Concrete Technology
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Lecture - 5
Cement: Types and Use

Welcome to module 1 lecture 5 of Concrete Technology, shall be discussing on types of cement and it is use today. We just started that in the last class in fact.

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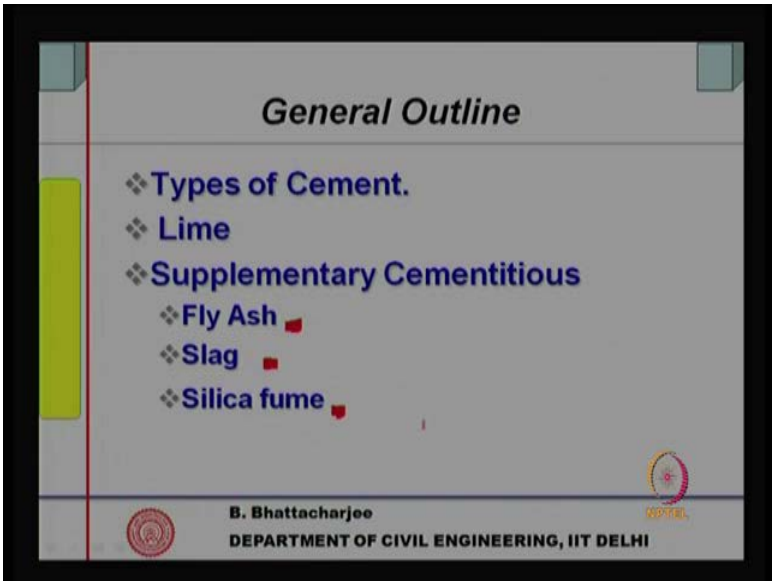

So, continuing from that point, we will be proceeding today, we just mentioned in the last class that by you know manipulating the chemical composition of the compounds of cement or in other words oxides composition of the cement which in turn allows you to manipulate the compound composition of cement somewhat and then by changing their physical characteristics. We can alter the properties of the cement and their performance in concrete, thereby we can get different varieties of cement. In addition to this other material other supplementary cementitious material like various pozzolana.

I will mention what they are or some other material such as lime stone powder. So, by using those materials, you can get additional cements, which are known as blended cements or composite cements, so we will look into those as well. So, pure cements blended and composite cements, this is what we will look into. So, general outline of our discussion would therefore, would remain type of cement followed by lime followed by

followed by supplementary cementitious materials supplementary cementitious material such as fly ash, slag, silica fume, etcetera.

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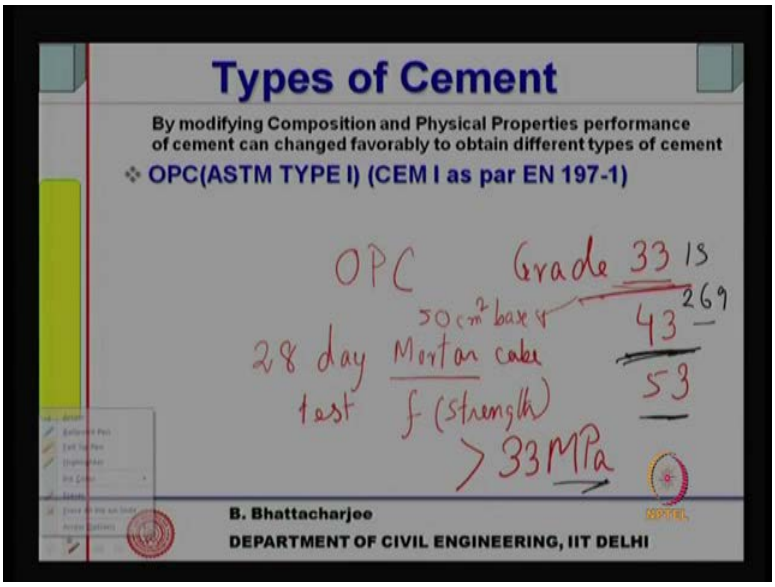

So, therefore, we can look into first the pure cements and the modified cements, what we said I repeat it again by modifying the composition and physical properties performance of cement can be changed favorability favorably to obtain different types of cement. So, composition, chemical composition of the cement can be changed and their physical characteristics can also be changed in order to get different types of cements. So, what are the types of cements, well ordinary port line cement is the most commonly used cement for many, many years.

However, currently perhaps it is not the most commonly used cement, because some of the blended cements have become quite popular all over the world. This cement is known as type one cement as far as American society of testing material A S T M or cement 1 CEM 1 as par E N 1971 that is the European standard. So, as the case with Indian or any other country standard in Indian standard I S 269 deals with 33 grade of O P C cement and other cements like 43 and 53 grade, which are classification by Indian standard, they are you know O P C also O P C grade.

So, O P C is 269, they are called O P C cement simply, now this is specific to Indian scenario, we talk of O P C grades 33 43 and 53. Grade 33 is that cement, which exhibits 28 days mortar, you know yesterday or last class, we discussed about strength test of

cement. So, 5 centimeter 50 centimeter square base mortar cube test when you do if the strength is more than 33 m p a f that is strength strength, if it is greater than 33 m p a then you call it grade 33 cement in Indian context. Similarly, when it is more than 43 when it is more than 43 when it is more than 43, the strength is more than 43 m p a 28 days standard mortar cube strength is more than 43 m p a, you call it grade 43. And if it is more than 53 m p a, then you call it 53 grade and we have 3 different codes for this. This is is 269 deals with this one, this particular one and that is the originally used ordinary Portland cement.

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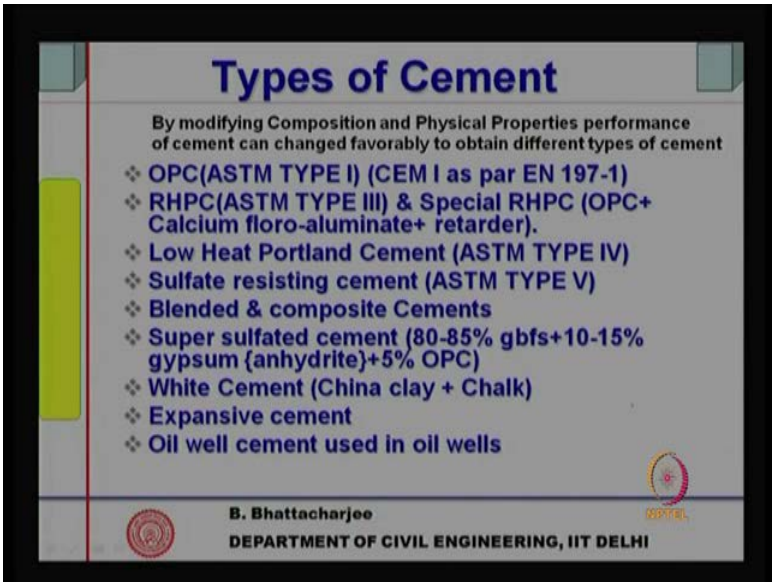

So, that is as par Indian standard is concerned A S T M of course, classify O P C as type 1 and O P C as type 1, same one is what E N 1971 says that is the European standard right. B S standard also used to call it, I mean now it is all integrated all European codes are integrated and this is CEM 1 as par European standard. Then the next cement is rapid hardening Portland cement R H P C stands for rapid hardening Portland cement. So, rapid hardening Portland cement, it is A S T M type 3. So, R H P C 3 is a code in Indian code of course, there is R H P C. So, this cement hardens fast. So, you get the strength, you know possibly 3 days strength in 1 day 7 days strength in 3 days and 28 days strength is nearly 3 days, you know 7 days and so on, so forth.

So, you get high early strength, you get high early strength high early strength, we look into it, how it is obtained. So, high early strength high early strength that is a

characteristics special R H C P, which could be with O P C plus calcium flora aluminates plus a retarder, we will come back to this a little bit later on. First, we will try to understand what is R H C P O P C may be, we will come back to this slide again back, if required. So, that is special rapid hardening cement is 1, which hardens much faster. So, they are basically flora aluminate type of cement.

Then you have got low heat Portland cement A S T M type 4, now this is A S T M type 3 and this is A S T M type 4. Now, A S T M type 4 is low heat low heat cement, you know, now low heat cement was used largely, low heat cement was used largely for mass concrete construction earlier mass concrete construction earlier right. It was used earlier for mass concrete construction. So, this type for heat of hydration produced is low. So, that is why it is called low heat cement, rate of heat evolution will be low and how it is done, we will look into.

Then sulphate resisting cement, which is A ST M type 5, I will come to type 2 A S T M type 5, a sulphate resisting cement and again, we will see how this cements are actually, how do you manipulate the composition of the compounds in cement to obtain all these. Then of course, you have blended and composite cements, super sulphated cement is a sulphate resistance cement, we will come back to this slide a little bit later on and white cement is used for decorative purposes expansive cement used for filling in grout holes or you know shrinkage compensation compensating cements. So, you want to fill in cracks or similar situation oil well cement is used in you know oils oil wells, you know petroleum crude oil wells actually, they have special setting characteristics, specific setting characteristics, stringent setting characteristics and of course, they should be sulphate resistance. So, we will look into some of this in details and maybe, we will come back again to this slide, if requires.

