Concrete Technology
Department Of Civil Engineering
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Lecture - 02
Cement: Structure and Hydration

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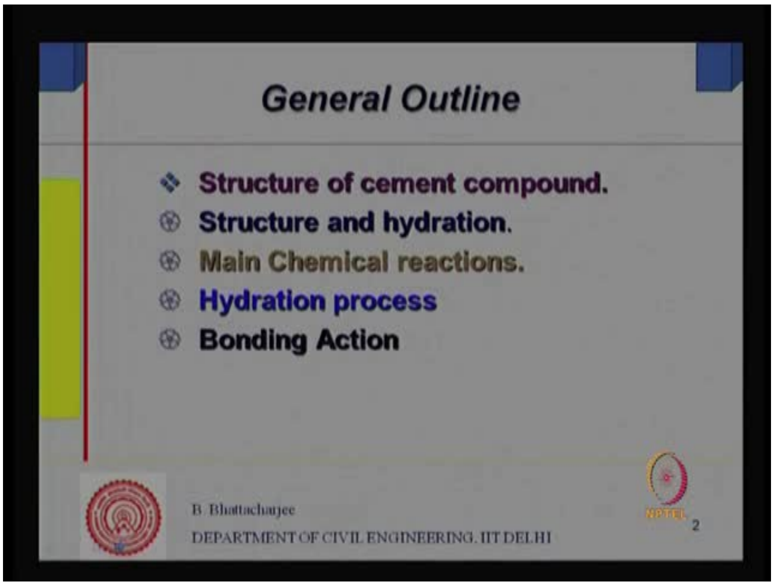

Welcome to module 1, lecture 2. Will follow up from where we stopped last time, but generally will be following this time structure of cement compound.

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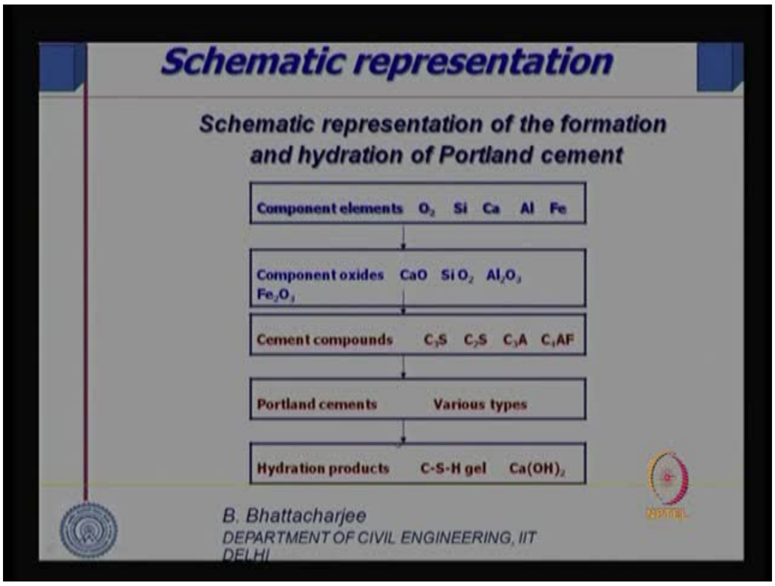

Then we look at structure and hydration, the main chemical reaction, hydration process and burning action. So, will be looking this time to structure of cement compound, after briefly looking at where we ended last class, we look into hydration product and they are structure main chemical process of hydration and the bonding action.

Remember last time, we looked into schematics representation of the formation of hydration of port line cement. We said that we start from element oxygen, silicon, calcium, melamine and iron, which forms oxides calcium oxide S i O 2 silicon oxide and aluminum oxide that is silicon and alumina, aluminum oxide then iron oxide.

Then this follows from the oxides, the compounds of cement and they are C 3 S, C 2 S, C 3 A, C 4 A F; all these combination gives us sport line cements of various type and when hydration occurs in presents water, it gives us 2 products C H S gel and calcium hydroxide. So, for you have not looked into this, so last class we stopped some are there.

