Admixtures and Special Concretes

Prof. Manu Santhanam

Indian Institute of Technology Madras

Department of Civil Engineering

Lecture -22

Chemical Admixtures: Viscosity Modifying Agents (VMA)

Viscosity modifying agents:

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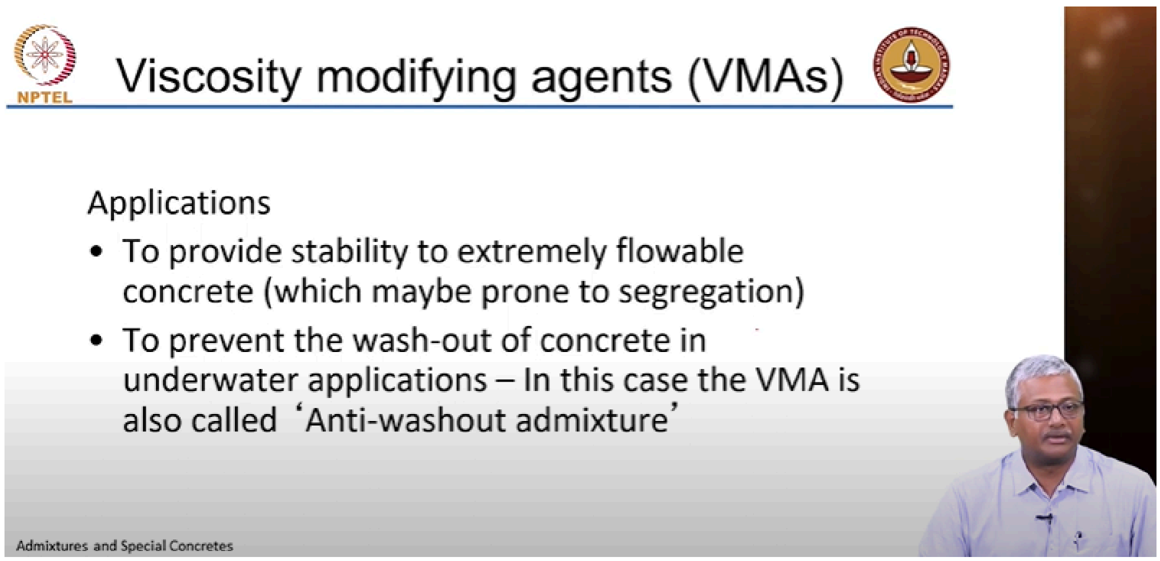

So let us look at how viscosity modifying agents are used. The primary idea of using viscosity modifying agents is to provide stability to extremely flowable concrete, mainly to help reduce the chances of segregation in flowable concrete. Because as you increase flowability, there is greater risk of segregation. So you need to control the viscosity so that segregation does not happen. The earlier use of viscosity modifying agent was as an anti-washout admixture. So when you do tremie concreting in a pile, you know that there is going to be water at the bottom of the pile. So when you put your concrete into this water, the concrete should displace the water and the water should not get mixed up with the concrete. So for underwater concreting, you need to ensure that the concrete is cohesive enough, more or less like putting a gum inside the concrete and causing the concrete to have some cohesiveness and that prevents the water from mixing with the internal water of the concrete. Of course you need the water inside the concrete to provide workability. External water, if it mixes with the internal water, concrete will get completely segregated or separated. To prevent that you need to make it cohesive and that was the original use of viscosity modifying agent like an anti-washout admixture.

