Concrete Technology
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Science, Delhi

Lecture - 13
Mineral Admixtures

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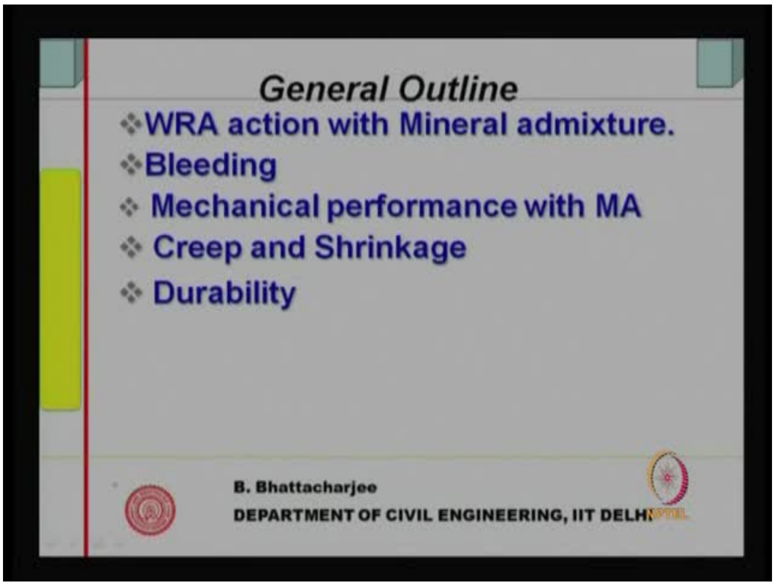

Welcome to module number 3, lecture 5; we will continue with the mineral admixtures. And we ended up in the last class action of water reducing agent on mineral admixtures. So, we will look at it again repeat it a little bit and we will talk about leading mechanical performance with mineral admixtures, Creep and Shrinkage and Durability.

So, if you look at action of super plasticizer, a is the case with no super plasticizer, so you will have particle cement or cementitious material, cement material not cementious only cement material if you have, they would be something like the clocked and with large words inside. But when you had for example, super plasticizer they get dispersed pushed a part and this cloaked scenario will be there they will be something like this, you know at contact points, they will be pushed about, but there is a contact point. But if, you act let us say fine mineral admixtures together with the super plasticizer, then you get the volt [speed place] spaced this volts get filled up this volts, this is the particle this volts gets filled up by the mineral admixtures themselves.

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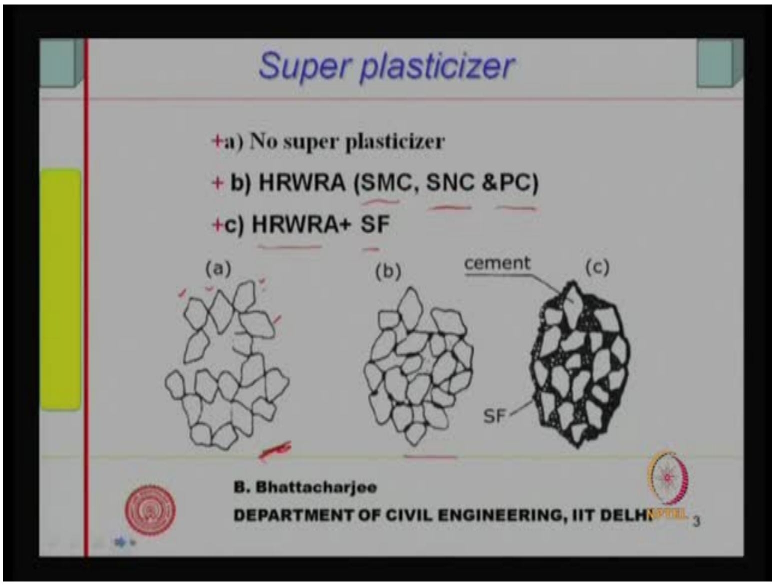

So, therefore, they give you a much better structure, so no super plasticizer is the scenario is this high range water reducing is getting that is, sulfernated melamine condone state or sulfernated nefthline condone state or PC gives you something like this. But when you have, high range water reducing range plus silica fume will get something like this. So, therefore, there are much better more dent structure and uniform and cement particles as well dispersed and that is what we saw in the last class.

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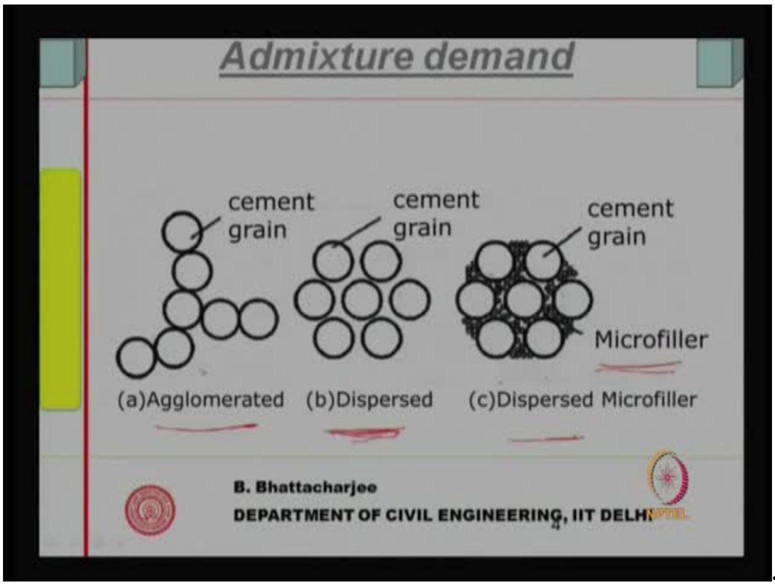

So, without the plasticizer, they are all are illuminated cement grins are illuminated. Well, these are idealize that diagrams cement grin are never spherically in nature with the super plasticizers they are dispersed and with micro fillers they are well dispersed together with the micro filler is nothing but the mineral admixtures, and they have a uniform and then structure compare to this dense because the mineral admixture has gone in between and that is how it gives you much better micro structure.

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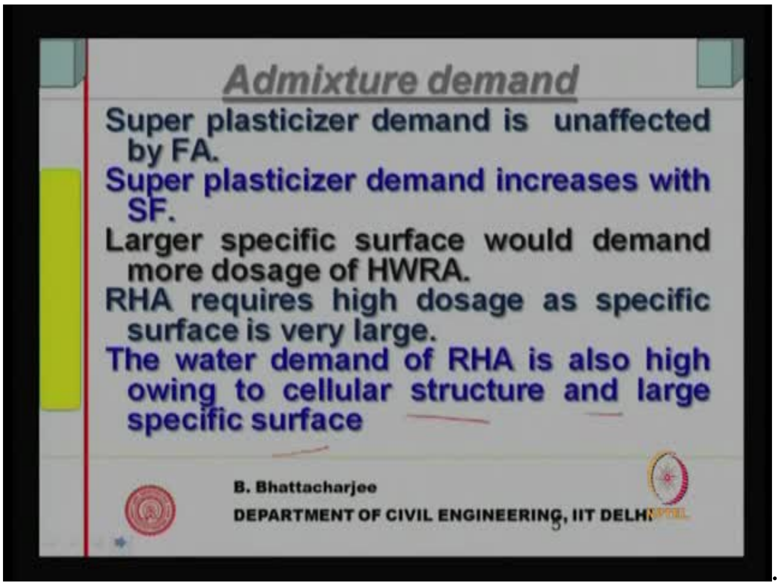

As we said, super plasticizer demand last class, we are mentioning the end that super plasticizer demand is unaffected by flyers. It does not change it does not increase the super plasticizer demand if anything is does it will reduce the requirement and little bit because flyers themselves has got some amount of plasticizing effect they can reduce they have some amount of water reducing you know, action.

So, this increases with silica fume super plasticizer demand will increase silica fume that is because silica fume is largely, silica fume is very fine that is because silica fume is very fine that is what we have looked into in your last class that they are very fine and therefore they cause little bit of increase with the super plasticizer. Say the demand, because they get absorbed to the surface of fine particle, so silica fume is fine it can absorb and lot of super plasticizer at their surface because they themselves also guest get pushed a part by the super plasticizer.

So, since the surface area is large they can consume more amount of super plasticizer they can consume the amount of super plasticizer larger specific surface would demand more dosage of high range water reducing agent. Rice husk hash requires high dosage as we mentioned earlier rise husk as requires very high dosage because specific surface is very large that is because of their cellular structure. They consume much better super plasticizer their specific surface is very high, much higher than even silica fume although the you know structure is somewhat different physical structure is self cellular rather than you know spherical or something of that kind.

So, as a result surface area is very, very large and high dosage of super plasticizer is required in case of rice husk ash and that is a different in fact in their use. Because if you have too much of super plasticizer the side effect the negative have the super plasticizer result quit often becomes apparent they will be axis bleeding may be setting is disturbed because it may not set within the reasonable time setting characteristics get affected. So, optical super plasticizer is the dosage used very high in the rice husk ash and that is usually is a deterring that is they determine in some cases. The water demand is you know, this is mainly because of the cellular structure and large specific surface that is what we are mentioning, so if I put it read it again the water demand of rice husk ash is also high going to cellular structure and large specific surface.