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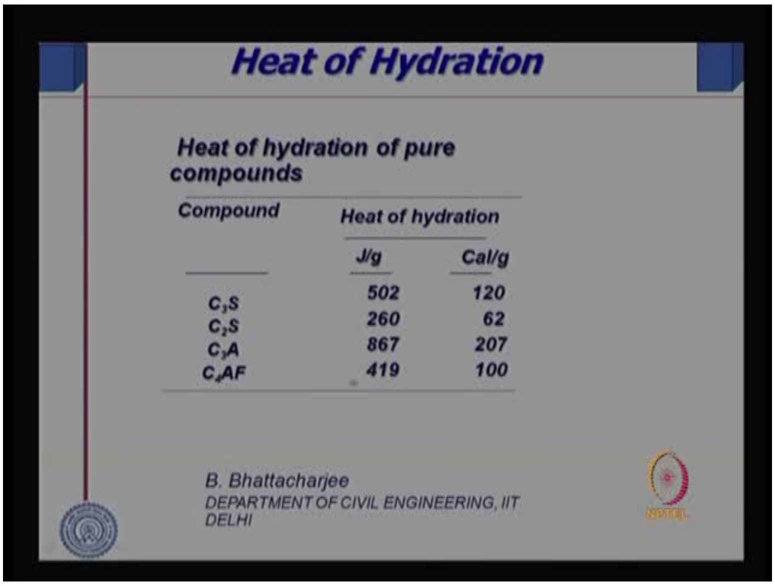

And we talk of also just heat of hydration, we said that out of all this compounds C 3 S produces 500 joules per gram C 2 S 260 joules per gram, and C 3 H 867 joules per gram and C 4 A F 419 corresponding calorie per gram is also given side by side. So, this is what we looked into in the last class.

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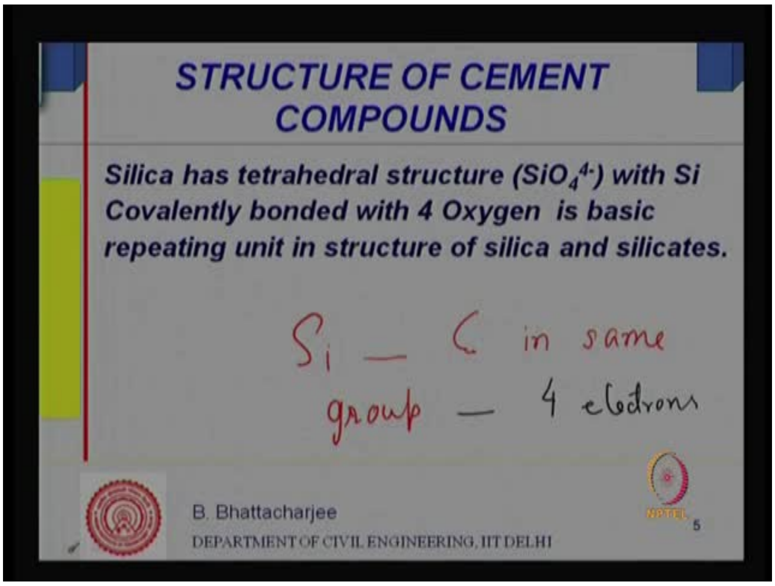

Now will follow in this class, we look into structure of compounds of cement. Now, we see silica S i silica, you know seas S i silica belongs to same group as carbon in periodic table in same group. And if you recall that, they have 4 electrons in their outer shell and this silicon silica generally, you know this silicon this silicon therefore combines with 4 oxygen combines with 4 oxygen forming S i O 4 iron with 4 negative valiancy.

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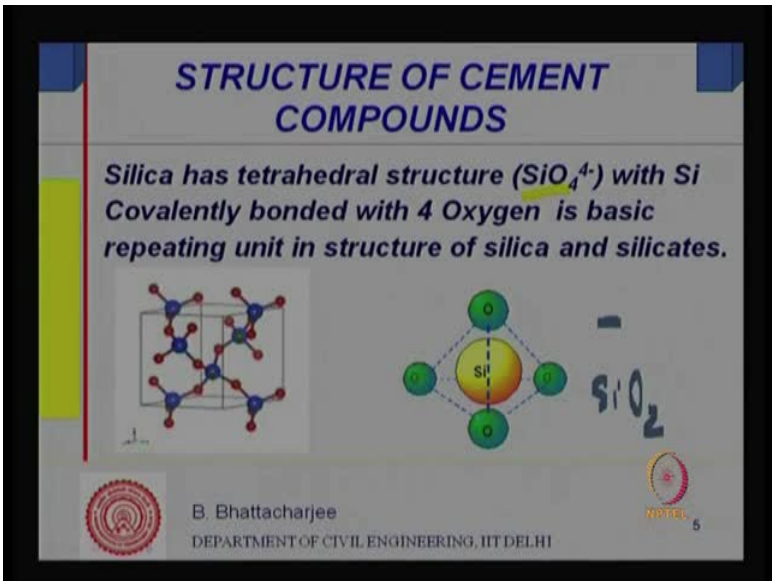

So, sincere has got 4 electrons. So, this 4 electron can combine 4 oxygen covalently and this will have it will be S i O 4 4 negative irons, silica is a S i O 2, you know that silica is

S i O 2. So, this has got tetrahedral structure with S i O 4 right and Si covalently bounded with 4 oxygen, this is the basic repeating unit in structure of silica and silicates. So, that is fundamental, now you know cement is calcium silicates try calcium silicate and di calcium silicate etcetera, we have seen, it is also aluminite.