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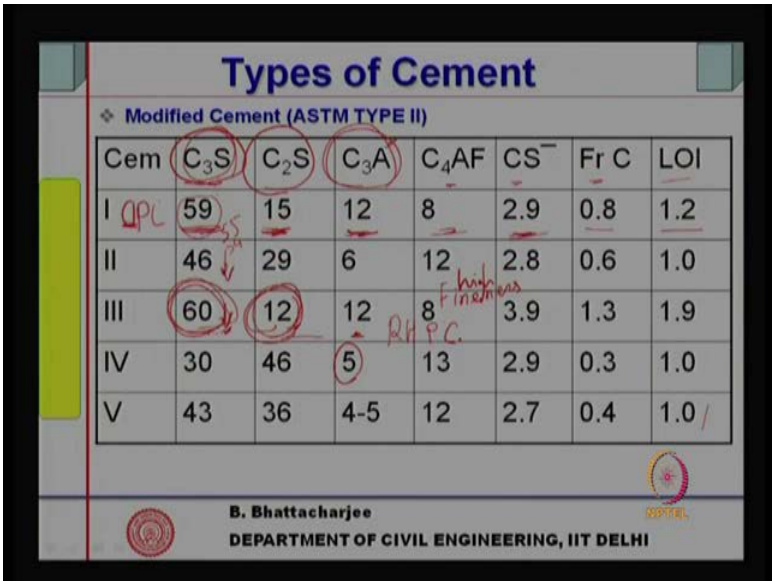

Cem	C_3S	C_2S	C_3A	C_4AF	CS^{-}	Fr C	LOI
I	59	15	12	8	2.9	0.8	1.2
II	46	29	6	12	2.8	0.6	1.0
III	60	12	12	8	3.9	1.3	1.9
IV	30	46	5	13	2.9	0.3	1.0
V	43	36	4-5	12	2.7	0.4	1.0

Now, if you recall, you know say cem 1, that is your type 1, type 1 cement A S T M type 1 or O P C, this is O P C had roughly around 59 percent of C 3 S, 15 percent of could be something of this order 15 20 55 etcetera, etcetera. This is that this is 1 O P C, let us say C 3 A 12 C 4 A F 8 and calcium sulphate, this is 2.9 and free lime could be something like this loss on ignition 1.2. So, this or composition will satisfy O P C, this composition will satisfy O P C. Now, if we recall that high C 3 S means relatively, high early strength high. So, this this this slightly higher could be even less something like 54 54 55 etcetera. So, high C 3 S means, high early strength C 2 S means, later strength C 3 A means, heat of hydration, high heat of hydration, it contributes maximum to the heat of hydration. And this has of course, much less effect calcium sulphate again has does not have much of an effect anywhere, and free lime of course, is as restricted as anywhere, it should be loss on ignition should be almost similar for all.

So, major effects comes from the quantity of C 3 S present and C 3 A present has got a role in type 4 cement, which is low heat cement. So, let us see let us see 1 by 1 type 2 cement is called modified cement, it is actually somewhere between type 4 and type 2, it is not exactly low heat, but it is between this 2. So, let us go downwards type 2, I will come to type 2 later on come to type 3, now this has got the highest C 3 S, this has got the highest C 3 S, therefore, it has got the highest C 3 S.

Therefore, it is it would it would give you high early strength remember recall type 3 is nothing, but R H C P rapid hardening Portland cement and it has got the highest C 3 S, least C 3 S compared to this 2, it has got the least C 2 S. So, it will have high early strength, least long terms strength would not be there as much and C 3 A content is relatively high again not very high almost similar as O P C, C 4 content A F content is almost similar rest of the things are more or less similar. Now, therefore, this cement is rapid hardening cement, because chemical composition wise, this is the, this has got the highest C 3 S. physically of course, fineness fineness governs high fineness, higher the fineness rate of hydration will be high and therefore, strength development will be faster.

So, physically R H C P has 2 things C 3 S is highest C 2 S is least, because after all, if you increase the C 3 S, you have to reduce down something. So, C T S C 2 S, so it is highly a light lot of a light component a light is less and then it has got high fineness, that is that is why, it reacts fast faster than any other cement, you know. So, therefore, rate of hydration is more. So, that is rapid hardening Portland cement very special variety of this will have high fineness, you know, which you want to set even quickly a jet cement, which will set very fast.

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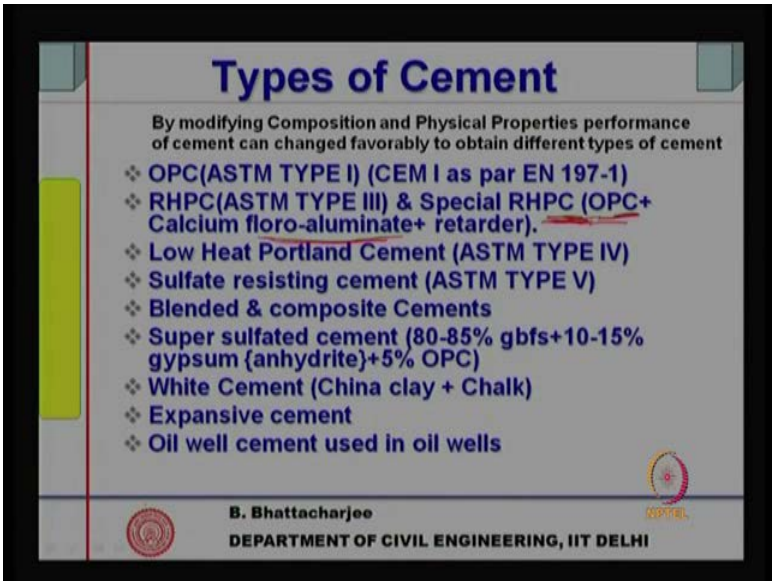

Now some special cement of this kind was is can be developed using composition of flora aluminates, you see special rapid hardening Portland cement can be generated with

calcium flora aluminates and some sort of retarder. So, this is this reacts extremely fast and sets also very quickly and it is grinded to a very fine level.

So, this cement is likely to be costly, because you are grinding it. So, grinding energy you know, you spend some energy in grinding and therefore, it is likely to be costly. So, that is what is the, you know rapid hardening Portland cement is and special rapid hardening, Portland cement uses Clara calcium flora aluminates with O P C and retarder and that gives you, in a flora aluminates system can give you, high early strength.

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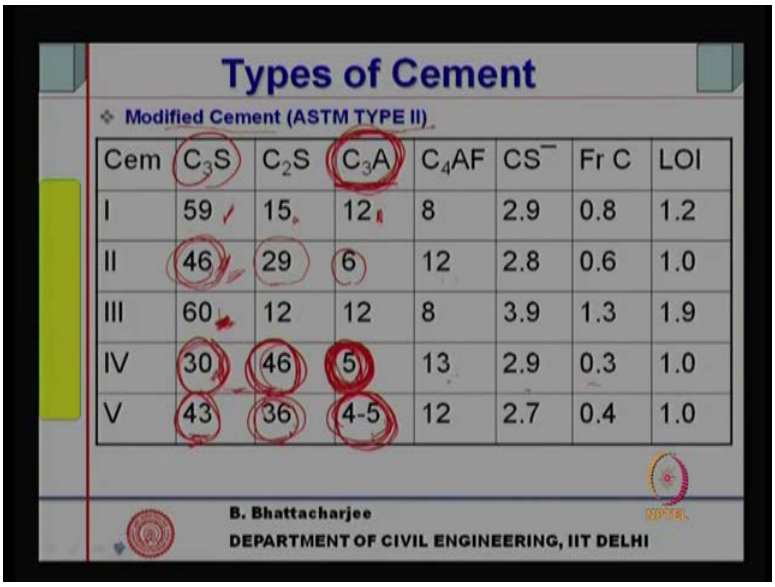

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So, now next, we can go to type 4, which is low heat cement, now what gives heat of hydration maximum, the maximum heat of hydration comes from C 3 A maximum heat of hydration comes from C 3 A. So, therefore, you can see the reduction here, maximum heat of hydration is here and therefore, this is reduced C 3 A content is only 5 percent and further to reduce, the heat of hydration, because this reacts early C 3 S reacts early. So, this is also much less, but long term strength will be better. So, you put higher C 2 S.

So, this is low heat cement low heat cement rest of the things of course, there is some changes, but not very significant marginal. So, a lot low heat cement will have less C 3 A less C 3 S less 3 A as well as less C 3 S, then something has to increase and it is the C 2 S, which increases it will, we have we will not have extra ordinary grinding.

In fact, the blames fineness in case of type 3 would be much higher than type 2, but here the blames fineness may not be higher. It could be same as 225 meter square par kg minimum and this could be much higher may be 300 and 54 100 or. So, or even higher depending upon the type how rapid, you know hardening, you want may be 700 meter square par kg and So on, so depending upon that situation.

