Advanced Concrete Technology
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Lecture – 15
Chemical Admixtures - Part 3

So, let us get back to our discussion on the study of compatibility between cements and super plasticizers. We talked about the fact yesterday that based on methodology suggested by certain researchers we can actually find out with very simple techniques as to whether a combination of cement and super plasticizers are going to be compatible or not. Essentially what we can do is involve in a simple test which is called Marsh cone test.

And this can be easily carried out in any quality control laboratory all you need is a Marsh cone which can be fabricated quite easily in the workshop. You need a stopwatch and of course you need equipment to mix the paste and you also need a measuring cylinder. That is all you need for doing this test and this test tells you the fluidity of the paste and as you increase the super plasticizer dosage, the fluidity keeps increasing.

Beyond a certain point there is no increase in fluidity because you have already saturated the amount of super plasticizers that can get adsorbed on Cementitious particles.

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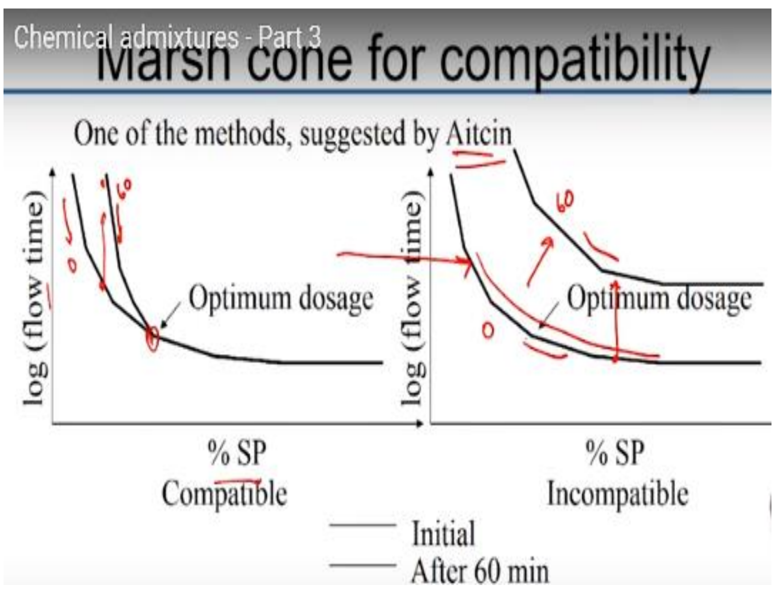

Now what Aitcin and his colleagues at Sherbrooke university have come up with is that for a compatible combination the flow curves at time=0 that means right after mixing the cement and water and at time T=60 minutes that means 60 minutes after mixing. The flow curves coincide after 60 minutes. So for a comparable combination the flow curves at 0 and 60 minutes coincide after the optimum dosage.

On the other hand, for an incompatible combination the entire curve shifts upwards obviously that means that for any super plasticizers dosage the flow time increases when you go more and more beyond the point of mixing. In other words, of course the slump is getting reduced but even when the dosage is higher than the optimum dosage you still have an increase in the flow time. That indicates a poor computability between the cement and the super plasticizers.

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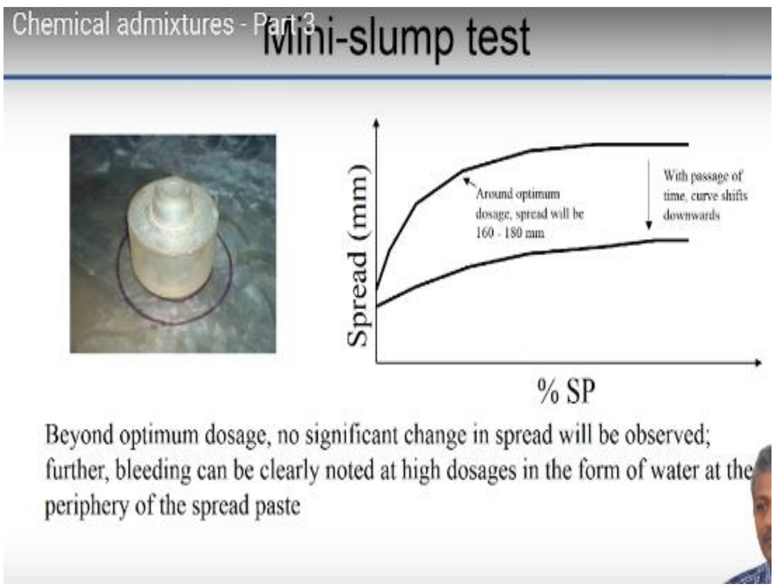

Okay there is another test which can be used and it is typically done alongside the Marsh cone test and this is called a mini slump test. As the name indicates it is actually just a miniatured version of the slump cone. So, here we are talking about an opening diameter on the top of about 20 millimeters. The diameter of the bottom which you do not see very clearly is about 40 millimeters and the height of the slump cone is 60 millimeters.