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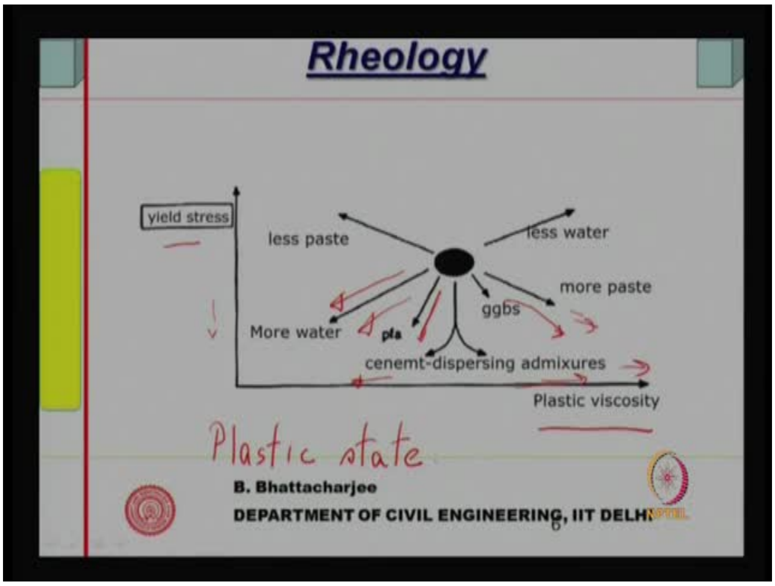

So, on one side is a fly ash which has got a least effect on to the super plasticizer demand and the extreme is rice husk ash which has got the highest you know high range water is reducing a demand silica fume is somewhat less than rises husk ash, GGBFS also will show something like this, so this diagram shows is the rheological characteristics which will discuss sometime later on when we talk of fresh concrete properties. You see the fresh concrete of fresh paste can be consider to get plastic material.

So a plastic material is one plastic state there in plastic state and plastic state is one where under the constant load it will deform continuously, a solid deforms under load and stress is proportional strain in whatever form it is, stress is proportional to strain. Plastic is one which will not deform I mean which will not behave like liquid initially, but if you apply some stress beyond a point of some stress which is called linier stress it will start behaving almost likely equate that is flow on its own.

So, at a given load it will keep on flowing on its own because without any addition of further load liquid on other hand just flows on a so on and fallows Newton's law of viscosity, so there are called Newton ion liquid that is stress is proportional to velocity. Gradient rate of shear to strain and the constant of proportionality is that viscosity so plastic after yield shear stress as reached it will be almost like liquid and you have got a plastic velocity.

So, if I look at plastic velocity and ill stress of this paste the plastic material paste then when you have in know if it this is my state if I add GGBFS what it does it reduces the yields shear stress, because it gives a little bit of you know sort of fine particle in material, but it also increases the viscosity so the friction. That means resistance again flow will be in paste more paste causes reduction in you know viscosity increase, but reduction has stress more water causes reduction.

In viscosity and reduction needs stress as well you reduce the paste you will increase the stress and viscosity may reduce somewhat cement dispersing admixtures they actually reduce they can you know increases the viscosity or reduces the viscosity as well, but the team spheres improve. And, if you look at flyers like thing pulverize as well as the causes so if you pulverize then the ash is generated pulverize actually behave like adding more water almost like adding more water. So, this gives us some idea how rheological properties are changed, rheological properties are changed and this would be more clear when you look to the rheological of concrete fresh concrete walk ability etcetera. So, one side is flyers the other extreme is of course, are the rises ash which increase the super plasticizer demand as per as geology is concerned flyers actually gives you a plasticizer effect like getting more water, but GGBFS which is angular in nature does reduces the initial stress, but of course, increases the plastic viscosity.

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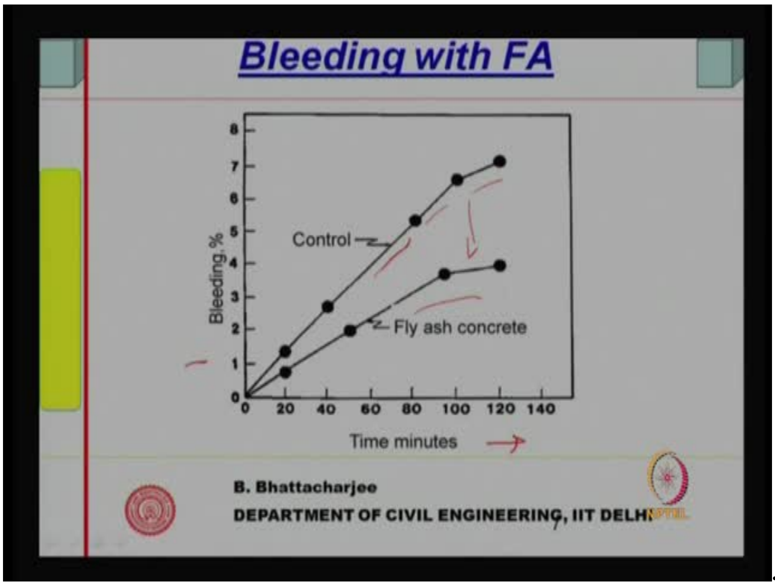

Bleeding with flyers if you look at it, flyers concrete uses bleeding, now what is bleeding? you see the since specific gravity of water is least among the constituents of concrete you know you add cement which is specific gravity of which is 3.14 specific gravity right that is mass of the cement divided by the volume of the cement solid. So, that is actually specific regarded in a you can talk in terms of generally by definition of course, specific gravity is related to the specific gravity of water. But we can understand this equivalent to mass of the solid divided by volume of the solid so that specific gravity is given 3.14 if you look at a water it is 1 aggregates around 2.6, 2.7 and flyers if you add mineral admixtures there more largely 2.1, 2.2.

So, water is the is the lightest material among all the ingredients of concrete so it will have a tendency it will come up and this can lead to a phenomena called bleeding. Water comes up at the top solid sub site that is basically bleeding, the bleeding of course. Some sort of bleeding is not really desirable axis bleeding is not desirable general bleeding is not desirable will know about general bleeding and other kind of bleeding sometime later on will talk of properties, of fresh concrete. But this materials mineral admixtures is any wet they reduce the bleeding because they are fine in system they are finer and of cement size finer than cement. So, they can retain the water more and what tendency of coming up becomes less. So, bleeding actually reduces down, bleeding reduces when you had this material that is mineral admixtures like flyers so is the case if the silica fume do not have a tendency to reduce the bleeding.

Now, you can see in this diagram bleeding percentage is a function of time you know bleeding percentage is the volume of water they would have come of subsidence. You can in terms of subsidence of the concrete that is original height you know the height or reduction in height divided by the original height that is we call it as subsidence we can measure in terms of in that manner. That if I express percentage we find that the normal concrete control concrete shows high amount of bleeding or even you can talk in terms of percentage of water, volume of water which has come in. So, this will be clear when we discuss bleeding itself, but flyers reduces this is understood flyers reduces the bleeding that can be easily understood the difference is quite significant.

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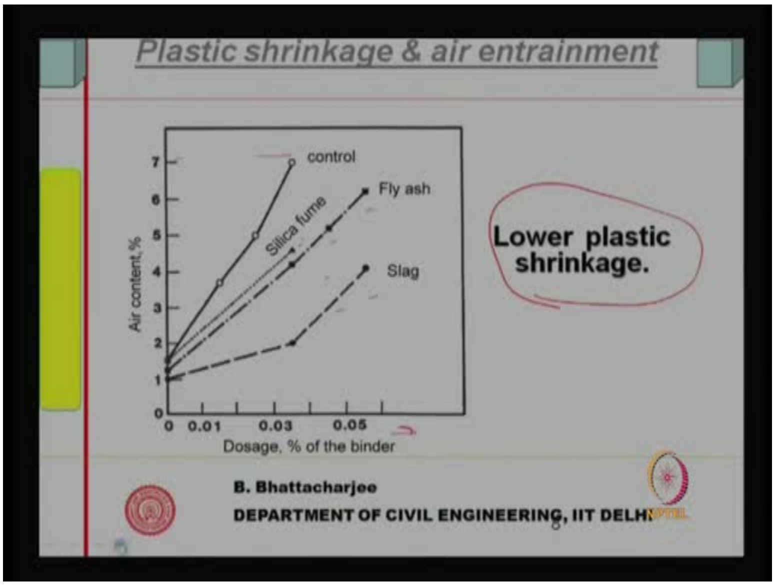

We look at plastic shrinkage well you know we add water to the segment and the volume of the cement paste is formed, it occupies somewhat less volume than the original overall volume there can be sudden shrinkage at the plastic state itself. And this, we can see that you know this gets reduce down, but if you look at air entrainment first we look at plastic shrinkage lower plastic shrinkage and now this is first let us say first shrinkage will have lower plastic shrinkage that is because water is retained you know the relatively water is retained in the volume changes are relatively less. So, they can hold together the water and therefore, overall volume change it is less besides they have the specific gravity somewhat lower than the cement.

So, cement has a tendency you know like cement when plastic cement shrinkage is essentially the volume reduction because the water will come under top and they might give up and they might give up the volume reduction. Now, this would to be less it follows from the same understandings that it has got less bleeding it can hold on to the water and therefore, plastic shrinkage will be less. Now air entrainment if you look at it, air entrainment is done in order to improve the first resistance where fusing in thorny is a problem for example, in cold climate.

So, you would like to have higher air entrainment and we generally add air entraining agent which I have mentioned earlier sometime that they actually change the surface tension of the paste, water in the paste and thereby they actually make it easy for bubble to form. If you recall the chemical admixture that when we are talking about which they have themselves retain and therefore, something is hydrophobic something is hydro fillip. Hydrophobic can has a tendency to hold down to air and thereby form air bubbles. Now, this entrainment percentage if it gets disturbed than it is you know mineral admixture performance in cold climate at over fusing thermo is possible it could be questionable. But let us see, what happens. So air content, obviously there is a reduction in air cont vent with all the, you know mineral admixtures. So if I have increase the dosage of the binder I find that there is reduction in the air content, whereas control gives you much higher content they all reduce the air content. So, it is not very it reduces down the efficiency of air entrainment it reduces down the efficiency air entrainment fine particles which you had this fine particles cementitious particles which you had, they reduced down the efficiency of entrainment. So, volume of air that gets entribe is another entertained is relatively less in these particular cases, so this is another effect.