So, first we are trying to be look at the silica structure. So, silica has tetrahedral structure like this the silicon here, there are 4 oxygen atom, they are covalently bounded with silica Si silicon atom. And it is 4 negative, it is got 4 negatives a balance is existing, it can be you know 4 negative 4 negative balance is exist in this one. The structure of silica there, for is something like this the blue one is the silicon with the red once the oxygen here off course, the yellow one is the silicon and this 4 are the oxygen.

So, you can see that the repeated (( )) and each oxygen is combined with 2 silicon, this one silicon here, another silicon here. Each oxygen is combine it combines with 2 silicon and this process, this repeats this repeats this repeats itself and therefore, you know with one silica one oxygen half of it if connected to S silica and half is connected to another silica. Therefore, therefore, therefore, therefore, you know each oxygen is connected to silica.

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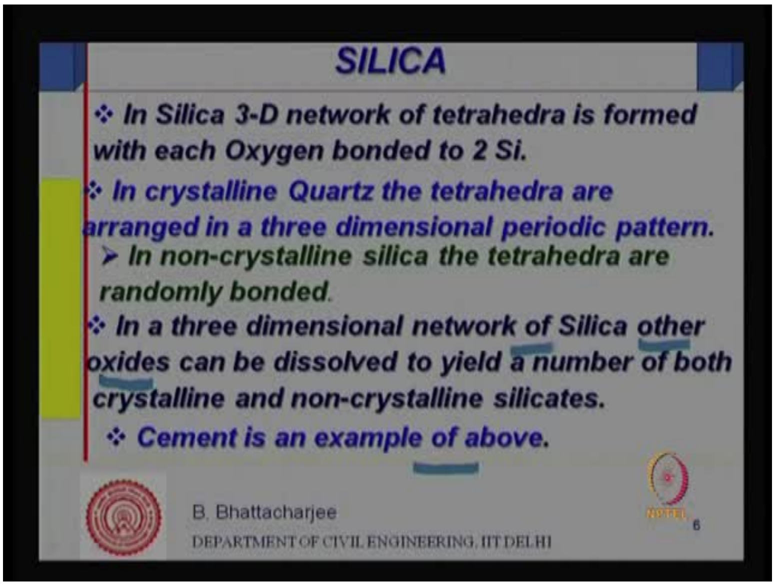

So, if there are 4 of this 1, 4 of the oxygen combined with 1 silicon, since oxygen combines with 2 silicon, each a therefore, structure of S i O 2 would be repetition, you know repetition of this tetrahedral, so this tetrahedral on repetition forms S i O 2 or compound silica compound silica compound silica.

So in silica, it is a 3 D network of tetrahedral formed three d network of tetrahedral formed with oxygen bounded to 2 S i. So, this is I you know S i O 2 structure or silica structure crystalline quartz is one of the silica, crystalline quartz is one of the most stable silica, the tetrahedral are arrange in 3 dimensional periodic pattern. This you know in crystalline quartz the tetrahedral, this tetrahedral S i O 4 with 4 negative bound available is arranged in 3 dimensional periodic pattern, in 3 dimensional periodic pattern all right.

In in Non crystalline silica tetrahedral are randomly bounded in non crystalline silica tetrahedral are randomly bounded tetrahedral, this are randomly bounded. So, this is the silica structure, this is the structure, now in cements in cements basically in cements silica can combine in cement actually, silica can combines with it can combine with other oxides in 3 dimensional network of silica. Other oxides can dissolve till number of crystalline and non crystalline silicates.

So, in you S i O 4 structure S i O 4 structure 3 dimensional network, S i O 4 3 dimensional network, other oxides can get dissolve right. And they can combine and therefore, you can get both crystalline as well as non crystalline materials as products.

So, various kind of silicates, you get know cement is one such example. So, cement is a example of such non silicate cement is example of such you know silica combining a oxo other oxides other oxides, silica in 3 dimensional network of silica, other oxides forms cement, that why I have got try calcium silicate and di calcium silicate. So, essentially this is the silicate structure of S i O 4, this repeats and in between, you will have calcium and oxygen a you know atoms coming in and forming, the structure of try calcium silicate and di calcium silicate.

