Admixtures and Special Concretes

Prof. Manu Santhanam

Indian Institute of Technology Madras

Department of Civil Engineering

Lecture- 13

Chemical Admixtures: Water reducers - Part 6

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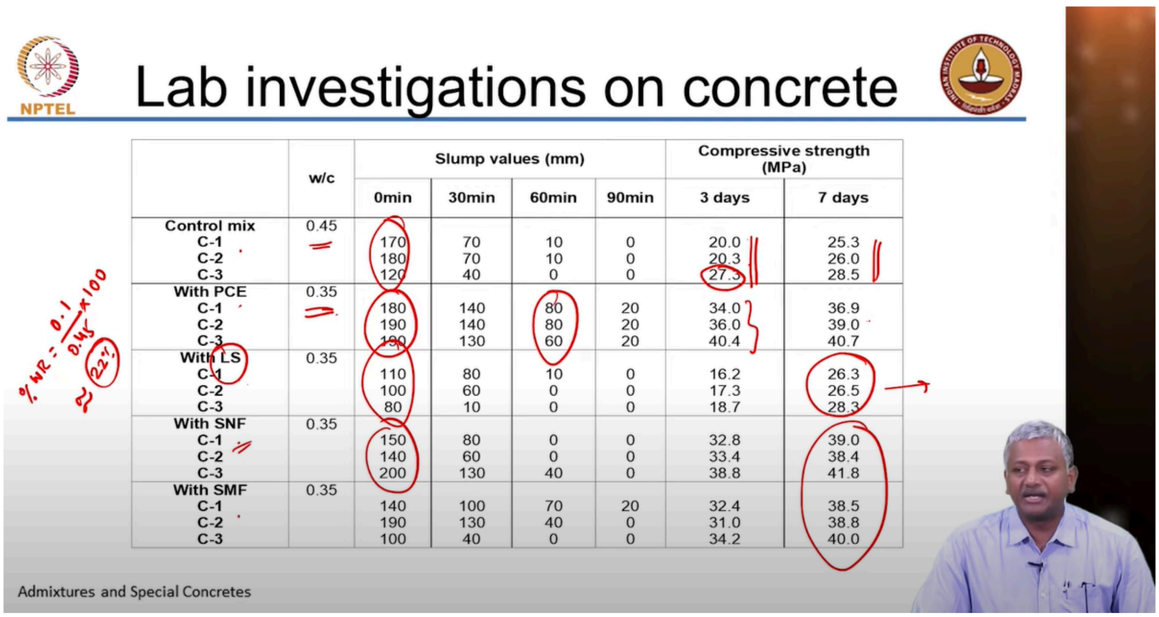

So, yeah as we had discussed previously when we look at this determination of saturation dosage in the paste, we can actually start making concrete with the similar dosage and expect a certain level of performance. I was talking primarily about this example where we looked at three different types of cements in conjunction with several different families of super plasticizers and very clearly you could see that the one super plasticizer that did not really have a major problem of compatibility was the polycarboxylic ether. You had difficulties in attaining the initial workability itself with lignosulfonate and very clearly you had difficulties in maintaining the workability when lignosulfonate or sulphonated naphthalene or melamine formaldehyde were used. Whereas PCE more or less gave you a concrete example of a very good workability which was maintained over a period of two hours, one and half hours rather.

Temperature effect on concrete:

