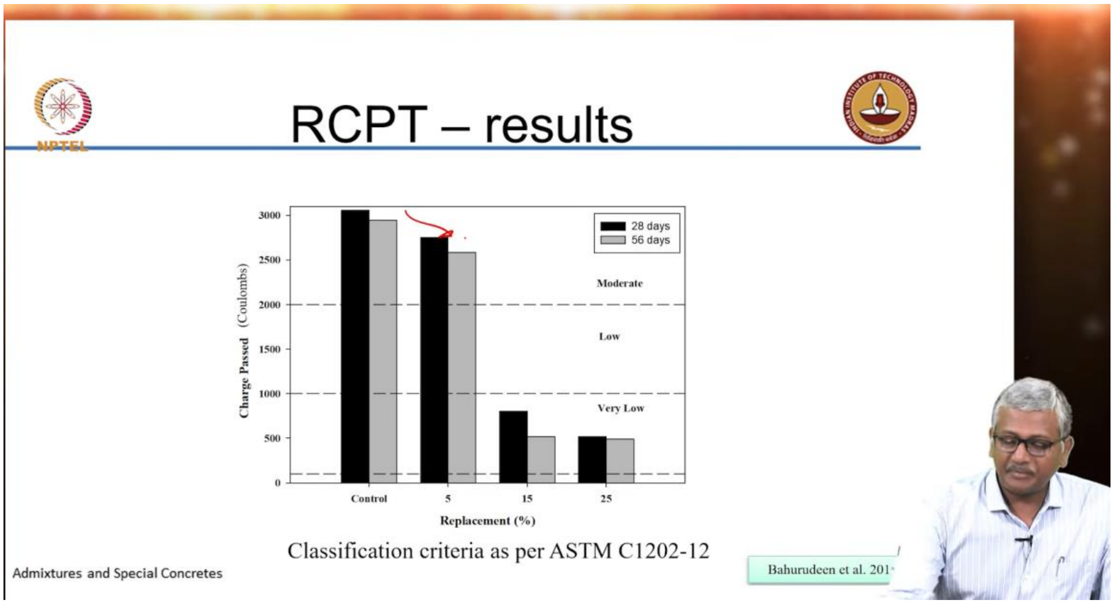

So in RCPT again for 5% replacement you do not see a major drop but at 15 and 25% your RCPT charge passed is falling to very low values less than 1000 Coulombs.

Chloride conductivity test results:

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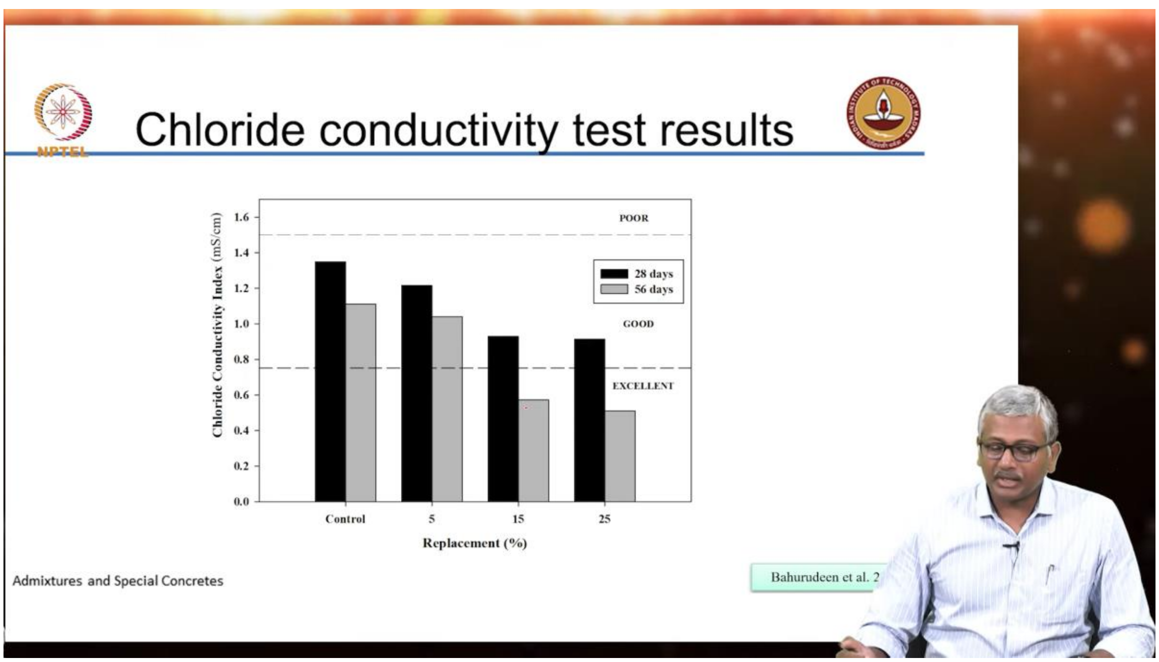