So, this is type 4, this is type 4, this is type 1, now 2 is in between, which is called modified cement as par American society of testing material classification. So, this is type 2 cement S T M type 2 cement is modified cement, you know type 2 is the modified cement as we call it, it is the modified cement. And modified cement is something in between it has got low heat of hydration low heat of hydration, but not as low as this low heat of hydration also means, the strength development rate will be slower therefore, you demolding time will be higher.

So, this is compromised between the 2 low heat is modified cement is compromised between the 2, it has got somewhat higher C 3 S than this and obviously, C 2 S also will be lower than this, but higher than this C 3 A content is also more than this etcetera etcetera. Now, why do you use O P C well most of the construction was carried out with O P C earlier, but in a mass concrete you cannot use O P C, because heat of hydration is very high in mass concrete large size has got volume to surface area ratio very high. Surface area is small volume is very high, if your thickness of the lift a particular lift, you know you concreting lift whose concretes are concrete casting is done in stages height wise.

So, if you have a very wide very large area and with sufficiently large thickness, which is the case, in case of say gravity dam some of those plane concrete retaining wall etcetera etcetera. Strength is low, but the heat of hydration is usually strength of the concrete required strength of the concrete is usually low. But, heat of hydration heat of hydration is a point there, because because of the surface area being small compared to the volume or surface area par unit volume being small heat dissipation rate is generally small.

Now, if the surface is not able to dissipate the heat, there will be, you know I mean surface is not dissipate the heat sufficiently from the core. So, it can, so happen that core is at higher temperature compared to the surface. Surface is in contact with the outside air. So, it has lost the heat, but the heat coming from the core to the surface that will

depend upon the thermal properties of the concrete material, concrete system and it is not very high it is an nearly insulating material.

We will discuss about that sometime later on, but heat from the core of the concrete is quite often is unable to reach to the surface as a result differential temperature gradient may exist, in case of mass concrete very thick raft and such situations. But, you do not, you know and this differential temperature if it is existing can cause cracking, because inside is warm outside is cool. So, you know differential contraction can occur and that can result in cracking. So, we will look in to that cracking later on, but what do, we understand at this moment is that heat dissipation is a requirement for mass concrete.

Now, well if I generate, you know, you can stop heat generation itself. So, that dissipation required will be less. So, therefore, you use low heat of hydration cement. So, low heat cements are used in mass concrete and that is why you know, you you reduce down your you reduce down your C 3 S content. So, usage of low heat cement is in mass concrete, if you look at rapid hardening cement, you will like to use it in places, where you want the strength gain to be very high.

For example, where you want to pre stress the structural element, you want to apply pre stressing force, you know you apply external force early. Low it has come to early, let us say or pre stressing force has to come early perhaps, you are aware of what is pre stressing, you pre stress the concrete in compression. So, that it can take lot more tension then it was capable of withstanding without pre stressing, so that that again, we might discuss that sometime later on some in, some other context.

So, where you want to do early, you know, you want to release the mold early, you want to pre stress the concrete excreta. Wherever you want high early strength, there you will be using rapid hardening Portland cement, but it is costly. Second aspect is quick setting, that is the separate issue, setting is quick, you know setting require rapid hardening Portland cement do not have setting time early setting time.

It sets same minimum 30 minutes same specification as the ordinary Portland cement, but you can have something called quick setting cement might use it in repair work may be some sort of construction in under water or near steam and things like that where, you want it to set a early, jet cement will of course, set very fast. So, the usage of this 2

cements, you have seen 3, this cement, cement 3 and this 2, 2 is somewhere in in between.

So, therefore, where you do not want that kind of heat of hydration as this generation, you know lower low heat of hydration has this, but you want some strength development there, you will be using this. Because, this will have very slow strength development, you have less quantity of this and you did not grind it too much. So, you will have less lower strength development, well look into the strength development sometimes later on.

This one has got a very high early strength, but later strength is not good, even that can have problems related to durability etcetera etcetera. But, at the moment this was the purpose why rapid hardening cement, you know used is usage is where, you want early strength. Now, coming to type 5 cement, this is sulphate resisting cement, now we shall see that when, we talk of durability of concrete that sulphate attacks concrete through C 3 A.

Well, we can remember or we can recall our discussions earlier discussion, we can recall our earlier discussion on ettringite formation. We discussed the formation of ettringite, if you recall, we added gypsum to cement, while grinding in order to control the setting property and gypsum reacts with C 3 A.

Now, gypsum occupies more volume then the original C 3 A and gypsum combine. So, gypsum combines with C 3 A forming ettringite that is what we have seen earlier. Now this occurs in plastic concrete no problem, you know ettringite occupies more volume well no problem, because this can be accommodated in a plastic concrete without cracking.

But, if gypsum or you know for example, sodium sulphate comes in contact with the concrete moist concrete or in presence of moisture sodium sulphate can react with calcium hydroxide to form calcium sulphate. And this calcium sulphate can react with C 3 A hydrates forming ettringite and this ettringite, now it is tries to occupy more volume then the original reactance, it will cause cracking of the concrete, that is sulphate attack any way, we will discuss this at at length sometime later on.

But, at the moment what, we got to understand is it is C 3 A, which is responsible for sulphate attack, you know sulphate attack takes place through C 3 A. So, therefore, in

this cement you have least C 3 A 4 to 5 only very small quantity of C 3 A. So, a sulphate resisting cement will have least quantity of C 3 A, but then C 3 S is also reduced and C 2 S is also reduced C 2 S is also reduced, I mean increase somewhat increase somewhat than this. So, C 3 A is C 3 S is reduced, but main aspect is that it should have low C 3 A in case of sulphate resistance.

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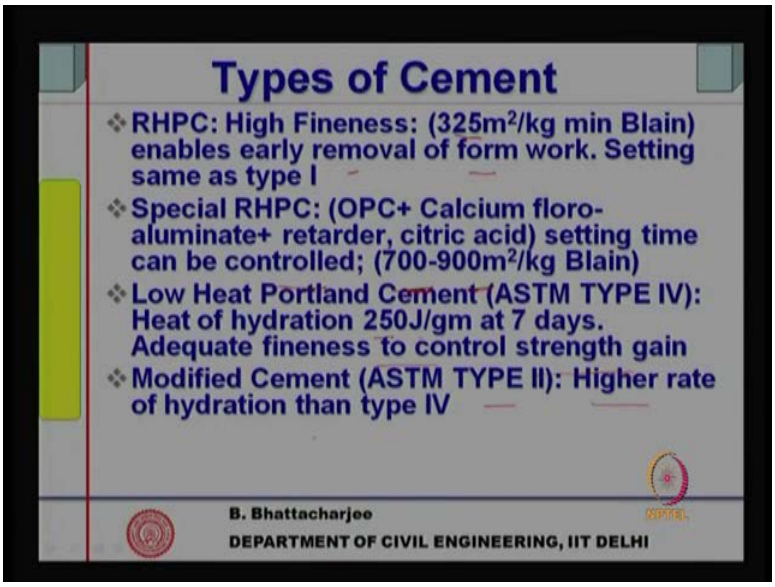

So, this cements we have looked into right, now we will go back to the first slide again. So, physically rapid hardening portable cement high fineness 325 meter per square k g minimum lengths enables early removal of form work setting same as type 1 as I mentioned. Special rapid hardening Portland cement O P C plus plus calcium flora aluminates retarder sometime, this retarder is the citric acid setting time can be controlled, it has got a very high specific surface.

700 to 900 meter square per k g blains specific surface, which we discussed yesterday. Low heat Portland cement A S T M type 4 heat of hydration is 250 joules per gram at 7 days adequate fineness to control strength gain. So, adequate fineness to control strength gain modified cement A S T M type 2 higher rate of hydration then type 4, you know it is in between.

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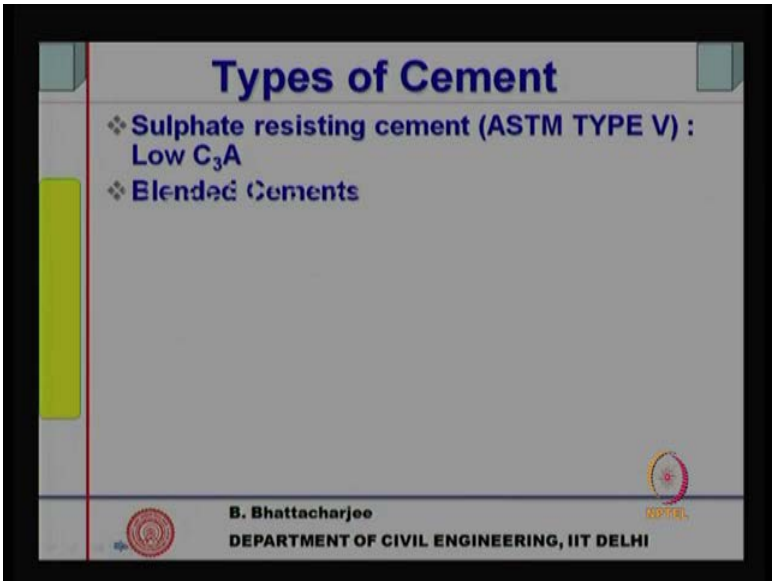

And type 5 of course, is sulphate resisting cement low C 3 A, that is the characteristics, I will come to blended cements lets go back to some of the cements those, who were there in our first slide.

