Admixtures And Special Concretes

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Lecture -45

Mineral Admixtures : LC3 - Part 3 : Durability Performance

Sorptivity Index:

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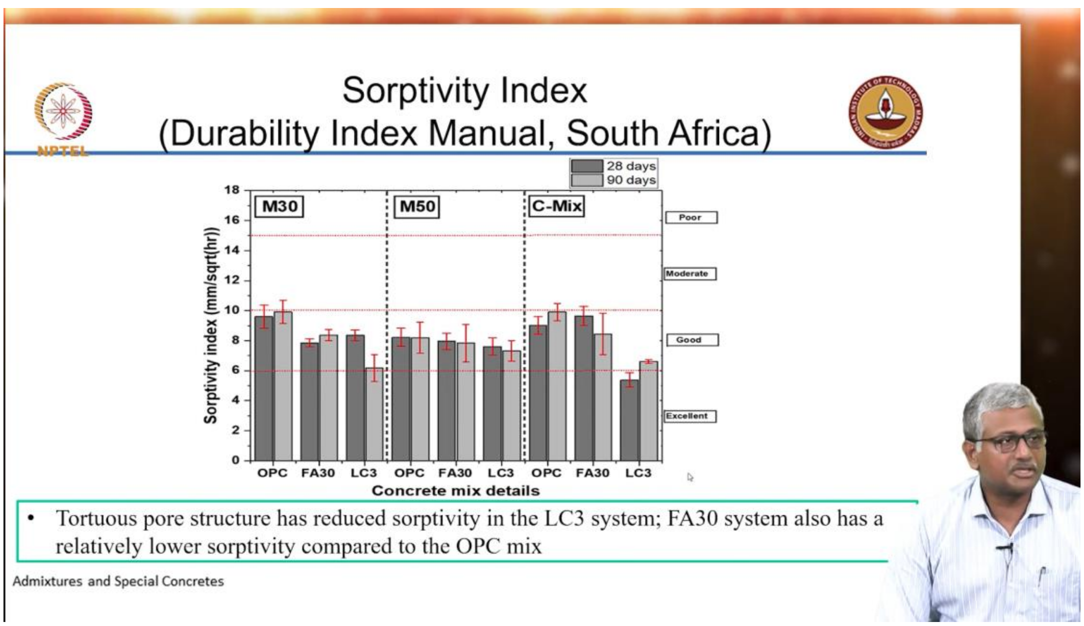

Okay, so we were discussing about the performance of limestone calcine clay cement and concrete prepared with it in comparison with regular ordinary Portland cement and 30% fly ash replaced Portland cement and what we saw is while the strength performance was almost equal there was a clear distinction in terms of the durability characteristics especially those measured with electrical methods pertaining to chloride exposure.

Water sorptivity:

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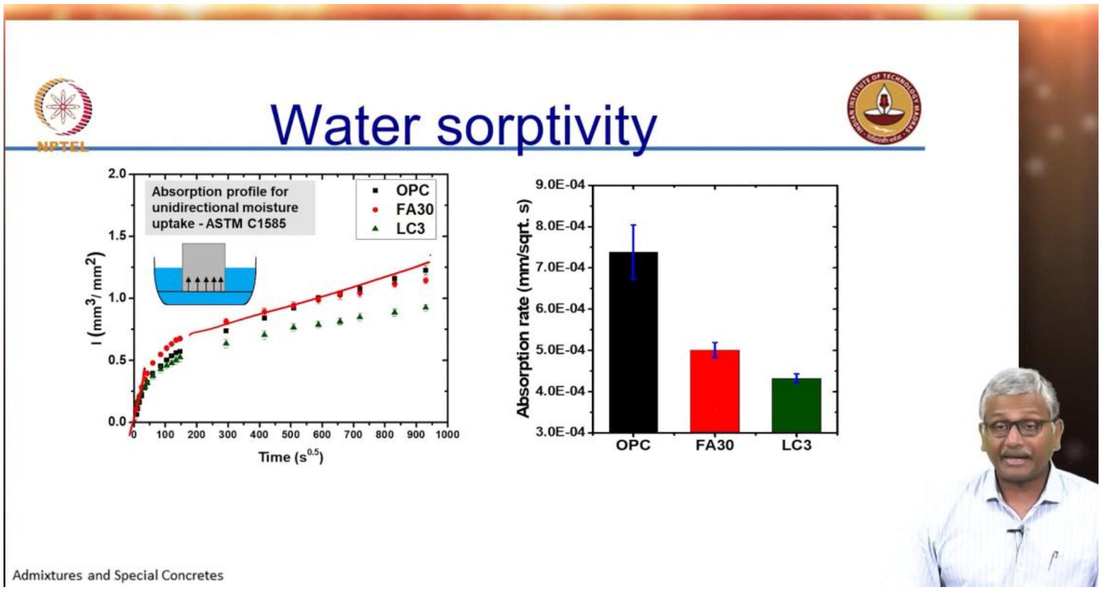