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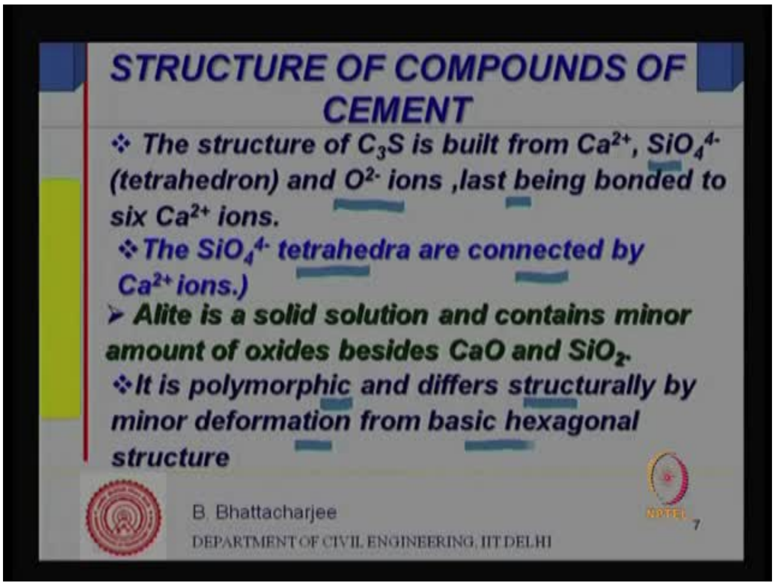

Let us look further into it more into it lets look more into it next look more into it the structure of compounds of cement C 3 S is built up from calcium iron S i O 4 iron. Tetrahedral ortho silica as it is called ortho silicate and oxygen iron just being bounded, you know last this is bonded to this oxygen answer bonded to six calcium irons like this, something like this, you know this S i O 4 tetrahedral connected by calcium iron. So, in structure of C 3 S is built up of calcium irons S i O 4 tetrahedral and oxygen iron.

So, these are bonded to calcium irons and the Si 4 tetrahedral are connected by calcium irons, let us see how it is let us see how it is C 3 S is also called it is mineralogical name is a light, which we seen earlier, it is a solute solution this solute solution. So, combining all this calcium oxygen and S i O 4 tetrahedral, but it has also got some minor compounds like sodium oxide, potassium oxide etcetera, etcetera.

So, those minor compounds magnesium oxides there there, generally it exhibits of polymorphic structure polymerstructures and difference structure it will by minor deformations of basic hexagonal structure. So, it has got basic hexagonal structure, it is polymorphic not the same crystal structure polymorphic, the morphology defers more than one morphology, defers more than one morphology exist and all this morphology defers from the basic hexagonal structure by minor deformations by minor deformations all right by minor deformation right.

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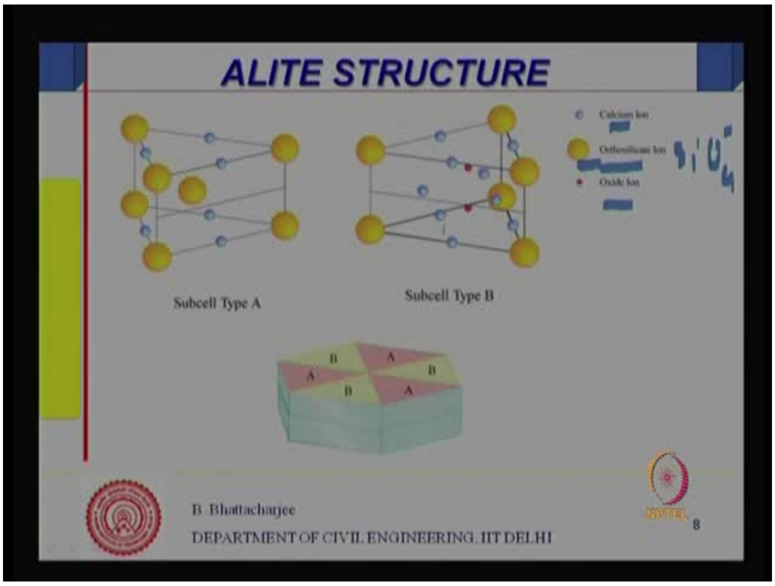

So, less look further into this cerotic calcium silicate hydrate or alite structures. This is got subsoil, if this is you know this one are the calcium irons, ortho silicate iron that is S i O 4, this is S i o 4, negative ortho silicate iron, oxide iron and calcium iron, they are arranged in subsoil's like this.