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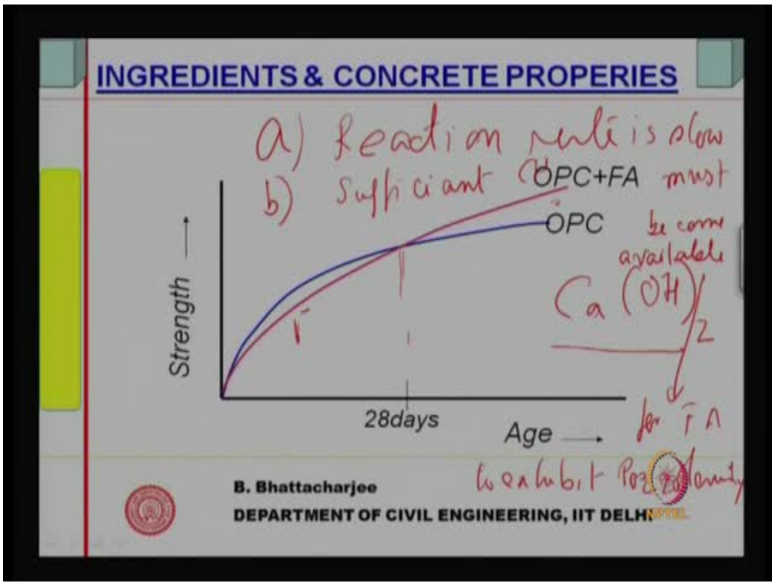

The strength part is important if you see strength for flyers concrete without flyer is something like this and if I have flyers concrete let us say I design for identical 28 days strength the a d strength will be less, but long time strength is much higher. If you recall, we looked into the micro structure development of this material when we are talking about of cement and you know hydration of cement etcetera etcetera. Now, reaction of flyers is generally slow, flyers reaction is slow pozzolanic reaction is not all slow as this way, but just look at flyers right now, reaction is flyers is slow besides unless I have sufficient liberation of calcium hydroxide you know it is with the calcium hydroxide the flyers reacts, so unless I have sufficient amount of calcium hydroxide. Concentration in the mix or in the hydration product the pozzolanic reaction due to flyers will not initiate and then again it is slow.

If you recall of lime reactivity test we queered it for 10 days first 48 hours one even does not try to demold it, because lime and pozzolana reaction is slow. So, the it does not harden sufficiently within first 48 hours so if you open the mould the surface will simply crumble because it is not sufficiently strong to hold itself, the framework is not ready. And then, we queered it at 100 percent relative humidity at 60 degree temperature for 8 days. Therefore, this indicates where as cement water system you can simply demote to 24 hours. So, 48 hours you do not demold and do not test strength cement system you can test for strength even after 24 hours or 3 days, but here you test it only after 8 days. Therefore, since you test it only after 8 days it shows the reaction process is very slow, that is one effect, so reaction rate is slow. So, a reaction rate is slow b sufficient line sufficient lime must be made available sufficient CH must become available for FA to exhibit pozzolanic reaction pozzolonic pozzolanicty.

So, I must have sufficient amount of lime in the system and therefore, 1st end is I do not see any strength gain. In fact, if you see same 28 days strength early strength is much less so this is the case with blended cement or fly ash addition. So, whenever you add pozzolona addition blended cement of course, grinding can be more to compensate for this somewhat, but if you add fly ash part of the fly ash in the mix and design it for same 28 days strength alde strength is unlikely to be high de molding time may be more. So, this one must keep in mind you know but, this is not a problem because you can always design for higher 28 days strength as well so that is not a problem, but the point is if you have same 28 days strength alde strength is usually less when you have mineral admixtures added in the like fly ash added in the system.

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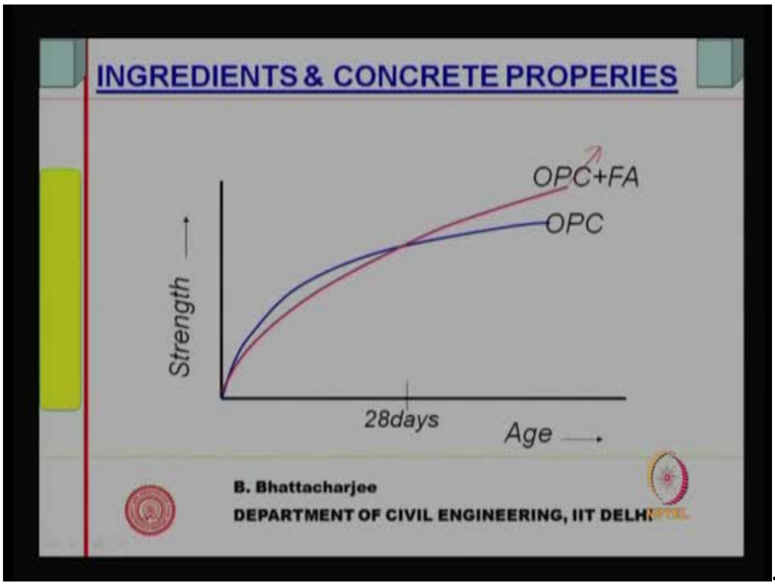

But what about long term strength, well long term strength of course, it shows significant increase because after the pozzolonic reaction has started the void space within the cement system, cement water system which was earlier occupied by simply fly ash particle. Now, as we have seen the hydration process that more and more fly ash will react with calcium hydroxide of course, there is a limit because we have seen the pure silica has got 15 percent pure silica can remain I mean react because the calcium hydroxide liberated would be would can consume only about you know only in maximum all silica fume that is added can be consumed by lime if it is about just 15 percent of the cement.

So, lime will consume the fly ash say about 28 percent or so because 55 percent type of fly ash, 55 percent silica is there in fly ash so 15 divided by 0.55 is somewhere around 28 percent so about 28 percent of the fly ash can be consumed gradually by the line in order to make the concrete more solid. Void space which was formed in the beginning would be now filled with hydration product replacing the non ceiling precipitate of calcium hydroxide calcium hydroxide is sparingly soluble non ceiling precipitate. So, this reduces down the void and since the voids are pores spaces capillary pores are reduce down there is a increase in strength since 4 sizes becomes final so both ways long term strength is much better with fly ash.

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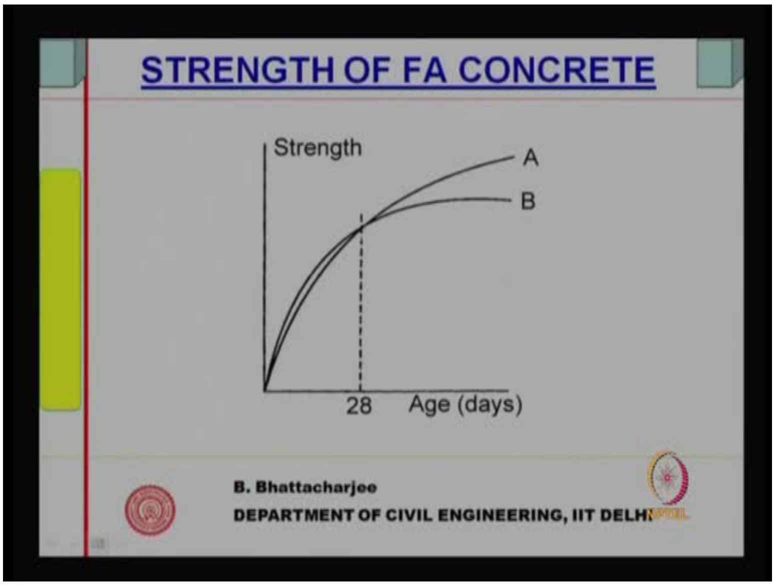

So, with 28 days A is the fly ash concrete, B is the normal strength concrete you know strength with fly ash concrete. In fact, if you see the calcium hydroxide content in case of B calcium hydroxide content is higher. Now, what is B? B is the ordinary concrete A is the fly ash concrete. So, this is fly ash, fly ash concrete fly ash and this is no fly ash, so B will have much higher calcium chloride I mean calcium hydroxide much higher whereas A has much less calcium hydroxide in the long run and that is how it makes it stronger in terms of load carrying capacity or this in terms of strength.

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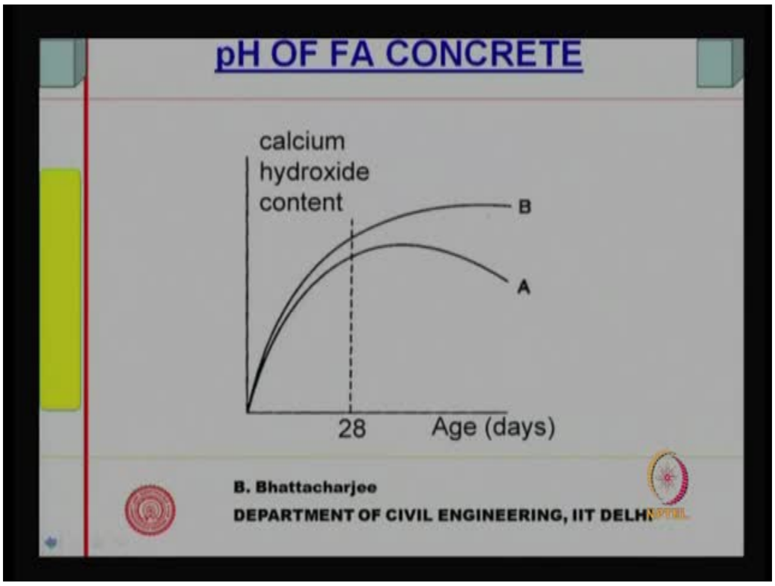

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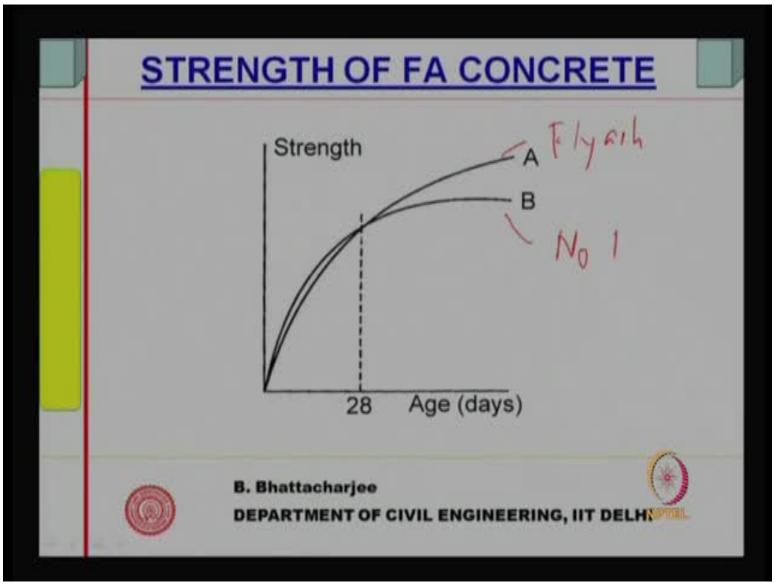

So, long term strength is better, short term strength is not so good. GGBFS behaves almost like FA as far as early strength development is concerned, now what is the mechanism of GGBFS if you recall we said that GGBFS can be activated in presence of cement and GGBFS actually exhibit cementitious product that is some hydration product of the GGBFS itself because it has got around 40 percent lime around similar percentage silica.