So, and I also mentioned that in water sorptivity studies there is often an issue of the comparison of the early age sorptivity to what you get in the long term. So essentially the absorption rate in the long term the secondary absorption rate you can clearly see the benefits of LC3 and fly ash-based systems as compared to ordinary Portland cement systems.

Oxygen permeability test:

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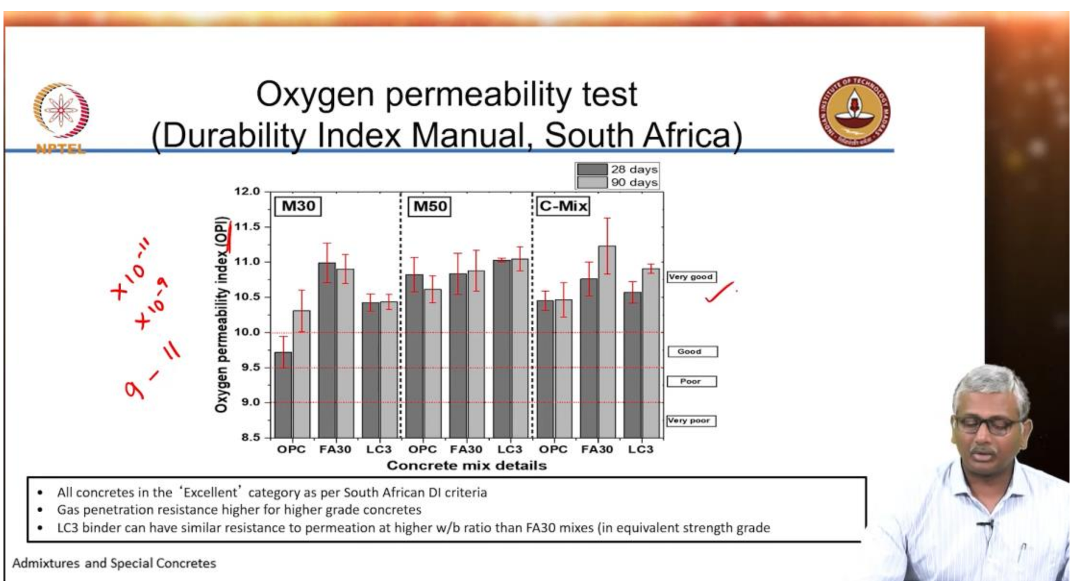

In terms of gas permeability, so oxygen permeability test is one of the common tests utilized to determine the permeation capabilities of a gas through a concrete system. The idea here is that you pressurize gas on one side of the concrete and look at the passage of the gas through the concrete by looking at the decrease in pressure on the side from which the pressure is being applied and that pressure is directly decreased and pressure is directly related to the permeability of the concrete. So more permeable the faster the pressure will decrease.

So here the permeability index is calculated as the negative log of the permeability coefficient. So usually permeability coefficient will be something like something into 10 to the power minus 11 or 10 to the power minus 9 or something like that. In that order let us say in meters per second or meter square per second depending upon what type of permeameter you use either a fixed head permeameter or a falling head permeameter. So in such a case the units will be obviously different but what happens is when you take a negative log you get actually a positive number you get either 9 to 11 in that order you will essentially end up getting your oxygen permeability index and that is what is being plotted here the oxygen permeability index has been plotted.

So the higher the index the lower the permeability. So you can see here clearly that again compared to OPC systems your fly ash and LC3 systems are marginally better although all the concrete seem to have a significantly good performance at least in terms of the qualitative classification proposed by the South Africans who developed this standard test method very clearly all the concretes almost are in the very good category.