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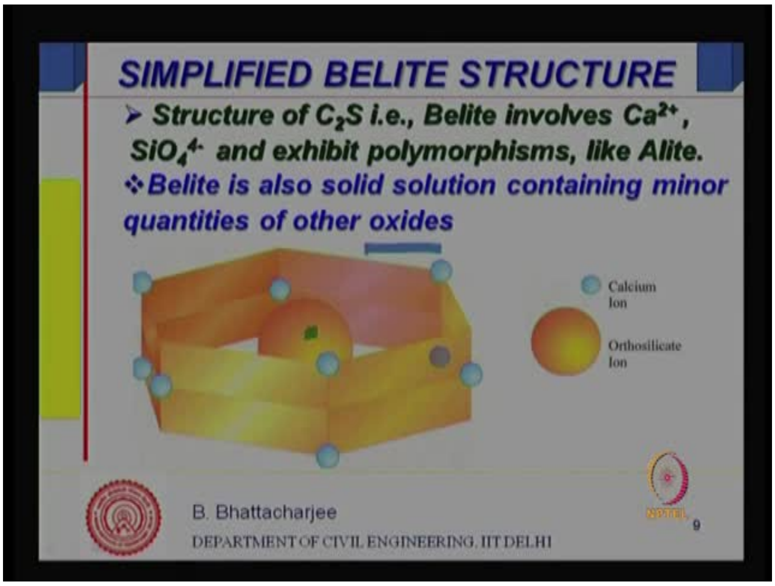

So, this is your ortho silicate iron, the calcium iron calcium calcium irons and in this one, you have got oxygen iron right and this combines together to form full shells with subsoil a b, a b etcetera etcetera. So, alite has got a structure that is C 3 S has got structure of this kind, structure of this kind with small calcium irons and not ortho silicate iron surrounding them in the manner as shown.

Simplified the alite structure, if I look at that is C 2 S, which we call mineralogical name is belite, which we have seen in the last class. So, structure of C 2 S that is belite involves calcium iron and ortho silicate iron and exhibit polymer prison like alite. So, structure of C 2 S the alite it also involves calcium iron, ortho silicate iron and exhibit same polymer prison like alite, but obliviously the structure should be different.

Belite also, off course is solid solutions containing minor quantities of other oxides, like sodium oxide, potassium oxide, del caulis and magnesium oxide, it is in wants. So, the mother compound other other minor compounds are there in small quantities in belite as well in belite as well.

So, this also is solid solution minor quantities of other oxides are present in structure belite as well and if we look at it same, it will look like this, the ortho silicate iron is here and these is their calcium irons calcium irons with ortho silicate iron please like this. So, this is the structure of C 2 S, if you look at structure of alluminate.

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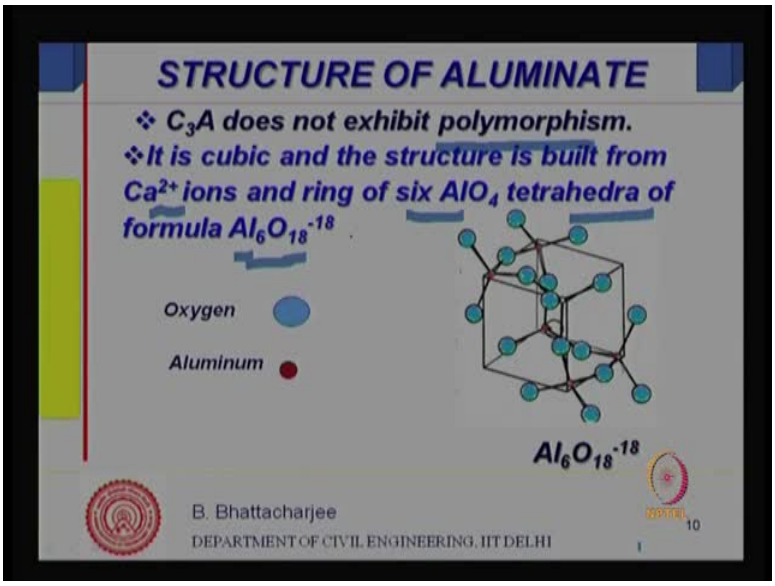

It has got one difference, it does not exhibit polymorphism it does not exhibit polymorphism. So, does not exhibit polymorphism, it has got a cubic structure of Al 6 O 18 with iron with 18 negative valiancy. So, cubic structure is built from calcium iron, it has got a cubic structure the illuminate, cubic structure build from calcium irons and ring of 6 ailte for tetrahedral of this formula.

Let us see this let us see this one, if this is oxygen and aluminum A l 6 O 18 tetrahedral is something like this, the oxygen is here connected to aluminum, smaller aluminum. So, 1 2 3 4 5 6 of them should be there 1 2 m, there should be 6. So, A l 6 with O 18 O 18 6 A l with O 18 or connected in this manner forming A l 6 O 18, structure is something like this.