Examples of VMA's:

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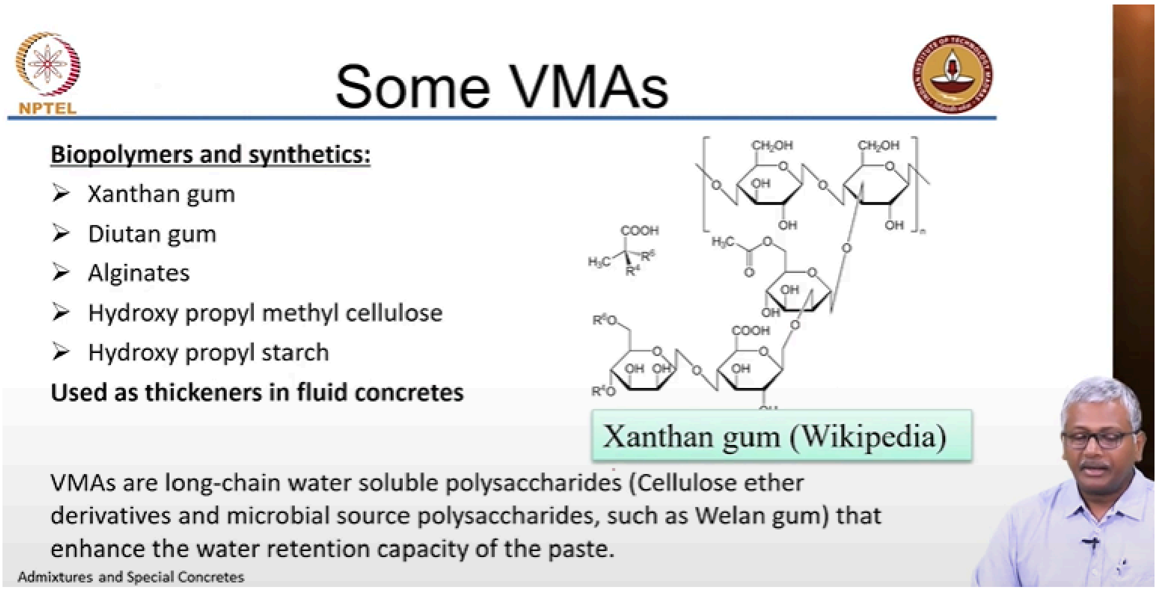

Examples of VMA's as I said this is more like a glue. So most of these are basically plant derivatives, gums, alginates or cellulose, starch, these are different types of biopolymers that are used typically as viscosity modifying agents. Similar to cooking, what we use is akin to this approach. Where do you want viscosity to be controlled in cooking? Soup exactly, you use corn syrup or corn flour not corn syrup, corn flour. Corn flour is used to control the viscosity of the soup otherwise all your vegetables are going to go and stick at the bottom and you will just have water at the top. So you want the thickener, it is basically a thickener, same way you are putting a thickener in your concrete and these are basically the examples of using thickeners. These are again water soluble polysaccharides, they are water soluble only to a certain extent, and you cannot really make a very high concentration solution. Water solubility is typically of the order of 2 to 3% and not more because of which you are mainly selling water when you sell viscosity modifying agent. Super plasticizers we saw that we can put 30 to 40% and solubility is more but anything beyond that will become a little bit difficult to control in concrete. So these are water soluble polysaccharides and the primary idea of adding these is to enhance the water retention capacity of the paste. So in other words the water inside the paste or inside the concrete because of the action of these chemicals stays inside and does not get intermingled with the water outside that is in the case of anti-washout admixture.

In the case of viscosity modifying admixture what happens is once the concrete is not yet getting sheared the viscosity of the paste is controlled to such an extent that the aggregates do not start settling. So that is the idea.

Mechanism of VMA:

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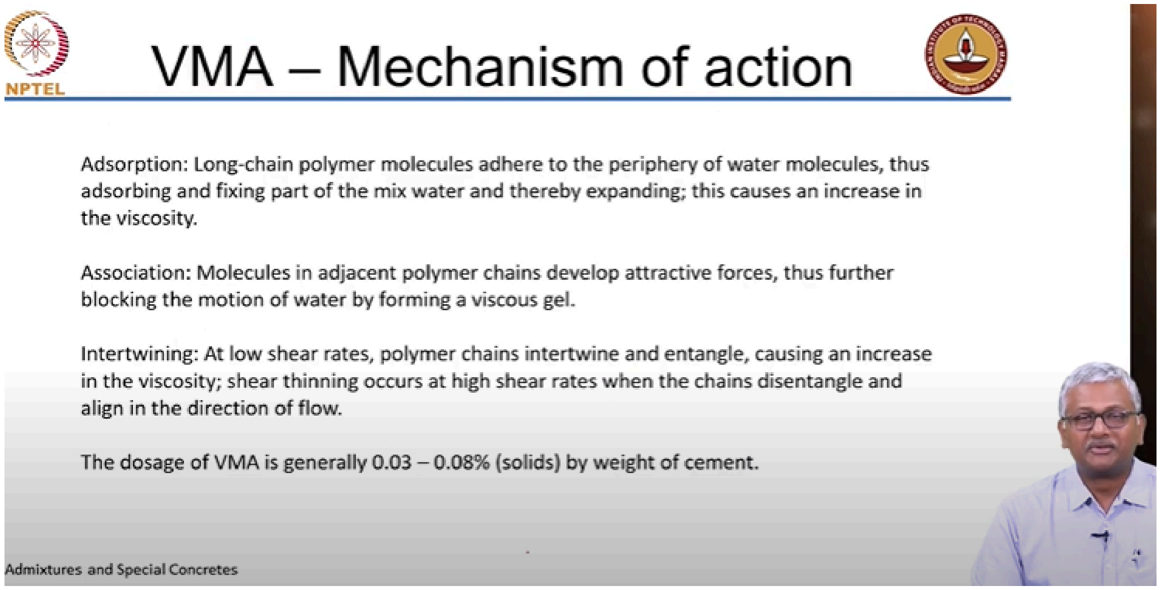

So how do you get these to work? There are different mechanisms by which viscosity modifying agents can work. One is called adsorption similar to your super plasticizers. So here adsorption is not happening to the cement but to the water. Some long chain polymers can adhere to the water and prevent the water from easily coming out. Now the problem here is if they are going to be adsorbing onto water molecules your water is not free enough to provide workability. So there will often be a competition between the viscosity modification that you need from VMA and the loss in workability that happens as a result of this association with water. So viscosity will enhance because your water is not free anymore but at the same time your workability may also get reduced to some extent.

Now association is when molecules in adjacent polymer chains develop attractive forces thus further blocking motion of water by forming a viscous gel. So assuming these are long chain polysaccharides, if they have attractive forces towards each other the water is trapped again inside it does not easily come out. And otherwise you have this issue of intertwining if you have long enough polysaccharides so when the shear rate is very low or when the concrete is at rest all of these chains are getting intertwined. But when you apply shear these chains will start getting straightened out and the concrete will flow. This is the behaviour that we want, we want the shear thinning type of behaviour where at high shear rates we want the concrete to be able to flow easily but when concrete comes to rest it needs to build up this internal structure that is why this intertwining basically helps these polymer chains start getting intertwined when you remove the shear. So there are various ways in which different types of admixtures can act these are three common approaches by which you can have. So dosage of VMA is typically small 0.03 to 0.08% of course depending upon the type of VMA this is in terms of solids content 0.03 to 0.08% solids. If you put more than this your retardation effects will dominate so much that you will totally lose effectiveness.

And in some instances we have also seen in our research work that if you put more than a certain dosage of the VMA it tends to form these agglomerated blocks inside the concrete which are almost like porosity and it reduces the strength of your concrete. So you have to be very careful when you use VMA's because there will be a loss of workability when you use a VMA. Second is that you are likely to result in lower strength of the concrete. So both ways you need to guard yourself against possible side effects when we start using VMA's.