Chloride conductivity again you are producing much lower conductive concrete with respect to chlorides.

Oxygen permeability test results:

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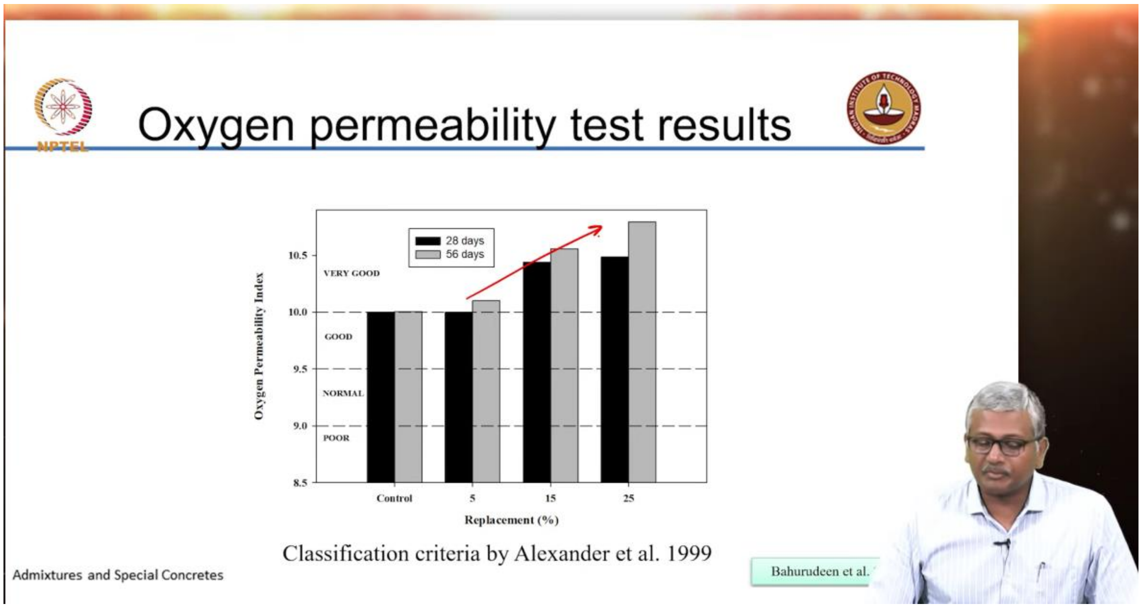

Oxygen permeability again your result here clearly this shows that with increasing levels of replacement, you are producing a concrete which is less permeable to gases. Of course qualitatively the performance of all concretes is a very good category.

Torrent air permeability test results:

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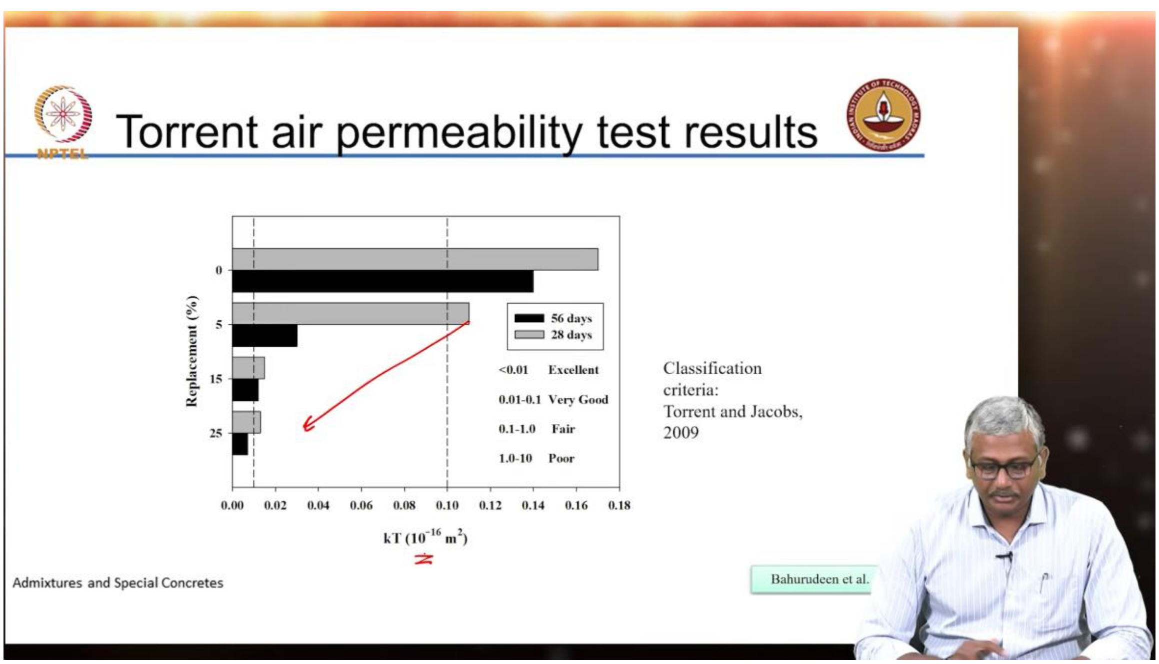

We also did another air permeability test on this concrete. This was based on an apparatus that is available for field testing. So this air permeability test method can be also applied to concrete in the field and again you see very clearly as you increase the level of replacement the permeability coefficient as measured by this test is coming down significantly. You see a major drop in permeability coefficient and of course the greater your cure the greater the drop.

Wenner Resistivity test results:

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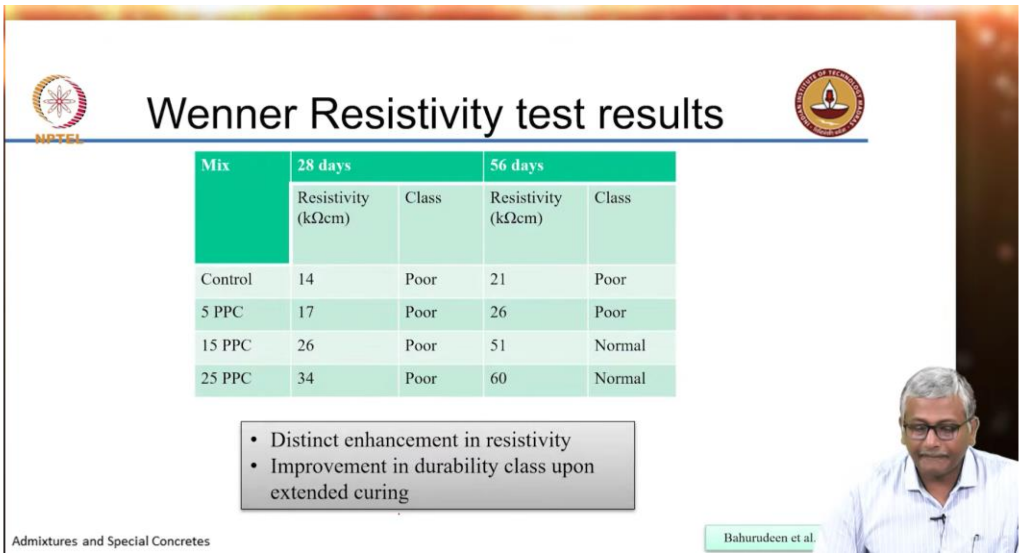

Resistivity once again you can clearly see at 56 days the increase in your replacement level increases the overall resistivity of your system indicating a better performance in corrosion.