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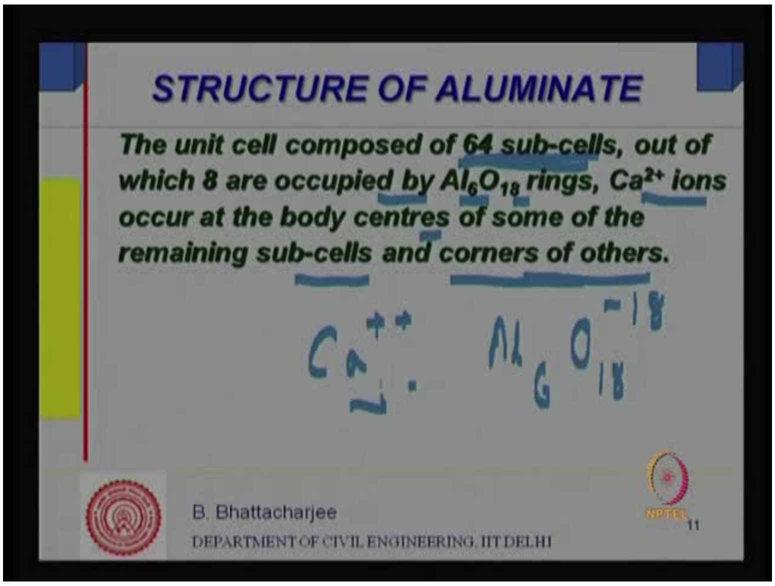

Now this is connected to calcium iron, this connected to calcium iron in case of Alluminate. So, you needs shell actually is compose of 64 subsoil’s out of, which 8 are occupied by A l 6 O 18 brings and calcium irons are you know, they occur at the body centre of some of the remaining subsoil’s and corners of the other.

So, aluminates structure is of something like this right, aluminates structure of this well, it is it has got Al 6 O 18 rings, it has got Al 6 O 18 rings calcium irons occurred the body centers of some of those sub selves and in case of and in case of some of the other sub selves, it occurs that the corners. So, 64 sub selves are there. So, essentially calcium iron in A l 6 O 18, the rings of this once are there and calcium answer please at the body centre position for some of them and remaining sub selves and you know in remaining sub selves, it remains at the this remains at the corner.

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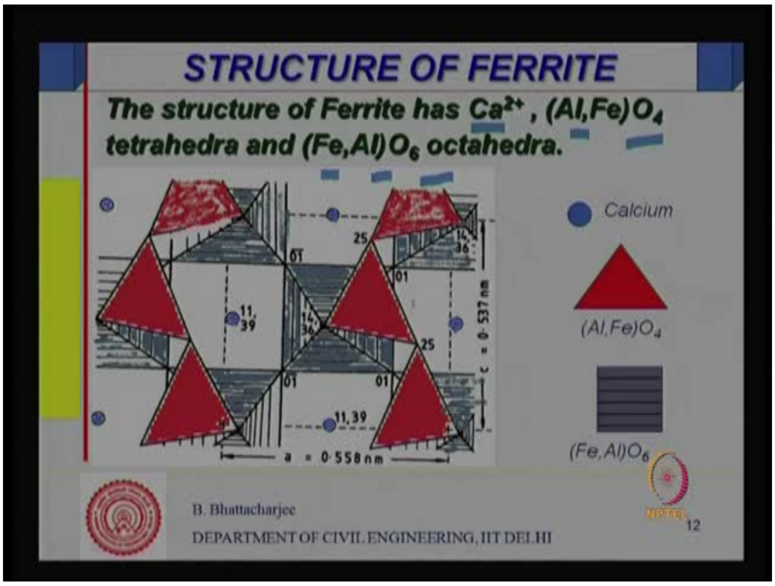

Structure of ferrite, if I look at it, it has got calcium iron Al Fe of 4 tetrahedral and Fe O 6 tetrahedral and looks something like this. This are the calcium blue once are the calcium the red try angles are the A l Fe O 4 and Fe Al O 6 are the once of this kind black once are the Al F e A l O 6. So, they have structures of something of this kind. So, that is how the structure of compounds of cement or the you know alite, blite alluminate and ferrite looks like.

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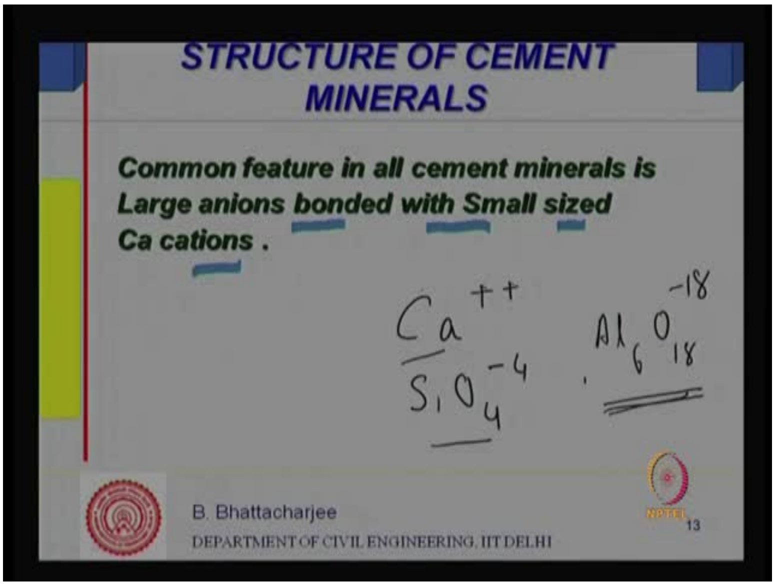