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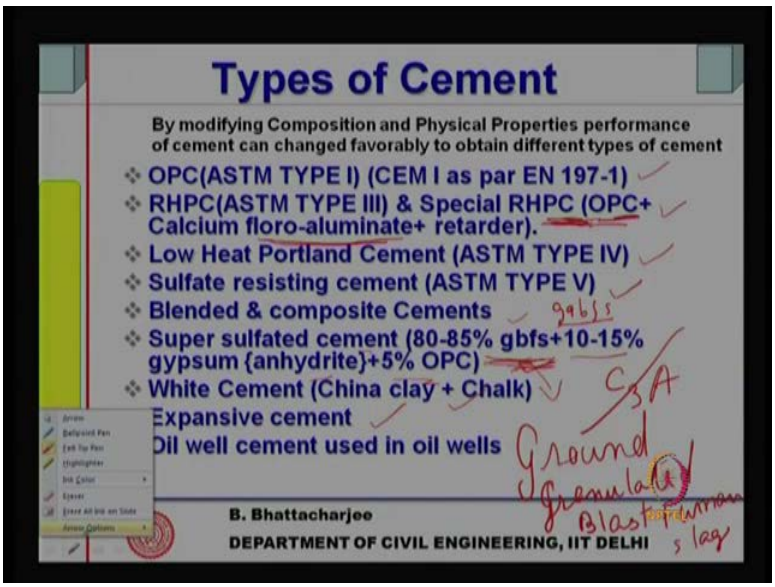

So, let us go to the first slide again back right. So, we have looked into this cement, we have looked into this cement looked into this cement this cement. So, we will be looking now into blended cements super sulphated cement, let me just tell, you right away and talk about white cement and expansive cement now, we will come back to the other

cements later on. Super sulphated cements is prepared from ground granulated blast furnace slag, we shall see that ground granulated ground granulated blast furnace slag ground means grind grind, it you know granulated blast furnace slag.

We will come to this again g g b g g b f s g b g g b f s actually g g b f s has got almost, you know it has got same oxides as the cement, we will see that a little bit later. And high quantity of this material is used in super sulphated cement around 80 to 85 percent mainly meant for sulphate resistance and 10 to 15 percent of gypsum with 5 percent of O P C.

So, we can see that it is not really with O P C, but with granulated blast furnace slag granulated ground granulated blast furnace slag is the one, which is you know through, which this cement is prepared. So, this is super sulphated cement, now properties of ground granulated blast furnace slag, we can see. This will not have C 3 A at all no C 3 A no C 3 A in this 1 no C 3 A, in this 1. So, the reaction of sulphate is respected to be simply not there. So, it is supposed to be highly highly sulphate resistance.

White cement essentially is prepared from for esthetic purpose and prepared from china clay, which is white and calcium carbonate source used is chalk. Now both are white because they are more or less pure right. Now, no iron iron should be present there, no other oxides, which can add color to it. So, therefore, this chain cement is costly very costly, because you are producing from certain specific raw material china clay and chalk.

So, it seem all similar properties same like like, you know O P C, similar type of composition would be like O P C, but only thing is no iron, no other such oxides, which can add color. So, this is why white cement and it is used for you know where, you want aesthetic. One example of course, in India in the city of new Delhi is a bahai temple the lotus temple, it used white cement, because it is absolutely sparking white and then marble stones, white marble stones have been used as aggregate. So, it is totally white completely white. So, when you want to give a complete white look, this is what is used, expansive cements or shrinkage compensating cements are those ones, which are used to fill in, let us say crack or gap or grout holes.

So, that after expansion, you know it will compensate the shrinkage right. So, the system essentially involves a tri calcium sometime lime system, sometime aluminates system,

aluminates same ettringite reaction is utilized may be I will discuss this a little bit more later on. Oil well cement has got high sulphate resistance and setting properties are strictly controlled anyway.

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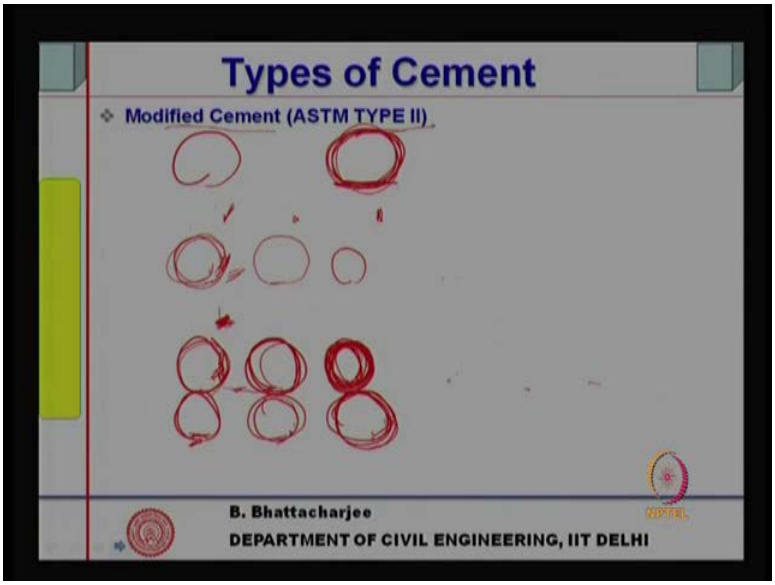

Now, we can go further ahead and discuss on the other high issues of different types of cements blended cements for example, blended cements.

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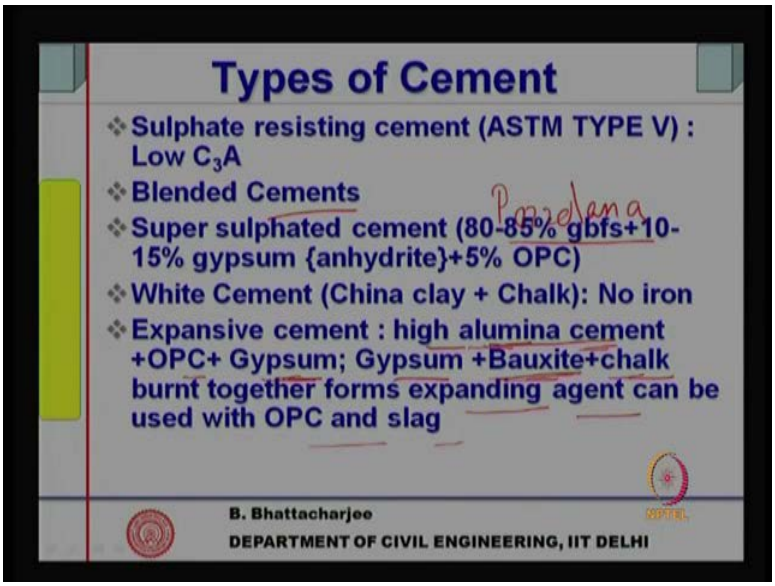

Now, this blended cements uses pozzolana a material, I might have mentioned earlier in the history when, I was talking in the introduction right. So, that is what so before that

just expansive cement lets cover it up fully, high alumina cement with O P C and gypsum, because you see ettringite formation would occur with this one. High alumina cement and gypsum and this ettringite occupies more volume then the original reactant, therefore, it causes expansion.

So, expensive effect of high alumina cement together with O P C and gypsum is used in expensive cement, other compositions are gypsum bauxite, you know is aluminum ore and chalk. So, they are one together. So, they produced similar sort of things are produced, but binding gypsum bauxite and chalk together and this forms expanding agent, that can be used in O P C and slag. So, this is what is the expansive cement, there are some lime based expansive cement as well.

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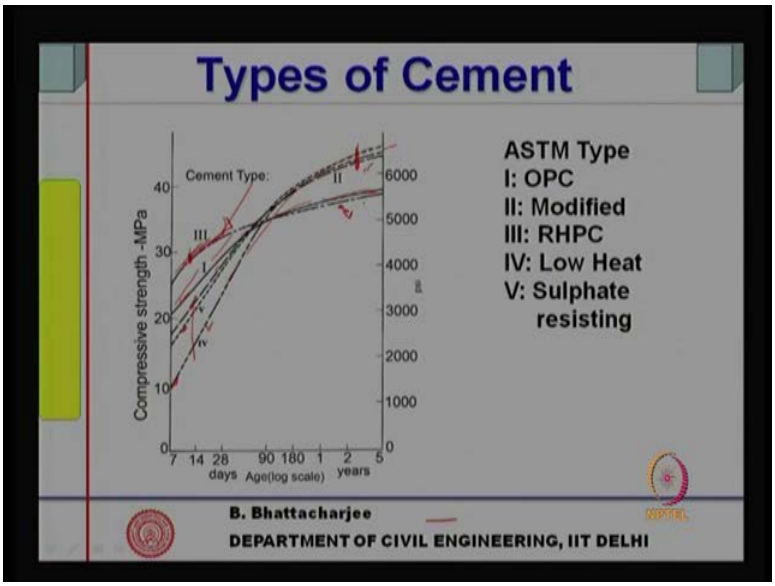

The strength that, we are looking into, if you look in the because different types, type 1 type 2 type 3 and type 4 type 5 cements, if you look at it right. Now type 1, if you see this is our O P C strength development is somewhere here, type 3 high early strength. So, it has got high early strength, but it is long term strength is in fact, slightly lower than the O P C modified cement, if you look at it, this is modified cement type 2, somewhere there modified cement it has got low initial strength then O P C, but long term strength is better, because more C 2 S.