So, essentially 1:2:3 ratios just like a regular slump cone. I hope all of you know that the regular Abram's cone which you use for concrete also has the same top diameter to bottom diameter to height ratio 1:2:3. What is the top diameter in the case of regular slump cone? 10 centimeter, bottom is 20 and the height is 30.

So essentially you have the same slump cone which is been miniaturized because it is going to be used only for paste. So, all you do is the same paste that you test for your Marsh cone, take some of the paste and put it into this mini slump cone. All you do is then just lift the slum cone up and allow the paste to spread out. So, what you can do is measure 2 things one is a total spread of the paste that gives the total flowability.

You can also use this information in another way that you calculate the amount of time taken for a spread of 115 millimeters. That is a spread of 115 millimeters but that I have not seen people using it all the time what people do use is the overall spread and you plot the overall spread against a super plasticizer dosage you will get a curve like this and again at the optimum dosage, beyond the optimum dosage if you want to see a significant increase in flow.

You will not see a significant increase in the spread when you cross the optimum dosage, for obvious reasons like we discussed for the Marsh cone test also. Now what will happen is generally this spread around optimum dosage will be of the order of 160 to 180 millimeters. If you are designing your concrete to be a flowable concrete. This is where it helps to do a mini slump test alongside the Marsh cone test.

We discussed yesterday that the optimum time, that the optimum dosage that is determined from the test may not result in the exact fluidity that you desire in the concrete mix. However when you use this Marsh cone test combined with the mini slump test and you check for the total amount of spread around optimum dosage, if that spread occurs to be about 160 to 180 you will get probably a optimized flowability in the concrete.

So, more often than not this kind of procedure is used to fix a super plasticizer dosage required to get your self-compatibility in concrete. So, when you want flowing concrete this is the kind of criteria we will be looking at. Of course this will depend a lot on the water to cement ratio for instance if the water cement ratio is very low, maybe obtaining that spread may be difficult in the first place.

Obtaining that extent of spread may be difficult in the first place. So, in that case you might want to add additional quantities or super plasticizers to get that spread. So, you may have to go much beyond optimum to actually obtain the required spread. We will look at that when we actually come to the section on fresh concrete a little bit later in the semester.

So, essentially the aggregate shape and the amount of the aggregate will make a difference with respect to the initial amount of yield stress that needs to be overcome for the flow to initiate. But for that we need to have a small discussion on rheology at this stage we are not really ready for that yet. So, I am restricting myself to saying that a paste with an optimum flowability in terms of the mini slump test will help you get towards a flowing concrete.

And this optimum flowability for a paste will be between 160 and 180 millimeters of spread in the mini slump test. So essentially you are starting from 40 milli meter diameter and going to 160 to 180. So, you are spreading your paste nearly 4 times the initial diameter. So, what you can also do is measure a couple of interesting characteristics with a spread measurement. What you can do is.

Do this test at 30 minutes, 60 minutes, 90 minutes, 120 minutes and measure workability retention how long is the paste able to maintain its workability. So, obviously with the passage of time this curve will start shifting downwards that means the spread will reduce for the same super plasticizers dosage as the time proceeds. Again we are not using it for compatibility we are actually using it for assessment of the workability retention.

One more thing you can do is look at whether this combination of super plasticizers and cement is leading to segregation or not and how that is looked at is if you if you see the spread, which would be almost circular. If you see the spread at the periphery you will see that there is a separation of water from the paste. At the periphery when segregation is starting to happen, at the periphery you will see there is a separation of water from the paste.

And that will happen when your SP dosages become very high much beyond the optimum because what is happening there is this water is simply now free to move out of the paste. And it does so by separating totally from the paste well it is more bleeding not really segregation. But in a paste bleeding and segregation are probably one in the same, because in the paste the part that is segregating is a cement, part that is bleeding is water.

So, in concrete bleeding means simply water is coming out but segregation means the aggregates are settling in a concrete. But here the particles that settle are the cement particles and the particles that come out or the molecules that come out are the water molecules. So, you have bleeding and segregation in paste is essentially the same thing.