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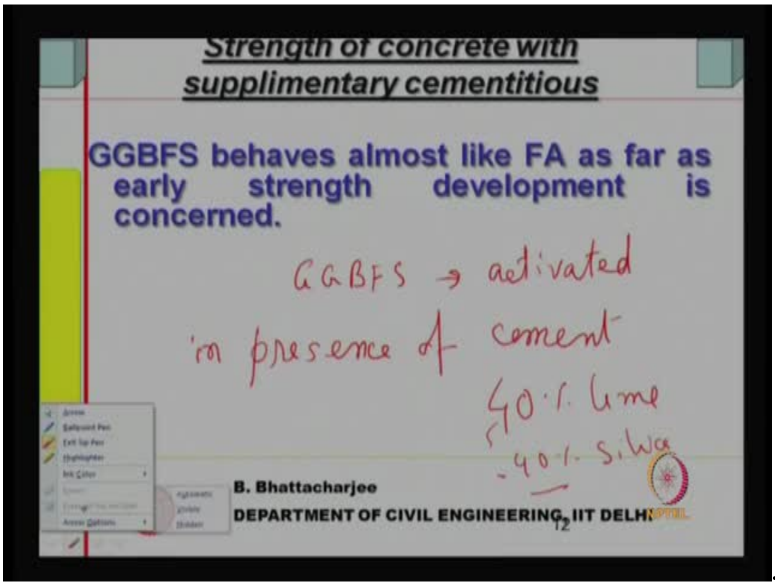

So, this lime together with the silica can give you CHS part of it and excess silica will of course, contribute to the pozzolano. So, when you add with the cement cause activation of the GGBFS, you know part of the cement like something like 60 percent, slag 40 percent cement this actually activate the slag and therefore, slag shows its own hydration product and together with the cement hydration product. And the lime liberated from the cement hydration product can react with the axis silica present which do not react with the lime of GGBFS and they will fill-in both space within.

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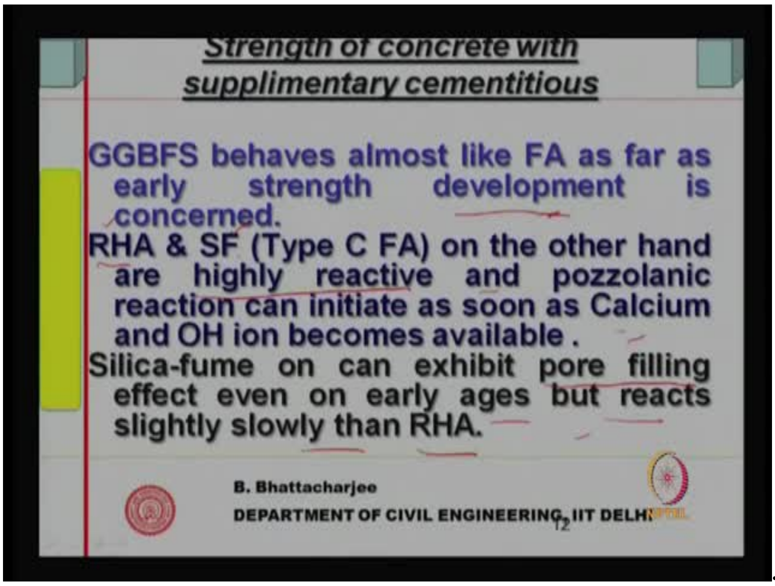

But however, again its activation requires in a activation of GGBFS will require cement dissolution of the cement material and it you know it does not start dial hardly and pozzolana advantage also comes I mean much later 1 sufficient lime is been produced. So, pozzolanaic benefits is obtains later. Therefore, early strength development is not very much as for as GGBFS is concerned is almost behave like fly ash right because the strength enhance is long run due to the secondary pozzolanic reaction that is again not available with GGBFS. You know that is only available after certain period of time after sufficient lime has consumed I mean has been produced by the cement reaction because it also has to depend on cement reaction. The product of GGBFS hydration that will come, but the still the what space is reaming between GGBFS and the cement particle is filled up by the product of pozzolanic reaction between the axis silica present and lime liberated from the cement and therefore, it is almost similar as before.

But silica fume and some you know silica fume and some type CFA rice husk ash on the other hand or highly reactive and pozzolanaic reaction. Particularly this, somewhat this is also relatively more reactive and can initiate as soon as calcium and hydra oxidation becomes available. So, sufficient concentration is not really required, you know besides silica fume is fine if you look at silica fume is the other extreme silica fume is very fine and fine silica fume gets into the force cement system therefore, there is some amount of micro filler effect some amount of pour filling effect micro filler effect which goes in. So, therefore, even writing beginning itself something like up to 5 micron size is our 0.3 out 0.4 average micron size up to total maximum of 5 micron size that fills in within the walls of the cement system right in the beginning itself and even if they remains in hertz they have a tendency to reduce down the porosity.

So, the micro filler effects starts acting right from the beginning and since in the surface area is very large it can exhibit a reaction it can execute a pozzolanaic reaction as soon as some amount of lime is available as soon as some amount of lime is available. So, this makes silica fume extremely reactive compare to flyers alright, so early strength is not a major problem as for silica fumes rises husk hash 1 the I know it has also got very high specific surface that is what we have seen. Therefore, it can also exhibit reaction rate of reaction high rate of reaction it can also execute and therefore, the problem of alder strength may not be a major problem with rises ash.

But other problem is defiantly there because rises ash is so cellular that it request to much of super plasticizer and therefore, as such getting it you know getting harden product itself may become some more problem, but silica fume do sent have anyone of these problem in any case right so silica fume exhibits 4 filling effects and it is highly reactive and even an RDGS, but reacts slightly slow than rises husk as still faster reaction process. So, alder strength wise this material has not problem where as in flyers and GGBFS they are somewhat problematic, so nature where we expect alde demolding you know these are not the best options straight away I mean you can still design the system because you can design the system with higher alder you know over all much higher strength so that alder strength itself is sufficiently high for your requirement.

If economics permit fine it is economics we know the behavior of the material how we use it that of course, is remains with us so when it comes to fly ash and GGBFS there alde strength is relatively less, but long term strength is much higher silica fume on the other hand has got high alde strength and even long term strength will be better. And therefore, we can use them in a we can use them for various purpose and it is one of the thing which can give you a relatively much higher strength then the concrete with any other material. That is what, that is why is resulted in you know it is a one which has resulted in development of let us say high strength concrete you know high strength or other kind of means some other you know very high strength concrete system etcetera.

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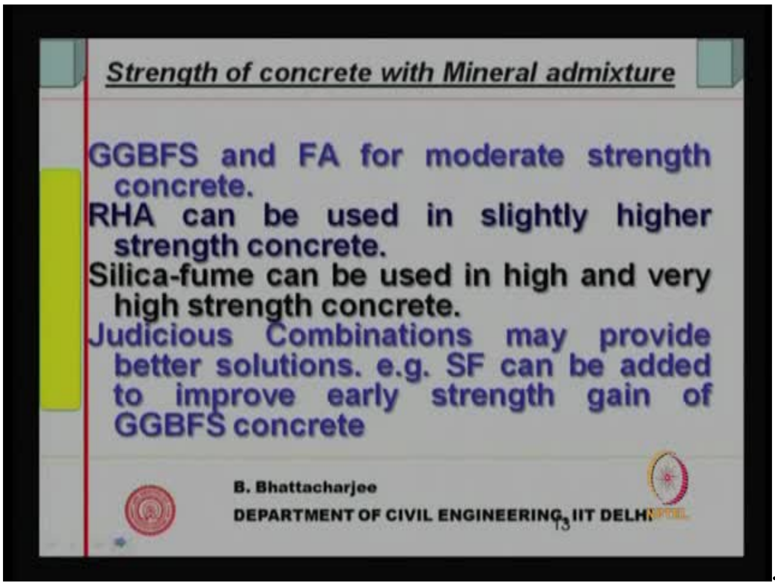

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Therefore, GGBFS I preferred for one would prefer for normal strength concrete to moderate strength concrete rice husk ash can also be designed for slightly higher strength concrete. Silica fume can be used for very high strength concrete and therefore, you can even judicious combinations of silica fume and fly ash etcetera. For example, another issue is of course, the cross part of it silica fume is the costliest in our country and many other countries as well which do not produce the silica fume.

So, silica fume is the costliest in those countries which do not produce it is 7 to 8 times costlier than cement you know let us say in UK or in India both the countries really do not produce this material. So therefore, if it is where it is produced it will be relatively cheaper so this is one thing since it is costlier therefore, one must use it judiciously now where you want very high strength concrete well silica fume is the only solution I mean you know up to say 90 100 MPA plus or 110 MPA etcetera, etcetera.

