Advanced Concrete Technology
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Lecture – 14
Chemical admixtures – Part 2

The discussion on chemical admixtures is continued in this lecture. In the last lecture, we saw the basic structures that go into making these molecules. Most of these super plasticizer that we were talking about are water reducing or the water soluble polymers and primarily they have the mechanism of surface adsorption; while the older class of polymers leads to an electrostatic repulsion after surface adsorption. The new class of polymers causes repulsion of the cement particles by steric hindrance which is associated with the bulky side chains that you have in these polymers because of which they have much superior water reduction properties as opposed to the older generation admixtures. Further the slump retention is also much better when we have poly carboxylic ether or graft chain copolymers which are essentially working with the principle of steric hindrance.

We also looked at some comparisons of different types of super plasticizers. We came across a term called modified lignosulphonates. So lignosulphonates as you know are water reducers, if you use them in high dosages, they do act as super plasticizers but the problem is they can lead to excessive air entrainment and retardation. So to ensure that these two aspects do not happen, we remove the low molecular weight components, which leads to air entrainment and we remove the sugars from the lignosulphonates by fermentation. Once you remove the sugars, you can modify the structure of lignosulphonates and make it much more effective as a super plasticizer. The advantage is that it can be blended with SNF or PCE admixtures and can effectively lower the cost of the SNF and PCE admixtures and at the same time provide some degree of retardation to the concrete to ensure that you are able to complete your concreting processes well in time.

So, those are the aspects that we were talking about in terms of comparison of properties and performance of different types of super plasticizers. Now, cost is something which is obviously uppermost in the minds of all project managers, they want to look at how the incorporation of new ingredients can change the costs of the concrete. One thing we ought to remember that the

cost is often related to the initial cost that we have for the raw materials that are used for preparation of the concrete.

The cost truly does not take into account the improvement in the concreting processes when you have super plasticizers that are added to the concrete. Work becomes more easier with super plasticizers because you are now working with a high workability as a result of which you are actually obtaining your concrete at lower total cost if you consider the time taken for the construction or energy spent on actually vibrating the concrete and so on and so forth.

So, if you take that cost into account, overall cost that you always get with super plasticizers will be definitely beneficial or lesser as compared to the cost without super plasticizers. We also discussed the fact that to produce concrete with low cementitious contents, it is always better to have super plasticizers in the blend to ensure that you are able to get workability at the lower water contents that are typically used.

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So, without super plasticizers we will be ending up spending much more on the quantity of cement that you add the concrete mixture. Nevertheless, if you look at the costs of the super plasticizing molecules that are available in the market today; what is presented here is the relative cost between acrylic polymer, melamine, naphthalene formaldehyde and modified lignosulphonates.

The cost of the dry polymer is expressed in arbitrary units here. The cost in Indian rupees for an acrylic polymer or a polycarboxylic ether based super plasticizers will be Rs.120 to Rs.150/kg. Comparing to this, Melamine formaldehyde would be about 80% of the cost of acrylic copolymer. Naphthalene will be about 40% of the cost, whereas modified lignosulphonates with will be only about 20% of that cost. But what you need to remember is the concentration the solution that you actually get in the market. Do typically acrylic copolymers or PCE's are available at 30% solids content whereas all the other plasticizers are available typically in around 40% solid concentrations. What is not given here is the effectiveness, which is marked as another column in the slide. So, I talked about the fact that super plasticizers based on graft chain copolymers like acrylic polymer or PCE are much more effective as compared to naphthalene formaldehydes or lignosulphonates.

So, let us say we need 1% by weight of cement of the PCE based admixture. So I had arbitrarily put this effectiveness as 1, let us say to get a 100 millimeter slump in a concrete which has 400 kilograms of cement, I need about 1% by weight of cement of the acrylic copolymer to get that workability. For melamine, I will probably need close to about 1.3% by weight. Naphthalene, probably even more, may be about 1.5% by weight of cement to actually obtain the same degree of workability as I have obtained with 1% of polycarboxylic ether and modified lignosulfonate, I will probably need 2% to get the same extent of workability as I get with the acrylic copolymer.