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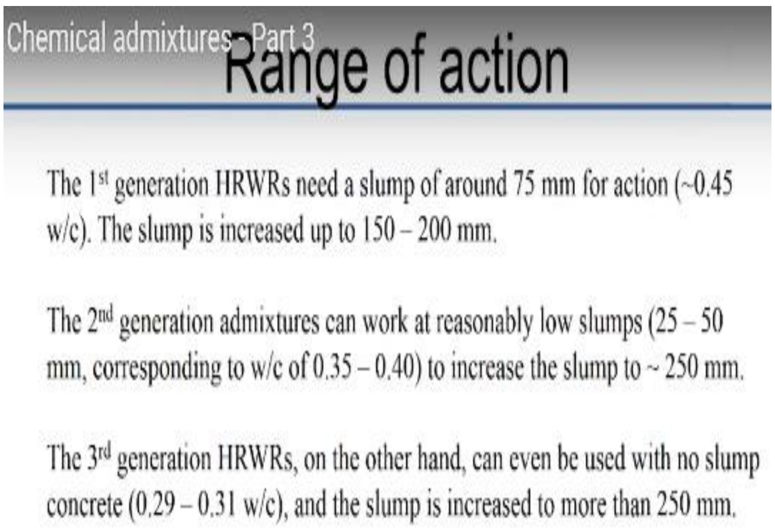

Now what we saw so far was what are the different mechanisms of action of different types of super plasticizers, how effective are each kind of super plasticizers in giving a specific workability for your concrete mix. We also saw what you can do with a simple test method to assess the combination of cement and super plasticizers and determine the suitability for making the concrete.

But one thing that the chemical admixture manufacturers typically do not tell you is what is the limitation of each chemical that is being used that means up to what extent can this chemical actually make a difference in concrete. And this is something which is not really based on science and of course it is based on science because all this relates to actually the mechanism of action of the chemicals.

But these numbers are essentially derived from practice, okay, what I am presenting on the slide is essentially derived from practice. So, the first generation high range water reduces that is your lignosulphonate based materials would need a slump of around 75 millimeters for suitable action that means they will be effective only if the water to cement ratio is around 0.45 and this 75 millimeter slump can be increased to about 150 to 200 millimeters.

With the action of the high range water reduces which are of the old type that is lignosulphonates. When you are talking about the second generation that is SNF or SMF admixtures they can work with concretes which are fairly dry consistencies or loose lumps between 25 and 50 and they can transform these concretes to a almost a flowing condition a slump of more than 250 millimeters.

So, essentially a flowing concrete we are talking about. So what this corresponds to is a water to cement ratio 0.35 to 0.4. Now very often on the site we come across conditions where people are trying to make very high performance concretes, in terms of water cement ratios you are talking about concrete of less than 0.35 water cement ratio. Sometimes in a bid to cut cost the contractors trying to make use of sulphonated naphthalene formaldehyde.

We saw earlier that in terms of costs, right, SNF is probably 40% of the cost of your PCE. Of course now we know the reality that 40% is only the initial cost of the material itself if you look at it in terms of the effectiveness in concrete the cost is only about 20 to 25% less than the PCE cost. But what people are not telling you these construction chemical manufacturers are not telling you.

And what the contractors are not aware of is that this SNF does not have the required effectiveness when you come to very low water cement ratios below 0.35. If you are trying to make concrete flow at less than 0.35 water cement ratio, then SNF is not the right choice of admixture to have in your system. But if you have sufficient amount of water in your system you will cause the slump to increase significantly to almost a flowing consistency.

So, let us look at a typical mix design let us say we are designing M40 concrete, what do you think would be an approximate cement content for M40 concrete, about 400 kilograms, what about water cement ratio 0.35 may be too low maybe we will talk about 0.4 - 0.42. Let us say 0.42.

So, we are in the range now where SNF can be quite effective, so at 0.42 water cement ratio my water content is how much? This it is 168 kg per cubic meter. So, at the water content of around 160 to 175 kg per cubic meter my second generation admixtures are quite effective. When I start coming below 160, I am not telling you this based on any scientific experiments done in the lab.

But this is from practice in the field, when you come to less than 160 kilograms per cubic meter of water the effectiveness of the SNF can be questionable. It may require a lot of SNF to make the concrete work and if you add to much SNF invariably the concrete will get retarded severely. It would not set for the first day or maybe even 2, 3 days. If you add very large quantities of SNF.

So, if you are less than 160, the admixtures that will work most effectively are your PCEs which can actually work with no slump concrete that means at very low water cement ratios and you can enhance a slump to more than 250 millimeter, you can make self-compacting concrete even at water cement rations of 0.25 to 0.3. Those of you who know about the reactor powder of concrete how many of you know reactive powder concrete.

Or you have heard about it some of you, okay, what is reactive powder concrete that is also called ultra-high strength concrete, ultra-high strength concrete and here we are talking about a concrete where there is no coarse aggregate, this is concrete only with fine aggregate. In other words, you are making concrete more and more homogenous you are reducing the heterogeneity reducing the effect of the interfacial transition zone by restricting aggregate size to only fine aggregate sizes.