So, you want to get silica fume is ours only solution, but you want you do not mind a little bit less strength somewhere you can operate on 90 strength you might use silica fume together with fly ash. Because fly ash is cheaply available you use some percentage of silica fume may be you know usually you do not use more than 10,15 percent never more than 15 percent about 10 percent is silica fume is a good amount, because it has fill in the spaces within the cement system and 10 percent is a good amount and you might still reduce it down and use fly ash. Now, if you use fly ash you are workability will improve water reducing agent demand will reduce down, a but they will be reduction in alde strength alde strength alright.

So, judicious use is possible you might improve the reduction in super plastic seizer demand, but compromise on strength. So, this kind of various kind of judicious use is possible you can use part fly ash plus part silica fume combinations and improve the strength gain as well as alde strength gain as well as you know overall you know strength and volubility or plastic seizer demand etcetera so strength wise this is the relationship.

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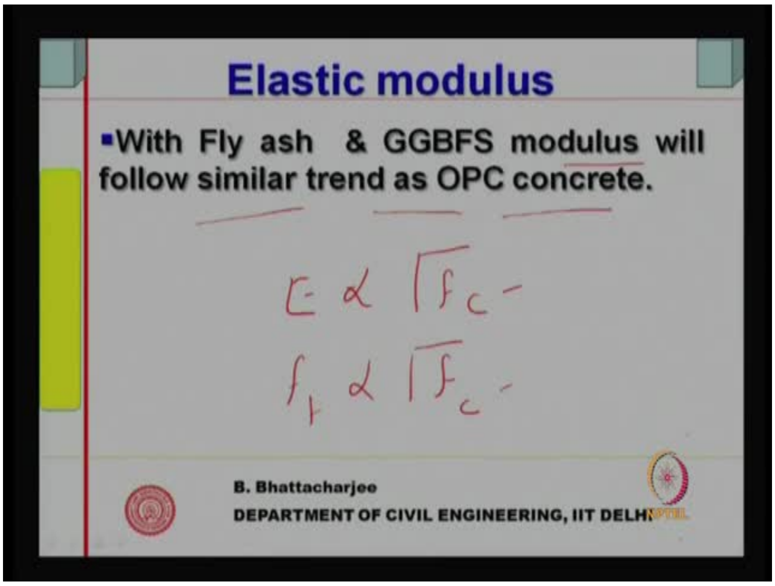

Now, if you look at other mechanical properties most of the mechanical properties are related to compressive strength if you recall you know E modulus of elasticity is perhaps we have not talked to you so far it can be shown that modulus of elasticity is actually proportional to under the root cubic cube strength or cylinder strength of concrete. Similarly, if we look at tensile strength sigma t you know or Ft you may call it Ft, so E is proportional to under root Fc. Similarly, Ft is proportional to under root Fc. Most of the mechanical properties of concrete can be related to the compressive strength and this type of relationships are still valid incase of fly ash concrete as well fly ash concrete as well.

So, modulus of elasticity they almost show similar kind of behavior so with fly ash and GGFBFS modulus of elasticity will follow similar trend as OPC concrete. Because there is no reason why should it change similar sort of behavior should be largely seen you know by a large and the empirical formulae, which is the code uses they are possible they are generally conservative values and they can possibly work well generally work well with the fly ash concrete as well. Why so? Because after all, you have not changed the basic nature of the particulate system bonded with some cementing material some sort of cementing system, so earlier also your doing the same thing now also you are doing the same thing. Only thing is instead of lime that was present which is actually at kind of non ceiling precipitate and sparingly soluble now moving more CHS so large religious behavior modulus of elasticity should not change you know you will find similar relationship similar type of behavior as the concrete without fly ash.

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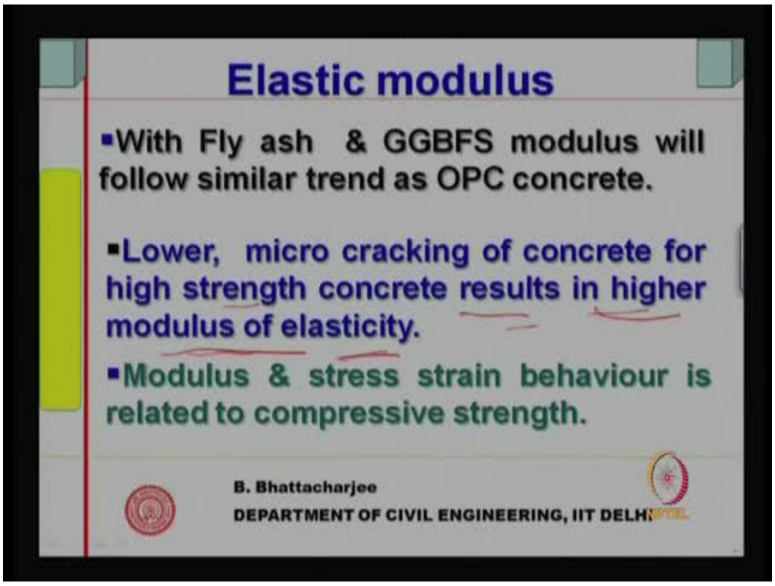

But when you have high strength concrete you know what your doing is your essentially deducing down the pores in the system we shall see that when we discuss about his and concrete system you are reducing down the pore in the system the pores are the one which have the weakness in the flow in the material and cracks initiate from such flaws cracks initiate from such flaws. So, if you reduce down the pores sizes larger the sizes initiation of cracks occur at lower stress level. So, if you have smaller size pores the crack will initiate only at large you know more stresses this is number 1 you reduces down the pore therefore, crack would be much less size of the pore reduce volume of the pore reduced cracks should be much less.

In fact, whole idea of high strength concrete is to reduce down pores of various sizes I mean larger sizes and improve the micro structure of the cement paste and what is called interfacial transition zone so this aspect we will look into which is between the aggregate and the paste system. Earlier, aggregate and paste whichever is weak that will dictate the strength in case of concrete aggregate paste and inter facial transfer zone whichever is weak will dictate the strength because that will fail early. Now, if I improve I to Z with very fine material like silica fume than crack cannot initiate there supposing in a material all three are of all similar strength then the failure would occur simultaneously all three of them therefore, there will be no micro cracking.

Earlier, there would have be micro cracking and the pores and this cracks would propagate there are lot of cracking before failure, but with fine material like silica fume added fine pozzolonic material like silica fume added the pores get refined paste strength. Interfacial transition zone strength and aggregate strength all tempt to become close to each other micro cracking is less that means the deformation at a given stress is lower which means modulus over elasticity is higher.

So, modulus over elasticity is higher in case of high strength concrete and this has got another aspects of silica fume when you add it can improve the modulus of elasticity significantly right, in high strength concrete and it has got another effect also the deformation failure is also less. So, stress strain behavior is basically this can be also related to the compressive strength at lower compressive strength level behavior is something like you know behavior is something like I will show you at lower stress strain level concrete would behave like this is at lower strength concrete high strength concrete will behave something like this.

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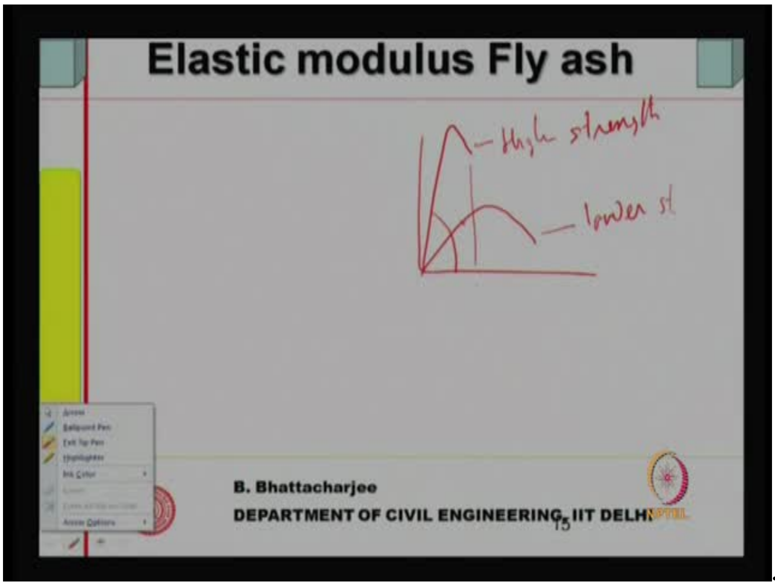

We will have discussion on these when you talk of high strength concrete so higher strength concrete so you can see the modulus of elasticity increase and the deformation at which it fails is also relatively less. Actually, cement you know this is this behavior is between the cement paste behavior and aggregate behavior since you improve the cement paste somewhat up there therefore, this behavior is realized in case of high strength concrete. So, you have higher modulus elasticity in case of high strength concrete.

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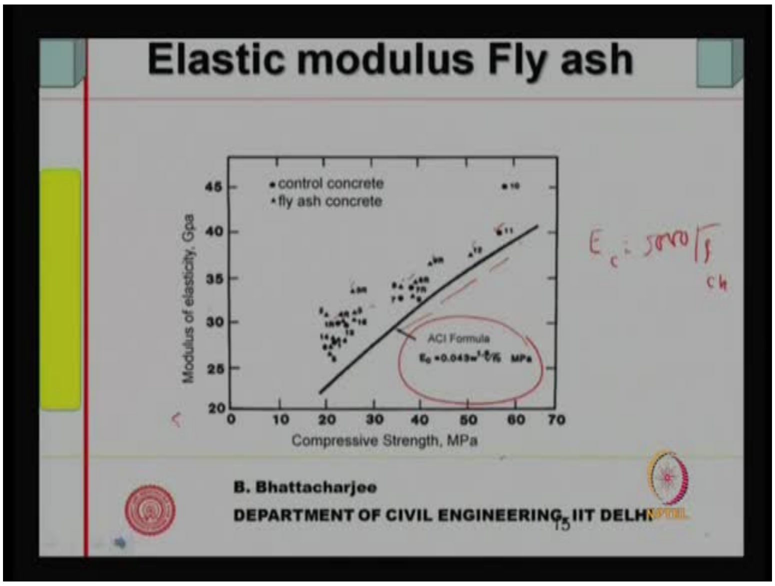

Now, if you look at the if you look at the behavior you know in general and codal diagram. You see the compressive strength versus I said that everything can related to compressive strength modulus of elasticity can be related to compressive strength like it is done in normal concrete and with mineral admixtures also you can you know related to compressive strength.