Chloride profile after bulk diffusion:

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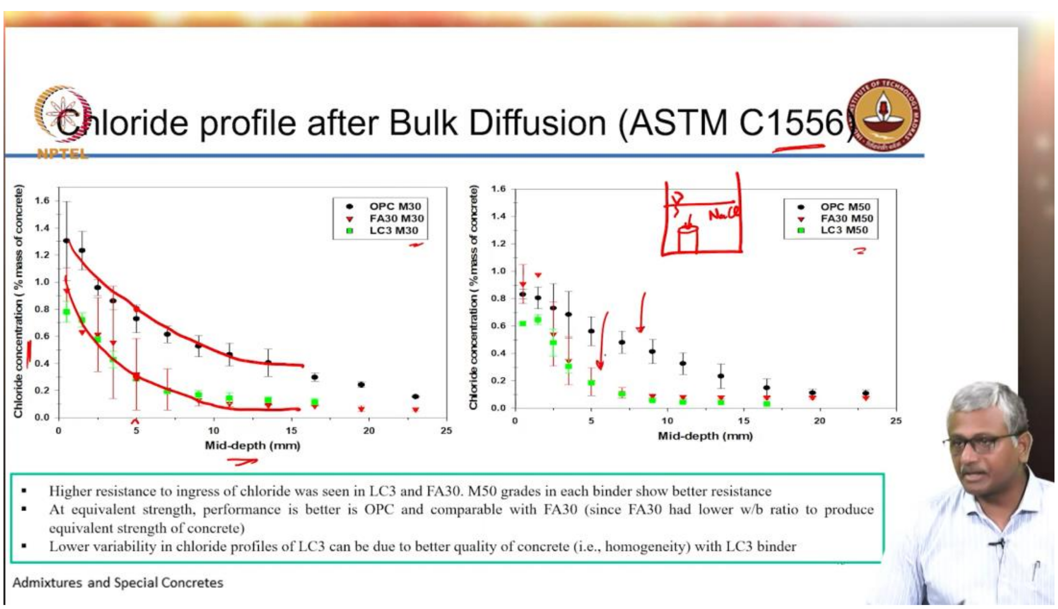

Now the previous methods I showed you with respect to chloride they were based on electrical migration which was enhancing the charge passing through the system but most commonly if you want to do a pure chloride diffusion-based study you will take the concrete specimens and put them you will have a bath of sodium chloride solution and you will put your concrete specimens which are typically cylinders inside the sodium chloride solution. The cylinder will be having only the top surface exposed and all the other surfaces will be coated so that there is no penetration of chlorides happening through the other surfaces and after a certain period for instance in this ASTM C1556 method after 28 days of curing you put the concrete cylinder inside this chloride solution which is about 15.6% sodium chloride and after you take it out you have to grind the surface in layers.

So you grind the first 1 mm then 2 to 3 mm, 4 to 7 mm like that so you grind in a layer-wise fashion and for each layer you determine the chloride content and then you plot the chloride concentration versus the mid-depth of that layer from which the specimen has been taken. It is a very laborious process it is not easy to do that is why everybody opts to do the electrical based methods like the rapid chloride penetration test or the migration test. There are much simpler to use but if you want to actually study chloride diffusion alone this is the right method to be chosen. So in this case also you clearly see that your chloride profiles are much lower for your fly ash and LC3-based system as compared to the OPC-based system. Now the only difference being here as compared to the ASTM standard is that all these concretes were actually cured for 1 year.

These concretes were cured for 1 full year before the chloride exposure. So that means all of them had a sufficient amount of time for completing whatever potential hydration they could actually complete. So 1 year of curing. So you can imagine that any negative impacts of fly ash at early ages would have been overcome because you have cured for so long. So you do not really have that negative impact.

So very clearly you see a distinctly better performance for LC3 and fly ash-based mix and for the M30 and M50 mix , very clearly you see that at an equivalent strength level LC3 and fly ash-based systems that have been cured appropriately are able to have a much better chloride profile. Why do we say better? Because at a given depth let us say 5 mm the chloride concentration that is present in the concrete with fly ash or LC3 is much lower as compared to the chloride concentration present in the case of a Portland cement-based mix. So you have a clear distinction in the performance seen there. As the grade of concrete is going up you can see that the profiles are coming further down that means the concrete is becoming less permeable because of the lower water-to-cement ratio and you can see clearly the effect again of the LC3 and fly ash-based mixes.