But we are working at already a lower solids concentration of the PCE. So, convert that 1% to the actual amount of solid content that is actually required and that would be 0.3% of the solid for acylic copolymer, about 0.52% of solid for melamine formaldehyde, 0.6% for napthalene and 0.8% of the solid super plasticizers for modified lignosulphonates. I am working out how much solid super plasticizers dosage, I require to produce a given slump in a concrete which has approximately about 400 kilograms of cement per cubic metre. So, what I see is; need a dosage of about 0.3 from acrylic copolymer, 0.52% from melamine, 0.6% from naphthalene, and about 0.8% from the modified lignosulphonate. Now, without going into this column here, if you translate this into the cost, we may arrive at a different conclusion.

As written in red in the slide, considering the cost of superplasticizers with respect to their effectiveness, cost of acrylic copolymer would be 0.3*100 = Rs.30 where 0.3 is the effectiveness and 100 is the cost of the dry polymer. These are some random units, we are not really talking about cost in rupees or dollars or whatever. In the same way, cost of melamine, naphthalene and modified lignosulphonates would be Rs.42, Rs.24 and Rs.16 respectively.

What I have probably done is underestimated the amount of modified lignosulphonates required to actually get the same effectiveness. If you use 2% of modified lignosulphonates, you will definitely get this effectiveness, the only problem is you will also get significant amount of retardation, so your concrete properties may not be to the level that you desire.

So, what we need to look at is a comparison of your PCE and SNF. So if you are able to assume that you are getting sufficient workability with 1.5% of the SNF or which results in 0.6% of the solid SNF, then what you are ending up with is not much of a difference in the actual cost in the concrete, whether you use a PCE or SNF based super plasticizer. Now, in the modern day concretes people still prefer the use of sulphonated naphthalene formaldehyde. Because the initial cost which is only about 40% of the acrylic copolymers or the PCE's but if you really compare the actual cost in concrete, 6 rupees out of 24, so percentage difference in cost is only about 25%. That is you may actually get better slump retention with the PCE with 25%, is it worthwhile to pay for the extra slump retention that you get? May be, yes!

To talk about the range of water cement ratio you will see is when a want cement ratio starts dipping to below 0.4, the effectiveness of SNF sharply declines, SNF needs about 0.4 water cement ratio or more to be effective in concrete. So, at that stage may be the difference may not be that large anyway, it will still come down. The Rs.6 will further come down to Re.1 or Rs.2. So more stringent the mixture design gets the more economically feasible will be the use of specialised additives like the polycarboxylic ethers or acrylic copolymers.

If you are dealing with day to day concrete construction, like 25MPa or 30MPa concretes, modified lignosulphonates or maybe just the SNF would be more than enough to really achieve the kind of properties that you want. But when you deal with concretes of grades M40, M50 and

above, you're dealing with water cement ratio is that are routinely below 0.4 and on that scale, the economy of using the SNF may be quite similar to the economy of using a PCE based super plasticizer and the effectiveness of the PCE would be better. So this cost analysis is important because it gives you a handle us to how you can approach mixed design for large infrastructure projects. Initial cost is only going to get you to an erroneous decision for example, if I just go with the initial cost, I will probably end up with much better cost analysis with the modified lignosulfonate in terms of effectiveness, they are probably not get the same extent of performance that they want from the concrete.

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Compatibility Issues

- Incompatibility may be defined as the lack of expected level of performance when a given combination of cement and superplasticizer is used
- Performance indicators:
  - Poor slump retention
  - Retardation
  - Bleeding / segregation
  - Low early strengths
- PCE known to have fewer compatibility problems compared to SNF

Very often we deal with situations in the field, where things do not go as planned especially, when in the age that we have been using extensively different types of chemical admixtures in concrete, the compatibility problems have been on the rise. Compatibility here refers to the performance characteristic expected from a combination of cement and super plasticizer or cementitious material and super plasticizer.

Incompatibility may result in one or more of these kinds of performance indications. You may have a poor slump retention with a concrete, you may have retardation,bleeding, segregation and low early strengths. These are some of the problems that we expect to happen, when we do not choose our mix design properly especially, if you do not have the right combination of cement and super plasticizer. In general the kind of polymers which have these long side chains are