Type 4 has got least initial strength right, which has, which is low heat, because it has got less C 3 S as well. So, more C 2 S as we have seen earlier, since we got high C 2 S, it

has got better long term strength, but very little, early strength heat of hydration is low that is the thing early strength requirement is not there. So, we will not use this cement were demolding, early demolding is requirement surely not use this cement.

Sulphate resisting cement has got properties less C 3 A less C 3 A. So, somewhat lower early strength then type 1 or O P C cement, but long term strength is again better then O P C cement surely. So, this is how the strength development of different cement takes place and now we understand also why does it occur that way, because we know what are the compounds there and what is the physical properties. Finest physical properties will be of rapid hardening Portland cement and it will have maximum C 3 S low heat cement will have least C 3 A A and C 3 S. Sulphate resisting cement will have low C 3 A and naturally, C 3 S is also reduced a little bit and therefore, the strength initial strength is low. So, all these cements has got initial strength low, but they have got better long term strength. This cement has got better early strength, but long term strength is worse than the ordinary Portland cement.

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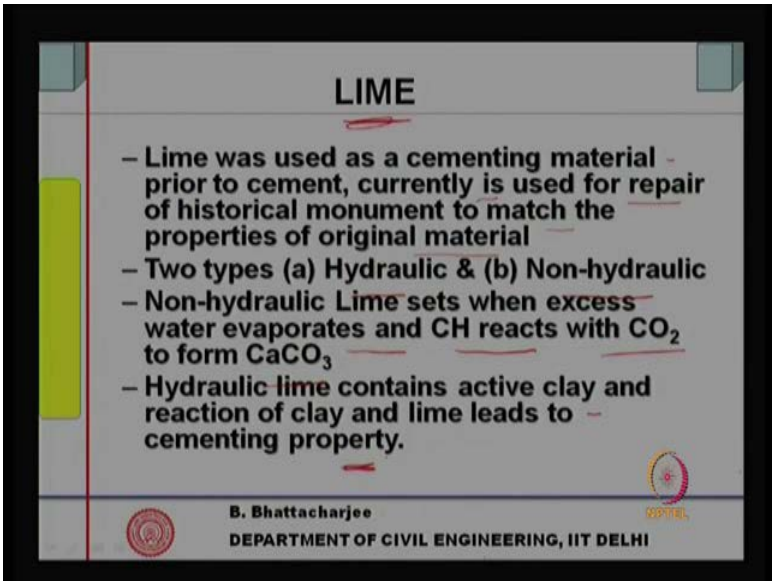

Now, let us come to blended cement, but before that we lets understand a little bit about this material lime, you know as I mentioned in the very first days discussion module 1, let us say 1. We said that lime was used as a cementing material prior to cement currently of course, used for repair of historical monument to match the properties of original material. So, lime has been in used as a construction material much before

actually, cement was invented lime has been used as as I said that is reported, it has been used something like 7000 years back as reported by professor Haroon Benthor in one of his article in in 2000 around 2001. So, this has been used for 7000 years, now in India of course, we have used lime together with what is called surkhi, which is nothing, but the when you burn the clay, the dust that is that remains below the brick klin is called surkhi.

So, its mud clay some form of fine powdered mud clay, we will come to that, now lime itself are 2 types hydraulic and non hydraulic lime. Non hydraulic lime sets when excess water evaporates and calcium hydroxide reacts with carbon dioxide to form calcium carbonate. So, non-hydraulic lime sets when it has got excess, it has got excess water and that evaporates and carbon dioxide from the atmosphere will react with it forming calcium carbonate therefore, the setting occurs. Hydraulic lime on the other hand it has got active clay and reaction of lime with clay leads to cementing property. So, hydraulic lime and non-hydraulic lime, this will have some active clay in it and reaction of clay with lime causes, you know leads to cementing property.

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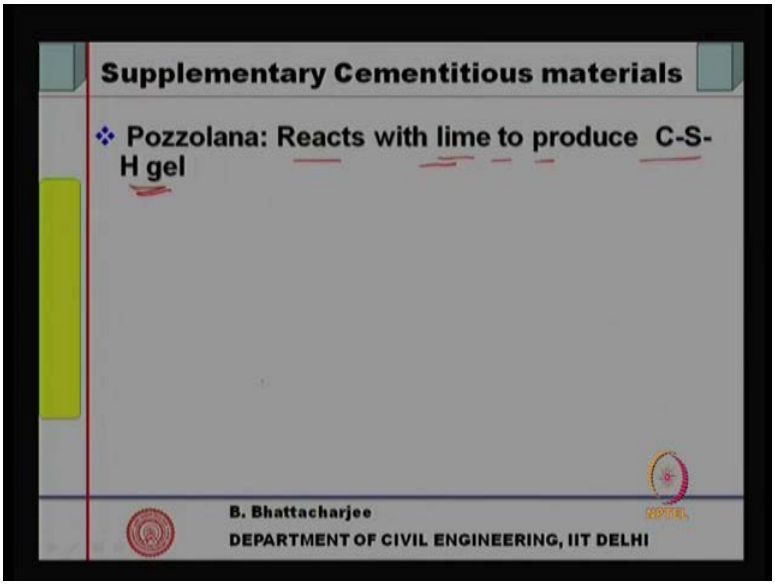

Now, this is what has been used for many many years. So, what we know is that some material some silica can react with lime to produce C S H gel like structure, you know lime with clay, that is what you say lime with contains active clay and reaction of clay and lime leads to cementing property. Now, this was actually discovered pretty early like

volcanic acids, I mention in roman in roman civilization, they used volcanic gas together with lime and they found that, it can give the similar cementing property.

In India as I said lime in surkhi, now surkhi is you know after burning the clay, the dust that is there fine particles, which are there that is that is what is surkhi. So, if that is nothing but bricks are manufactured from clay so therefore, that is nothing, but burnt quickly, you know you burnt the clay heat it up I mean not burning really heating it up to sufficiently high temperature may be 1400 degree centigrade. And cooling it rapidly, because that dust, which comes out from the clay bricks, they just get deposited on to the ground and therefore, they started losing their heat very fast, rapidly starts cooling. And the final ones of those one can react with lime and that is what has been used in many of the monuments lime surkhi construction has been very well known, similarly the volcanic ash with lime also can react and produce cementing material.

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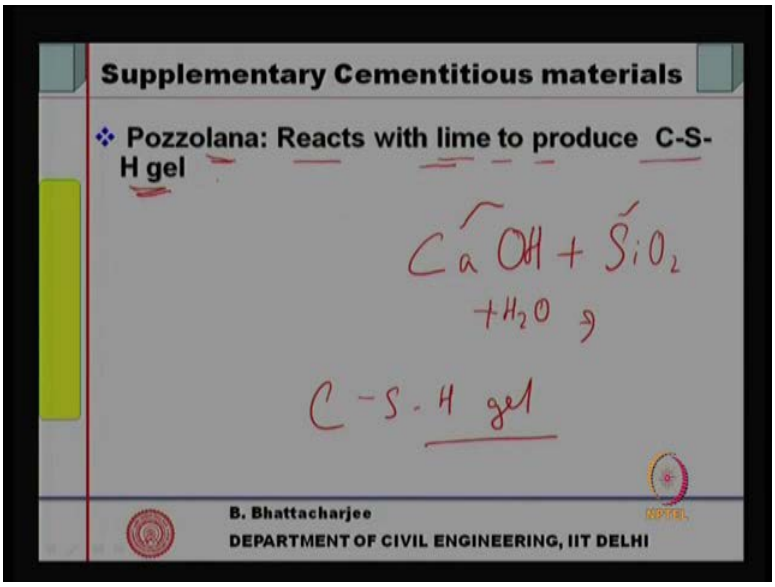

Now, this materials are nothing, but you see lime is calcium, if it was lime means calcium hydroxide plus the silica or alumina in presence of water. So, you see the same ingredients as the cement. So, actually the producers produce C S H and gel C S H gel, now from the original name of the volcanic ashes this class of materials are called as pozzalona right. So, the pozzalonas are those material, they are basically reactive silica, which reacts with lime in presence of water to produce C S H gel.