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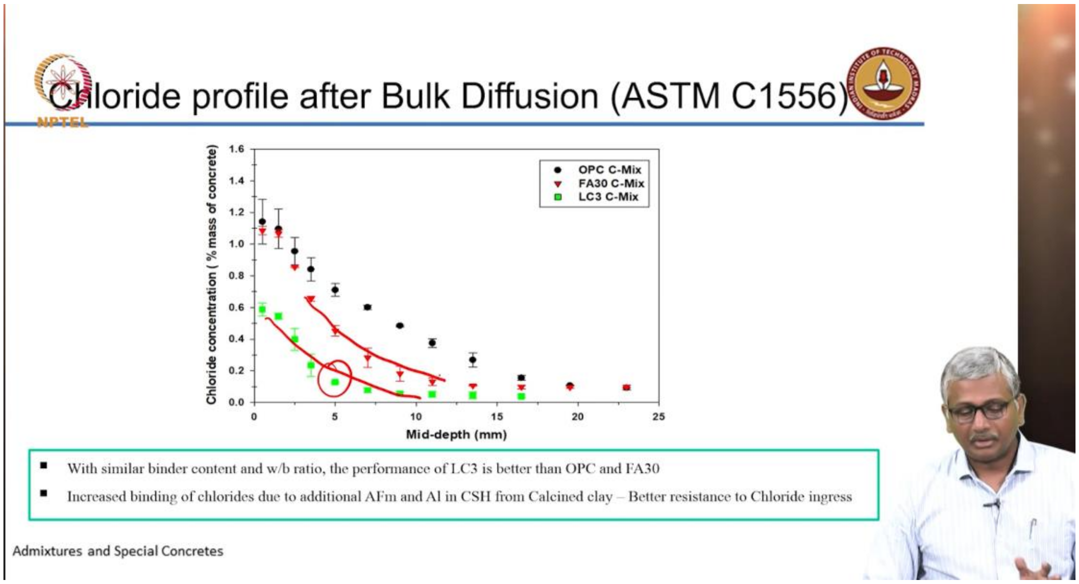

In the case of a common mix where you had an equivalent binder content and water binder ratio once again you saw much better performance with LC3 and fly ash but the LC3 system is working even better than the fly ash-based system in the case of a common mix where you have the same water binder ratio and same binder content.

So overall it can be clearly said that the benefits of calcium clay in terms of chloride diffusion are clearly being observed in the chloride diffusion test.

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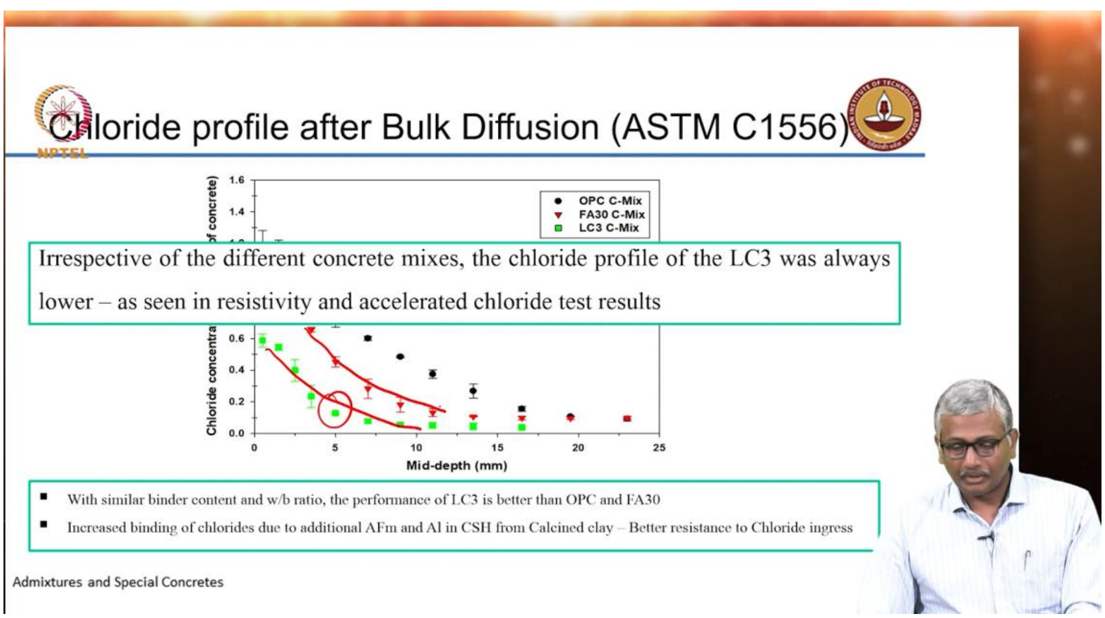

LC3- Durability performance:

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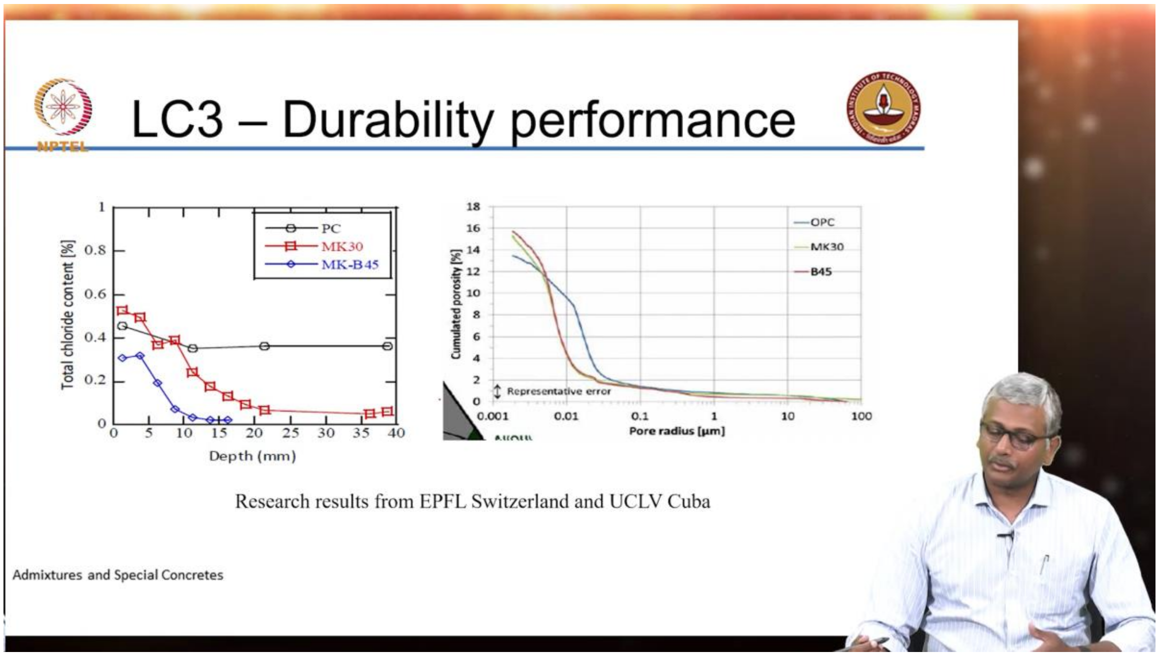

Okay. This is also been reported in studies elsewhere of course this is the older results from EPFL Switzerland and UCLV Cuba same kind of trends are seen there also.

Tests on slabs- cured in field-like conditions:

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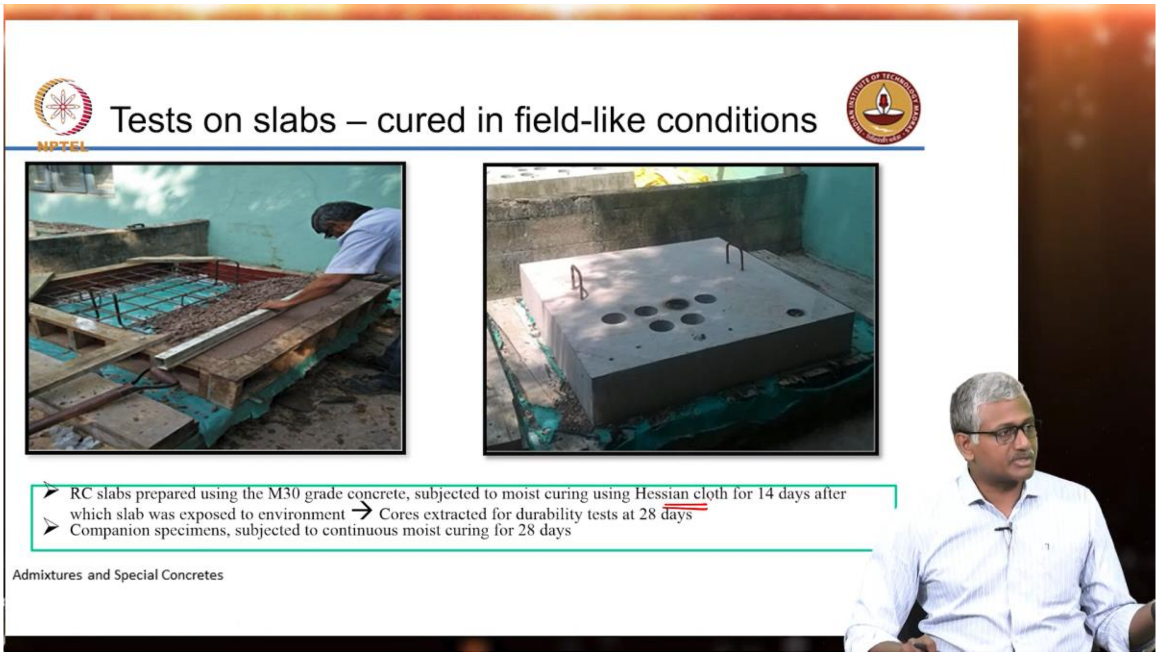