When you make this type of concrete it is intended for strengths of more than 150 mega pascals. We are talking about 200 - 300 mega pascals compressible strengths that cannot be achieved with water cement ratios of more than 0.2. So, we are talking about water cement ratio of less than 0.2 may be close to 0.15, and it is a system which is heavily cement rich it has got a lot of cement, its got more supplementary materials like silica fume.

Very fine additions like silica fume to extend the cementitious powder content in the mix, and invariably we make use of very small scale fibers to ensure that were leading to an enhancement in the characteristics of the concrete. So, we will look at the actual hardened properties as to how they will get enhanced with the help of fibers in the later session, but what I wanted to point out was here we are talking about water cement ratios 0.15 to 0.2.

And at that range the only admixture that can come about to give any effectiveness is the PCE admixture and truly speaking, even with the PCE the amount of the admixture required is typically of the order of 2.5 to 3%. So, we are not talking about regular concrete, in regular concrete we hardly use more than 1.5% of the PCE admixture.

But when we come to reactive powder concrete we are talking about 2.5 to 3%, very large quantities of admixture required to provide some degree of flowability and if you read literature on RPC or reactive powder concrete, you will see that these super plasticizers will take nearly 30 to 40 minutes of mixing to really gain good enough effectiveness to achieve the flowability required and that lower water cement ratio.

So, again please remember when the super plasticizer is added to the concrete you have all seen in job sites when super plasticizers are added to the concrete. At what stage the SP is added to the concrete, along with the water or right after the water? With part of the mix water you mix the super plasticizers and then you add to the concrete. Most of the water is added in the beginning itself without the super plasticizers.

And all that is done primarily because of that issue we talked about earlier that the C_3A needs to react with the sulfate from the cement before the sulfate from the super plasticizers comes to the system. So super plasticizers added with the remaining part of the water into the mix, and when this happens when its added with the water.

That is dispersion of the SP across the entire volume of the concrete is automatically ascertained. So here we are talking about water cement ratios which are so low that the water content in the mix itself is extremely low. So, when you are adding very high amounts of super plasticizers and into this system it will take a long while before this SP actually interacts with all the cement particles present in the system.

That is why the mixing time has to be enhanced more and more as you are going to lower and lower water to cement ratios. So, now talking about 0.15 to 0.2 water cement ratio, mixing time is already enhanced to about 30 to 40 minutes. Now what is the typical mixing time in a ready mix concretes scenario or on site when you have batching plants how long does the mixer actually spin? Numbers are coming across people say 3 minutes, 5 to 10 minutes.

If you have seen some of the sites in action you would be surprised as to how they actually produce concrete because I have seen mixing times as low as 30 seconds. So, all the materials get bashed into the mixer, bush a few times it spins, and your material comes out into the truck. Now while this may be okay for systems which have a fairly large water content. So, again we are talking about this kind of a concrete about 160 to 175 kg of the water content.

So that any super plasticizers that you add can effectively dissipate all the cement particles. But when you talk about low water contents, the mixing of the concrete has to be very proper especially when the concrete has additional fine particulate ingredients like silica fume for instance. Whenever you substitute cement with very fine particulate ingredients like silica fume you need to ensure that there is sufficient time given from for mixing.

Because we want to break down these particles into their actual size, silica fumes available in densified form, needs to be broken down into the actual sizes and that is made into that happens because of effective mixing and coupled by the action of the super plasticizers which may take some time when your mixing is done at low water to cement ratios.

So when you do go to job sites when you start practicing concrete technology ensure that mixing time is enhanced when you are dealing with special mixes. Everybody will tell you that it is reducing the productivity but I do not think that is true. So, if you operate the concrete mixer continuously you need to ensure that each batch of concrete is that least getting mixed for at least 5 minutes, 5 minutes is a good time for most concretes to have a uniform consistency.

30 seconds is way too inadequate to do anything with the concrete, but all that practice has to change because people have to adapt a new type of materials primarily looking at new ingredients which are used as cement replacements in concrete. So, what you have to be aware of is practical limitations of using one type of admixture over another. It is not always the cost you need to also be aware of what is the effectiveness.