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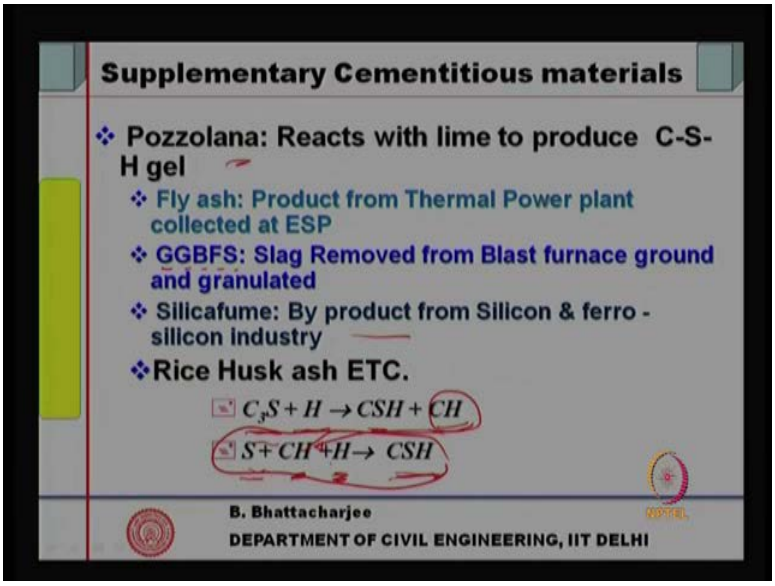

Volcanic ash are natural pozzalona surkhi of course, is not natural pozzalona. So, there are many natural pozzalonas, but there are certain other industrial, I will not call it waste nor call it byproduct, but I will call it industrial product. Because, from this from you know for a student and concrete technology, it is not a waste product, but thermal power plant would of course, they they they treat this material as a waste. So, many other many other products from industrial products, they also show this kind of property pozzolanicity or pozzolanic behavior that means, they react with lime. Now, consider this material fly ash, it is a product from thermal power plant collected at electro static precipitators right. Thermal power plant collected at electro static precipitators, I will discuss this somewhat in more details when you talk about mineral admixtures, coal has obtained from the mines contains lot of impurity.

Mainly the clay, because clay is the material abundantly available on the earth's surface earth crust top of the earth crust or from those zones where we mined the coal or do any mining for that matter. So, whenever you are trying to extract anything from the mines it contains sufficient amount of clay this clay, which is present as impurity in the coal is grinded together with the coal, if you wash the coal of course, some of it will go away. However, it is impossible to remove all this clay from the coal from the ore actually and this is this coal is I mean sorry from the coal and the coal is grinded and after grinding the coal is burnt.

The coal is carbon the carbon sulphur, they will actually get converted into carbon dioxide or sulphide dioxide etcetera and many other you know and so on. Many small quantities of those are there, they will go away what about clay, it is SiO2 A l 2 O 3 S i O 2 A l 2 O 3 etcetera, A l 2 O 3 F e 2 O 3, this materials will remain. Now, since they are very those fines one from this they will remain as ash they will remain as ash. Now, these ash material the finer ones from this ash material will actually, go away with the flue gas and it is stepped in electro static precipitators. We will discuss this at some more at length when, we talk of mineral admixtures slightly more.

So, they will be captured at electro static precipitators for environmental reasons, you cannot through them to the environment, because they are health hazard. So, it collected in electro static precipitators and if you can handle them dry then this material shows pozzolanic property. In other words this is actually clay grinded heated to a very high temperature of around 1800 degree centigrade and then suddenly exposed to air at 25 degree centigrade. So, they rapidly cool like surkhi, which cools rapidly like volcanic ash, which cools rapidly, the clay material heated up very fast and then cooled rapidly, this material is also cooled rapidly.

So, when you cool rapidly actually, it structure remains amorphous. So, fine amorphous material and you know amorphous material can react compare to crystalline materials, which are stable. We will discuss this point some time more sometime during mineral, you know discussion on mineral admixtures more on to this. So, fly ash is a is a pozzalonic material, but not only fly ash. Ground granulated blast furnace slag ground granulated blast furnace slag actually, iron are also contains clears impurity and when one removes wants to remove it in the blast furnace slag lime is added to remove it. So, then lime reacts with or lime gets mixed up not very lime, lime the hot condition gets mixed up with the clay, that is silica and this 2 together then form what is called slag.

The slag will be floating over the slag will be floating over the molten iron, which can be drained from the bottom and slag is taken away floating slag is taken from the top when, you grind it, granulate it, this also contains both lime as well as silica. Therefore, this also can react under conducive condition. So, this also shows some similar property as this, but before that it can also show some sort of cementing properties. So, these are the main pozzalon as besides that silica fume is relatively recent addition to the classes of pozzolana. This comes from silicon and Ferro silicon industries where, cords is heated up

to high temperature as high as 1800 degree centigrade to obtain pure silica. And there is a the fume that comes out when, it is condensed what is produced is called micro silica contains largely silica silicon dioxide alone the other materials are very, very small and it is extremely.

And fine size this material is very important, because this is the one, which has made it possible to generate or produced high strength concrete, very high strength concrete or even high strength concrete, some of this high strength concrete itself. So, this is another one rice husk ash is another kind of pozzolana, a rice husk ash, if you process it up you know finally, it will be silica. So, if you process it up, you can get another pozzolanic, because a husk when, you burn it rice husk when you burn it it will carbonatious material will burnt away leaving the siliceous and aluminous aluminous, you know those materials and they will form the pozzolana.

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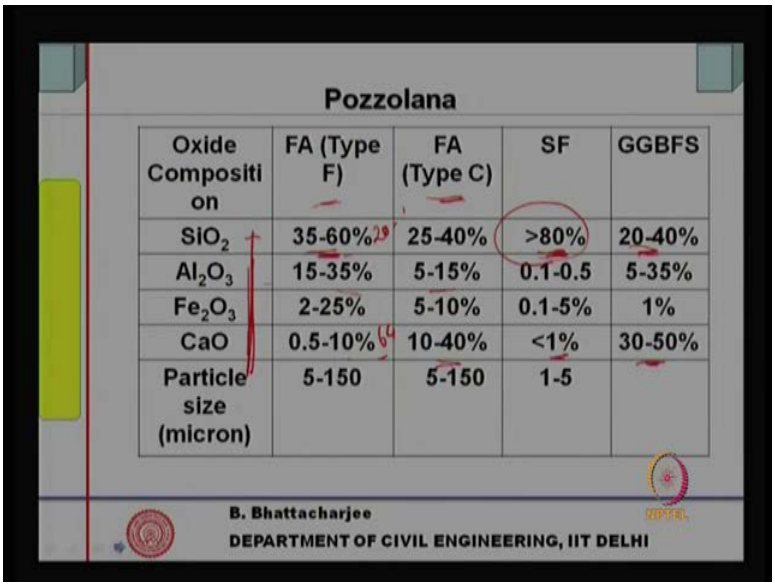

Typical some of those pozzolana just, I have listed down for example, fly ash at type F i will discuss type F later on and type C is another kind of fly ash, you can see S i O 2 silica fume S i O 2 is more than 85 percent in fact, g g b f s S I O2 is of this order and A l 2 O 3 aluminum oxide. So, there oxides are same as cement in ordinary Portland cement. This was around 64 65 percent, this was around 20 percent, you know, if you recall only thing is the oxide, same oxides are there, but the oxide composition quantity of oxides have changed. Now, here C a O varies from 5 to 10 percent is type F fly ash in type C, it

is 10 to 40 percent silica fume less than 1 percent, slag it is 30 to 50 percent as S i O 2, you can see the silica silly silica in this is of this order where, this is very high. So, same oxide as the O P C cement, but the proportions are different, largely the S i O 2, which can react with wherever S i O 2 is large, this shows extremely high pozzolanic reaction.

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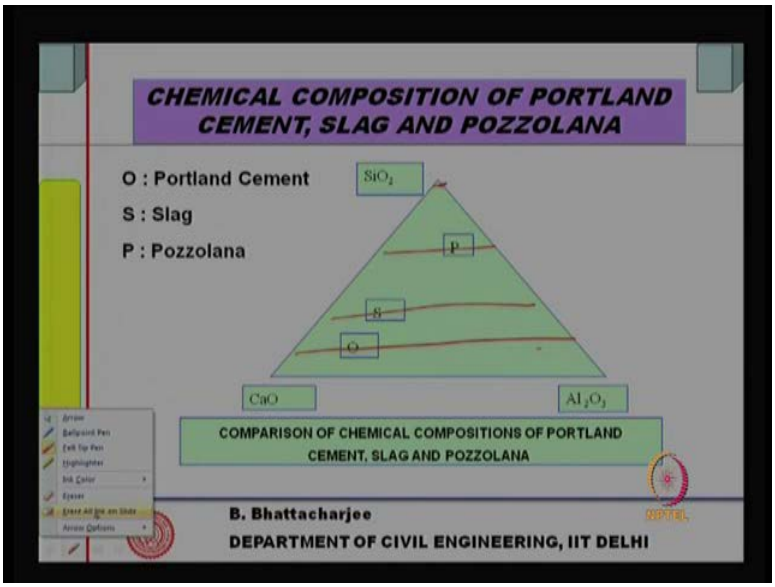

So, this materials can be put into the cement and partially, you know mixed up with the cement linker to form what, you call blended cements. So, pozzolanas are added make composite cements adding may be more than 1 1 or 2 of this 1's.

So, today they are is all possibilities, you can add up cement fly ash, slag all together and make cements utilize, the best property of all of them. So, blended cements are essentially, cements where, we add one of the pozzolanas pozolanas together with cement. Blend them together fly ash together with fly ash when, Portland pozzolana cement is produced what is done is you actually, Portland you take the Portland cement linker one of the popular routes.