known to have few compatibility problems as compared to the ones which work with an electrostatic repulsion.
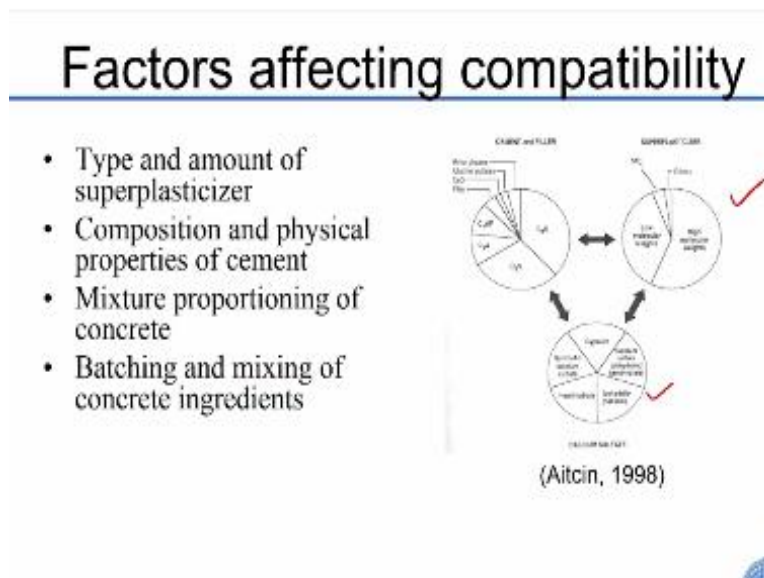
If you really want to get into an in depth understanding of what constitutes compatibility or what are the factors that affect compatibility, this will take as a whole lot of time to actually do this because if you really look at what people have done in literature, trying to look at different parameters as to how they affect the compatibility, there is a whole lot of things that can be looked at.

One is the type of cement and the composition of the cement, cement is also having several other additives for example, gypsum, alkalis which are present as impurities in the Alite and Belite itself, free CaO that is present in the cement and other minor phases which may or may not have an effect on the compatibility issues.

But the type of sulphate can make a major difference in the kind of the hydration process that happen in the early ages. If you have unhydrate or hemi hydrate or di hydrate, you can get completely different rates of solubility and that may cause very different performance in the initial stages. We talked a little bit about how the presence of low molecular weight components can entrain air in the system, the presence of sugars can actually lead to retardation and so on and so forth and the fact that when you have high molecular weight components, which are present in

the super plasticizer, the adsorption is much better and that leads to a much higher workability in the initial stages.

Now, all these effects will also depends on how the interaction with the cement happens; will affect the early age performance of the concrete and what is present at the bottom (in the slide) is the kind of gypsum that you have in your system that is your either gypsum or hemi hydrate or un hydrate or natural un hydrate. So you can have different kinds of calcium sulphate which will have different effects at the rate at which your reaction proceeds further, at the rate at which your cement interacts with the super plasticizer also.

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Compatibility Issues

Influence of :

1) C_3A
2) $C_3A/CaSO_4$ ratio
3) Alkali content
4) Fineness of cement

We will primarily look at 4 major issues, what is the influence of the C_3A on the compatibility, then influence of C_3A to sulphate ratio, the alkali content and also the fineness of the cement. The effect of fineness of cement on compatibility is that, if you choose finest cement, since there is a greater surface area, there will be more adsorption of the super plasticizer molecule. These adsorption has to happen in stages, first the adsorption should be on the unhydrated cement grains but soon these cement grains start hydrating and producing the early phases of hydration like CSH and ettringite, so you must have some super plasticizer still left in solution to further adsorb on these particles to still keep them in suspension because we need to extend the workability as long as possible. So the finer of the cement, the faster will be the rate of

adsorption of the super plasticizer and probably that may lead to a lower effectiveness of the super plasticizer. In terms of maintaining the slump, your SP may not be as effective as before.

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Looking at C_3A, the process of grinding of cement producers particles that get charged and C_3A generally ends up with a positive charge. So the positively charged C_3A will start attracting the negatively charged super plasticizer molecules. We saw earlier, the structure of the super plasticizer, there is a charge imbalance that leads to the negative charge being imparted to the cement particles after the super plasticizer is adsorbed on the cement particles.

So, here there will be a preferential adsorption of the super plasticizer molecules on the C_3A grains because of the positive charge of C_3A. There is also a lesser positive charge or almost neutral charge on the other grains, which will again lead to more adsorption by the chemical admixture but you may lose most of it to the C_3A because of the affinity to the sulphonate molecules and if SNF is used, we have the sulphonate contributed by the SNF also. As a result of that there will be a competition between gypsum and the super plasticizer molecule for the sites on which you have more C_3A content available. So because of this will happen is part of your super plasticizer may get ineffective and blocked the C_3A site. This can lead to a retardation of the reaction of C_3A because more super plasticizer is getting absorbed on the C_3A molecules.

