Concrete Technology
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Lecture - 31
Fundamental Concepts, Degradation Processes, Attacks

Welcome to module 8. In this module we shall be looking into durability of concrete. So, in the lecture 1, we will talk about some Fundamental Concepts, look at the Degradation Process some definitions actually in the beginning, then some degradation process, process in some attacks in this one.

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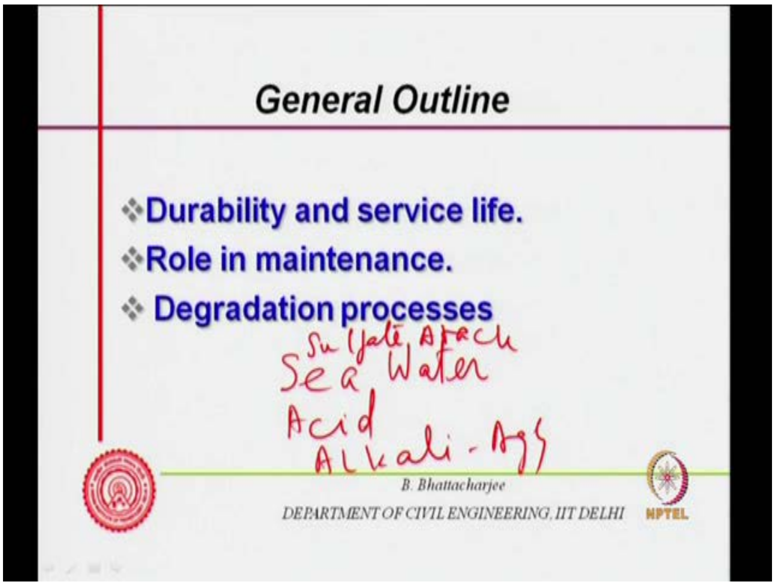

We will look into particularly, we will look into durability and service life definition and degradation process, in which we will look into actually, we look into first of all we look into seawater attack, sulfate attack, seawater attack, acid and we look at alkali aggregate reaction, alkali aggregate reaction. So, the fourth things we look at sulfate attack, seawater attack, acid attack and alkali aggregate reactivity. So, this is the fourth things we look into in today’s lecture 1, in lecture 1, we look into this one’s.

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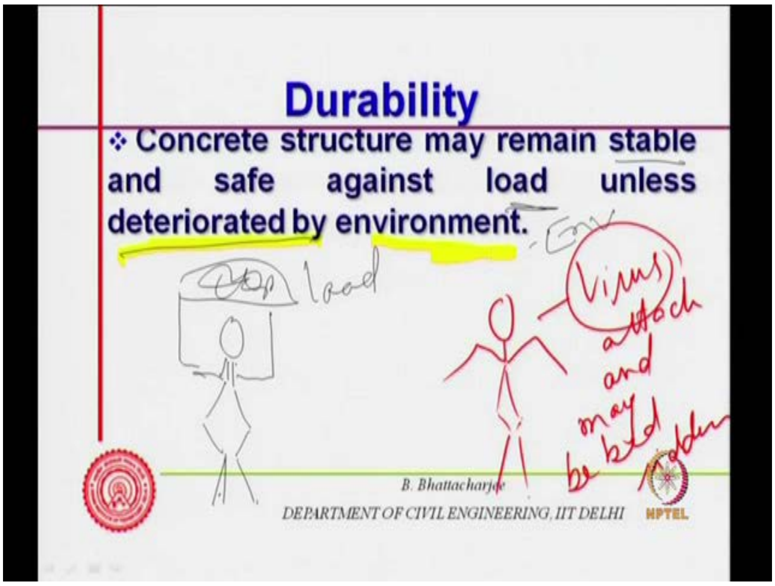

So, what is durability? Well concrete structure may remain stable and safe against load unless deteriorated by environment. You know load carrying capacity is one thing for example, a person you know a person may be able to withstand a lot of load, carry a lot of load. So, that is the actually stable against load, but same person may be attacked, but some virus, virus attack and may be bed ridden not able to do it is function.

So, even though strong able to carry a lot of load, even though is strong and able to carry a lot of load may be effected by virus. So, therefore, environment and this virus comes from, where it comes from environment, it comes from you know it is comes from environment, it comes from it comes from environment, it comes from the environment you know it comes from the environment.

So, load carrying is one thing, but remaining un effected by virus is something different, durability related, concrete durability or durability of actually structural systems or materials actually relates to the effect by the environment, that is what we are saying unless deteriorated by the environment, unless deteriorated by the environment. So, durability’s concrete structure may remain stable and safe against load, but it may not still may be safe, but whenever remain, may not be able to do it is function, may not be able to perform it is function, if attacked by deteriorated by the environment, if deteriorated by the environment all right so that is what we are talking of.

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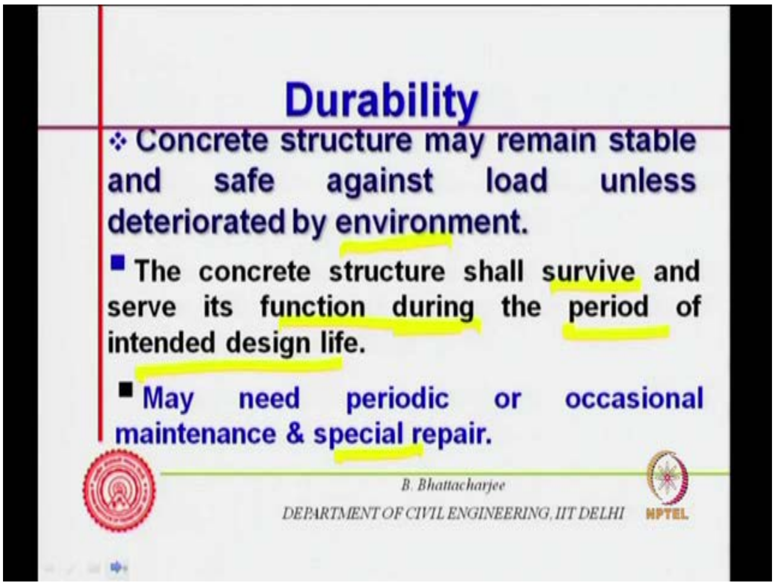

So, the concrete structure shall survive and serve it is function during the period of intended design life. So, durability is related to this actually, the concrete structure shall survive and serve it is function during the period of intended design life, function means if it is a bridge should be able to carry the load, if it is a building should be able to provide the shelter, the structural system you may know concrete structural system it is part of the building then it should be able to provide the shelter support everything. So, that is the function actually.

So, it should be able to carry the function, but then you cannot rule out periodic or occasional maintenance and special repair because this cannot be ruled out because may may effect. So, when this it is not able to perform it is function, not able to perform it is function as desired you know, then you may have to do periodic or occasional maintenance and special repairs.

So, define durability, durability of the structure durability of the structure component etcetera, is it is capability to maintain minimum performance level, over a specified time when exposed to degradation environment. So, durability of the structure or component etcetera it is capability to maintain and minimum performance level, over a specified period of time when exposed to degradation environment. So, if it is an degradation environment, it should be able to perform it is function, for a specified time and that is what is durability related to durability right.

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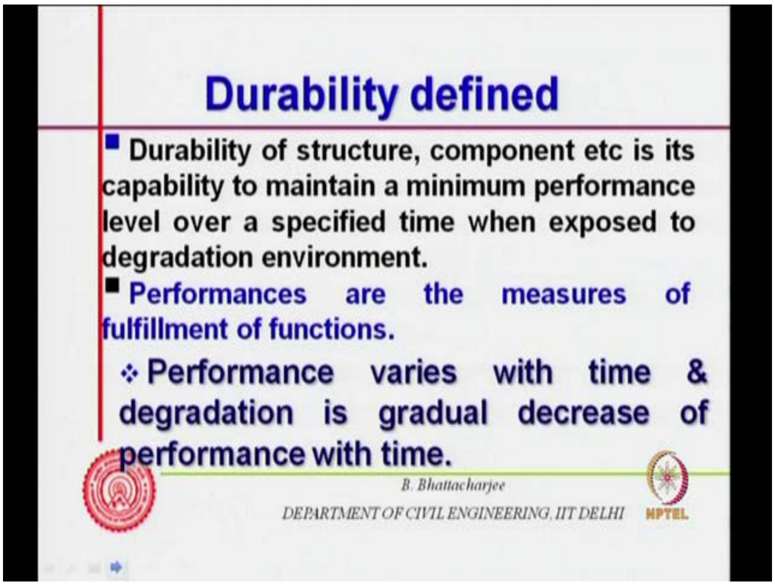

So, durability is defined in this manner, right and performance are the measures of fulfillment of functions, that is what by definitions, performance varies with time and degradation is defined as a gradual decrease of performance with time. So, this two are related, degradation is gradual decrease of performance and if you are able to maintain the performance that is related to durability right. So, it is capability maintain this performance in the environment, it is capability to maintain this environment right, but degradation would you know it is it will cause actually performance it it will cause decrease in performance.

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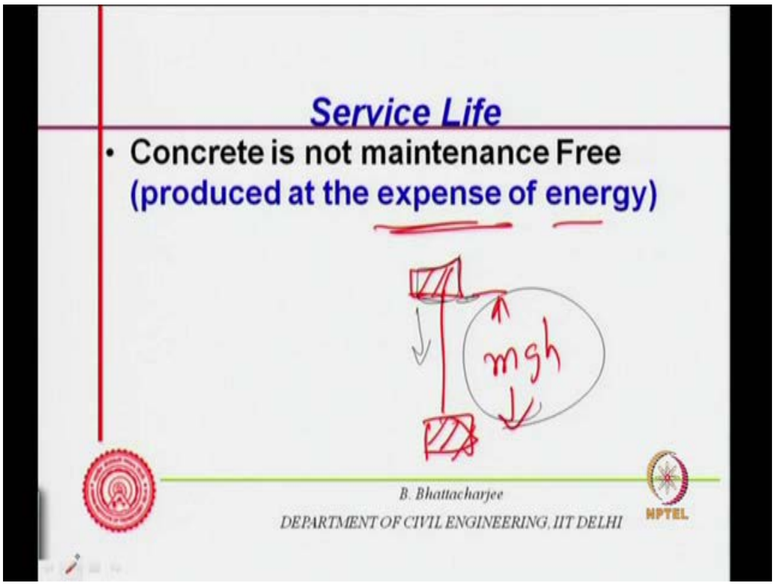

So, therefore it is kind of a qualitative statement that we maintain, you know that is a qualitative statement that we remain may all these are qualitative statement, you should be able to maintain it performance, how do you define this performance, but you said for a given life, given time. So, it is given life time you know we defined it as a given time. So, for a period you know specified time when expose to degradation environment therefore, it is link to life what time.