Fixing dosage of VMA:

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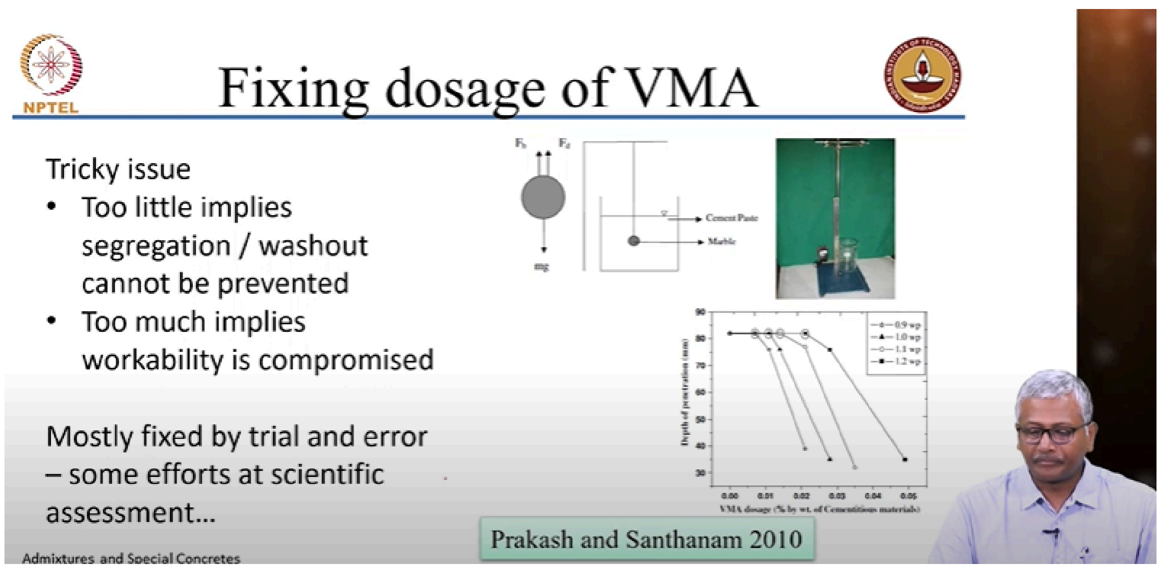

Now we had done some work about how one could fix the dosage of VMA. We talked about super plasticizers in the case of SP. It was easy to use a marsh cone test to look at the saturation dosage that could be a good starting point for the amount of SP required to produce a certain workability in concrete. But what about the VMA? As I said if you add too little of it, it is not going to work. If you add too much of it, it causes excessive retardation and it likely reduces strength also. And it is going to compromise your workability if you add too much also. So there are some ways in which you can actually fix this dosage. We had described this methodology in a paper that is published in Materials and Structures. The idea was quite simple: you have a string to which you attach the spherical marble. You get the marble to rest on the surface first. You get the marble to rest on the surface. So what will happen because concrete is still fresh? Your marble is going to start sinking into the cement paste. Marble will start sinking into the cement paste. Now what you can do is look at the depth of penetration of marble into the cement paste and here what we decided was the particular depth wherever the depth of penetration basically starts reducing because the paste is very fresh and less viscous the marble is going to go to the maximum depth. But if the VMA dosage is just enough you will have a slight reduction in the penetration depth as you increase the VMA more and more the marble is not going to be able to penetrate into the system. So obviously the assumption here is that the cement is not setting there is no setting happening so you have to do this test fairly fast so that there are no effects of setting of the cement paste. So all this is done on fresh cement paste and you simply make the cement paste with more and more dosage of VMA.

You can essentially fix the optimal dosage as the point from where the curve starts moving in the other direction that means the penetration starts reducing after that point of VMA addition. And this could be a good starting point and we found that VMA dosage fixed in this way was able to work quite well to produce the characteristics of self-compacting concrete that we wanted. Again when we discuss the SCC chapter you will see the effects of this in a much better way. So this is a very crude way but it seemed to work quite nicely. So we will stop this section with that but we will again come back to rheology when we talk about self-compacting and 3D printed concrete.

If you want to understand rheology well this is a must read publication by Banfill, Rheology of Fresh Cement and Concrete. It is extremely well written, it is quite long but then it gives you a very good understanding of rheology.