So, the effectiveness of the super plasticizer is coming down; that means initial workability may also come down or retention of workability may be affected but at the same time, the setting of the C_3A may also get delayed. Now this is a unique problem, you generally expect that when the slump is not retained for a long time, the setting should happen fast but here it is the opposite which is happening. Neither is the slump getting retained nor as setting happening fast because your C_3A molecules are getting adsorbed by the C_3A particles. So you get loss in slump and you get delayed setting also, as C_3A needs to react the gypsum to produce the ettringite that leads to the initial stiffening and setting of the cement paste. Instead of that, if its combining with the super plasticizer's sulphonate, then it is not really going to be leading to the right kind of reactions that lead to setting.

Here, you have loss in slump and delayed setting that generally happens when you have combination of SNF super plasticizer with cementitious materials having high C_3A contents. The other effect that SNF can have is that it inhibits the nucleation of gypsum. For example if your sulphates are available in the form of anhydrite or hemi hydrate, when they come into contact with water, they will first transform to gypsum.

$$CaSO4.\frac{1}{2} H2O + \frac{3}{2} H2O \rightarrow CaSO4.2H2O$$
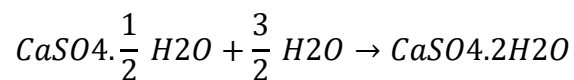
This initial combination of unhydrate or hemi hydrate with water leads to a unique condition in your concrete, which is called false set.

Now, when SNF is present in the system, it can inhibit the nucleation of gypsum, so it can actually lower the possibility of false set. The false set can be overcome by mixing further. So SNF gets attracted to the C_3A molecules, loses its effectiveness because it goes in preferentially adsorbs on the C_3A, it causes a loss in slump, it causes retardation because C_3A is no longer available to interact with gypsum.

Now, what I can do in this kind of condition is that I can add my SNF a little bit late to the system. First, I add the water to the cement and it will promote the interaction between sulphate

and C_3A first and then I add the SNF and that will lead to an improved dispersion of not just the unhydrated grains but also the initial hydrates that are actually forming in the system.

Because this way, C_3A is first already combined to some extent with the sulphate and SNF is not going to compete with the sulphate anymore for C_3A, sites. So delayed addition is quite a good very effective strategy to work with as far as SNF is concerned. With PCE, delayed in addition may or may not do anything because PCE does not have this issue of preferential adsorption on the C_3A.

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Influence of C_3A/Gypsum ratio

- Relative amounts
- Relative reactivity

Both determine compatibility

Now the interaction between the C_3A and the gypsum will be discussed. The relative amounts and the reactivity of the C_3A phase in gypsum that are present in the system can govern to a large extent what happens in the initial stages and especially, when you have a super plasticizer into the system, you may actually create different conditions of incompatibility that may exist in the system.

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Influence of C₃A/Gypsum ratio

Reactivity of C₃A	Availability of sulfate ion	Setting time
Low	Low	Normal (2-4 h)
High	High	Normal (1-2 h)
High	Low	Quick set (10-45 minutes)
High	Nil	Flash set (<10 minutes)
Low	High	False set (<10 minutes)

Based on Mehta and Monteiro, 2003

So, let us look at what happens when you have different types of C₃A and gypsum in the system. For all practical discussions, I will be restricting my discussion to sulphonated naphthalene formaldehyde not PCE. Because what we know from practice at least in the last 20 years or so is that whatever problems we have with SNF, we typically do not have with PCE.

If I have different reactivity of C₃A and different availability of sulphate ions, I may actually get different setting times in my system. So first let us look at a case when the C₃A has a low reactivity and sulphate ions are not available fast enough in solution. That means that I have dehydrate or gypsum in system and not unhydrate or semihydrate as there are rapidly dissolving.. My reactivity of C₃A is also low and that will lead to a normal setting which happens in about 2 to 4 hours. That is a condition which we can live with because in this case, when I put in my super plasticizer, what will happen? If I have an SNF super plasticizer coming in I may cause retardation as this SNF is now going to be attracted to the C₃A. The sulphate is available very slowly, so my interaction of the C₃A with sulphate may not happen immediately. In the meantime, SNF may start going in getting attracted to the C₃A particle and lose the effectiveness which may result in loss of slump, right and retardation because C₃A is getting blocked and setting time may be extended to 6 to 8 hours in this case.The possibility could be a slump loss and retardation.