Now, we can understand concrete will not be maintenance free, it will degrade, why it will degrade, because all those material or system thus produced at the expense of energy, by spending energy you know they will have a tendency to dissipate that energy. For example lifting a body up lifting a body up lifting a body up to this level increase it potential to m g h, so it will have a tendency to come down, it will have a tendency to come down.

So, if you give some energy m g h increase it potential, it will try to comedown. Now, this is of course, mechanical you know this is a gravity potential I have increase, but when I am producing a material with the expense of energy, actually you know I am actually energy is input to it I am increasing it is chemical chemical energy or chemical potential, it is chemical potential or Gibbs free energy and so on, so forth. So, it is chemical potential actually I am increasing.

So, when increase a chemical potential it will have a tendency to react and dissipate that energy, you know get involved in an exothermic reaction and dissipate that energy. Now, cement is produced with considerable amount of energy. And therefore, cement reacts with water and dissipates some of this energy, but all the energy is not dissipated, it is not 100 percent stable material, had it been stable material c h s would not have reacted with anything else and c h s would have been available in nature.

The material those you get in the nature, let us say quad sand it is available in nature, it has dissipated all it is energy and come to a stable state, crystalline stable state you know molecules has it is perfect minimum potential level. So, whatever materials, whichever material you produce. So, the expanse of energy as a tendency to dissipate this and therefore, cement concrete is no exception, cement concrete is no exception and therefore, it will not be maintenance free.

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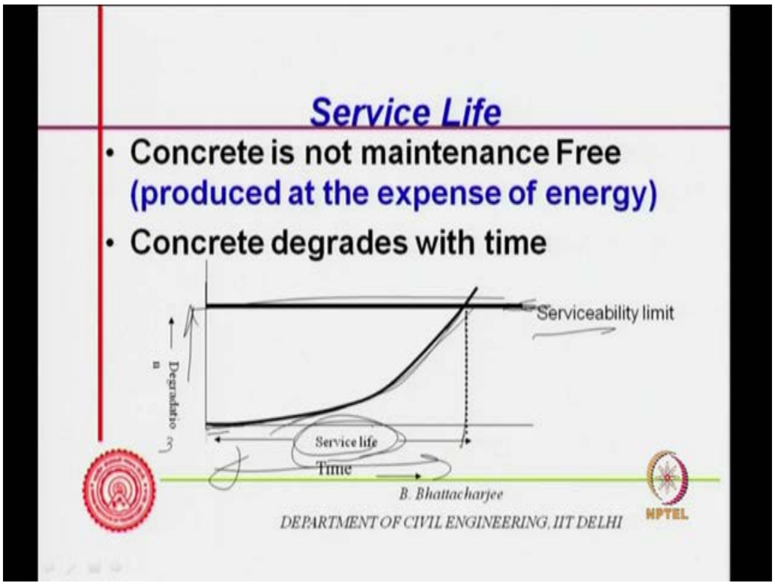

So, it will have a tendency to react, concrete will some component of concrete particularly cement systems, cement hydrates system that was not dissipated it is energy fully and therefore, it will have a tendency to react. Aggregates actually if it is fine powder, then you know like after a brush on natural process fine sand, very fine sand, large sizes also has got to reduced.

So, all the fracture you know it has dissipated by fracture all energy possible and come to the final size that is actually a stable material, rocks may not be all the time stable, compare to of course, fine powder of the same material because it will have, it can still break into new surfaces and dissipate some more energy and create new surface, you know dissipate some fracture energy and create new surface.

So, aggregate some of the aggregate some energy might be logged in aggregates, but not necessary it is mainly the cement paste and cement hydrates system that has a tendency to it is it is you know it is it has somewhat higher chemical potential and you actually tend to dissipate that given in conducive condition.

So, cement paste steel also you know many other material, all materials that we produce if the expense of energy, will have a tendency to dissipate. So, therefore, cement concrete is the exception and it also degrades with time, it will react and degrades with time. All reaction may not be dangerous, but if the reaction is causing is creating a problem, as far as it is functional performance is concerned, it is not able to maintenance functional performance then we will call it degradation.

So, functional performance should be reduced. So, you see the degradation if if I kind of plot it along this direction, to start with you know it is 0 here and then with time it degradation increases. And this somewhere we define a limit up to which I cannot beyond which I cannot accept I cannot accept the the degradation anymore that limit is I call as serviceability limit because it will not you know we are talking of elements, not the structure as a whole.

Structure as a whole will never deteriorated altogether very rare cases it will, mostly part of the structure or one of the elements will actually degrade, degradation you will see in elements, concrete will degrade in some of the elements only and when degrades the element, the element might reaches serviceable limit For example, I may define those serviceable limit I mean which I cannot tolerate, say deflection, large deflection usually the cracks what is falling.

So, when it cracks as appeared at certain level I may say that well it is not no more acceptable to me, this size of the cracks and that is my serviceability limit. So, degradation causes those cracks to appear and when it reaches this I call this is a service life and service life when I am talking, I am talking of elements, you know not of the whole building. So, it is it is of the element. So, the element concrete element I mean degradation normally do not cause failure of the structure, unless you have allowed it to go through.

So, a component might show degradation and cracking might results now, one element abeam in a large building shows a exhibits crack, it does not mean building is going to immediately fall down. So, all all you can do is you can repair it, essentially and do some maintenance work and it will come back to it is original, you know it can you can bring it back to it is original stage.

So, this may not most of the degradation do not lead to immediate failure and whenever talking of life, service life we are talking with respect to element, I am talking on the context of concrete, you can imagine even in a steel bridge, cross bridge an element shows some cracking because of fatigue may be over the years, reverse of a stresses it shows a fatigue crack fracture. So, you remove that element put it in another one back, the bridge is they locate can last for longer period of time.

So, such kind of long term durability or one element shows some kind of lasting. So, you remove that element and then put in another one. So, this you know it you can repair it basically, but during in the mean time you have to see that it remains stable because one critical element if you remember remove it may cause secondary of reverse that is other issues, but all I am trying to say is with respect to concrete when, we talk of service life we are not talking of the whole structure, we are talking of only an element where feasible crack or something is there appear.

Now, this is the way we can actually quantify the durability also. So, you know we said the time up to which it maintains the functions, it is able to perform, you know and able to do it is function properly. So, service life is in a way quantification of the durability right, service life is in a way quantification of the durability all right. So, this is related to the durability.

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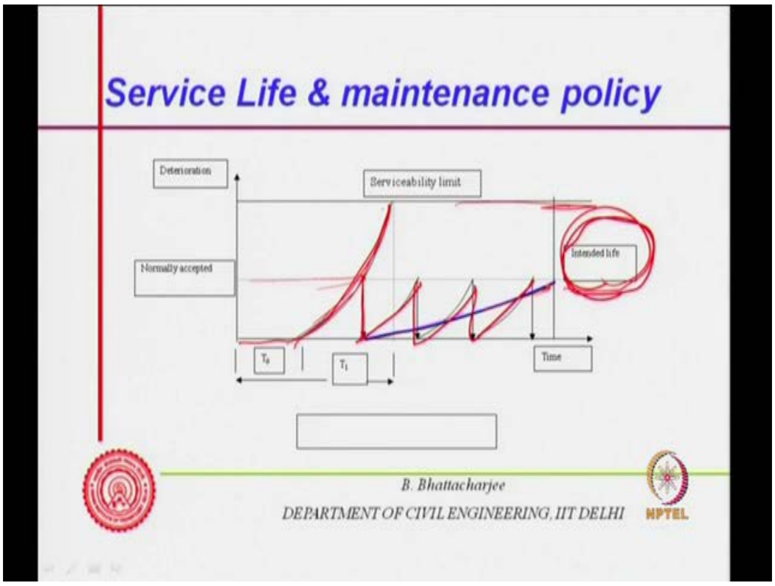

Now, maintenance policy if I look at it, you know this as I said with time with time the degradation will progress, degradation will progress initially there may not be any degradation and then degradation may start and this is my serviceability limit and this largely repair to related to maintenance policies and a repair of structures, degradations are large related to maintenance policy and you know repair of structures, concrete structures, but the cost involved could be very, very large.

So, because there are rather cause cause such as deception cause, you stop a bridge there is a cost involved in that therefore, we would not like, would like a maintenance free service life, maintenance free intended design life, intended design life is that life for which I have designed the structure I have taken the load, the worst load that can come during the intended design life and the structure should last, during that period and I prefer that there is no repair or maintenance during that period of time because otherwise it will involve cost, but supposing it happens also.

Then this is what the deterioration or degradation will it reaches this limit, you know and am I do a normal normally you know this is the acceptable limit, but I might do at this stage itself I might do some repair and bring it back and go on doing this repair, again and again, this could be one of the strategies, but a better strategy and this is the intended design life of the structure itself, intended design life of the structure itself.

So, I can have several service life of element within the intended design life and I can go on repairing with the original system itself, but I can do a better maintenance or better repairs, such that it reaches straight over the intended design life. So, there can be different maintenance policies and durability of concrete is related to this issues, actually durability of concrete is related to this issues all right. So, maintenance policies are related to this.

So, degradation process is in concrete, we now digress or rather go into the material with discussion that we have related to durability right. Due to the degradation, deterioration occurs, deterioration occurs of the structure or the element occurs because of degradation. So, degrades degradation is going from functional performance reduces and therefore, the structure deteriorates. So, deterioration degradation this confusion should not be there.