Now what is important for us from this point of view is one feature, which is common in all this structure is that large anions are bounded to with small size cations calcium cations, you know your cations are (( )) irons are cations are calcium, anions are S i O 4 minus 4 Al 6 O 18 minus 18 etcetera. So, you can see the sizes of this anions of very very large cations are small calcium cations.

So, this is one common feature and this has role in its chemical reaction with water all right. So, this is one major feature, common feature for all this chemicals, which is important from our point of view is that it has got small cations, that is calcium once with large anions.

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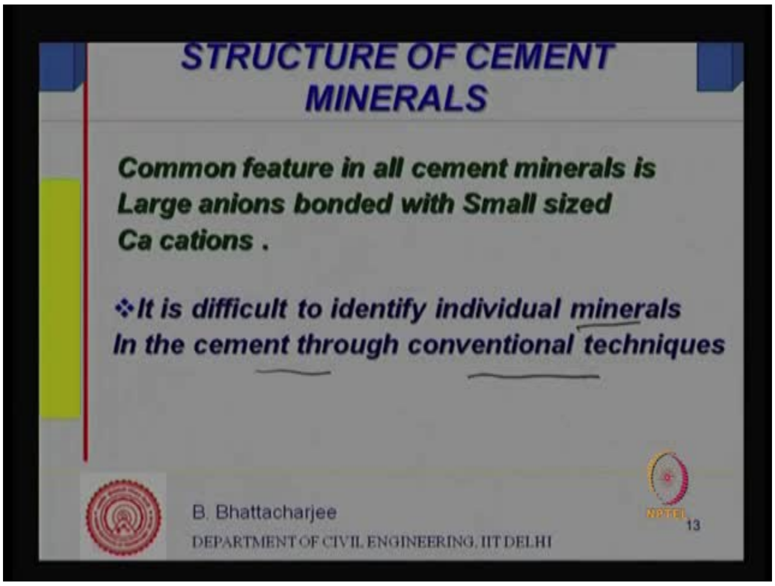

View off course know, that it is difficult to identify this individual minerals in the cements through conventional technique, if you take cement by conventional technique. It is difficult to identify this chemical compounds, you cannot just separate out one from the other, they are all together. Now this win mix with water or comes in contact with water it reacts, lets see why does it reacts the purpose of discussing about the structure is the structure has a role, in it is chemical reaction with water, we call this reaction has hydration.

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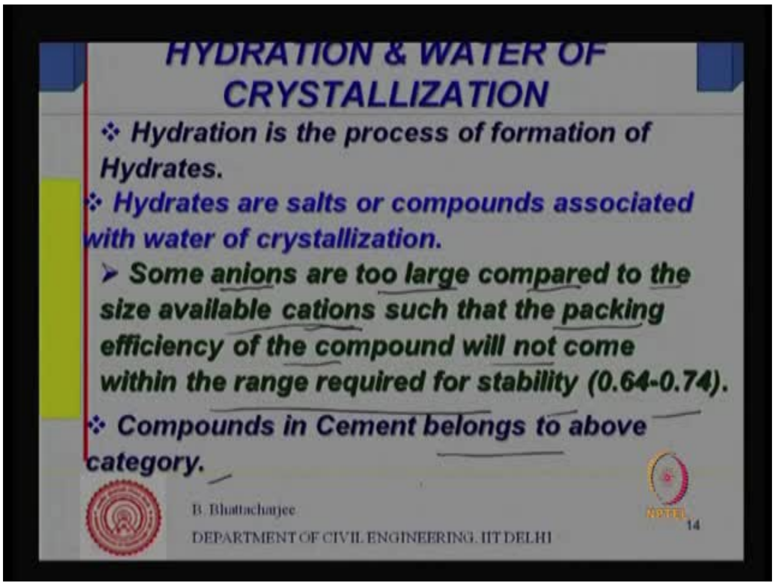

But, in general hydration is as term used is process of formation of hydrates, it is used in the contacts of processor of formation of hydrates, hydrates are solved are compounds associated with water of crystallization. So, hydrates are solved are compounds associated with water of crystallization that means, cement when it comes in contact with water takes, water of crystallization and becomes hydrates.