For the second condition, I have a high reactivity of C_3A and sulphate ion is available very fast. That means there are sources like unhydrate or hemi hydrate also present which can release sulphate very fast and in the absence of super plasticizer, I will probably get a normal set within 1 or 2 hours. That is because I have very quick reaction between the C_3A and the sulphate. So when I add the SNF, there may not be a slump loss. Even in this case, there will be affinity of the SNF to the C_3A, but my sulphate is already very rapidly dissolving. So I may not lose my effectiveness by losing my SNF to the C_3A. So I may not have slump loss and retardation when the reactivity of C_3A is high and availability of sulphate is also high. So that may be a desirable circumstance to have except the fact that it will result in a fairly quick set between 1 and 2 hours. That gives you much lesser time for playing around with concrete in terms of the workability, open time and so on and so forth. So for example if you are looking at the ready mix applications, this may be a useful combination to use if your travel times are less.

Now, in the third case, when the reactivity of C_3A is high and sulphate is not becoming available fast enough in a normal condition this will lead to a quick set. It is called so because you may have some formation of calcium aluminate hydrate because of reaction of C_3A with water. Some reaction of sulphate with C_3A may happen in the early stages. Now in this condition you need to be obviously extremely careful when you add the SNF. When you add the SNF, your slump loss will be rapid and retardation may be sufficient to bring your setting time to normal. You will get a rapid slump loss and probably your setting time will come to normal because of the effective retardation that happens with the SNF.

In this case, it is not much to discuss obviously because of reactivity of C_3A is high and there is no sulphate in the system that will lead to flash setting that happens because the formations of calcium aluminate hydrate. This is a system that does not exist, so we are not really going to talk about that.

Looking at the last condition when you have a low reactivity of C_3A and a high availability of sulphate ions. That means you have a lot of unhydrate and hemihydrate present in the system. So as we discussed earlier this will lead to the false set condition which happens within 10 minutes but this set is getting broken down, right by further agitation of the mix. Now if I add SNF to this system, as SNF inhibits the nucleation of gypsum, there will be no false set. Slump loss may not

happen, and retardation also may not happen because sulphate is available quite rapidly. It can interact with aluminate even though the aluminate is not as reactive, so no retardation.

So, what is the critical situation for us to deal with in this; all these 5 cases? The fourth case is not really true in regular cement. So the most critical cases for us are; the first one as well as the third one. In the first and the third we have either a low or a high reactivity of C_3A and mostly a low availability of the sulphate ion. So what we have to ensure is in our cement, we end up having a combination of sulphates which is able to give me a very high rate of availability in the beginning itself. So, in both these cases, sulphate ion availability is low in the beginning. So whenever I have sulphates available early enough in the system from the gypsum type that has been added to the cement, I will be able to overcome this problem to some extent. If reactivity of the C_3A is low that again will lead to a process of retardation. So, what should my cement have in order to be compatible in an SNF kind of system?

I should have high reactivity of C_3A and mixed forms of sulphate so that there is lot of availability of sulphate from the very beginning in the system. So if you can fine tune your cement to produce something which has the reactive C_3A, but at the same time you also need to be careful that the high reactivity of C_3A will obviously cause much faster reaction to happen, and you also have to be worried about the fact that this high reactivity C_3A might lead to greater adsorption of the super plasticizer, in case there is not sufficient sulphate available in the system.

So, you have to use it together, the high reactivity C_3A as well as the higher availability of the sulphate ion in solution and that will lead to a situation, where incompatibility may be avoided to some extent. Even in that case, you grinding of the cement all that also still will have some effect in altering the compatibility of the system but for the most part, use of a high reactivity C_3A and a mixed sulphates availability in your system in terms of unhydrate and hemi hydrate contributing sulphate rapidly and gypsum contributing sulphate in the later stages that lead to an effective performance in your cementitious system.