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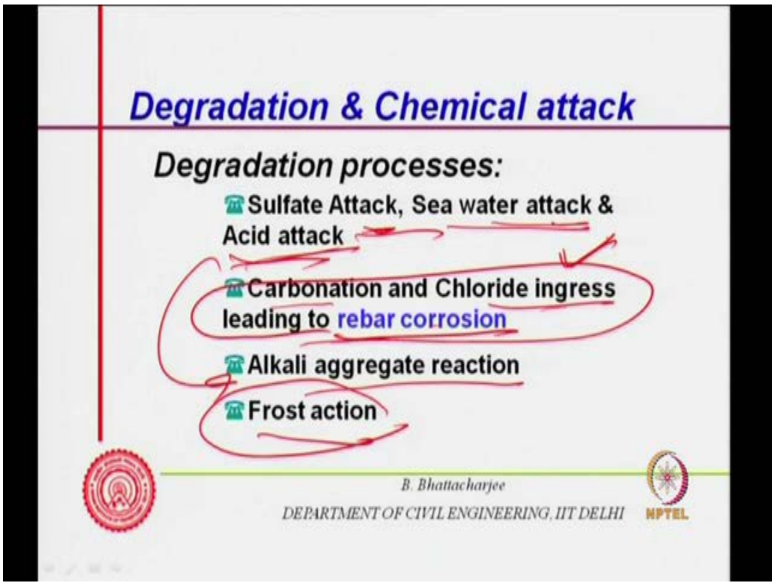

Now, we are talking of degradation processes by which actually concrete element will get deteriorated. So, sulfate attack is one of them, sea water attack is other, acid attack is other. Concrete is an alkaline material or cement paste, cement hydride is an alkaline material because calcium hydroxide is produced, calcium silicate hydrates are produced. So, they are generally you know alkaline in nature, relatively alkaline in nature and therefore, they do not get attack by everything, it is relatively stable compare to many other.

Let us say man made material which can you know. So, all manmade material do not get attacked by the same mechanism by the same agents. So, sulfate can attack cement base material. So, concrete seawater can attack the cement based material and concrete and acid can attack the cement base materials because it is alkaline this two carbonation and chloride ingress, they are not degradation process for concrete per say, but they are problem for reinforce concrete and feasters concrete because they can cause rebar reinforcement still reinforcement corrosion.

So, carbonation and chloride ingress leads to rebar corrosion, other one is alkali aggregate reaction this is another kind of deterioration, involves aggregate themselves, this involves cement paste and frost action involves everything of course, not the reinforcement. So, we will look into first this one and then look into this sometime later on we can look into this one after of course, this discussion because this is very, very important, good law of structures all over the world are affected by this one and the maximum cost, you know for repair is involved with this particular one.

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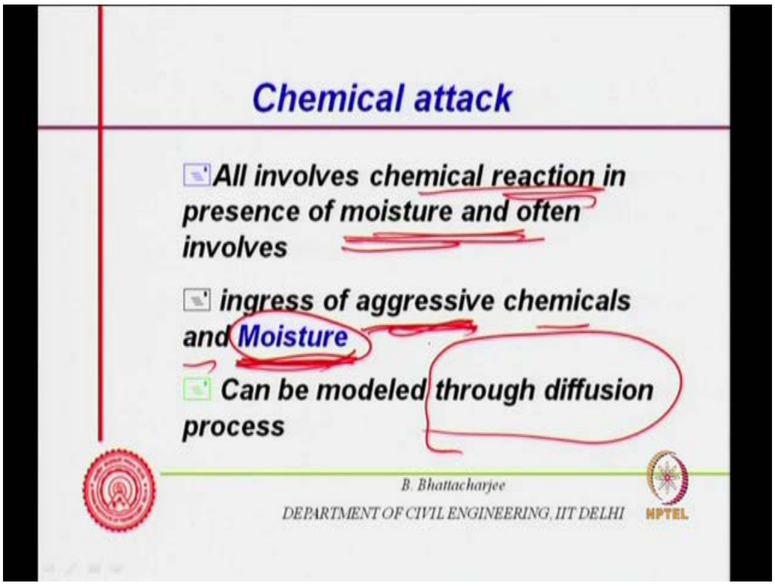

But, one thing important there are many deterioration process, but all involves actually chemical reaction and this is most of an presence of moisture is you know it is it is absolutely must for most of this reaction to occur, very valid dry concrete get effected by anything. So, therefore, it is very important that we keep this out, if you keep this out of the concrete system, then it will not you know it is durability will be infinite, right and many cases of course, ingress of aggressive chemical from outside takes place.

So, some cases you can model them to diffusion processes because if the process if the processes is of diffusion, coming it you know diffusion will define this somewhat some time later on. So, if the process some process can be actually model through diffusion. So, but what we got to understand this is most important, moisture is most important if you can keep moisture out all problems are solved.

And in some other cases other aggressive chemicals from outside, it is mostly aggressive chemical from outside that common attack the concrete and causes degradation of the material.

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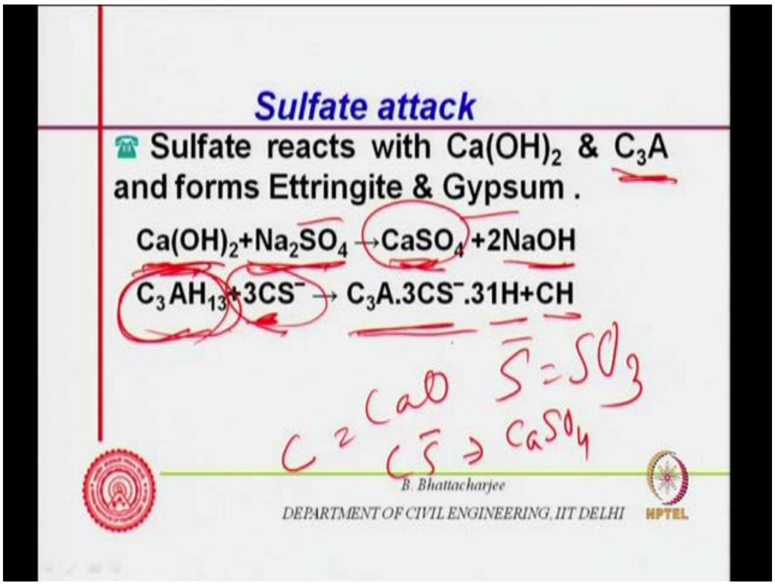

So, let us look at first the sulfate attack. Sulfate reacts with calcium hydroxide and tri calcium aluminate and forms two compounds, you know found compounds like ettringite and gypsum this you have seen earlier, formation of ettringite we have seen earlier, when we talked of setting of concrete, remember we add a little bit of gypsum you know calcium sulfate, we add to the cement in order to control the you know setting process of cement cement and c 3 has a high affinity for sulfate or gypsum.

So, if you have some sulfate other kind of sulfate say sodium sulfate, is available in the ground water and here is concrete is in contact to the ground water or similar other situations, where it is in contact with sodium sulfate, it will react with sodium sulfate or potassium sulfate or similar sulfate, you know alkali sulfate are more soluble. So, there will be again it has to work, it has to it works you know it react sin the solution phase.

So, therefore, there readily soluble and they can react with calcium hydroxide form in calcium sulfate and sodium hydroxide, you know forming calcium sulfate and sodium hydroxide right. Now, calcium sulfate is a ettringite sorry calcium sulfate is something you know in the there in the gypsum you remember it was calcium sulfate 2 H 2 O is the gypsum. So, calcium sulfate can easily react with calcium aluminate hydrate, you know this way of writing calcium sulfate if you remember when we talked of cement chemistry we said S bar stands for S O 3.

So, C stands for C a O therefore, C S bar stands for calcium sulfate. So, calcium sulfate reacts with tri calcium aluminate hydrate for me take forming a complex salt of aluminoah alumino alumina sulfate calcium, alumina sulfate with so much of water and calcium hydroxide and this are ettringite these are this is this is ettringite, this is ettringite.

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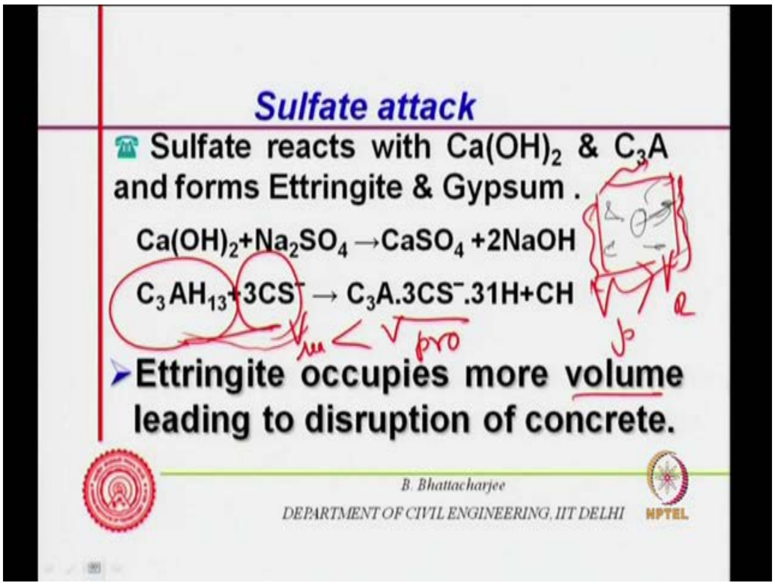

Now, this ettringite when form during the hydration process or initial setting process there is no problem because the volume expansion this this material it occupies more volume then the reactants, you know these are the reactant, this is the reactants and this is the volume of the other reactant.

So, volume of this one, v of this one is less than the v of the product, v of reactant is less than the volume of the product. So, therefore, there will be a kind of it will try to expand, but this expansion is not a problem, when when it is actually you know volume of product is greater than volume of reactant. So, it is not a problem when it is occurring in plastic paste because this can accommodate this expansion, this can accommodate this expansion and this ettringite is of course, converted into mono sulfate and so on. So, forth which is stable, but this can expand.