So what we wanted to understand is we have talked about the fact that yes curing does not seem to affect LC3 concrete as much as it affects fly ash concrete. So can we start looking at specimens that are not ideally cured. In the laboratory we make specimens and we cure them in 100% moist environment until the time of testing.

But in the field curing only happens for 7 days or 14 days. So we wanted to compare a fly ash-based system and an LC3-based system by making specimens cured in field-like conditions. So we actually made these slab specimens and these were moist cured using hessian cloth wet hessian cloth was draped on top of the slab and cured. Moist curing was done only for 14 days and after that the hessian cloth was removed and your specimen was exposed to the external atmosphere. And the cores were then extracted from the slab at 28 days to perform the durability tests. And of course, we also made companion specimens that were stored in laboratory for the same period of time. Not for the same period, for the entire duration that means they were stored in ideal curing conditions just like we would for a regular concrete specimen.

Comparative performance of lab and field specimens:

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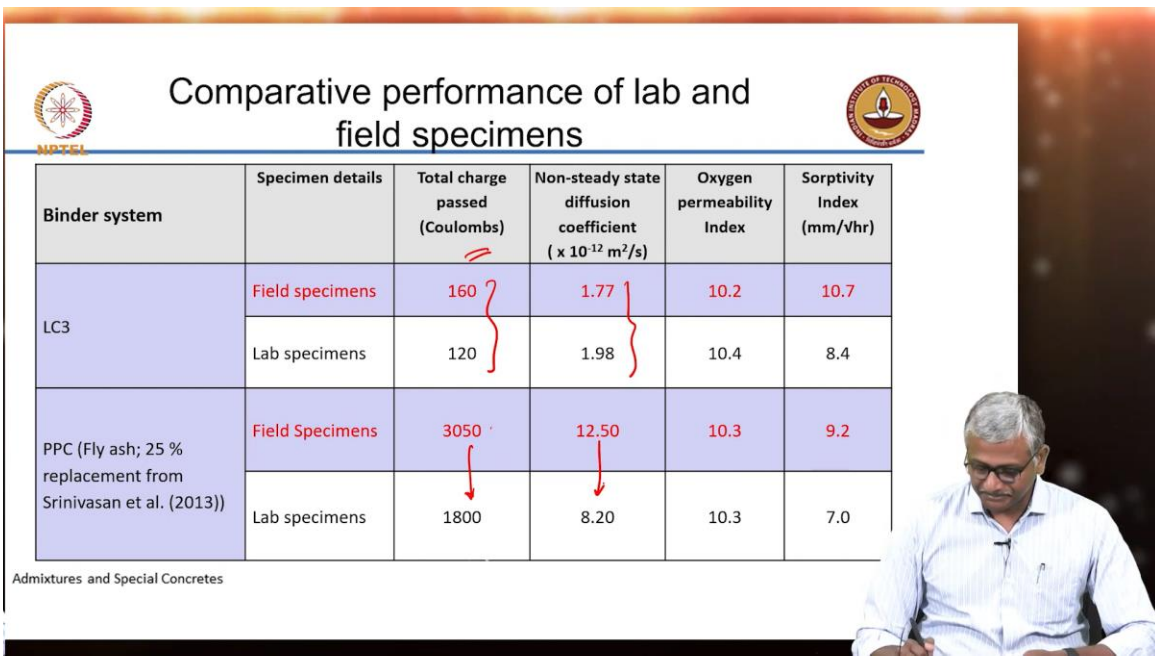

Binder system	Specimen details	Total charge passed (Coulombs)	Non-steady state diffusion coefficient (x 10^{-12} m^2/s)	Oxygen permeability Index	Sorptivity Index (mm/√hr)
LC3	Field specimens	160	1.77	10.2	10.7
	Lab specimens	120	1.98	10.4	8.4
PPC (Fly ash; 25 % replacement from Srinivasan et al. (2013))	Field Specimens	3050	12.50	10.3	9.2
	Lab specimens	1800	8.20	10.3	7.0

So you can see now the distinction between LC3 and fly ash-based concrete in terms of how different the numbers are for the field-cured and the lab-cured specimens. So what you can clearly see is in such tests like the RCPT you really do not see much difference in the performance. Again migration coefficient in both these cases you see that you have very good performance overall for migration coefficient. Of course the concretes were not of the same grade so I cannot compare the numbers directly but what I want to compare as a result of the field specimens to the lab specimens. Whereas in the case of fly ash-based concrete you can see the major improvement for lab-cured concrete as compared to the field-cured concrete, major improvement for the non-steady state migration coefficient also for lab-cured and field-cured systems.