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Effect of Alkalies

➢Modern cements have higher alkali contents

➢High alkali contents lead to poorer rheology

Alkalis are something that generally lead to a poor rheology. Modern cements have higher alkali contents. Even with lower alkali cements, the durability is not affected in terms of pH. Higher alkali contents basically, lead to a higher reactivity. Especially, when we talk about C_3S phases, the higher alkali content can lead to much greater reactivity because alkali sulphates very quickly come into the solution, so sulphate from alkalis are also available in the solution. So if you have higher amount of alkalis present in a system generally, your reactivity of your cementitious phases particularly your C_3S and C_3A phases is much higher.

And we want always a very higher early strength from cement, so because of that higher reactivity is generally preferred. So most cements would tend to have high alkali contents. In India, we have alkali contents of about 0.6 to 0.8% of sodium oxide equivalent or Na_2O_{eq}, and US cements would have about 1 to 1.2% of alkali content..

The alkali oxides present in cement are sodium oxide and possession oxide. It is converted to an equivalent sodium oxide percentage. That is how you will be seeing the proportion represented on the cement mill sheet. So in the US, you routinely deal with alkali contents which are of the order of 1 to 1.2%. So, in higher alkali cements, you have to really ensure that you put in more super plasticizer to get sufficient amount of workability in the system because higher alkali cement have poorer rheology or poorer flow behaviour. **(Refer Slide Time: 34:07)**

Materials for good compatibility

CEMENT
- Not ground too fine ✓
- C_3A in cubic form ✓
- Low alkali content ✓
- Gypsum polymorph of high solubility

SNF
- Low in dimers and trimers
- SO_4 in β position

PCE
- Usually compatible

In QC, we should be able to judge the combination for its compatibility
Let's look at some tests which can help…

So to have a good compatibility, if you look at cement, too much fineness is not preferred. If I have too much fineness, it tends to increase the rate of adsorption. Butthis is something which you cannot really govern because the fineness will be dictated by the kind of strength gain properties that you desire from the cement, right, depending upon what is the expected level of performance in terms of strength. So when you have the chance to grind cement finer or coarser, not grinding too fine may help in reducing the compatibility problems, or if you are having a compatibility problem with the cement, opting for a lower fineness may actually help get rid of some of that compatibility problem.

Generally it is seen that C_3A in cubic form which presents a high reactivity as opposed to a orthorhombic form can lead to a much better compatibility in a cementitious medium. Lower alkali content is always better and gypsum polymorph of high solubility or a mixed gypsum polymorph for example, mixed combination of unhydrate, hemi hydrate and di hydrate in the system is preferred.

In case of SNF; we need to avoid low molecular weight materials because that leads to air entrainment and sometimes the sugars present in lignosulphonates or SNF can also cause retardation and we also saw earlier that in the structure of the SNF, if your sulphonate is present in β location, enhances the effectiveness of the SNF.

In PCE usually, there is not much compatibility issues. However there may be some reports of slump loss even in cases, where PCE admixtures is used that is because they are generally being used in concretes which have lower water to cement ratio.

But, in quality control, we do not really have a choice about what is the composition and what is the nature of the cement in terms of the type of C_3A, the form of C_3A and so on and so forth. We also cannot control the molecular weight of the super plasticizer; the fact that your sulphonate is in the beta position or whatever. All that is governed by the manufacturer of the cement or the construction chemical.
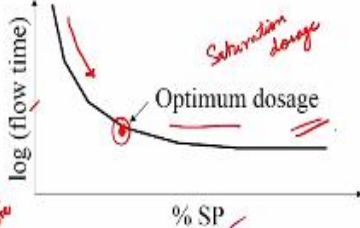
In most cases, as a quality control specialist on the job site you will have to deal with what we are getting. But before you set out to make a concrete, there is some simple test methods that can be done to evaluate the compatibility between cement and super plasticizer, so let us take a look at some of these.

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One simple test is the Marsh cone test. This test itself is derived from something that is being used for long time for grouts. So as the name implies it is just a cone or a funnel essentially, which has an orifice of the bottom and the size of this orifice is typically 8mm for cement pastes and 12mm for mortars.

So, what is done here is that you prepare your cementitious paste with different dosage of super plasticiser and you prepare about 1 litre of paste that can be poured in to this funnel. Close the bottom of this funnel with the tip of your finger and after you put the required volume of paste into this funnel, you then remove the tip of your finger, open the orifice and allow the cement paste to flow out of the cone. The time taken for 500ml paste to flow out is measured. So cement paste mixtures with varying super plasticizer dosage increasing from 0 to the maximum permitted value in the system is prepared and when you plot the flow time against the SP dosage, you will have a reduction in your flow time. But what you will see is, beyond a certain point, there is no significant decrease in flow time with an addition of extra super plasticizer. If you were to compare this to a law in economics, it would be to the law of diminishing marginal returns.