Water Penetration test results:

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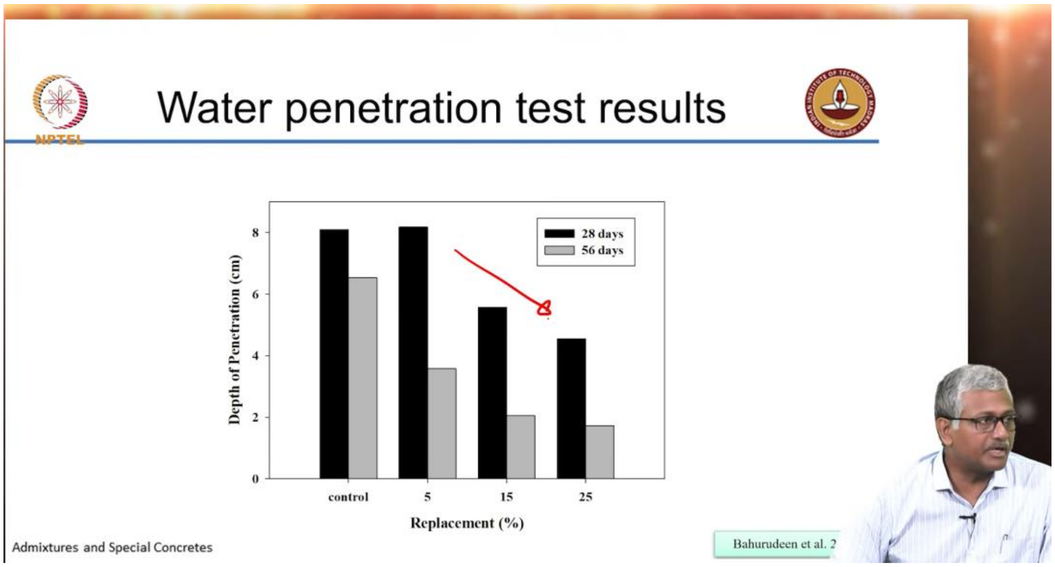

Water penetration test this is basically the common test that we used in the site where the concrete cubes are actually subjected to water pressure of 5 bar for a period of 3 days and then you split open the concrete cube to determine the depth of penetration of water and various job sites have their own specified standards for evaluation of the quality of concrete with that test method. So again you can see very clearly that in reality you are seeing a distinction when you have a greater amount of bagasse in your ash in your system you are getting much superior water penetration performance.

Conclusions:

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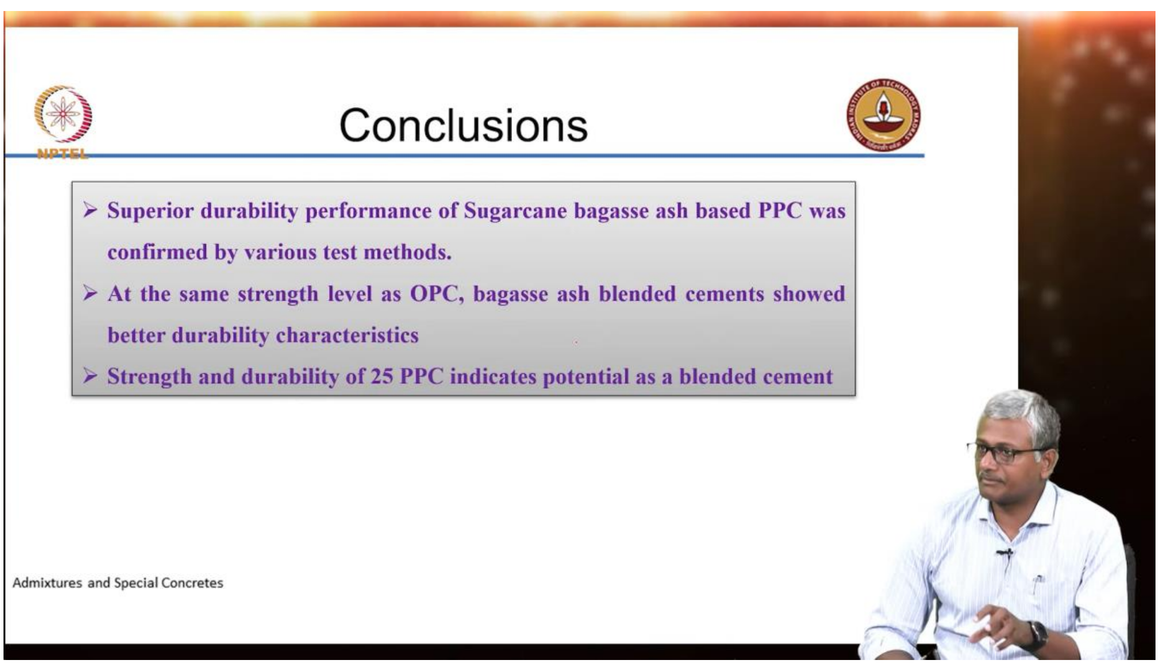