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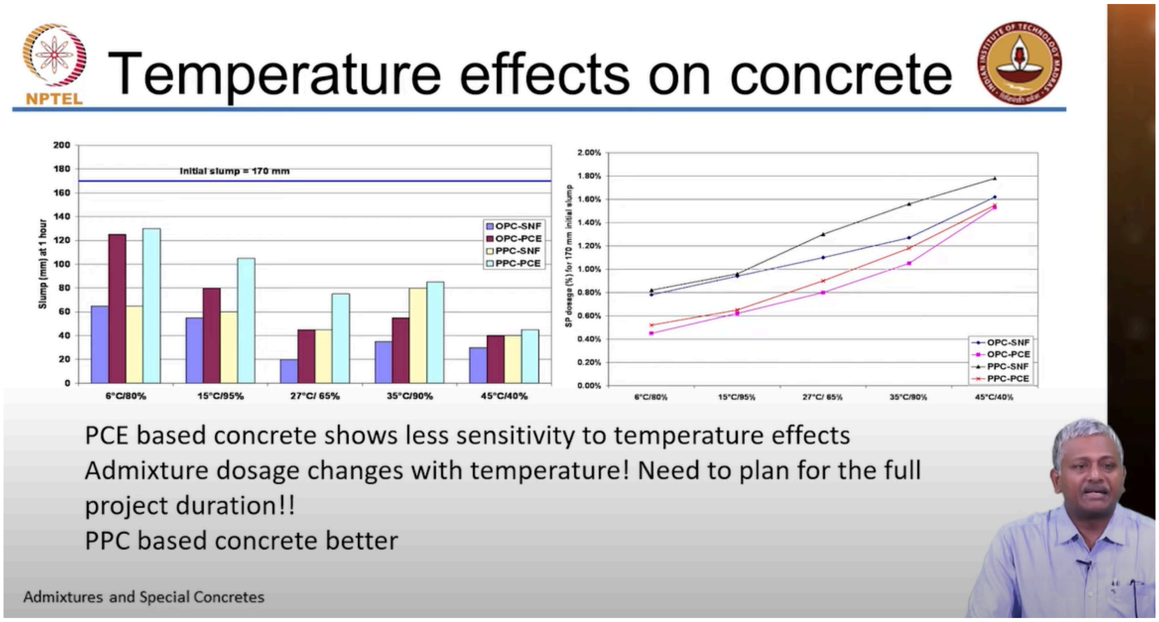

Now as it turns out in your project there are other extraneous factors that may also have an influence on the way that super plasticizer and cement interact together. Now in this study, this again done by a student of IIT Madras, in this study we wanted to see what happens when the weather conditions change in terms of temperature and humidity.

Now in our laboratory we have a controlled environmental chamber which is large enough that you can actually move your concrete mixer into the chamber, condition your materials at a particular temperature and humidity and do the test at the same temperature and humidity. Idea was to maintain the same weather conditions as you would expect in times of changing weather during a construction project. And we maintained the temperature for a period of one day and then shifted the specimens to normal curing. But more importantly our idea was to see what happens to the super plasticizer dosage required when temperature increases and what happens to the retention of the slump as the temperature increases.

Now here first let us look at the graph on the right, what is plotted as the super plasticizer dosage versus the temperature. Of course humidity is variable, it is not perfectly linearly varying because we chose certain types of weather conditions. It is not always temperature increasing, humidity increasing type of a condition. Temperature was increasing but humidity was controlled to such an extent that it would mimic a certain geographical region. Nevertheless what this tries to say is as the temperature increases there is a clear trend of increase in the amount of super plasticizer required to produce a

170 mm initial slump. Why is this happening? Why do we need more super plasticizers at higher temperatures? At higher temperatures there is a chance of greater water loss from the system. At the same time there is greater adsorption happening of the super plasticizer. More adsorption is happening so you are quickly adsorbing the super plasticizer may be more quantity of super plasticizer getting adsorbed on to the system.

So see here there is a little bit of a difference when you consider a paste system versus a concrete system. In the paste system we saw that or we understood that as temperature increases because of increased adsorption you may actually get very high initial workability. But here yes maybe you do get that workability but you need a higher dosage to get there. Increase in temperature may also increase the extent of super plasticizer adsorption onto the fine grains of sand for instance. Sand also has grain sizes well below 150 microns sometimes. There is a possibility that your admixture may be getting lost on the sand grains also. So there is a distinct trend of increase in admixture dosage as the temperature increases. What about the slump retention? So all the concrete was designed to obtain the same initial slump of 170 mm. And what we saw was the slump at 1 hour maintained at the same temperature condition. For instance here this is 6 °C and at the other end we have 45°C. Not a very comfortable atmosphere to work in 45°C degrees situated but that is the reality in many of our job conditions 45°C in summer. Quite often you find that kind of a condition. So you clearly see again here that as the temperature increases the slump at 1 hour keeps dropping. Although all the concrete were designed to the same initial slump it is very clear that the concrete at the lower temperature is able to retain its slump better as compared to concrete at higher temperature. Because there is more water loss from the system at higher temperatures. Even if you keep the system such that there is no water loss, you keep the mixer closed also there will be a greater amount of moisture absorption at a higher temperature. So your free water may start getting lost. Now assuming that you have done your design with appropriate moisture corrections to ensure that the moisture for absorption with the aggregate has also been added, it is not very easy to maintain the same level of water in your system throughout the process up to 1 hour or maybe even up to 2 hours.