But, here this expansion in harden concrete cannot be cannot be you know it is cannot withstand it. So, if you have hardened concrete and is something is trying to expand from inside, something is trying to expand for inside, you know something is trying to expand it will push actually, it will push the harden concrete push it, push it and normally popping out from the surface will result. So, therefore, disruption of the concrete will occur because of sulfate because of sulfate attack because of sulfate attack. So, disruption you know it is popping out could be occurring.

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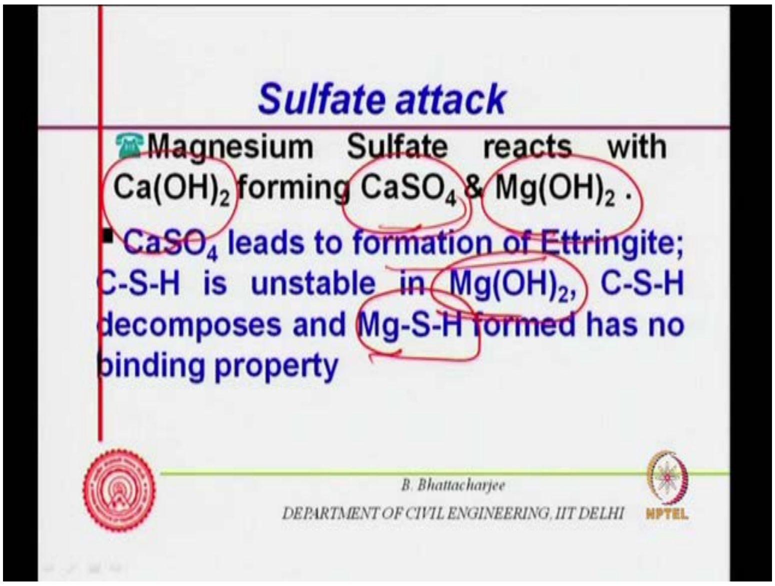

So, this is what happens when you have, any other sulfate other than magnesium sulfate coming into the system, instead of you know sodium sulfate comes, potassium sulfate comes the react with calcium hydroxide, forming calcium sulfate and sodium hydroxide or potassium hydroxide.

Now, potassium hydroxide, sodium hydroxide do not create much of the problem to the concrete because there any with there in the system as well may alkalis are there, but magnesium sulfate, when it comes it of course, reacts with the calcium hydroxide when it is contact with the concrete, but it forms calcium sulfate, but forms also magnesium hydroxide.

Magnesium hydroxide of course, can react you know can form magnesium sulfate, but that is not the case usually, may this this this calcium sulfate of course, will lead to formation of etrringite, but problem is C S H is unstable in the presence of magnesium hydroxide. Calcium silicate hydrate is unstable in environment of magnesium hydroxide it is quite stable, in an calcium hydroxide environment or in magnesium hydroxide environment it tends to form this magnesium silicate hydrate.

And this magnesium silicate hydrate does not have the cementing property, this does not have the cementing property as our ordinary cement, it does not have cementing property like our you know binding property, does not have binding property like our ordinary for our cement or calcium silicate hydrates and this can results in further, decomposition of the concrete, this can results in further decomposition of the concrete.

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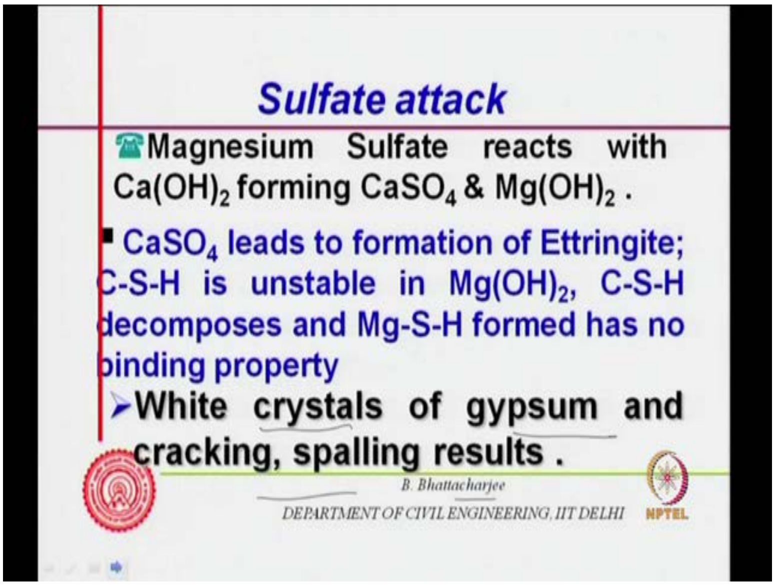

So, what you see, normally will see white crystals of gypsum cracking and spalling. So, one thing important from this discussion, so for is that magnesium sulfate is more dangerous, then sodium sulfate potassium sulfate. If calcium sulfate comes in contact with the concrete, well there is no need for formation of calcium hydroxide to calcium sulfate, it will state away react with the tri calcium eliminate hydrate.

So, you see actually white crystals of gypsum cracking and spalling in all cases, in case of sulfate attack all right. So, this sulfate attack the lot react people you know the some lot of research goes on sulfate attack, it is it is generally comes from the ground water, ground water you know contaminated with sulfate foundations could be affected by them by the sulfate attack.

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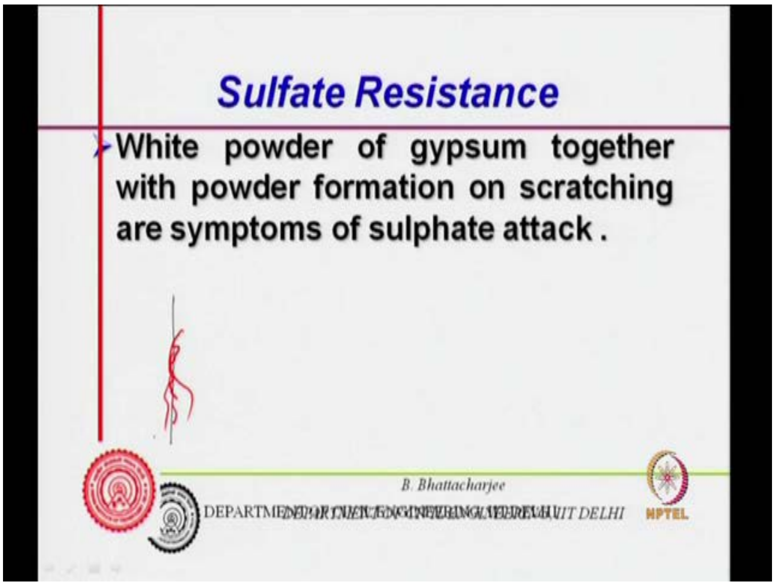

White powder of gypsum together with white with powder formation of scratching are symptoms of sulfate attack. So, we will see white powder and if you scratch the concrete you know you just scratch the concrete, if this is your concrete surface and you scratch it you will find that materials are coming out. So, on scratching material will just simply loss from the surface because the expansion is actually we can the concrete state away and sometime later on it itself will come out. So, that is that is a symptom of sulfate attack.

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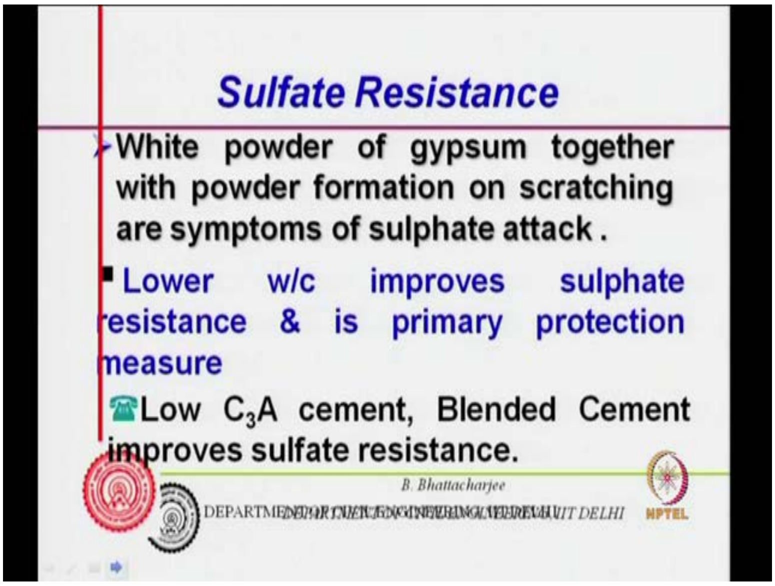

Now, how do you reduce it down if you are, you know if you forcey the sulfate attack, then lower water cement ratio is a good solution, it improves a sulfate resistance and it is primary protection measures. So, basically you have to reduce on the water cement ratio what it what it is sulfate will not be able to penetrate into to the concrete, sulfate will not be able to penetrate into the concrete, you know as we said moisture has to come in the other material has to come in to the concrete.

So, sulfate will not be able penetrate into the concrete and that is how it saves it saves, low C 3 A cement, sulfate registering cement remember we talked about sulfate registering cement when we are talking of type of cement, this has got C 3 accountant restricted low C 3 accountant, blended cement of course, cement with pozzolana also improves sulfate resistance why because first of all what it do is, it would reduce down it would reduce down the you know it will reduce down the C 3 A active C 3 A content because cement will be 70 percent let us say 30 percent is my fly ash.

So; obviously, C 3 A gets reduced by 30 percent itself, if it was 8 percent it will now become 5.6 percent, if I have I am using about 50 percent slag in this blended cement that is your blast furnace, you know port land slag cement. So, you will have now 8 percent C 3 was there originally now it will become 4 percent C 3 A. So, there is dilution effect straight away and that improves sulfate resistance beside normally pozzolanic or blended cement has got better micro structure then solidify the whole thing and therefore, they improve the sulfate resistance they improve the sulfate resistance.