So, this is for example, SCI design formulae which is suggested we have Is code and any other code we will have similar kind of thing and the relating in fact if you see IS code it will be 5000 under root Fck that is the relationship. So, that kind of empirical value relationship with ac, Ic, cI you know American concrete institute there do have similar kind of formulae. And this is actually conservative real lines with control concrete that is without fly ash etcetera like somewhere there this line is much lower than that. It is usually conservative design values are kept lower than you know we should not be you know like to cover a little bit of to have it less risky.

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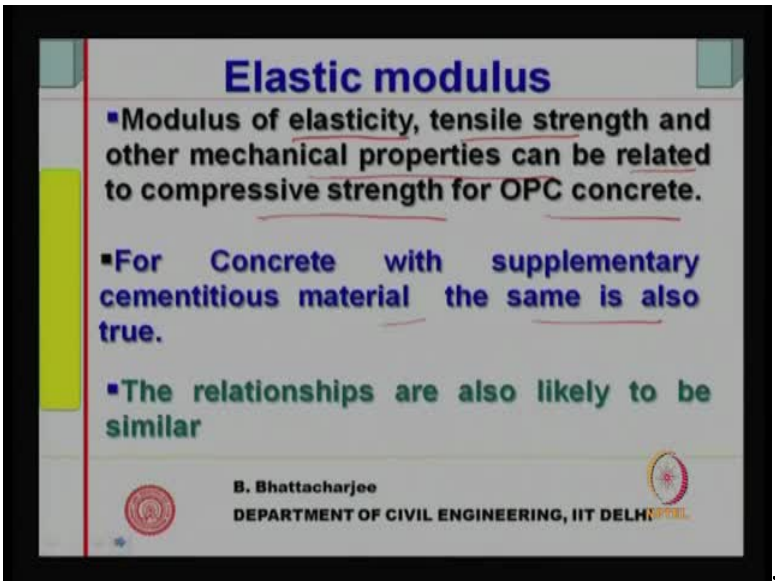

So, you keep e values smaller, but it has been observed the fly ash with fly ash concrete the values are also above this line. That means your design formulae really would be effected by a distort action of fly ash really would not be affected by addition of fly ash. So, alright see this is again the same thing were righting modulus of elasticity tensile strength and other mechanical properties can be related to composite strength of OPC concrete.

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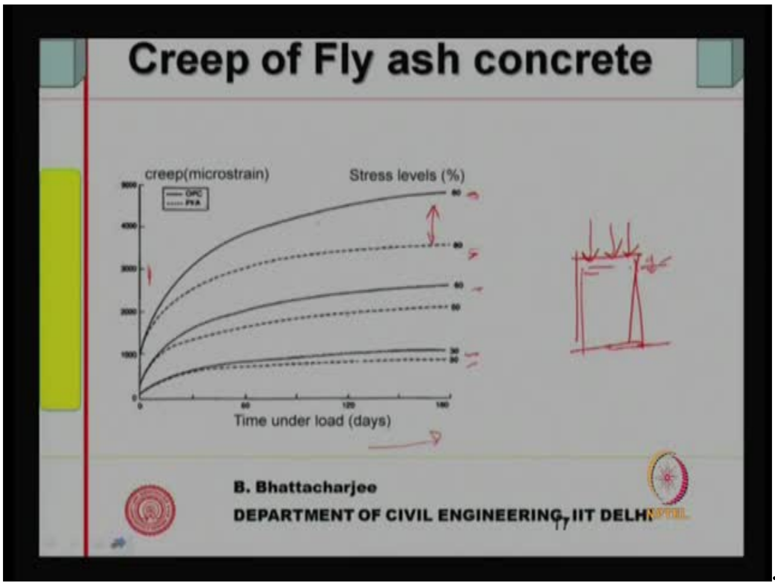

For concrete with supplementary cementations material same is also true, same is also true and the relationship is similar may be coefficient might change a little bit here and there but largely same is also valid because after all the basic nature of the material has not been changed earlier also particle system bounded by an inorganic product of hydration.

And now, also it is same so if you apply load its deformation characteristics will not be significantly different than you know the nature of the behavior talking nature of the behavior it will not be significantly different then the concrete without search mineral admixtures right. Therefore, relationship are also likely to be similar, this is important quite often when one is using this material one would like to know what are the effect on creep shrinkage and modulus of elasticity and other properties.

Now, creep is the deformation under sustain load concrete exhibit creep many other materials steel for example, exhibit creep at very high temperature. Many other materials exhibit creep that is you keep the load constant it will show deformation it will continuously go on deforming. So, you keep the concrete something like this able to apply the load let us say fix and hold it in position after sometime you will find that you know first is the elastic deformation and then there is some creep deformation after time.

So, this creep deformation would occur, now this is important in long span breezes precious concrete breezes because loss of creep due to creep there can be loss of precious. It is important in tall structures sometime later on when you talk of mechanical properties of concrete will be discussing about that in a little bit more detail. Now, this creep with fly ash let us see what happens you see this is the creep in terms of micro strain stress level OPC and these dotted lines are the PFA.

So, you have same you know this is the time of loading time under load 180 days so, stress level if you have put it 80 percent of the static strength or 90 percent of the static strength you see the creep is much less in case of fly ash concrete. If you keep it at 60 percent same percentage 30, 30 you will find that, so what you generally observed is a PFA concrete has got much less creep much less creep because of the change of the micro structure which is there in a other words the water held in the micro structure or gel force. It has this has got something to do with the creep and they are with the more gel space available gel structure hydration gel available creep behavior also change and it changes positively in case of fly ash concrete.

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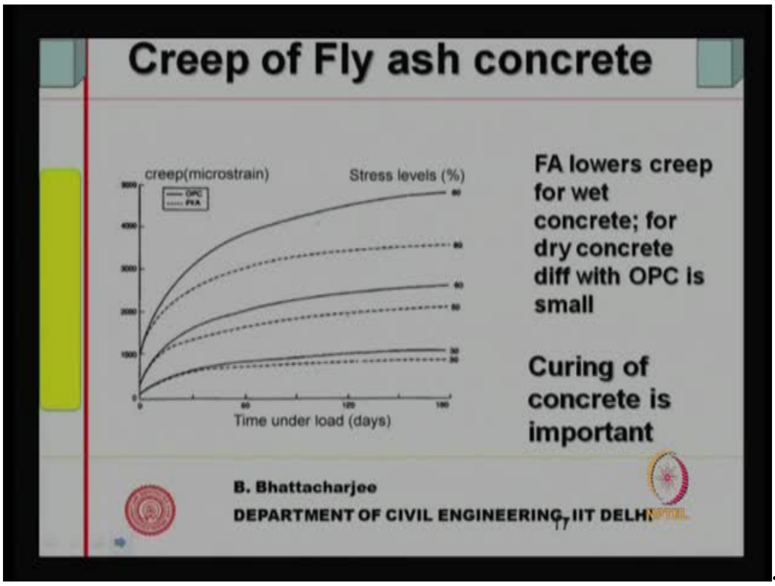

So, creep of fly ash concrete pulp praised fly ash concrete absorbed to be lower so fly ash lowers for wet concrete for dry concrete difference with OPC is usually small so if you keep it more rest both then of course the difference reduces down however still will have some amount of reduction.

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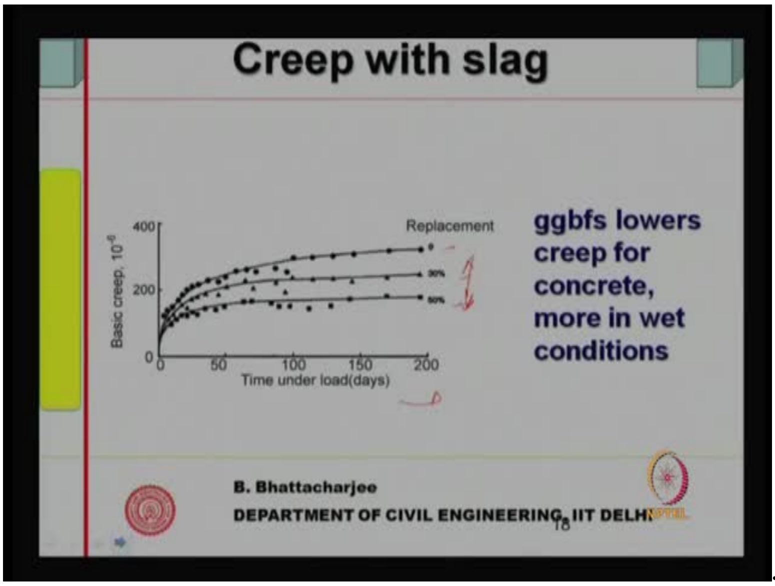

So, that is the observation curing is concrete definitely important and you know you have to cure more in case of fly ash because you want to ensure that the pozzolonic reaction really initiates and lime production always takes place. So, curing is very, very important and curing is also related to creep and shrinkage. Creep with slag if you look at it zero replacement percentage require 30 percent and 80 percent replacement and basic creep therefore, you can see that the yet the slag creep really reduces down time under load same.