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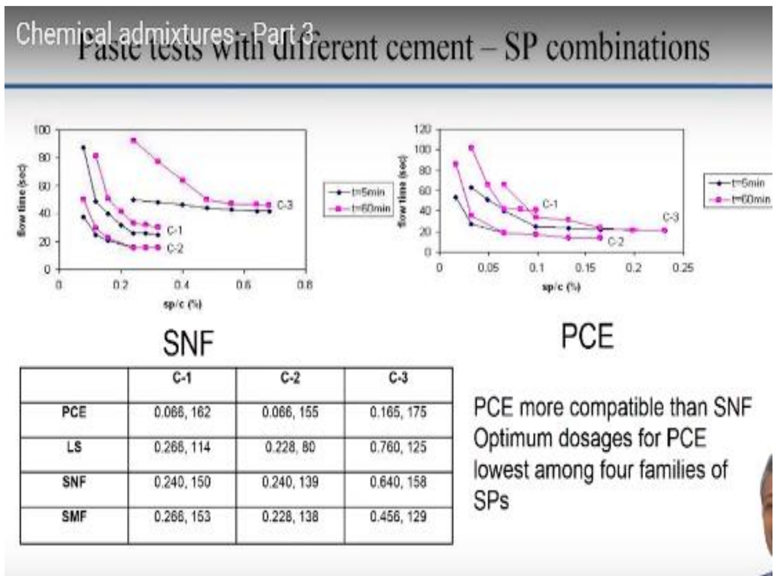

Now what I would like to show you is how we can actually use this methodology that we discussed as far as the Marsh cone test was concerned to detect compatible combinations and does that compatibility affect the concrete properties also similarly. So, here I am describing you some tests that were conducted at our laboratory we used 3 types of cement, we had 3 types of cement one is your C1, C2 and C3.

We had some differences in their chemical compositions and they also had difference in their fineness. C3 was a very fine cement where the C1 and C2 were of similar finesse. I am not giving you the properties of the cement and the chemical composition here. Because that will lead to a much more elaborate presentation I just wanted to give you a proof of the concept of compatibility as per what has been defined by Aintin and his colleagues in Sherbrooke.

So, here we were looking at 2 different admixtures one was SNF based one was PCE based. Of course we have done the study for Lignosulfonate and sulfonate melamine formaldehyde also. But I am presenting the flow curves only for SNF and PCE. So, what is happening here is you T=5-minute curve and T=60 minutes curve. 5-minute curve means 5 minutes after the cement and water come into contact that means right after mixing.

60 minutes is you wait for 60 minutes keep the material in the mixer itself after 60minutes to give it a spin take the material out and determine the Marsh cone flow time. So here for C1 and C2 please see the flow curves the dark blue lines are the initial curves the dark blue or the black lines are the initial flow curves and the pink lines are the flow curves at 60 minutes. So, from our discussion previously with SNF, which is a compatible combination?

C2 definitely looks compatible because the flow curves are coinciding beyond some dosage here which I do not know if you can pick it out as optimum dosage but it looks like it is an optimum dosage because there is no significant change in flow time beyond that. What about C1 it looks like the flow curve have separated and it looks like there is a problem with the compatibility. Even though the difference is not significant.

But still the curves are not coinciding beyond the optimum dosage. C3 again the flow curve is separated at lower dosages but after optimum the separation is quite small. So, we are plotting this on a linear scale we are talking about flow time in seconds, the difference in flow time is probably only about 5 to 10 seconds. So, it may be substantial in some cases but here it may not be that critical.

Nevertheless, what you see is, this cement among the 3 cements C1 is showing some lack of compatibility, C3 again shows some compatibility problems especially with respect to the higher optimum dosage, okay, if you see the C3 it has got a much higher optimum dosage as compared to C1 and C2 and that is happening primarily because of the higher fineness of the C3 cement, okay. So, we are directly seeing the effect of compatibility.

And the effect of fineness of the cement here. What about PCE? What about PCE? We see in the literature is that, PCE should not be having the kind of problems that SNF has. The compatibility should be good, yes, we are seeing in all cases that the flow curves at high dosages of the super plasticizers are coinciding, in all cases C1, C2 and C3, there is no problem with the compatibility in this case.

Except of course again with C3 the dosages required to attain the optimum are much higher than that with C1 and C2. So, again what you see here in this table are the optimum dosages presented for the super plasticizers, okay. Again the dosages here are presented in terms of percentage solids of SP as a fraction of the weight of the cement in the mix, okay. Percentage solids in the SP expressed as a function of the weight of cement in the mix.

So, here you have for C1 the amount of PCE required is 0.066% to get optimum dosage. And at this optimum dosage the spread of the mini slump cone is 162 millimeters. So, at the optimum dosage determined from the Marsh cone test the spread is 162. For lignosulfonate your optimum dosage that means at which you start seeing the saturation in the curve being attained is about 0.266% that means you are more than 4 times the dosage of your PCE.