So, this sulfate attack you know and beyond that of course, So, using using sulfate resisting cement, blended cement, low water cement ratio these are usually the strategies against sulfate attack provided you can see them. It is it is is the is there, but Indian scenario less come on then let us say reinforcement corrosion, reinforcement corrosion is one of the major problem.

Seawater attack well, seawater contains sulfate and it also contains chloride, sodium chloride. So, seawater contains sulfates, sulfates are there magnesium sulfate, calcium sulfate they are there and one difference is that ettringite and gypsum are soluble in chloride solution. So, if you have sodium chloride solution which is the sea water, the ettringite that would form within the concrete and gypsum those will form within the concrete that will dissolved.

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So, therefore, there is no scope of actually expansion and cracking. So, the action is slightly different although you have seen sulfate, but the action is different because now the sodium you know I mean the chloride solution will dissolve this ettringite but results in what leaching. So, therefore, severe leaching could be there, if sulfate attack is prominent, dissolution of gypsum and ettringite would result in actually very porous concrete, so if you have very porous concrete now more water, more sea water can gain going.

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So, crystallization of the salt in the pores can occur and this can cause expansion and cracking. So, some slat pores will, it will become more, it will become porous, it will become porous this skeleton will become porous and therefore, more material can be go in solidified there and has the crystallization of you know solid occurs within this can cause expansion and cracking.

But, major problem comes from the reinforcement corrosion because the chloride that goes in that can initiate corrosion, we will discuss about that sometime later on, but it is a chloride which is more dangerous because this can initiate rebar corrosion. So, see in the sea water environment rebar corrosion is more important therefore, one you know sulfate attack directly may not affect it no may not cause cracking, but it makes it porous, the skeleton becomes porous and therefore, more chloride can get in and it can initiate the corrosion first.

So, indirectly it will actually helps the reinforcement corrosion, blended cement performs best in sea water, lower water cement ratio and quality of concrete of course, is the other material measure of protection. Now, why blended cement you see remember in sea water, you need protection against both chloride, as well as sulfate. Now, it has been observed that the penetration leaves of chloride or you know, the hinges of chloride is not restricted by sulfate registering cement.

Sulfate registering cement does not perform very well in a chloride environment because chloride can still penetrate in, in fact chloride we will see that chloride binding becomes lower, if you it is sulfate resistance because C 3 helps in chloride binding or c C is you know c tri calcium aluminate hydrates, they help in chloride, binding the chloride chemically and sulfate registering cement.

So, if you reduce on the C 3 A action of chloride may become more pronounced, while in blast furnace slag cement this effect is not same. So, this performs vary well both against chloride as well as sulfate. So, in sea water blast furnace slag cement would perform much better, then of course, the sulfate registering cement sulfate registering cement sulfate registering cement.

So, sea is water attack is it is different. Now, magnesium sulfate also can be present in sea water and they, as I as we told it attacks the skeleton of the concrete itself, it you know it attacks the skeleton of the concrete itself. So, in sea water situation magnesium sulfate can be more dangerous, they can attack the CHS and there the where more CHS is there, basic structure can still be attacked by magnesium sulfate, you know magnesium sulfate.

So, that is that is more dangerous one has to really looked into, you know lot of research are going on because with advent of high high strength concrete, we are using, we are trying to form more CHS in the skeleton, replacing calcium hydroxide as much as possible and calcium hydroxide, of course is vulnerable you have sodium sulfate because it will form calcium sulfate but CHS more means less calcium hydroxides.

So, it is good, if the concrete is exposed to sodium sulfate or calcium sulfate, but magnesium sulfate high CHS may not be a solution. So, lot of research are going on and it will request possible more research look into this ratio.

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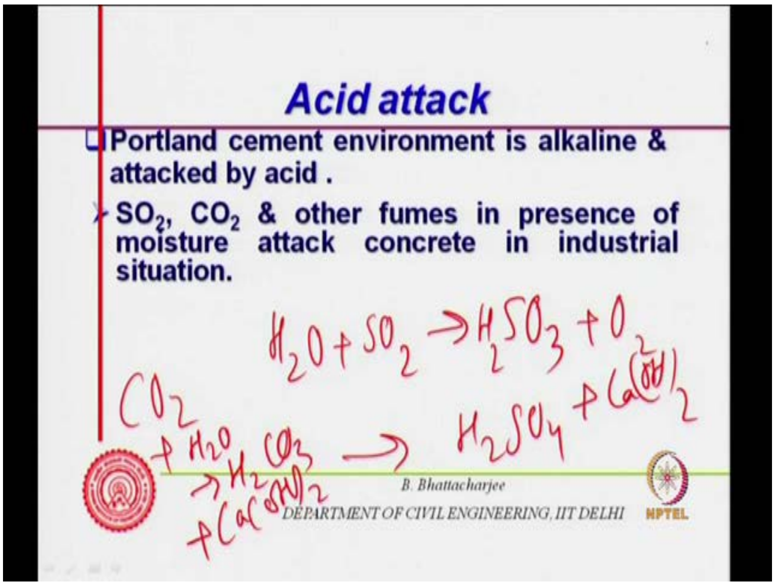

So, next we can look into acid attack, concrete is alkaline, port land cement environment is alkaline therefore, it will be attacked by acid. So, acid comes from where, sulfide dioxide, carbon dioxide in such other fumes if presence of in presence of moisture for example, you have H 2 O plus S O 2 will form actually h 2 S O 3 sulfuric acid which might get oxidized to you know which might form actually H 2 S O 4 you know H 2 S O 4 in presence of water etcetera, etcetera.

So, it might form actually it might form H 2 S O 4 which is which gives stable actually similarly carbon dioxide plus water forms H 2 C O 3 bi carbonic acid, weak carbonic acid. Now, this acids can react with calcium hydroxides, this can reacts with calcium hydroxide, this can reacts with calcium hydroxide.

So, acids can reacts with calcium hydroxide, acids can react with calcium hydroxide right acid can reacts with calcium hydroxide, and this can result in acid can react with calcium hydroxide. And this can result in this can result in acid can result in you know it can results in a reaction of acid can result in reaction of acid can result in actually degradation of the concrete because calcium hydroxide reacting with acid calcium hydroxide reacting with the acid would form salt and you know this can this can result in formation of this can result in formation of products which would result in degradation.

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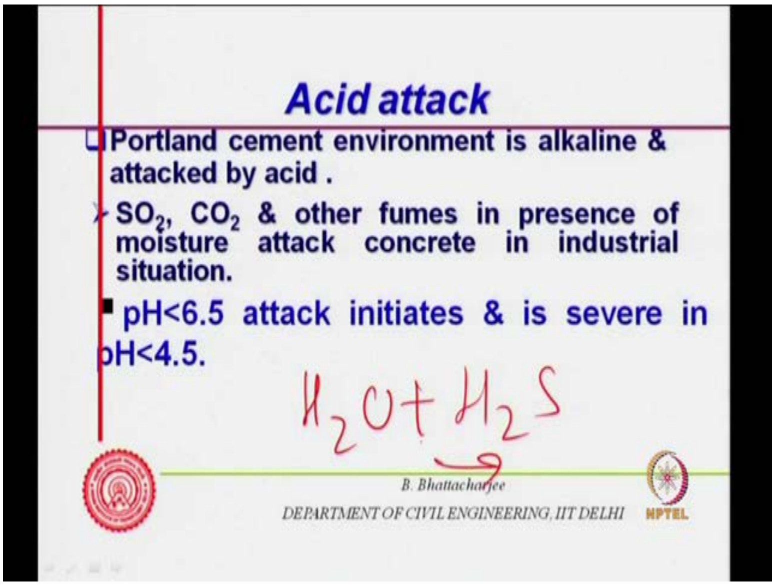

So, acid can attack concrete acid can attack concrete acid can attack concrete acid can attack concrete right. Now, p H below 6.5 attack initiates and a severe if p H is 4.5. So, concentration of the acid matters, sulfuric acid I mean the formation of sulfurous acid or similar one or C O 2 carbonic acid if it if it concrete come soon in contact with p H less than 6.5 attacks initiate and it is very sever in 4.5. So, it is actually cause lot of loss of the material from the concrete itself.

Another acid attack would be because of H 2 O reacting with H 2 S which can actually form sulfuric acid, which can again form actually sulfuric acid.

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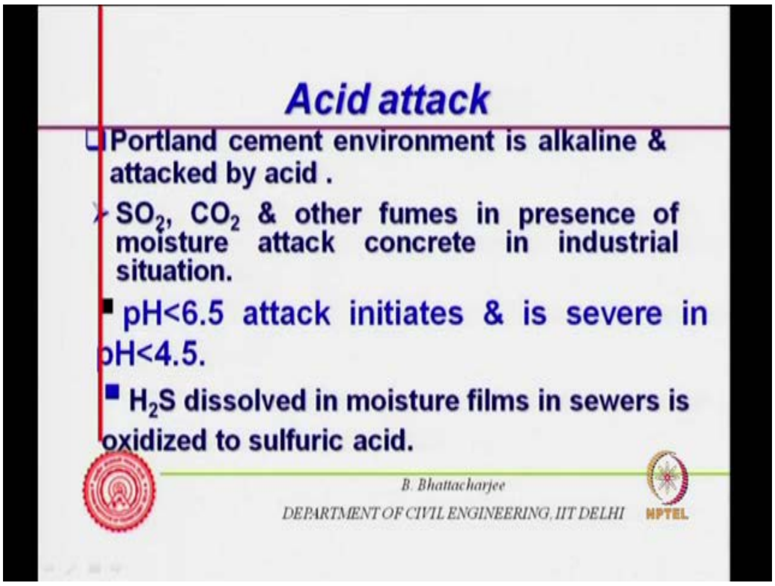

So, this is in in you know this is in in H 2 O dissolved in moisture films in sewer is oxidized to sulfuric acid. So, H 2 S, H 2 O plus oxygen in the atmosphere it is dissolved film it can actually results in formation of sulfuric acid. So, sulfuric acid you know this can result in again, reaction with the similar kind as we have discussed.