So in general what you are seeing here is that the benefit of bagasse ash is clearly established in terms of durability at the same strength level. So when you compare it at the same strength level in this case of course all the cements at the same fineness the compensation of the extra consistency was done by increasing super plasticizer dosage and not the water content. So all of those things you need to keep in mind while designing with alternative supplementary cementing materials.

So the upshot is that you have an option available in case fly ash is not there. You can start looking at agricultural ashes in case fly ash is not available.

RICE HUSK ASH:

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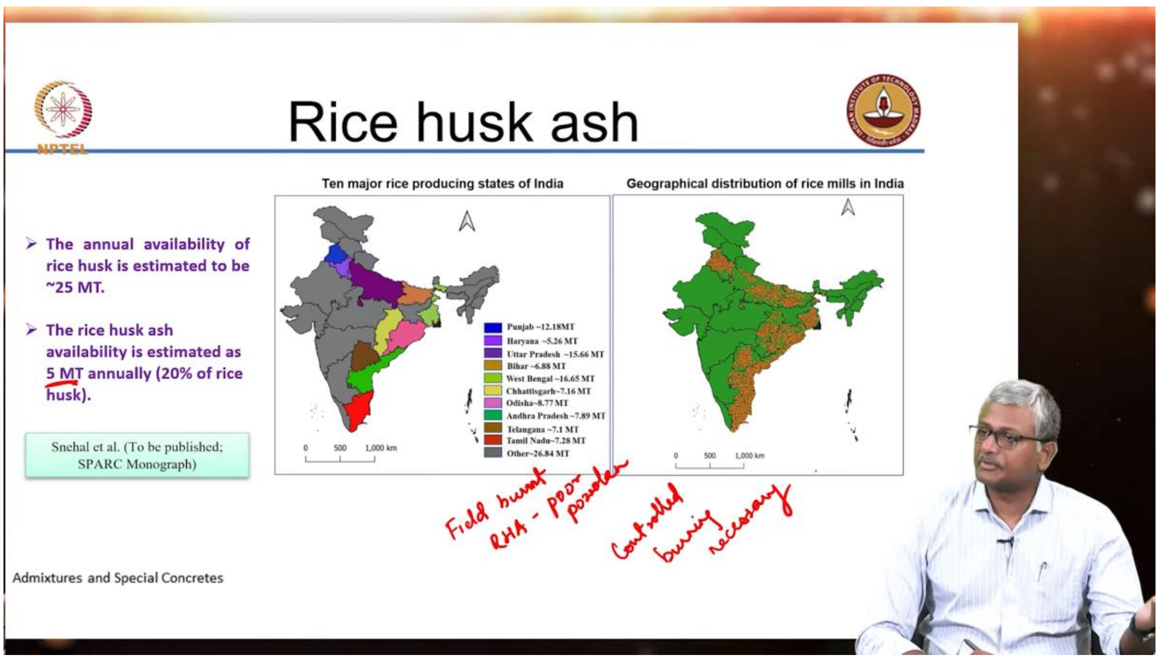

Now the other agricultural ash that is common in India is rice husk ash. Again the distribution of rice-producing states little bit different as compared to your sugarcane but some states are common in this case also. Annual availability of rice husk is about 25 million tons and rice husk ash which is about 20% of rice husk is again 5 million tons.

Quite a large amount. Now interestingly in rice husk much of the processing is actually done in the field itself. In sugarcane, the processing can only be done by bringing the entire cane to the sugarcane processing plant. But rice husk is not the same. They do threshing and they remove the rice husk on site itself and a lot of the rice husk is basically burnt on site itself. The field burning of rice husk leads to the production of a very poor pozzolan.