There are other routes also Portland cement linker, grind the fly ash together with the gypsum together with the gypsum to get, what is called Portland pozzolana cement by proper grinding and adding additives, you can actually compensate for somewhat slow strength development in case of pozzolana. Pozzolana strength development is relatively slow for 2 reasons, 1 the reaction itself is relatively slow.

Second reason is that pozzolana, you know depends upon reaction of the reaction of the reaction of the pozzolana depends upon the reaction, of the pozzolana depends upon the reaction of the depends upon the reaction of the pozzolana depends upon the reaction of the cement, because calcium hydroxide when, if it is produced then only the pozzolana can be when, you know can react with the calcium hydroxide.

So, this is we will discuss, this sometime later on when, we talk of mineral admixtures. Now, let us see though schematically where, the oxide composition stands for O P C, this is O P C, this is o p c for o p c this is o p c this is o p c.

Now, calcium hydroxide is around 60 percent very small quantity of A l 2 and relatively small quantity. So, calcium hydroxide 100 percent is here, 100 percent A l 2 O 3 is here and 100 percent S i O 2 is here. So, you can see that, it has got high C a O small quantity of S i O 2 and small quantity of A l 2 O 3, we come to pozzolana, it has got high S i O 2 right. And small quantity of A l 2 O 3 small quantity of a l two o three sorry, this would be this this will have similar, A l 2 O 3 not this 1.

So, this will have parallel lines has to be drawn right, this is the A l 2 O 3 line maximum C a O line will be like this C a O line will be like this and S i O 2 line will be like this. So, S i O 2 will increase in this direction, you know together.

So, this one has got this much amount of calcium hydroxide, because calcium hydroxide 0 is this line 0, 100 is here, calcium hydroxide is small in pozzolana. Slag it is somewhat higher calcium hydroxide calcium oxide, but less than the O P C, you look for S i O 2 s i o two is 100 percent here, this has got maximum S i O 2 slag still has got more S i O 2 than O P C o p c as got this much S i O 2. Aluminum oxide 0 here 100 percent here, so all have got low A l 2 O 3. So, you see their oxides are same only proportions are differing and this diagram also shows same thing.

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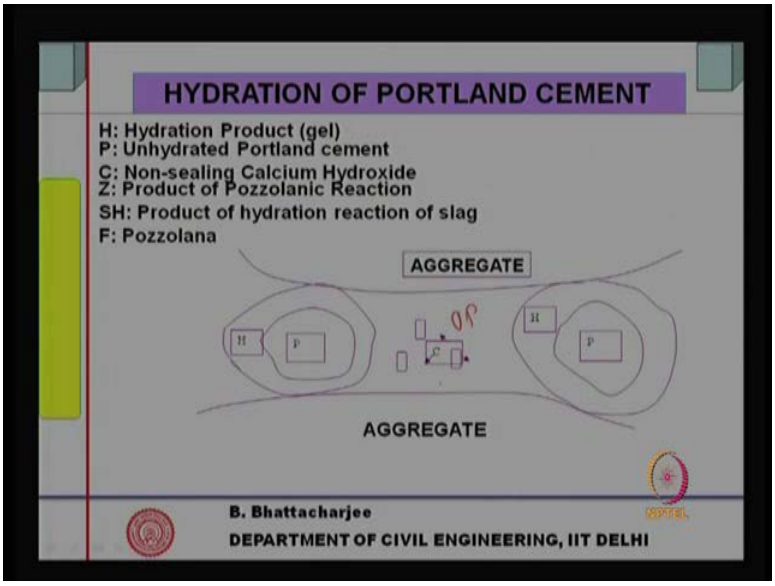

Now, let us see their hydration characteristics, if you see hydration product of Portland cement. This was my Portland cement and recall, these are inner product H stands for hydration product gel, inner product this is inner product, this is the Portland cement original grain boundary and. So, is this is hydration product, this is my aggregate and here, I will have calcium hydroxide coming into picture, this this place I will have calcium hydroxide C, which is non-sealing precipitate.

So, here I will have calcium hydroxide, non-sealing precipitate of calcium hydroxide right. So, this this is this this is what, we will have calcium non-sealing precipitate of calcium hydroxide, you will have and outer product obviously, the outer product will also be there. Now, if I look at right and this will fill in gradually as much as voids it can fill in.

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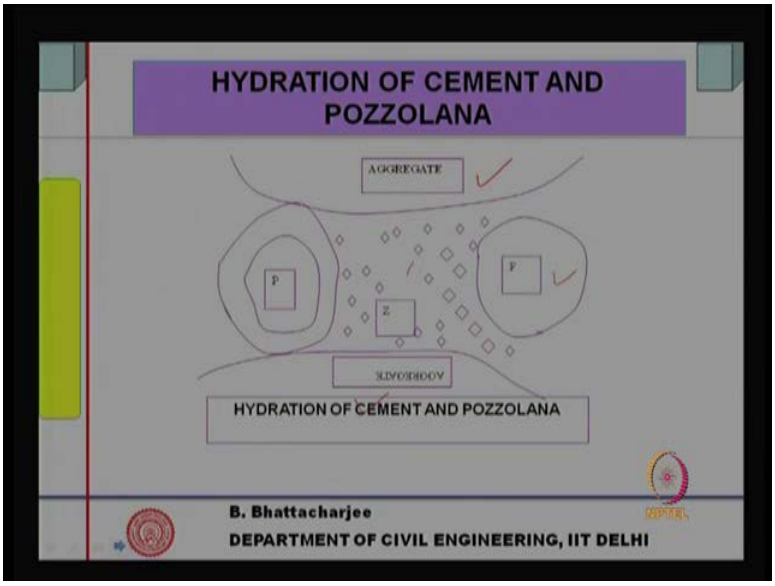

But, if you look at reaction with slag, this is my Portland pozzolana and this is my slag, now slag remember has got calcium oxide also.

So, it has got almost cement like composition only thing is it has got less calcium hydroxide. So, it should react with water itself, but it does not it reacts in presence of an activator. So, we can activate the slag, slag will react, if you can activate the slag slag will react. So, the activation of the slag is required and cement various materials in cement when, it reacts with water for example, gypsum alkalis etcetera can act as an activator.

So, slag is an you know slag can also hydrate and hydration product of slag is here and because it has got excess silica, this can react with the calcium hydroxide, that was there originally. And it can produce Z, which is you know pozzolanic material, we said that Z is nothing, but for product of pozzolanic reaction. So, you will find that pozzolanic reaction product is here and since, it is more C H S gel and not calcium hydroxide calcium hydroxide calcium hydroxide is actually, a non-sealing precipitate does not having bounding capacity, but C H S gel has.

So, slag converts excess silica in slag converts the calcium hydroxide into C H S, which is more of a bounding or sealing material. Thereby, it provides better micro structure in terms of you known cementing property porosity etcetera becomes capillary porosity becomes lower.

So, is the case with fly ash, these are the aggregates, this are the aggregate, this is the pozzolana, but then these does not react on it is own, this does not react on its own right. And calcium hydroxide coming from here, can produce pozzolanic material here and seal. So, calcium both these materials consumes calcium hydroxide and then seal does us you know non-sealing precipitate is reduced out.

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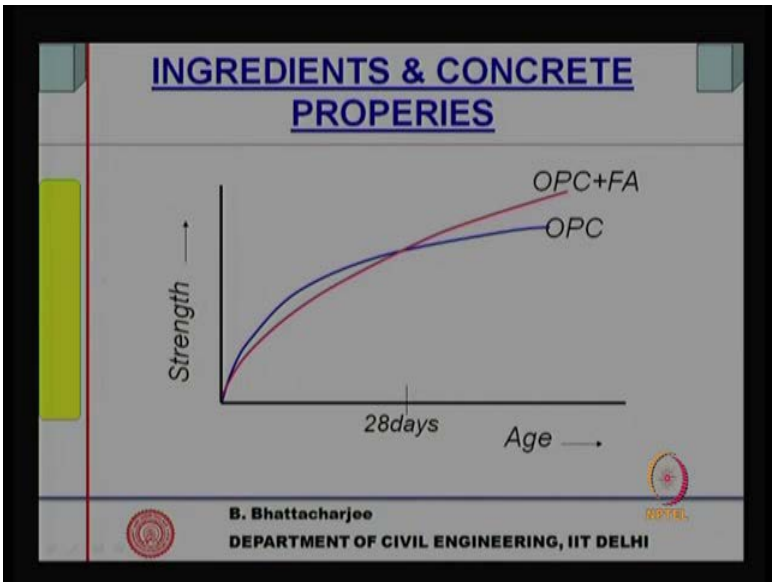

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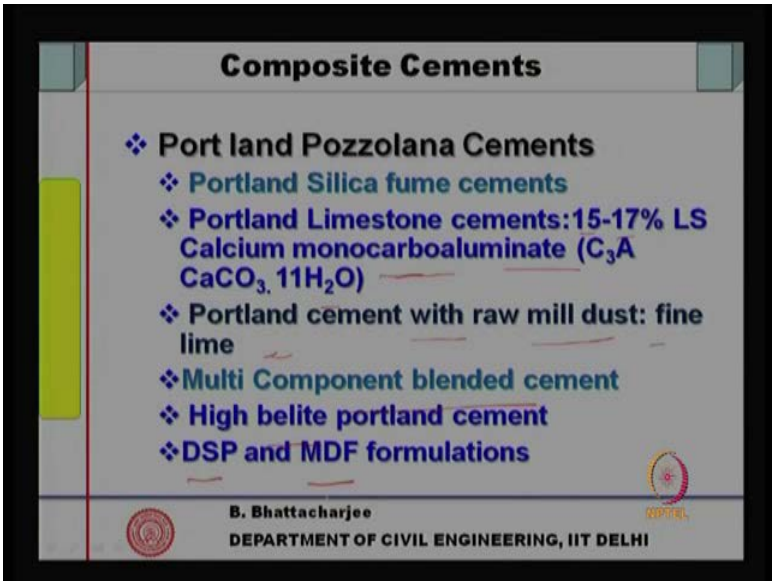

So, blended cements are blended cements are produced from this, one important issue is that such cements when, you produced by inter grinding gypsum clinker and the

pozzolona, their strength initial strength is lower, but long term strength is better particularly with fly ash on. So, is the case with slag, but silica fume can show, you high early strength as well.