But in spite of that the mini slump spread that you get at that optimum dosage is only 114. What did it tell you, even at saturation your effectiveness is reduced considerably when you are changing from PCE to lignosulfonate. With SNF again you have a fairly high dosage required to obtain optimum but at optimum dosage your flowability is quite similar to that of PCE.

SMF again high optimum dosage but your initial workability is quite good in terms of the spread at the optimum dosage. Again with C2 what you see is, you require a small amount of PCE you produce a fairly high flowability, you require very high amounts of lignosulfonate but your flowability is restricted, with sulphonated naphthalene formaldehyde you need a high dosage but your flowability is still not at the level of the PCE.

Again you see that the effectiveness is lesser as opposed to your PCE based super plasticizers. Again with SMF you need high dosage and lowered flowability. With C3 look at the increase in dosage 0.066 to 0.165%. So, we are increasing nearly 2 and 1/2 times the dosage because of the higher fineness of the C3. But at the optimum dosage the flow is reasonably good 175 millimeters spread in the mini slump cone.

Again flowability is reduced significantly with lignosulfonate, marginally with SNF and again significantly with SMF, while the dosages required are always higher with the other type of admixture. So, please understand that we are talking about compatibility, we are talking about effective fineness and we are also talking about the effectiveness of the super plasticizers molecules to provide a given dispersibility in the mix.

I think in these cases the water cement ratio is 0.35. In all these concretes the water cement ratio is 0.35. So now what we did was having done this, we saw whether these effects will translate into concrete mixtures of suitable proportions of suitable properties in terms of the fresh properties or fresh characteristics.

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Chemical admixtures - Part 3

Lab investigations on concrete

	w/c	Slump values (mm)				Compressive strength (MPa)	
		0min	30min	60min	90min	3 days	7 days
Control mix	0.45						
C-1		170	70	10	0	20.0	25.3
C-2		180	70	10	0	20.3	26.0
C-3		120	40	0	0	27.3	28.5
With PCE	0.35						
C-1		180	140	80	20	34.0	36.9
C-2		190	140	80	20	36.0	39.0
C-3		190	130	60	20	40.4	40.7
With LS	0.35						
C-1		110	80	10	0	16.2	26.3
C-2		100	60	0	0	17.3	26.5
C-3		80	10	0	0	18.7	28.3
With SNF	0.35						
C-1		150	80	0	0	32.8	39.0
C-2		140	60	0	0	33.4	38.4
C-3		200	130	40	0	38.8	41.8
With SMF	0.35						
C-1		140	100	70	20	32.4	38.5
C-2		190	130	40	0	31.0	38.8
C-3		100	40	0	0	34.2	40.0

So, these concretes were also prepared with the same water cement ratio as what was used in the paste, for each of the cements we used the optimum dosage as obtained from the paste studies as a starting point for the concrete mixes also, and we were trying to obtain at that optimum dosage we wanted a good slump. So, with PCE you can see for all 3 cements at optimum dosage we are producing a fairly high slump of 180 to 190 millimeters.

With lignosulfonate in spite of very high optimum dosages my slumps are restricted to 80 to 110, with SNF I may be getting effectiveness only in the third case that means with C3 where my dosage is quite high 0.64, only in that case I am actually obtaining a slump which is nearly equal to what is there in PCE. For the other 2 cases C1 and C2 my slump obtained is a little bit lesser than what I obtained with PCE.

With SMF, my slumps are severely compromised except with C2 only C2, okay. So, here you see that C2 is giving a compatible combination with SNF, we saw the same thing happening with SMF also which I have not presented here. But with that you are getting actually a flowability which is similar to what is there with the PCE. What is interesting to see is how this translates into the properties of the concrete after 1 hour.

So, we take slump after 1 hour and the only mixes that had a reasonably good slump retention are the ones with the PCE, at 1 hour you still have about 60 to 80 millimeters slump left in the mixes. With lignosulfonate even at 1/2 an hour you have substantially reduced your slump, at by 1 hour or by 90 minutes you are down to 0 slump. With SNF only with C3 where we had a very high dosage of admixture to begin with that may have led to retardation.

So, we have a significant; some slump at 60 minutes but at 90 minutes that slump is down to 0. With SMF again there is very limited slump retention, okay. So, what this goes to show is for the most part compatibility is better with PCE. Effectiveness in concrete in terms of providing a high slump at optimum dosage obtained from paste studies is also higher with PCE. And slump retention is also better with PCE based admixtures.

Now interestingly if you look at the strength obtained by these concretes, by 7 days your PCE, SNF and SMF all these concrete with 3 types of good quality super plasticizers all of them have attained almost the same strengths. Nearly 40 mega pascals, 36 to 40 mega pascals. Your concrete with lignosulfonate on the other hand is only down at about 26 to 28 mega pascals. What you think is happened there even though my water cement ratio is still the same 0.35.