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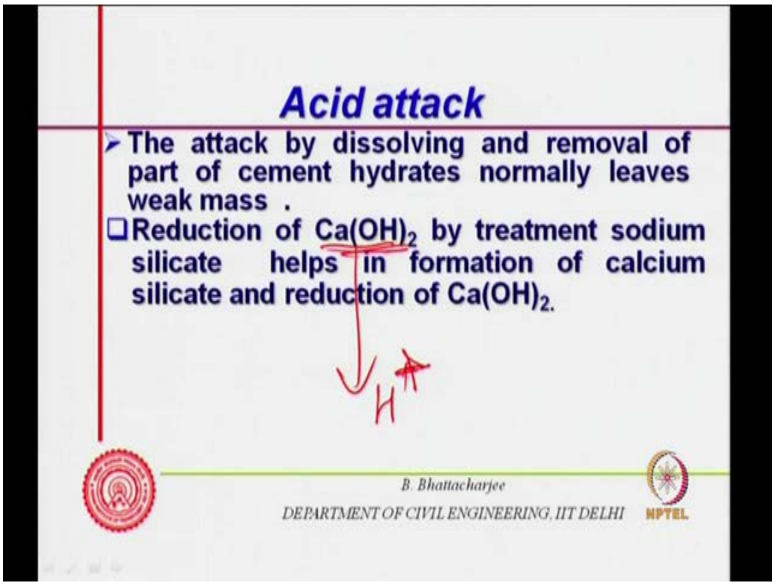

Now, attack by dissolving and removal of part of the cement hydrates normally leaves weak mass. So, that is what it is, it is actually causes kind of leaching. So, it will attack calcium hydroxide and in calcium hydroxide and it will be removed and if it is this mass becomes weak, I mean you know in lower alkaline environment lower alkaline environment CHS itself may not be as stable, as it was otherwise and it is not actually it is porous, also at the same time, because calcium hydroxide has been removed, by you know that by formation of salts.

Normally acid leaves a kind of weak mass and this weak mass gradually tend to pop out gradually tend to pop out. Reduction of calcium hydroxide by treatment with sodium silicate calcium formation of calcium silicate and reduction of calcium hydroxide because if this link is calcium hydroxide, the link is calcium hydroxide, this is what reacts with any kind of acid, this is what reacts with any kind of acids.

Therefore, if I remove, if I know that there is a possibility of acid attack I can actually reduce down this calcium hydroxide by treatment with sodium silicate and calcium silicate would be there and this is reduced on the calcium hydroxide and potential acid attack potential acid attack it can reduce down the potential acid attack you know potential acid attack can be reduced all right.

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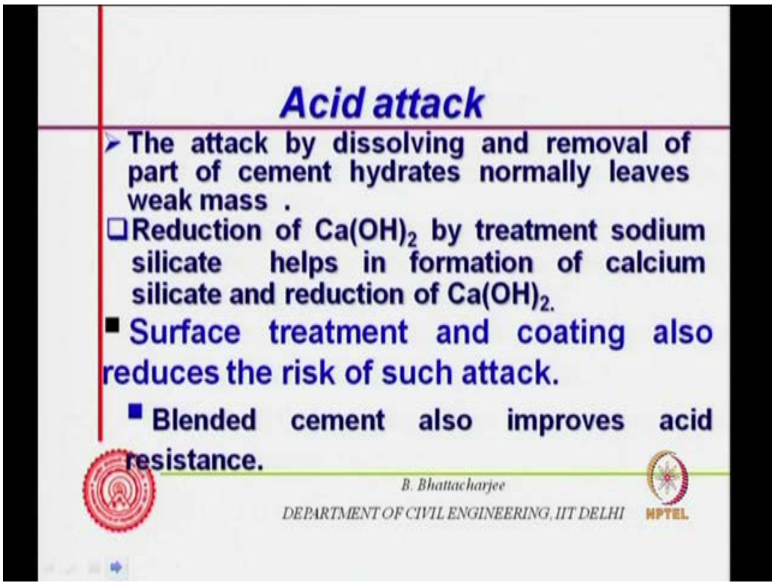

So, surface treatment and coating also reduces the risk of such attack, even even you know even even water pure water 7 p H water, you know distilled water they have a tendency to actually leach out because leaching from the concrete. So, concrete close to neutral or less than neutral that is acidic water, as a tendency to actually become more porous and in the process they can be, they can form weak mass.

In fact, you might see white crystals of calcium sulfate in the sewer line between the maximum water and the minimum water line and weak mass of concrete in the gradually give rise to popping out of the surface concrete or surface concrete loss. So, coating etcetera, etcetera they reduces the risk of such attack and blended cement they improve acid resistance blended cement improves the acid resistance.

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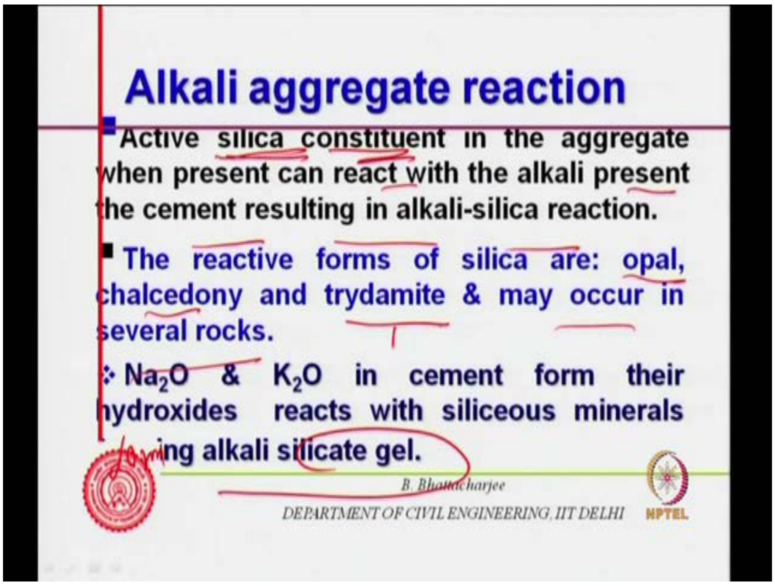

Because, low permeability nothing can penetrate. So, blending cement gives you a much better microstructure and therefore, they you know nothing is able to penetrate. Alkali aggregate reaction, this is another kind of degradation process of you know, concrete and concrete deteriorates deteriorates with alkali aggregate reaction. Now, some aggregates execute this not all aggregate will actually execute this, some aggregate which has got active silica, they can react with the alkali present in the cement resulting in alkali silica reaction.

So, some of the aggregates not all some active silica constituent in aggregate when present can react with alkali present in the cement resulting in alkali silica reaction. The reactive forms of silica of course, some of them I have just note it down opal, chalcedony, trydamite and there are many others and they occur in many rocks, you know opal quartz for example. So, they occur in many other rocks as well.

Now, sodium hydroxide and potassium oxide in cement, they form their hydroxyl ion and then reacts with the silicon silicate siliceous materials forming alkali silicate gel forming alkali silicate gel.

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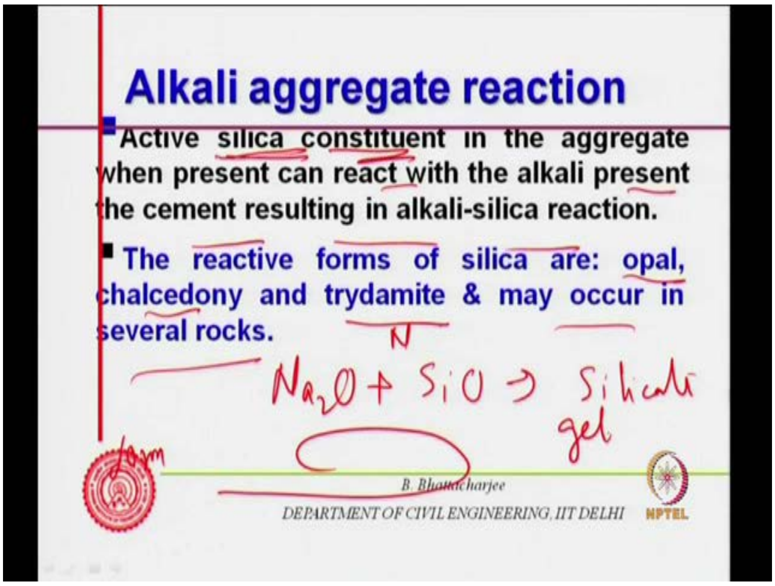

So, actually sodium oxide sodium oxide sodium oxide can react with some S i O forming silicate gel silicate gel, this gel can actually absorb water this is a gillitaneous structure and can absorb water this gilitaneous structures you know they can absorbed water. So, water can absorbed and then they actually occupy more volume. So, they can absorb water and occupy more volume. So, sodium oxide potassium oxide in cement form their hydroxide and forming silicate gels and then silicate gels can occupy more volume the silicate gels can occupy actually more volume.

So, they attract actually water, they attract water right, by absorption or by osmosis and tend to increase the volume and tend to increase the volume and this volume you know this can because because of the the you know this gel, can the solution concentrations could be different concentration could be difference and thereby by osmosis they can actually attract water.

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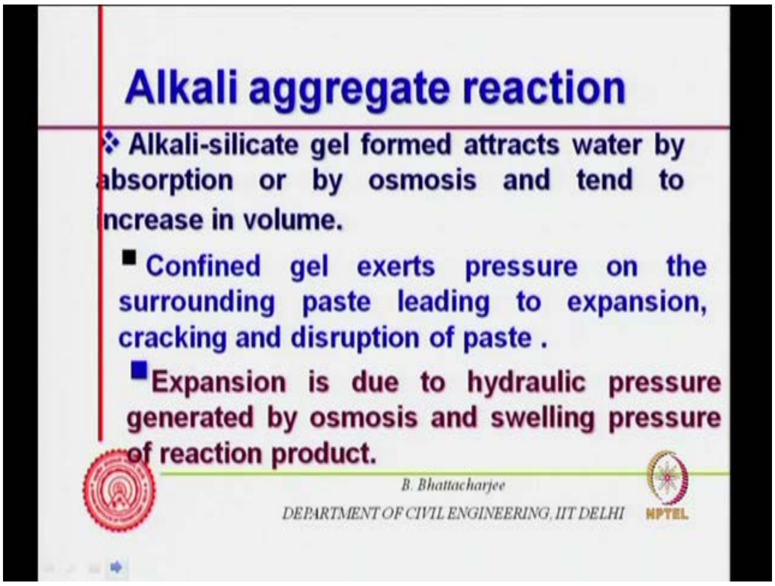

And once they attract the water, they tend to increase in volume and volume expansion you know, this volume expansion of this confine gel tends to exact pressure on to the surrounding paste leading to expansion, on cracking and disruption of paste, leading to expansion and cracking and disruption of the paste, right doing to expansion and disruption of the paste.