We will discuss this sometime later on composite cements Portland pozzolana cement Portland silica fume cement Portland limestone cement, now, this lime stone is just a new you know, you can you can add small amount of limestone. It is not purely inert material some 15 to 17 percent limestone has been added to the cement system and it has been observed that, it can form compounds like calcium mono carbo aluminates, which has got some sort of bounding property.

So, some amount of lime stones are used, but otherwise limestone are used as a filler definitely definitely is a filler increase the paste content or cohesiveness of the paste. So, this we will discuss sometime later on in the case of mineral admixtures Portland cement with raw mill raw mill dust. So, raw mill dust that is dust of clinker or dust of limestone, they can be added to fine lime that can be added to the cement and they seems to also improve properties some of them going to the blended cement as well.

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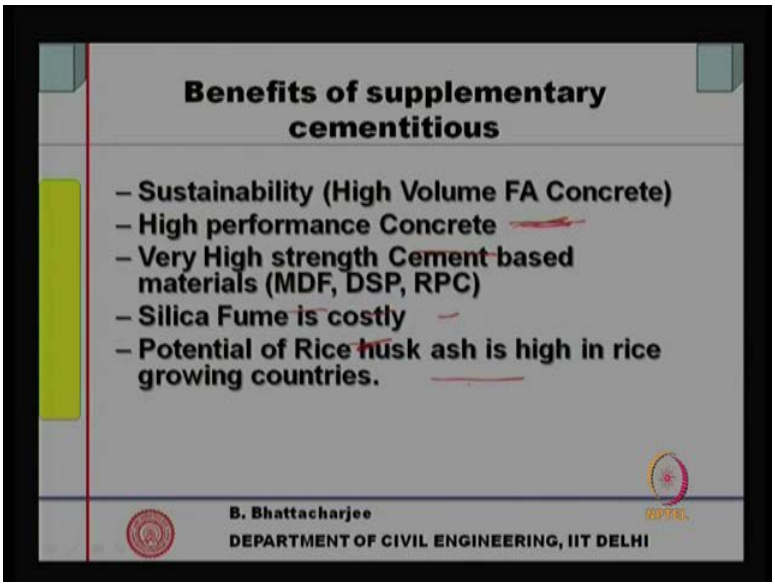

So, you can multi component blended cement, slag fly ash, everything together there is another cement with high belite that is C 3 C 2 S high C 2 S cement that something like modified cement. Strength development would be slower and very high strength system like densified with small particles and macro defect free formulations will discuss in the

context of higher high, you know. They use both use silica fume some use polyvinyl alcohol, we will discuss about this and high alumina cement combination, we will discuss about this when, we talk of high strength material.

So, these are other such formulations cementitious formulation well benefits from the supplementary cementitious materials are since, they you reduce down the cement clinker carbon di oxide emission is reduced. Fly ash being an environmentally, hazardous material can be stored can be used in cement. Therefore, they can give you sustainability in high volume fly ash concrete, you use as much as 50 percent fly ash, we will discuss this sometime later on. In high performance concrete silica fume is generally, used high strength concrete, in fact.

Very high strength concrete M D F R S D S P and R P C use silica fume, but it is costly very costly in Indian scenario 7 to 8 times that of cement. Potential of rice husk ashes is well, it is yet to be really verified.

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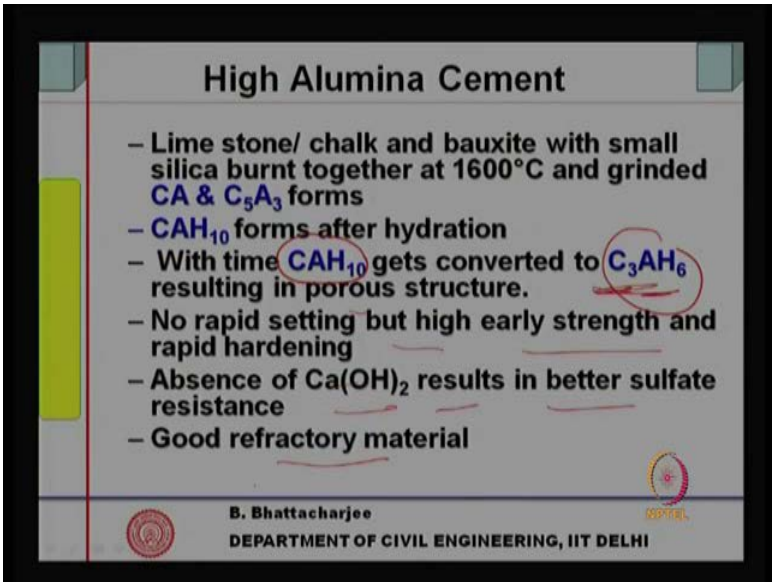

And getting popular in this country one more cement, I will just before we stop is a limestone, you know high alumina cement. This was used extreme very much earlier generally, produced from lime stone or chalk and bauxite with small silica. So, this will have high quantity of C calcium illuminate of kind C A and C 5 A 3 not C A C, you know C 3 A, but these are the product, that is formed the first product formed is calcium hydro C A H T T 10 after hydration slightly different then what, we use to get earlier.

But, this product is unstable and it gets converted in to C 3 A H 6. Finally, since this occupies more volume than this this final product occupies less volume then the original material. Thereby causes what is called extra porosity, it result in porosity in the structure final harden structure, because of this phenomena known as conversation no rapid setting, but early strength in rapid hardening, this has been observed.

Absence of calcium hydroxide results in better sulfate resistance, but this cement, because of this conversation phenomena is not really popular, you say high alumina cements are good refractory material well.

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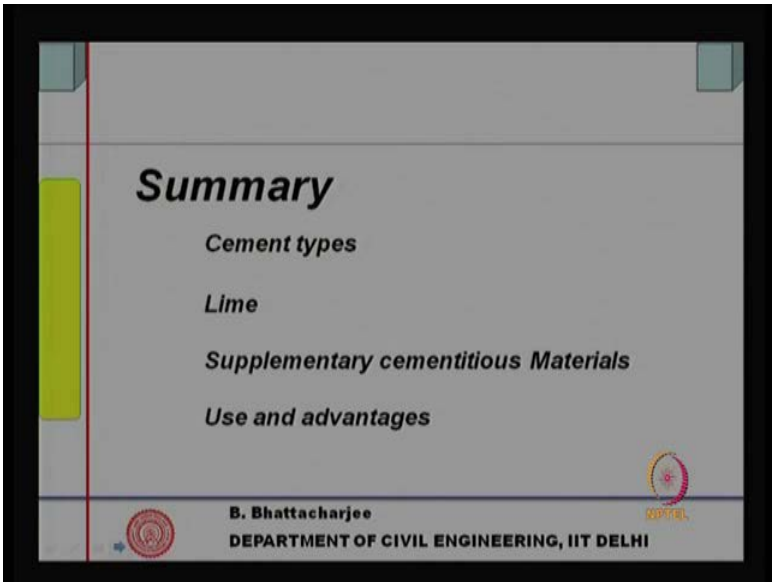

So, therefore, today what we looked into is the cement types, lime supplementary cementitious material, we will discuss about the supplementary cementitious more material, more in detail, because they not only, you can produce, if they mean with cement, you know, you can use them in cement. But, they can be sometime I mean, they can be added directly of course, sometime I say this correct, because you are adding one more ingredients into the system.

So, they can be added directly to the cement concrete concrete as an admixtures. So, at this at that point of time some of those issues related to pozzolana cement will discuss and we also talked about usage and advantages.

The only cement out of all this is the high alumina cement, which is not being used much anymore, because of this problem of conversion. Originally, it shows high it is original product formed has got high volume, final product occupies less volume therefore, it results in some pore formation. And that is how it actually, you know creates a porous structure and it has not been found very suitable, that is how C 3 A cement has is it is uses has been highly restricted.

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I think with this, we finish our discussion on cement and the first module.

Thank you.