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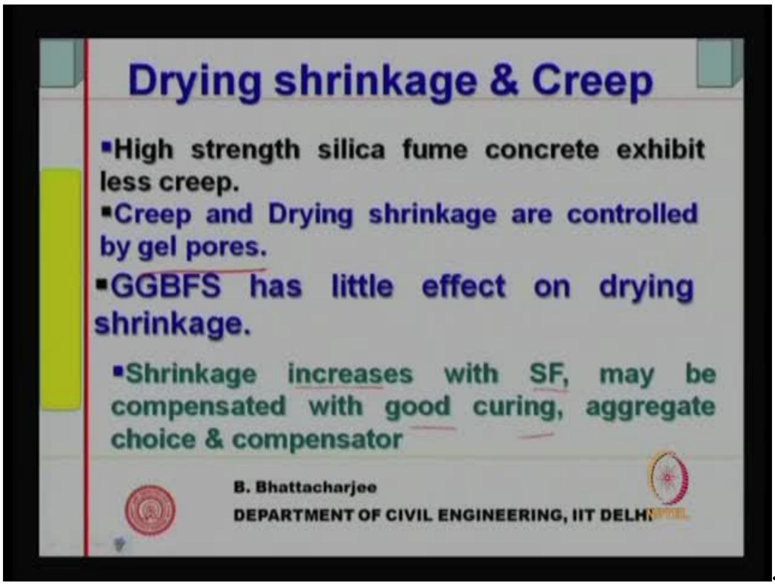

So, basically GGBFS slower script for concrete more and obviously wet condition same like fly ash the behavior is almost similar like fly ash. Then drying shrinkage and creep high strength silica fume concrete exhibit less creep that is also is been observed even silica fume shows less creep. Creep and during shrinkage are controlled by gel pores that is what I have mentioning that is the gel pores on the one which controls the creep and drying shrinkage. Drying shrinkage occurs when water moves on without from the capillary force and then gel water will have a; you know the vapor present gradient into exhibit the gel with the capillary force itself. Gel water itself will have moment drying of and this causes collapse of the gel structure or change in dimension and therefore, that is what is drying shrinkage.

So, drying shrinkage both are controlled gel pores and gel water if you gel water longer period of time you know drying would be effectively much less and shrinkage also creepers effect would be also less. GGBFS of course has little effect on drying shrinkage not much, where as fly ash and silica fume does that. Shrinkage increases with silica fume I mean silica fume with concrete has less creep shrinkage of course increases with silica fume may be compensative with the good curing and aggregate choice and some shrinkage compensating admixture that we have mentioned. Silica fume reacts very early and that can cause actually you know slight increase in the shrinkage although creep is reduced.

So, shrinkage and creep properties with different types of mineral admixtures are something like this so fly ash seems to be reducing down the creep as well as shrinkage. GGBFS of course, reduces down the creep, but is shrinkage it has little effect on drying shrinkage.

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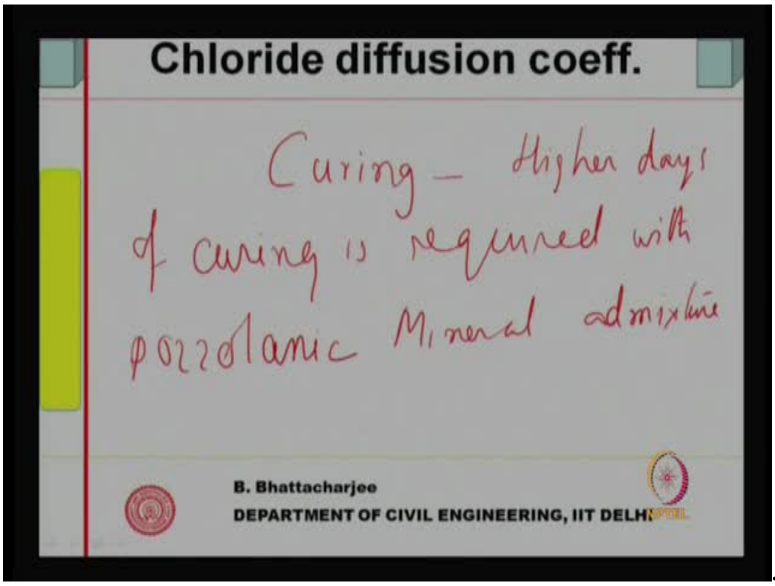

Silica fume reduce exhibit to less creep, but drying shrinkage it has actually has higher drying shrinkage compare to you know it increases the drying shrinkage and you can compensate with gift curing and aggregate choice etcetera etcetera and shrinkage compensate effect. Now, before you come to durability I just like to point out this curing is very important for mineral admixtures curing you need higher days of curing with pozzolanic mineral admixtures because there reaction itself is slow.

And sufficient lime must be produced before pozzolanic reaction can be realized so that is the case you must cure it for a slightly longer period of time so that it has got sufficient strength gain for removal of the side shattering strength gain is slower. So, wherever strength gain is slower we need to do more curing and we got to ensure also what is called capillary segmentation. Therefore, why you require 7 days curing with only OPC and fly ash you would possibly require 10 days, where you need 10days in a dry condition as far as OPC is concerned with OPC and fly ash you will possibly require 14 days so curing required is more for this material.

Next is the durability issues see if you look at one of the properties say chloride diffusion coefficient.

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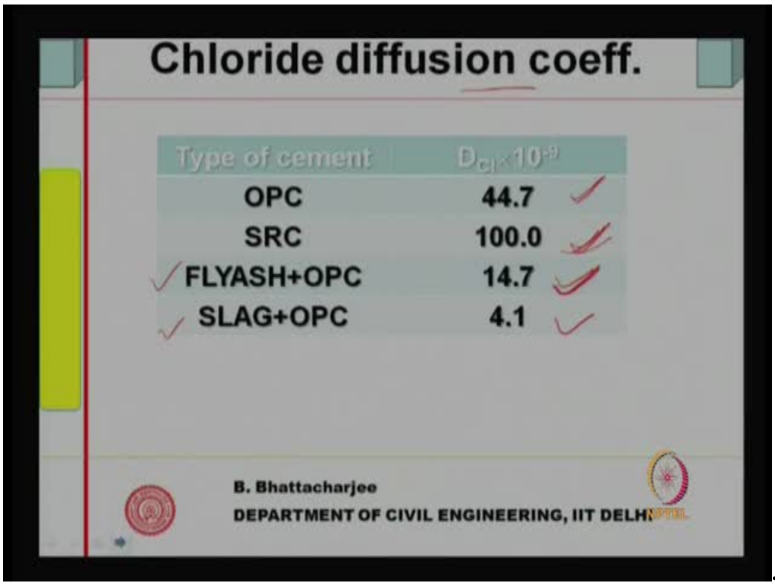

Now, durability firstly related to incase of material from outside. So, in case of moisture for example, that is a main cause because almost all durability problem as we shall be seeing later on is associated with chemical reaction of some sort of aggressive agent or you know contaminant coming from outside they may be inside also. Even if they are inside since the (( )) reaction any most of the (( )) reaction requires presence of water that is they occur in solution phase. Therefore, water ingredient is a must now water would be coming from outside initial water is too small that will get reacted and if you do not do anything will evaporate.

But in future the moisture penetrates into the concrete (( )) process can follow; you know depending upon the situation aggressive agent may come in water in solution or some sort of aggressive agent already in the concrete can become. You know reaction process can term start because there will be pore solution not available with water coming in. Therefore, when more of the ingredients more ingredients comes possible you know when ingredients becomes more possible or it gets reduced if it is more than durability is less if it is less durability is more.

Now, we have already said that with fly ash GGBFS or silica fume pores structure gets refined, micro structure gets refined pores becomes less, pores sizes becomes more and in fact with appropriate amount of curing pores should be easily segmented into inter connectivity will also would be reduced. So therefore, durability of such concrete is likely to be better than OPC concrete; some of the specific durability problem let us see one of them is but there are other issues also let us see one of them is for example, chloride diffusion coefficient. Just let to use you know how chloride you know chloride diffusion coefficient is a measure of basically possibility or you know like the flow of chloride inside the concrete which ever value has high diffusion coefficient it means it allows slightly to allow more chloride to come in.

So, what is observed is that if you have OPC this value is somewhere like this, but if you have Sulfate resisting cement the value increases significantly fly, ash and OPC reduces down and slag and OPC can still reduces down. There are two aspects in this, one all the chloride that goes into the concrete some of them gets bound. Now, this binding is associate with C three a bi calcium aluminate.

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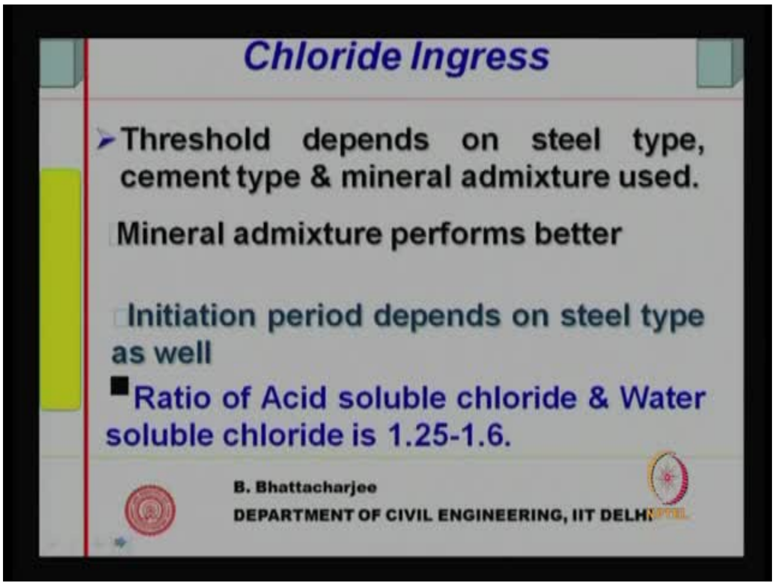

So, Sulfate resisting cement which has got least C3 a shows high chloride diffusivity OPC has got some C3 a therefore, it has got high diffusivity compared to others. But this has got this will improve because the pores structure itself will be improved and nothing can penetrate through it, the penetration process will become less and possibly chloride binding is also furnace is not you know the slag and PPC fly ash may be able to you know able to physically bind some chloride but more importantly to make the concrete more pervious. Therefore, you can find the fly ash n o p c slag and OPC they perform mineral admixtures addition perform better as far as chloride diffusion coefficient is concerned. So, chloride ingress means you know; now obviously the threshold at which corrosion will start chloride is important the corrosion point of view and this will understand when you look at durability of concrete.