So, expansion is due to hydraulic pressure generated by osmosis and swelling pressure of reaction product both because reaction swelling pressure of the reaction you know, swelling pressure will come because gel with water this product will try to expand, but at the same time there will be hydraulic pressure, the material within you know this if there is a concentration difference the the tendency of the solute would be to move from higher concentration to lower concentration.

And if you apply a pressure, at the solvent level, at the lower concentration end you will see that this is not actually occurring, in other words when there is a concentration difference there is a pressure this is the kind of pressure that exist. So, if there is a concentration difference that causes a kind of pressure and this pressure is nothing but osmosis osmotic pressure and this kind of pressure, that is that would exist within the gel and outside. And also the swelling pressure of the reaction product that would have a tendency, to cause disruption of the concrete and that is alkali aggregate reaction that is alkali aggregate reaction you know.

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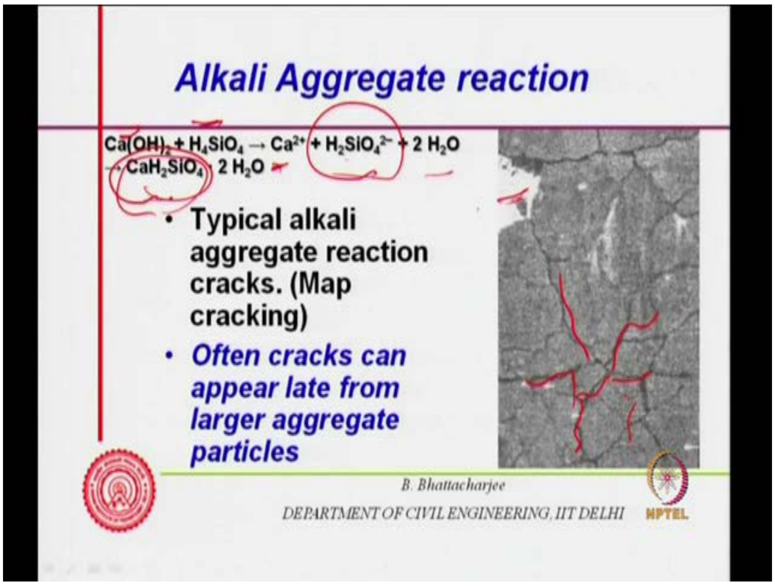

And this is the kind of reaction you can think of, this is one of the reaction calcium hydroxide reacting with silicic acid forming calcium ion and this is c plus 2 water and this is then these two together forming this product and water. So, these product is gilitaneuos has got agilitaneuos structure C a H 2 S i O 4 this is got a gilitaneuos structure and this gilitaneuos structure it can absorb water and swell and result in formation of the resulting formation of the resulting formation of the you know resulting formation of the gilitaneous, material and expands expansion causing cracking.

Typically, they might look like this, this is what we call as map cracking, this is what we will call as map map cracking, you know this structures you can see the cracks all around the places all around the places. So, this is called map cracking actually cracks can appear late from larger aggregate particle. So, this is from the larger aggregate particle you may not see the crack in past 5, 10 years of a service and they might come much, much later and an extreme case it will simply fall of also fall of also.

So, some of the other examples of alkali aggregate reaction, so in the structure is something of this kind something of this kind something of this kind alkali aggregate reaction would be something of this kind all right, you know there is a there is there is there can be there can be formation of formation of large scale cracks in the system large scale cracks in the system, it will look something like this it will look something like this.

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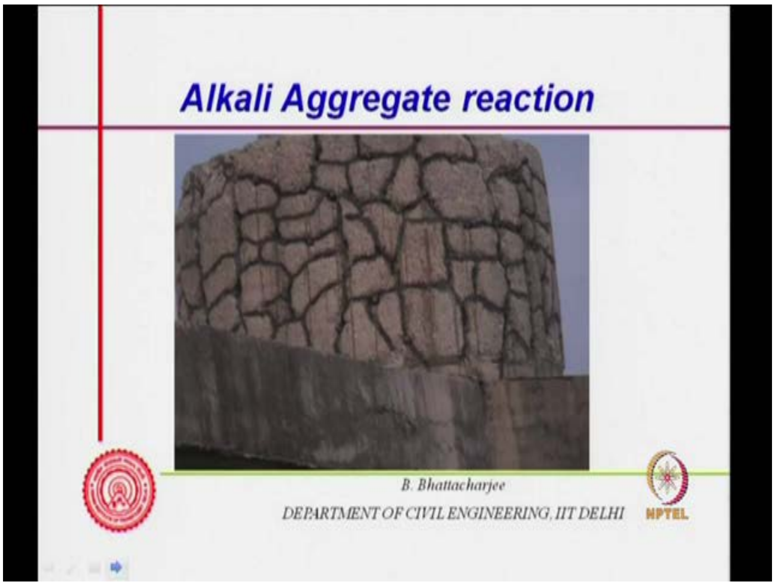

This is the real case, where the alkali aggregate reaction is caused this particular structure, you know this all source of splintering out practically, everything is going out everything is popping out. So, this is an example of alkali aggregate reaction.

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Some more example, now what happens you have the aggregate and you can see around the surrounding the aggregate, you can see this is the original aggregate and surrounding the aggregate there are white gel formation, this is also similarly it shows this was the original aggregate, there are white gel formation all around it. So, you can see the gel you know surrounding each aggregate, if you look at the aggregate you will find white kind of gel formation that is occurred.

This is the broken piece of the aggregate, you know concrete and from this you can find gel formation occurring and in early stages you might see crack fine cracks of this kind.

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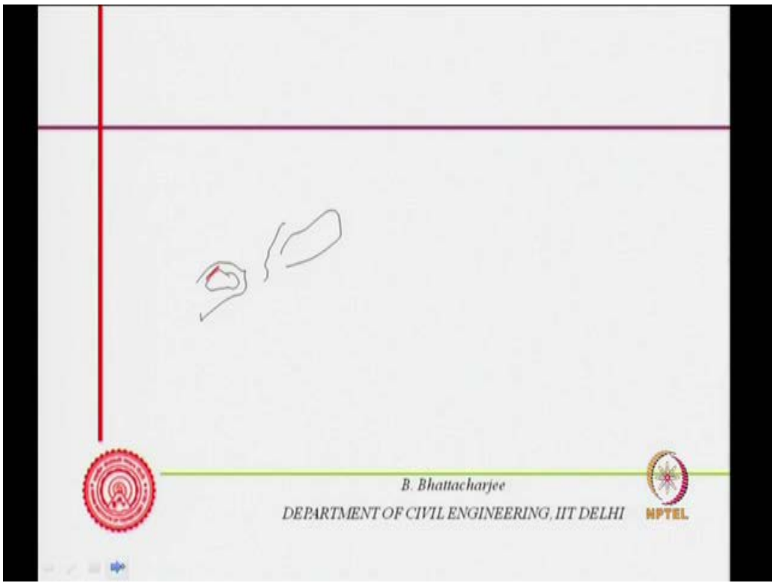

And later stages, this will result in formation of a this kind of a you know is a complete crack all around crack complete crack all around the places formation of complete crack all around the places and structural disintegrate.

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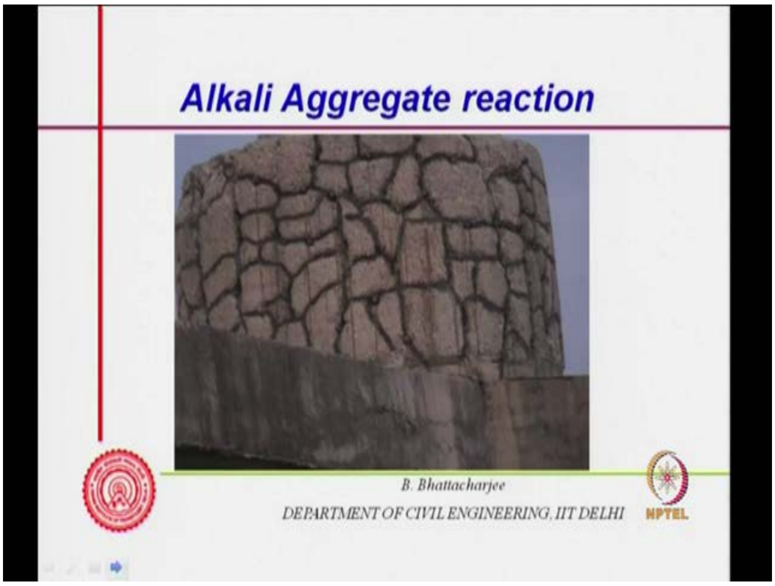

Remember this does not occur you know. So, this is the concrete complete crack in the later stages, remember this does not occur in the beginning, it takes at least 5, 10 years time. In India era could damage an example of you know it phase this problem. So, normally aggregates are tested prior to their use aggregates are tested prior to their use.