My strengths have been severely reduced when I use lignosulfonate why, that may have to do with the high dosage of the lignosulfonate that are required to produce a given workability because of which lignosulfonate has provided very high retardation, by 7 days your strength still has not caught up unfortunately we do not have 28 day strength data for this, the student who did this project did not turn in the 28-day value.

And by the time I found out it was only beyond the review time so I do not have the 28 day values. By 28 days I assume that the things would have been equal, I assume that there would not have been much difference because all the retardation effects would be over by then. The control concrete, the control mix was prepared at 0.45 water cement ratio, okay. So, essentially we are looking at a water reduction of how much 0.1 water cement ratio.

That corresponds to about 20% water reduction. At 0.45 water cement ratio my slumps very high with the C1 and C2 but lower with C3, why C3 was finer cement so obviously the slump is reduced. The slump retention again was quite poor because by 60 minutes your slump is almost down to 0, again in a normal cement you do not really have super plasticizers which is going to help in retaining the slump. So, because of that your slump is reduced there.

And your strengths are how much lower than your super plasticizers concretes? So here its let us say about 36 to 40. Here we are talking about 25 to 29, so again approximately about 25% lower strengths, 25 - 30% lower strengths as compared to the mixes with the super plasticizers. So you have reduced 20% water so your strength is enhanced by about 30%, okay. So, you are seeing all the effects that we talked about so far. With respect to the action of super plasticizers.

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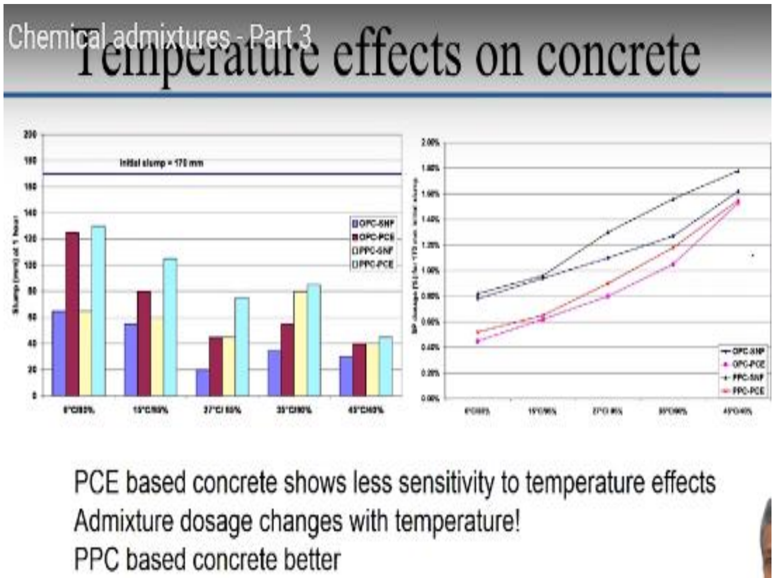

Now interestingly we deal with projects whose duration is quite long, sometimes the projects are starting in summer they go through the winter season then they go to the next summer. And then they will through one more phase of winter and so on and so forth. Then what is happening with this change in temperature is that the super plasticizers requirement also gets changed.

You can easily imagine that like any other chemical reaction with the temperatures higher, the rate of adsorption of the super plasticizers also will increase, more super plasticizers may get adsorbed in the beginning itself, that means your slump initially may be good but then with time with high temperatures your slump retention is expected to become poorer, ok, again that is what we are seeing here for a temperature of between 6, 15, 27, 35 and 45 degrees Celsius you see that the slump which was initially 170 millimeters in all the concrete mixes.

Reduced after 1 hour more and more as the temperature increase, as the temperature increase there is a greater fall in slump from the initial value of 170 millimeters. So, all these tests were done in a controlled chamber you have seen in our lab we have this walk in chamber we took all our materials as well as a concrete mixer into this chamber and we set the conditions at these temperatures 6 degrees 15 degrees 27, 35 and 45 degrees Celsius.

So, at these conditions we wanted to see what the temperature effect would be on the slump retention assuming that you start off from a particular slump 170 millimeters slump. What is also interesting is that the dosage required to attain that initial slump, 170 millimeter slump, is also higher with higher temperatures, as the temperature increases you need more and more super plasticizers because greater amount is getting adsorbed.

You need more and more super plasticizers to saturate the system, so what does this tell you about a construction project which has a long duration, the mix design should be dynamic you need to be adaptable in terms of the change in temperatures or the requirement of super plasticizers also will change because of which your mix design should be flexible in terms of the super plasticizers dosage that you add to the system.