So, threshold depends on steel type, cement type and mineral type mixtures mineral admixtures performs better that is what we have understood. Therefore, corrosion initiation time can be longer, but type of steel has some role to play as well. Well, there are two types of chlorides one is acid soluble chloride and water soluble chloride and this ratio acid soluble chloride is bound chloride chemically bound chloride it also includes and generally this varies from 1.25 to 1.6 for many of these blended cements and is surely high for blended cements compare to let us say sulfate resisting cement.

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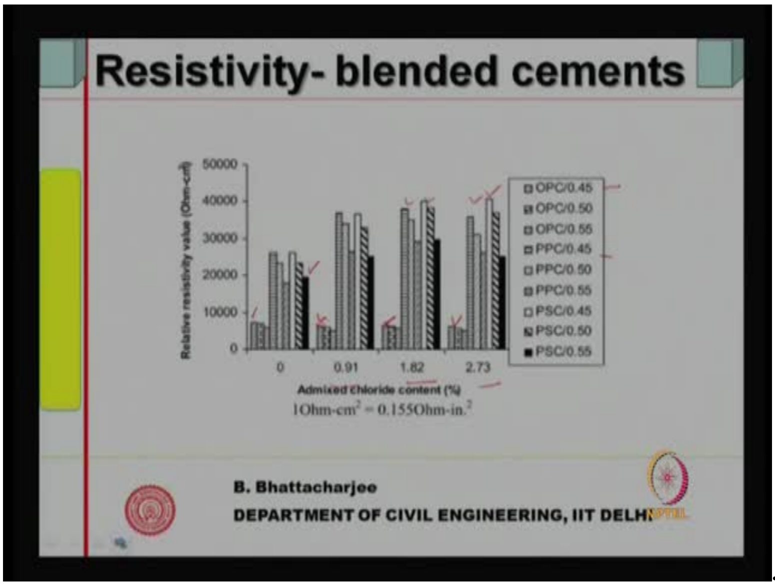

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Now, another accept is the resistivity of concrete. This is important with respect to with respect to rain forcemeat corrosion because which is an electro chemical process so, resistivity of concrete higher the resistivity, higher the resistivity generally concrete will perform better against rework corrosion. Because high resistivity means less current will be flow less electrolytic current will flow and you will have some look at that sometime later on when we look at the durability. But let see relativity resistivity you can see that OPC you know and EPC so this is OPC, PSC is the complete dark one so any cases any cases with various kind of chloride percentages; this is the chloride continuum in all cases you will see they were 2, 3 cement water cement ratios you will find that the relative resistivity of OPC some are here and with PPC and APC they some are here OPC some are here the small. So, resistivity increase with pozzolana material and therefore, they can provide better protection in rework corrosion.

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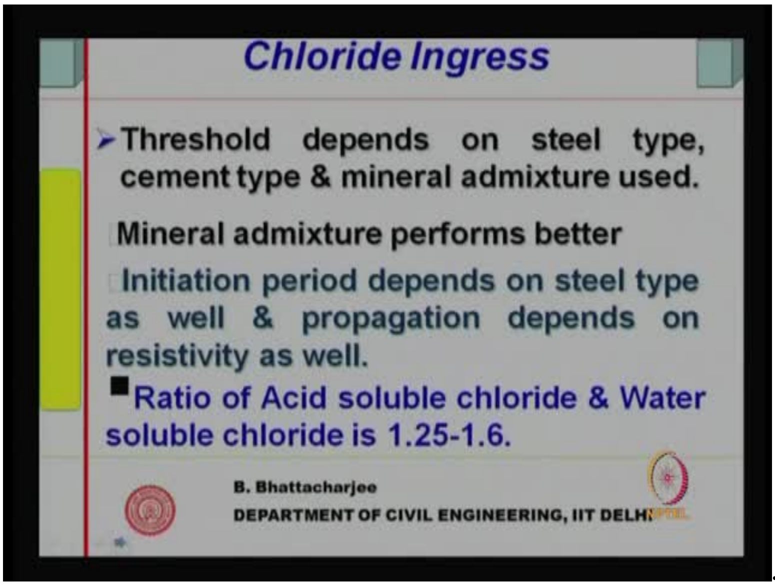

So, mineral admixtures therefore, they would perform better because the tent will increase right so this again is mechanism etcetera will look into sometime later on when look at durability so this is important because resistivity is an important issue and it reduces down the corrosion rate so this we can look into later on.

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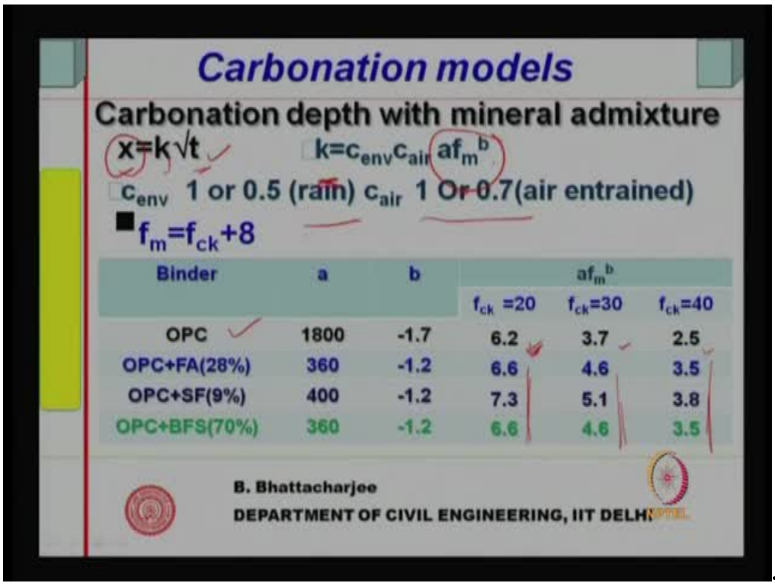

Well, the other one more durability is related to corrosion process carbonation depth with mineral admixtures this will reduce down this will surly reduce down with mineral admixtures because they consume this depends upon alkali unity calcium hydroxide. So, if you have calcium hydroxide is consume by the atmospheric carbon dioxide and PH of concrete reduces down in the carbonation. So, it has been absorbed that if you use OPC with you know the carbonation depth carbonation this value carbonation depth is given by this factor K higher the k for a given time carbonation removed and this values of (( )) this term which depends upon the type of cementious material, you find that you know it is OPC shows 6.2, 3.7 for different strength of concrete. But PPC etcetera that shows you know OPC flayer 28 percent and it shows a somewhat higher values which means that K will be higher it shows somewhere higher values which means K will be higher.

So, for a given time carbonation depth is higher with the mineral admixtures will discuss this sometime later on so with mineral admixture carbonation depth increases. You know rate of carbonation actually increases because calcium hydroxide are consume by them right in the beginning right so this are the other part of formula which we might discuss sometime later on.

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Relativity, but carbonation depth increases with addition of mineral addition this will be clearly need talk of durably so mineral admixture perfume by alkali aggregate reaction this we know because permeability diffusion is reduces large batter post structure reduces down the moister injures. And therefore, mineral admixtures perfume better against alkali aggregates reaction good resistance again score propagation against magnesium sulfate is still are certain in at the

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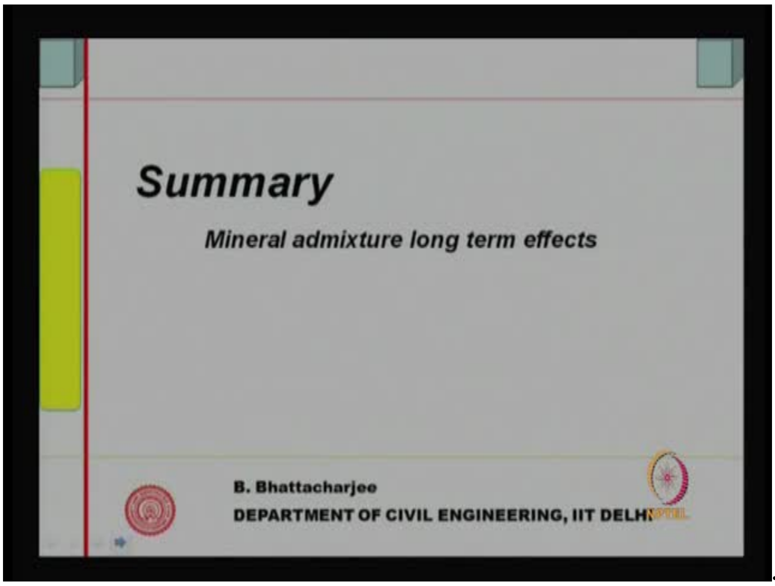

Movement there are some report that they are not very good against magnesium sulfate but, other sulfate attack they are again better. So, mineral admixtures generally improve durability properties have concrete resolve this will be again further disuses when we talk about durability. So, we can summarize the whole thing now this module this is the last lecture of this module we have looked first into the chemical admixtures and then into the mineral admixtures. And this part of the mineral admixtures we have first looked into their characterization than we looked into their effect on fresh concrete then into the harden concrete crimp shrinkage strength crimp shrinkage and then the durability as far as durability is concerned. We perform mostly they perform better except for carbonation were carbonation depth to increase with addition of mineral.