Here what we also looked at was the relative effect of OPC and PPC. PPC is fly ash based cement. So what you see is with PPC the slump retention is generally better than with OPC. You retain a better slump with PPC as opposed to OPC. Now this could definitely be because of the nature of fly ash particles but this could also be due to the fact that fly ash is slowing down the setting of your cement, slowing down the hydration of your cement. Because of that you get a better performance with PPC as far as the slump retention is concerned.

Between PCE and SNF what do you see from the result? PCE gives you better retention of slump. So the slump is dropping significantly when it starts dropping to below 80 mm the concrete does not remain pumpable. Pumpability requires that concrete has a certain slump. So if the slump is dropping below 80, concrete is no longer pumpable. In fact for good pumpability people would still want more than 100 mm slump. Now it turns out when you design these tests in the laboratory slump retention tests the choice of the initial slump also makes a difference. Why is this? Because if you want a much higher slump initially let us say 200 to 220 mm slump you would have overdosed the admixture anyway. So when you overdose the admixture you are going much beyond the saturation dosage. Around 80 to 100 mm slump is where you get saturation dosage. This is not a scientific assessment, this is more of a data based assessment that when you are close to the saturation dosage of the admixture you have about an 80 to 100 mm slump. So that means the higher the slump that you design initially for your mix the greater will be the overdose of the admixture. So if the same test had been done at an initial slump value of 220 mm probably the slump retention could have been better than 100 mm at 1 hour. So this is exactly what we do when we plan for operations involving concreting where concrete is delivered from the RMC to the job site. We need to ascertain what would be the loss in slump over the period of 1 hour and design appropriately for that.

So it is important to pay attention not just to the internal factors that is cement composition, type of super plasticizer, amount of super plasticizer but here we are also seeing that the temperature can also affect the rate at which super plasticizer is getting adsorbed as well as the rate at which slump is getting lost. Now that is a little complicated because typical jobs, concreting jobs let us say for a metro project can go two full cycles of weather, two years for instance. You have cold temperatures, you have medium temperatures, and you have warm temperatures, hot temperatures so your temperatures actually vary significantly.

Let us say you are in Delhi obviously all of these temperatures are realistic. In Chennai perhaps you are more towards this side but if you are in a place like Delhi 6°C is possible, 45°C is also possible. So how do you design your concrete mixture to be suitable throughout the process of the construction? Just imagine here you only need about 0.5% dosage whereas here you need 1.4 or 1.5% dosage. So a major difference in dosage of the admixture is happening to reach the same initial level of workability. So one has to be aware of this.

We ran into a problem like this once when there was a project in which we had to submit our opinion of the mix design and the government client basically said that your admixture content is so much, any season your admixture content should be exactly this much. That is not possible. One has to understand that the admixture dosage has to be adjusted to obtain the initial workability. That cannot remain constant. Now from the other side, the project scheduling and planning side or project billing side that may be a matter of concern because your admixture quantity is changing seasonally.

So what do you actually estimate in the beginning? So what does this go to show you? What does this tell you? It tells you that the planning for concreting has to be done well in advance of the start of the construction project. I come back to the same point. In most of our construction projects, concrete mix design is sought the day before concreting is to be done on site. That is the reality. But all of these factors will affect. There was another project in which we were using silica fume as a cement replacement in concrete. It was needed because the requirement of early strength was quite high. It was a precast concrete subjected to steam curing. So to cut down the cement content to ensure that we got the required strength, we had to use silica fume. We will talk about silica fumes later. But half way through that project, the client told the contractor they are not going to pay for the silica fume. Why? Because it was not there in the initial specification, it was not allowed initially. The contractor worked with the best strategy possible to get the required strength with the least amount of cement that could be used in the system. But here they are facing a situation where silica fumes are not getting permitted. What do they do? Obviously they have to look for another design which has greater cement content without any silica fumes because the price difference is quite significant. Silica fume is nearly 3 to 4 times the cost of cement. So for every kilogram of silica fume that you use, you are paying a significantly higher amount of money as compared to paying for cement. But the client did not understand that the price to pay is to increase the cement content of your system and that has its own problems. Increase of heat, all of those kinds of troubles will come when you start thinking about that.