So distinctly different performances can be seen from the fact that if you use a fly ash based system the lack of curing on the field is likely to affect its performance significantly and LC3 based system you do not really foresee that level of a problem.

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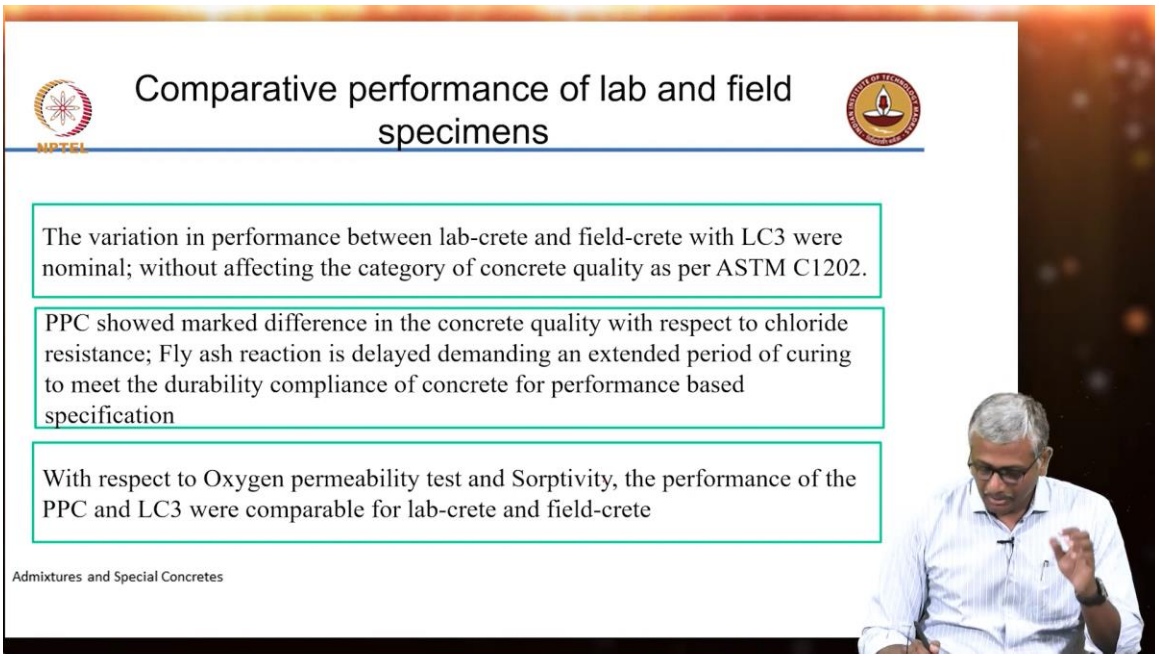

So just to give this in words variation between lab cured and field cured with LC3 was nominal so again you are not able to clearly distinguish the lack of curing and its effects and PPC shows clearly these effects. So again all of these factors need to be considered when you design the curing strategy in the field. It is not just based on the strength considerations you also need to worry about when durability is likely to be achieved to the level that you want for protecting your structure in the long run. Right. So I think with that we end this segment of the mineral admixtures chapter and then we will move on to the next segment dealing with agricultural ashes but if you have any questions we can take those now

Carbonation:

Yeah okay. So carbonation again I will go back to the same results I showed you previously with respect to your fly ash and slag. Whenever you have increased replacement of cement clinker by mineral admixtures the carbonation depth generally increases and with LC3 the same sort of system was actually seen with LC3 also the carbonation effect was quite severe because you are now consuming almost all of the calcium hydroxide even compared to fly ash or slag based mixes the consumption of calcium hydroxide is even greater. So certainly carbonation is going to be a negative effect as far as LC3 is concerned if you are going to be using it at the replacement levels which we have been doing 50% replacement. If you are trying to do it at lower replacement levels like 25% maybe you will not see that difference at all but at 50% distinctly LC3 systems will have much more carbonation depth as compared to plain Portland cement systems. But again you can design for that by taking an additional cover depth and lowering water binder ratio that will help you counter this difference in carbonation tendencies.