And very often when you are dealing with government clients they want everything written very clearly so when you do your mix design for these projects which are involving government clients you need to ensure that you specify what could be the range of super plasticizers dosages that are permissible in this concrete. For example, for this concrete mix, you see that for 6 degree Celsius we are down of about 0.4%.

Let us say this pink line here 0.4% and here we are up about 1.5% look at the increase in super plasticizers dosage between 6 and 45 degrees, this dosage is going up nearly 4 times or nearly 3 times right. So, you can liken this to a condition like Delhi for instance, in Delhi temperatures can fluctuate between extremely cold and extremely warm climates and this could be a realistic situation.

That in a project that runs over several months your dosage of the admixture required to produce a given initial slump changes significantly. So all that has to be reflected in your mix design. So, what is interesting to see here is that the loss in slump was less in the case of PCE and specifically the combination of PPC and PCE; Portland pozzolan cement and PCE, in all the cases that ordinary Portland cement lost most slump as opposed to the Portland Pozzolan cement.

And the super plasticizers dosage required also was lower for the combination of PCE based admixtures with OPC and PPC. So, the upshot is that for a construction project you need to be aware of the change in demand with respect to super plasticizers dosage of the concrete mix and this has to be accommodated in your mix design process.

Now that leads us to the fact that oftentimes in most major projects, the time given for concrete mix design is only minimal, they maximum gives you 28 days to do a mixing. But then within that time to actually completely complete a study of understanding the requirement of SP over different season it is almost next to impossible. So, all these aspects have to be taken into account before you really do a design for a construction project.

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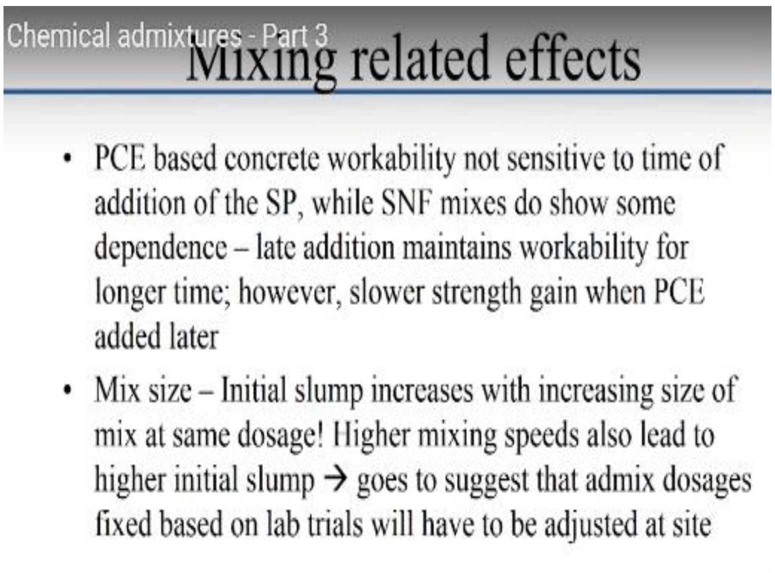

Now it is not just the cement and super plasticizers type, it turns out that the mixes that you design based on laboratory trials may or may not always work when you go for large scale mixes in the field, what we have seen is when we change the size of the mixer and the speed of rotation that also can have a significant effect in the initial slump that you obtained and the longevity of the retention time.

Now this leads us to a totally confusing situation what do we do then we are doing all our mix designs for field applications based on lab studies. What I am just trying to see is very often it helps to do an actual field trial before you completely fix on your super plasticizers dosage. That is one thing you need to leave to the field trial stage to ensure that you get the required workability.

And retention based on the type of mixing equipment and mixing durations that are going to be used at the site and do not always rely on laboratory data in the case of SP dosage, that is where we need to be extremely careful. So, all these were actually results that came out of a very large research study that we had undertaken over a period of 3 to 5 years where we looked at various different combination of cement and chemical admixtures.

We tried to work out effect of sulphate content, effect of the fineness, all that lead us towards more and more confusion. But what I am trying to present you are the issues that were more or less well resolved. I am not really leading into the other issues that caused a lot more controversy and confusion. I am just explaining the aspects that we were able to correctly conclude and bring to light in a good workshop that we conducted with the Indian concrete institute.

Where we disseminated all this information and because of this there has been some development in the construction sites where people have started, cement companies and admixture providers have started looking at this usage of Marsh cone and Mini Slump tests and now it is almost become a routine practice to actually adopt this for large scale projects where we can really have major repercussions of the mix does not have a compatible combination.

Okay, so we will stop with this and well get into the next part which is set controlling chemicals in the class.