Mixing related effects:

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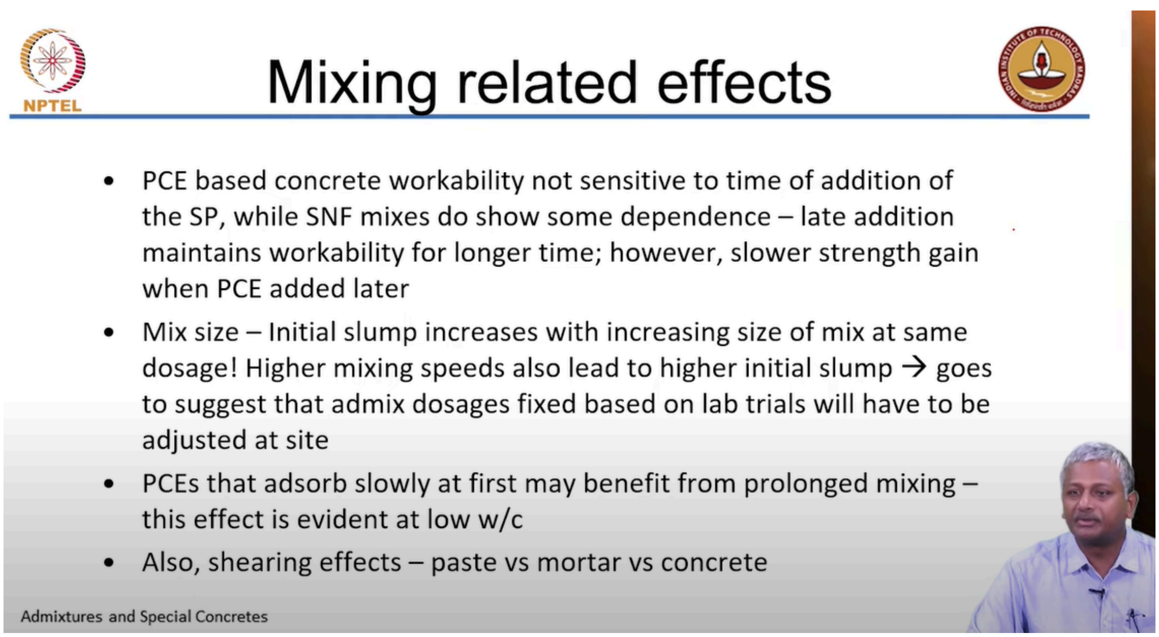

So again concreting requires significant planning in a construction project. Now of course it goes to a different dimension here. There are also mixing related effects. We also saw that the size of the mix that you made also made a difference with respect to the effectiveness of the superplasticizer and the compatibility of the admixture and cement combination.

So of course late addition is something that we discussed previously that if the sulphonated naphthalene formaldehyde admixture is added late to the system, it is beneficial otherwise you start losing its effectiveness fast because the sulphonate from the SNF starts getting attracted towards the C_3A.

With PCE this dependence is not as much because there is no sulphonate in PCE. So there is no competitive adsorption that happens with PCE. But if PCE is added late, it may lead to retardation and that is what we saw from our concrete studies in the lab. Interestingly we also saw that initial slump increases with increasing size of the mix at the same dosage. We have the same dosage. Dosage is represented in terms of percentage by weight of cement. So maintain the same dosage in a small mix and a large mix. What we saw was that the large mix was actually giving you a higher initial slump.

So what simple lesson that this tells you is that the dosage that you have fixed based on your laboratory studies involving a small mixer where we are mixing hardly about $0.1m^3$, at a larger scale you are mixing $0.1m^3$, otherwise you are only mixing about $0.03m^3$. Compared to this when you start mixing in the RMC plant which is 0.5 m^3or 1 m^3, in such cases the difference in the mix characteristics can be significant. Not saying will be but can be. So whenever you have a mix design that is tested in the lab, always follow it up with a field test. It is an absolute requirement to do a field test also of the same.