But you have to keep in mind that carbonation is realistically a problem for concrete mixes where water binder ratio is generally much more than 0.45 or the grade of concrete we are talking about is generally M30 or below. In case of concretes which are of much higher grades data from the field has shown that you really do not have a problem with carbonation. For concretes which are more residential construction-oriented where grades are low and water binder ratios are high you certainly have to worry about carbonation. But again please remember our initial discussion carbonation depth being greater does not necessarily always mean that carbonation-induced corrosion will also happen.

For corrosion to happen you need moisture and in many of these blended cement concrete availability of moisture is avoided to a large extent. So all factors need to be considered together. So there is still this is a subject of lot of interest worldwide that people are trying to understand what are the rates of corrosion that happen when blended cementitious systems are used. Only thing is we have to understand today that it is not right of us to be using ordinary portland cement at all. We have to use in our projects blended cements completely.

I am not even going to say as far as possible but completely all OPC needs to be replaced with blended cement or concretes incorporating mineral additives. It is absolutely essential from the point of view of extending the life of the cement that we have or raw materials for cement that we have on the surface of the earth. Because otherwise we are simply not going to be able to cope up with construction until we obviously find an alternative solution of which there are not too many at the current stage. So that is something that we have to think about. So even if there is a negative aspect we need to design and see how well we can design against that negative aspect.

So there are obvious ways in which we can do that. We can use waterproofing materials, we can use lime-based binders which can be used as a coating on the surface to form a layer of calcite which happens with typical ordinary portland cement. All these are options that have been explored in various research studies and certainly, these are the way forward if you want to really increase the level of cement substitution with blending materials.

Summary:

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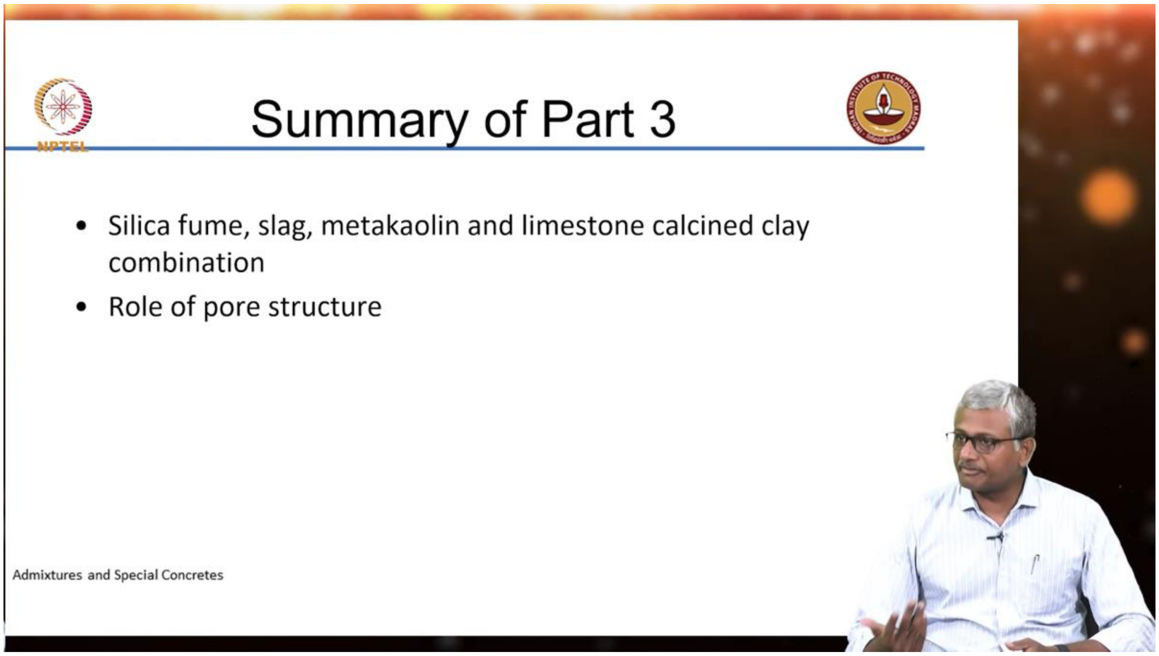

So from our discussion on silica fume slag, metakaolin and LC3 and looking at how the pore structure that was refined a lot by mineral additives and how that led to better durability.