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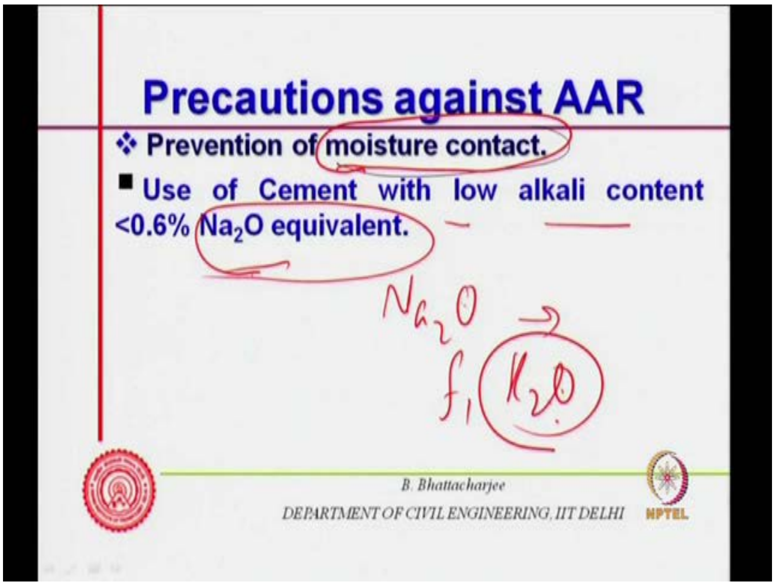

And then you try to eliminate out the kind of you know kind of aggregate that can cause, the aggregate alkali aggregate reaction. So, So, far we talked of alkali silica reaction, this another kind I will just come back come to that later on, prevention of moisture again is the most important, because this reaction also takes place in presence of moisture, this reaction also takes place in presence of moisture, the reaction that we shown it occurs only in presence of moisture, if there is no moisture there will be no alkali aggregate reaction.

So, even after alkali aggregate reaction is occurred, if one can protect the structure from moisture, alkali aggregate reaction will not continue further right in the beginning if you are able to and we says that there will be alkali aggregate reaction, moisture prevention becomes very important. Use of cement with low alkali content, you know is low alkali content is important, what you do is actually sodium oxide equivalent to use.

Now, sodium oxide, potassium oxide there molecular weight differs right. So, molecular weight of for potassium oxide and sodium oxides are different. So, therefore, when equivalent sodium oxide content would be multiply the potassium oxide content by a factor, I think it is 0.5, 0.8 or something close to that, so such that which is the ratio of molecular weight of the 2. So, multiply by this is by factor and find out the sodium equivalent. So, if you use cement having less than 0.6 sodium oxide equivalent or even still lesser than that then chance of alkali aggregate reaction will be low.

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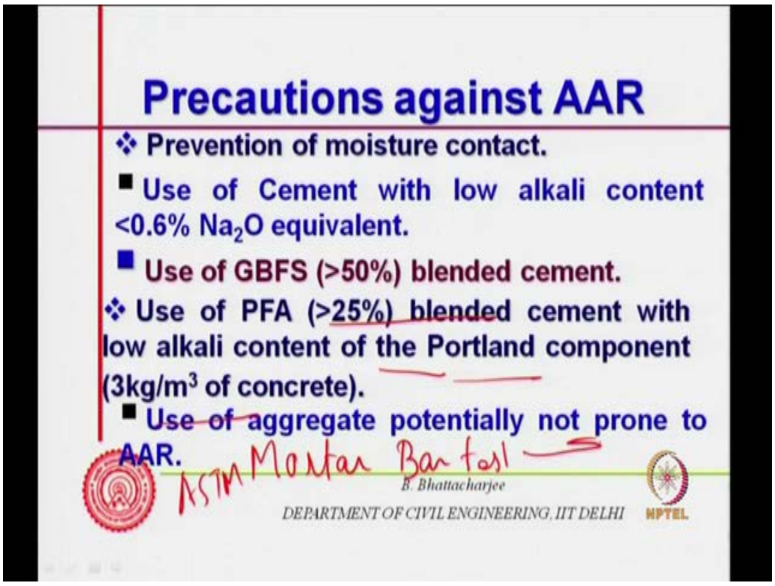

Use of ground granulated blast furnace slag or blended cement or fly ash, they actually reduce the alkali aggregate reactivity, the alkali use are alkali aggregate reactivity you know. So, blended cement because 50 percent the alkali content will get reduced by 50 percent, alkalis in the blast furnace slag or fly ash they do not contribute to alkali aggregate reaction.

So, therefore, you know although they are present, they do not contribute aggregate the situation therefore, using blended cement or fly ash directly or slag directly in the system helps in reducing down the alkali aggregate reaction.

Use of Portland of fly ash as I said, you know pulverized fuel ash, pulverized fuel ash or fly ash in the blended cement which alkali content of Portland cement not more than 3 k g per meter cube of concrete, they do have. And do not use aggregate potentially prone to AAR now how that is done. So, you do what is called first you do spectrographic examination, that is you know the geological origin of the aggregates are looked into, by geological test looking into microscope and so on, and so forth identifying the mineralogical composition, x-ray refraction etcetera, etcetera find out what is the mineralogical composition.

And those minerals which are potentially, you know prone to alkali aggregate reaction you remove them, normally say where construction is going on for years together and same aggregate has been used, you would not find this problem occurring because already prove an aggregate, but if you are using a new aggregate source, one must do this test, first do those spectrographic examination and also do mortar bar test, mortar ASTM mortar bar test, ASTM mortar bar test, mortar bar test test to identify whether the aggregate is prone to alkali aggregate reaction.

This you know this test mortar bar test is done you make powder out of the concrete I mean powder out of the fine aggregate sorry aggregate, make powder, make mortar out of it and then test all right. So, find out the aggregates which are potentially, potential potential potentially alkali aggregate reactive and do not use them, if it is a new source.

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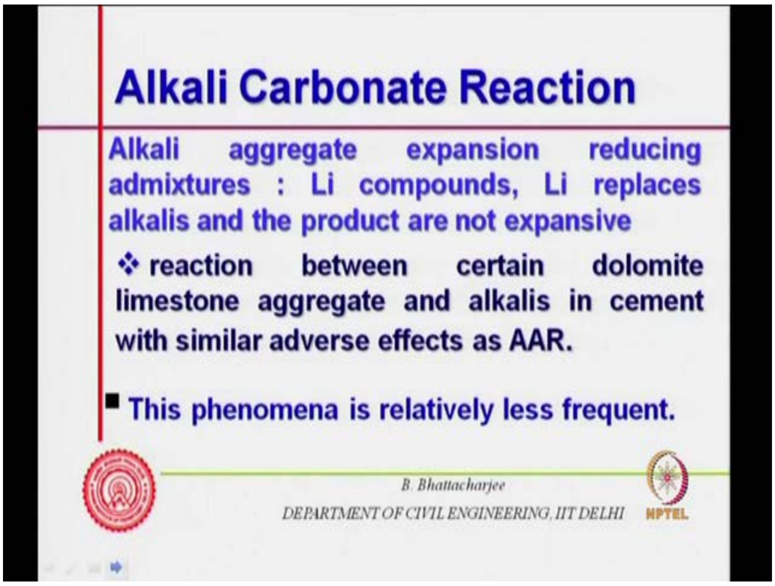

So, this is other way of prevention, alkali aggregate expansion reducing admixtures are used for example, lithium compound, lithium replaces alkali and products are not expansive, you know lithium compounds are alkali aggregate expansion reducing admixtures. So, you use this ones and they can reduce down, but best is to find out that aggregate is not alkali aggregate reaction, but if you still think that you should be playing safer, you can use this admixtures also use low cement low, so alkali cement actually.

Reaction between certain now alkali carbonate reaction, this is important in some cases, reaction between certain dolomite limestone aggregate and alkalis of cement show similar kind of adverse effect and this is called alkali carbonate reaction. So, so so far we looked into alkali silica reaction or alkali silicate reactions and this is actually alkali carbonate, alkali carbonate reactions of course, this is relatively less frequent, this is relatively less frequent. So, this phenomena is relatively less frequent all right.

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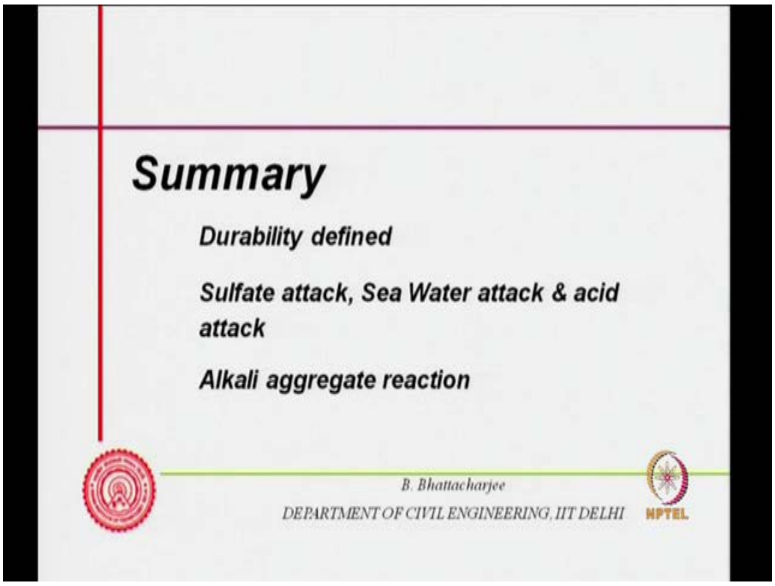

So, with this actually what we have looked into today, we have looked into we have defined the durability and then we also define service life, we have defined, we have talked about sulfate attack, sea water attack and acidic attack and we also looked into alkali aggregate reaction, alkali aggregate reaction all right we have looked into alkali aggregate reaction right.

And in all cases we have discussed, what causes them, what causes them and the how to actually mitigate, one common point in all kind of attacks in concrete, is essentially the presence of moisture, some cases moisture and oxygen is also regret for example, reinforcement corrosion, but most of an it is a moisture and in all cases, we have seen that one thing is we must keep the moisture out and if you can keep the moisture out no deterioration concrete will occur actually.

And one more thing, in all cases we have seen low water cement ratio performs the job. So, when finally, we actually conclude or rather we end up summarize our and the strategies for better durability and service life of concrete, will see that low water cement ratio is recommend because it is the permeation properties of concrete which is important because and low water cement ratio actually reduces on the permeability. So, this we conclude this lecture.

Thank you.