It is not reactive at all. So if you really have to burn it to produce a reactive pozzolan you have to bring it to a factory and have a clear temperature and time of burning established in order to get the right performance out of the rice husk ash. That is where the problem with rice husk comes. So although a large amount of it is available much of it is burnt in the field itself. So field burnt rice husk ash is a poor pozzolan.

So what you have to do is do controlled burning. So controlled burning implies keeping control on the temperature and the time. Because temperature is important from the point of view of the fact that if you have too high a temperature you will convert many of the phases to crystalline phases. They will not be reactive. If your temperature exceeds 850 to 900 degree Celsius you may actually end up converting many of the silica phases into crystobalite-type phases. And you do not want too much conversion to happen otherwise you will not get sufficient reactivity.

You want amorphous silica and that is what your rice husk ash is rich in. It has got much higher amorphous silica content as compared to bagasse. Bagasse ash gives you about 70 to 75%. Rice husk can give you almost close to 90% amorphous silica.

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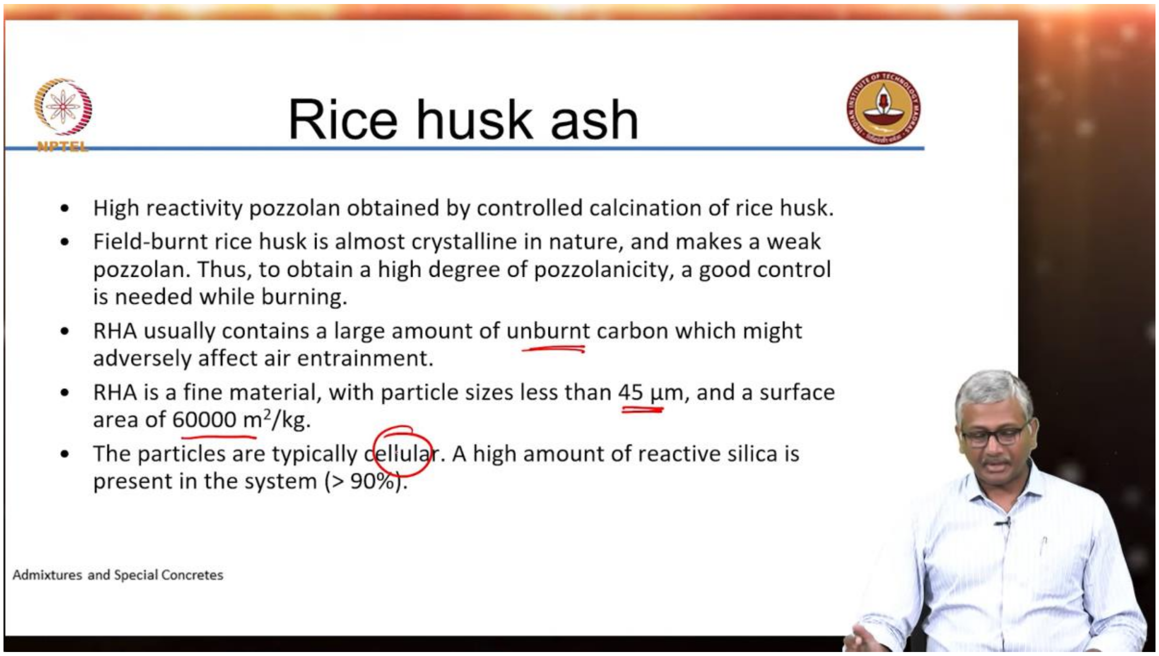

So, as I said high reactivity pozzolan is obtained by controlled calcination of rice husk. A field burnt rice husk ash is not really a good method. It contains as compared to other ashes I mean as compared to fly ash the unburned carbon in any agricultural ash is expected to be greater because the burning is not always uniform and some of the carbon may not get burnt just like your bagasse ash you may have a high unburned carbon rice husk ash also. So processing has to be done properly. Interestingly what you ultimately get with rice husk ash is a very fine material with particle size is less than 45 microns and surface area of 60,000 square meters per kilogram. Now this is looking quite different right. In cement we had a particle size of 15 micron but surface area was only 300 square meters per kilogram.

So, there must be some difference in the structure of the particles which increases surface area so much. That is because the particles are cellular they have a lot of air cavities inside and thus large air cavities increase the extent of reactive surface that is available and the fact that you have most of this material as silica makes it a high reactivity pozzolan.