So, you put in more and more super plasticizer beyond a given point, you see that there is not much significant reduction in flow time. So, what do you think is happening in that dosage beyond which extra SP is not really doing much in your system?

Since there is no extra cement surface left, whatever extra SP that is added will simply go to wate. It is not really doing anything for further plasticising the cement grains. So effectiveness of SP beyond this dosage is not significant and as a result, the flow time does not get enhanced significantly beyond that dosage. So that dosage is called either optimum dosage or saturation dosage.

If the same dosage of superplasticiser is used in concrete, the workability may be less. Since aggregates are present which are porous and having a surface charge, super plasticizer may also start getting adsorbed on the aggregate particles. So some effectiveness of the SP will get lost. In other words, in concrete you will definitely need a dosage greater than optimum dosage to result in any degree of flowability that you may want. That doesn't mean that at optimum dosage in concrete, you may not get any workability at all; you may get some level of workability. But you may want to plan as to how much additional SP that you need to add to concrete to give you the correct level of workability in a concrete, So the optimum dosage in paste may or may not translate into the required workability in concrete because in some cases in concrete, you want to

workability of 200 mm slump, in other cases you may want to slump flow of 600 millimetres. So generally what you do is; you use in combination with another test called mini slump test. (**Refer Slide Time: 42:02**)
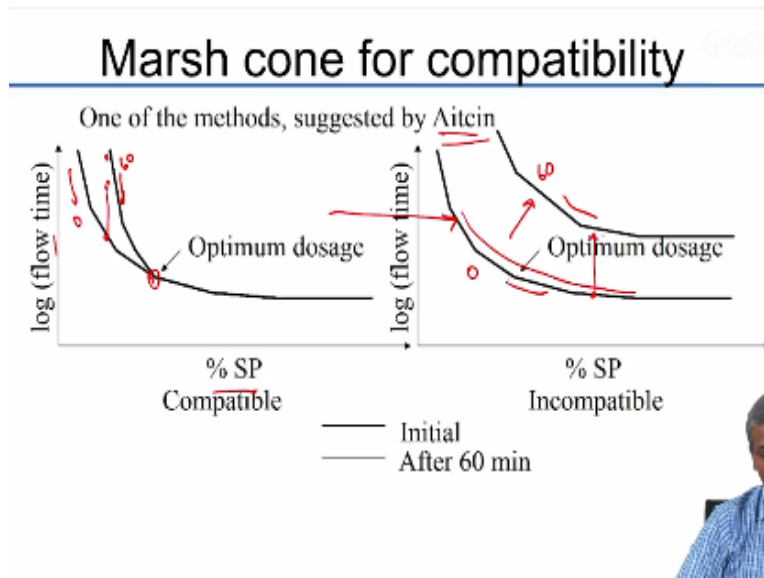
How do we use this marsh cone for compatibility standards? So, this is one of the methods that is suggested by one of the leading researchers of our times, Pierre-Claude Aitcin and he has worked with lot of super plasticizer systems and based on the work done by researchers that his university in Sherbrooke in Canada, they came up with this sort of the scheme that for a compatible combination of cement and super plasticizer, if you do the test at time t = 0, and the same test is repeated with the same paste after 60 minutes, the curves of the flow time verses percentage of super plasticizer will coincide beyond the optimum dosage. After 60 minutes, flow time is going to get higher, because the slump is getting lost.

But at SP dosage which is optimal, there is sufficient super plasticizer in there that even after 60 minutes the paste has the same flow time as it had initially. So that is one of the definitions that Aitcin et.al. have come up with for a compatible combination of cement and the super plasticizer. In the same token an incompatible combination means that this curve entirely shifts after 60 minutes to the top. If you test the same paste after its been remaining in your mixer, you mix it again after 60 minutes and then test the flowability the curves completely get separated if incompatible.

So, for any dosage of SP, the flow time gets increased even after optimum dosage. So in the next lecture we will think about the physical significance of this and apply this to some real experiments that we have done in the lab and see whether this actually holds good in terms of assessment of compatibility.