So one more aspect of PCE is that it is absorbed slowly at first. See SNFs are charged. So the adsorption is almost immediate. But PCEs are not like that. They have long side chains, they are bulky, they do not move around that fast and they adsorb slowly under the cement. Now in such cases if you mix for a prolonged period of time, you may benefit better from the use of PCE. This is especially true when we talk about ultra-high strength concrete, concrete where we need strengths of 150 MPa or more where the water cement ratio is less than 0.2. In such cases there is not enough water to do a proper mix in a quick period of time unless you mix at very high shear, very high speeds. In such cases when you use PCEs, prolonged mixing actually helps.

Now this prolonged mixing may be a problem for many of the sites because they have certain things that are set up already in their batching plant. How long does the mixing take in a batching plant typically? After all the batching has been done, how long do they mix you think? How long do they mix the concrete after the batching has been done? Any guesses? People on site should know.

Mixing in the batching plant happens for less than 1 minute and they do this 1 minute mixing. Of course, batching will take a little bit longer because all the aggregate, cement, admixture, water everything has to come into the mixing drum but after it comes mixing is hardly done for 1 minute. Now this 1 minute mixing is actually not optimal at all for concrete. When we do this 5 minute or 10 minute mixing it is in the lab typically.

How long should you mix actually? What is the objective of mixing longer? You want to make the mix as homogeneous as possible. It should not fall off in chunks on one side and then start flowing on the other side. It has to have uniformity of concrete to be good. For that mixing longer is obviously important. But if you mix longer it reduces the productivity of a plant. You need to fill up a truck which is of how much volume? About 6 m^3 on an average and your mixer is 0.5 m^3. That means you need 12 times mixing to happen to fill up one truck. 12 times concrete has to be mixed to fill up one truck. Now if you take 2 minutes instead of 1 minute you are doubling the time that your entire operation lasts. You have to see what the most optimal condition is but when you are concreting with low order to cement ratio mixing longer is absolutely a necessity.

When you are making M25, M30 concrete no big deal. Mixing fast, mixing slowly does not really matter. But when you start moving towards the M60, M70 mixing for a longer period of time is very important especially because the PCE's provide better effectiveness when you mix it for long. Especially if you have silica fumes in the system, I will talk about this later also, to ensure that silica fume dispersion happens properly in the system you have to mix for a longer time.

Now again when you work in the laboratory you can work at the paste scale, mortar scale or concrete scale. We saw that we did the marsh cone mini slump test on paste, flow table on mortar, slump on concrete.

When you mix paste versus mixing cement, mortar or concrete there is a difference. What is the difference? Shearing effects. The aggregates are basically shearing the paste in between. If you just mix paste there is nothing causing that shearing. So you cannot effectively predict concrete properties from just the paste mix. Incidentally it turns out that the saturation dosage estimation from the paste does produce a fairly good quality concrete that is what we saw earlier. But your mixing depends a lot on the presence of the aggregate, there is better shearing, there is better mixing possible when aggregates are present in your system. So when you design paste versus mortar versus concrete in the lab make sure that the mixing process is adequate. All these are complications which we have to work out well in advance before we sort out this problem of compatibility on site.

Delayed addition of SP:

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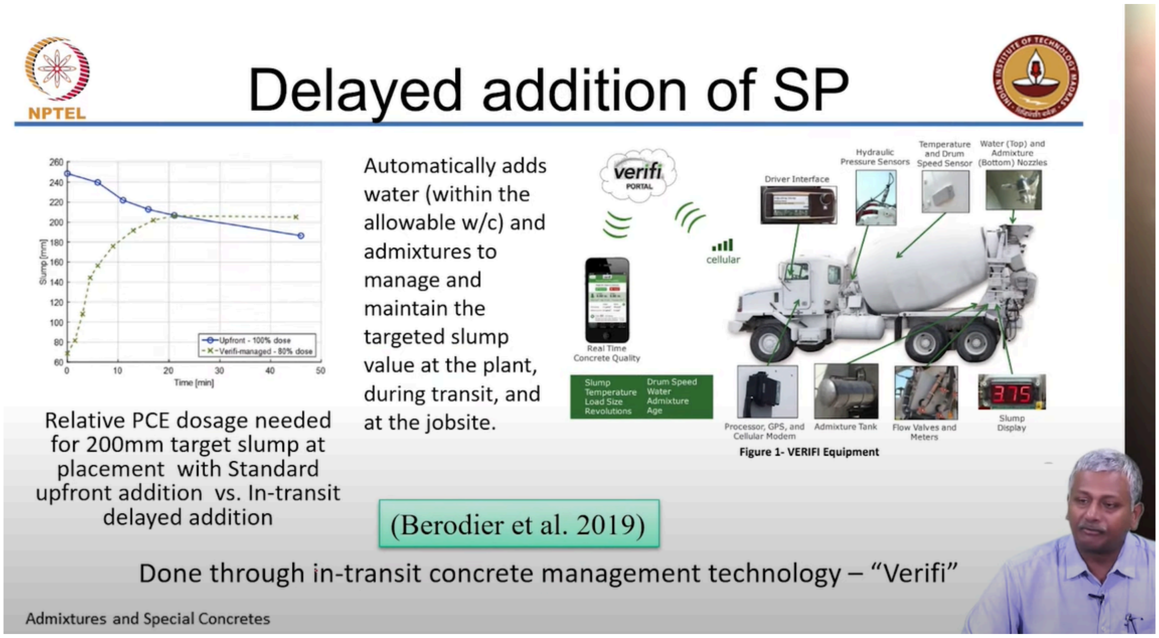

Now this is a case study from the US where they had actually perfected this system of studying the slump of the concrete in the truck and ensuring that while this truck is in transit to the job site they are able to dose the admixture properly. We have a system called "**Verifi**". Now there are instances where the truck driver can find out by the sound of the concrete sloshing at the truck what the slump of the concrete is. Slump is going to get lost as the truck goes to the job site. So how do you actively control the super plasticizer dosage? One thing you can do is not mix all of the SP at the plant and keep some for the site. But then dosing appropriate amounts of SP becomes a problematic thing unless your truck is fitted with a proper dosing of the super plasticizer. So in such cases you need to do that, you need to have that kind of a dose possible.

So here what it says is the blue curve is the upfront 100% dosing. So the slump initially was 250 mm; it came down to about 180 mm or so after a period of about 45 minutes during transit. Now in the other case what they did was this was a managed dosage of the super plasticizer. So the slump was low to begin with because they did not add all of the super plasticizer. As the truck was in transit they kept on adding more and finally ended up with the slump of 200 mm which was desired at the time of arrival of the truck to the job site. So there are ways and means to do this, this is just an example. So what you do is either hold back the super plasticizer load or both water and super plasticizer for this your truck needs to be fitted with a proper dosage system. Otherwise the truck driver has a hose with which they can add the water, but that does not serve the purpose you do not know how much water is getting added.

I mean this is not just in India, I do not know if I told you this example. I used to work for an admixture company in the US and we went to an RMC plant for a field trial of one of the new formulations that we had made. So I was waiting with my friend with all the equipment to prepare the slump to make the concrete cylinders and all that. So this truck was waiting by the discharging point of the Ready mix concrete plant.

I was waiting for a long time for this guy did not arrive. I asked my friend what was going on, then I heard two long horns, the truck driver beeped his horn twice very long. So I asked my friend why he is not coming here and delivering the concrete that is taking him so long. This guy said you heard those two long horns each longhorn is 10 gallons of water to be added to the mix. So the guy is able to hear the sound of the concrete in the truck and make out the slump. The slump is not enough so each longhorn means you add 10 more gallons of water and make the concrete more workable. Now I was wondering, here I am in a so called developed country, concrete is the same anywhere whether you are in India or the US.

Only thing is of course the people there are very highly trained and qualified. Here you know the conditions on our job site: the people who work with the concrete are hardly having any real skills in concreting. They have learnt on the site, they have learnt on the job, they do not really understand why we need to cut down the water in the system but there is a different story but on both sides the potential of losing out if you do not get the job done is a very realistic situation. So technical aspects sometimes take a back seat unfortunately.