Therefore, we take we say hydration of cement that, why you say hydration of cement hydration reaction of cement right. Hydration is a general time use in chemistry, this oc why does it happen, why some of the some of the irons, you know some some compounds show exhibit or chemically combined with water to form hydrates well.

Because, anions are to large compare to the cations to the size of available cations, such that the packing officials of the compound will not come with in the range of reguards stability. You see cations are small anions are large, cations are arrange with the anions in some manner, now the size or to small they do not pack with appropriate packing density.

Now what is packing density, which will talk about later on also is the volume of solid divided by volume total volume, volume of solids divided by total volume. So, the cations and anions must pack such that, they occupied 64 to 74 percent of the volume to have a stable structure, when cations are small, anions are large, the space between the anions are not field completely by the cation therefore, the packing density is not stable packing density.

And when you do not have a stable packing density, you know they actually taking water well cements belong to this kind of compounds. Because, your cations are small, calcium carions are small and calcium cations are small and this and this small calcium cations with large anions, the packing is not a stable packing packing density is not stable. And in such situation what happens to recur to achieve, this recurred packing efficiency.

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The unstable compounds in corporate water of crystallization within, they are structure in or else to feel the space left around the cations. So, to achieve this required efficiency, this compounds where, cat irons are small anions are large, they incorporate water of crystallization within the a structure in order to feel the space left around the cation. And cement is like this right, simple and cement like this right cement like this right cement like this. So, cat iron is there an artificially enlarge. So, that stability is achieved crystallization occurs stability is right by crystallization.

So, cations is then artificially analyze, therefore you can see that y cement readily take water and reactive to a water, it takes quickly it gets hydrate hydrate, because it cat irons sizes are small anions the larger therefore, it readily you know take and water and reactive to water and water of crystallization and hydrate are found.

Hydrated water has got the property that it is chemically bound, it is chemically bound in the structure at therefore, not available for process such as fungal growth, these water is not feely available this water is not feely available, it is not available for fungal growth, it is attach chemically, it is attach chemically right. So, it is not available for fungal growth.

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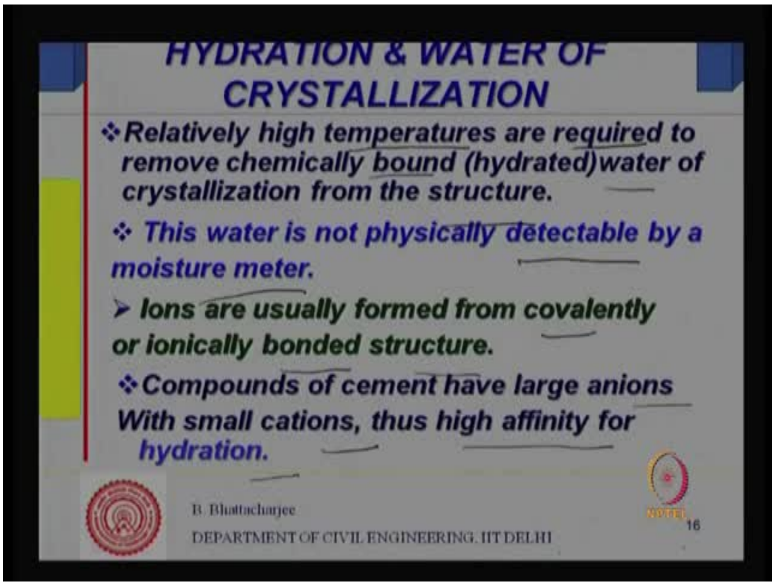

If you want to remove this water, you want to remove this water, high temperature is required high temperature is required to remove, this chemically bound water of crystallization from the structure, because it is now chemically bound. So, you cannot remove them. So, easily so you have to heat it up supply a lot of energy to detach this water, out from the system, out from the hydrated system right.

This water is also not physically detectable by a moisture meter that means, it does not you know you just cannot measure them simply it is part of the solid system and if you put a moisture meter like let us say electrical conductivity etcetera, etcetera. This is not readily detectable by any kind of moisture meter that, you have it will not evaporate, if you heat to 100 degree centigrade, it will not evaporate, because it is much strongly block bound then the free water.

Irons are usually found from covalently or inimically bounded structures right and compounds of cement have large anions, which small cations, those high affinity for hydrations. So, that is what we are understood that in cement, we have got large anions and small cat irons. So, readily can readily hydrates that is why it readily hydrates and from the hydrated structure.

So, that why the structure of cement compounds where, important, you know because to understand that there anions are large, cations are small and therefore, they can readily hydrated. And it is therefore, you know, we understand process of hydration and that is why cement reacts, the main chemical reaction, if you look at it.

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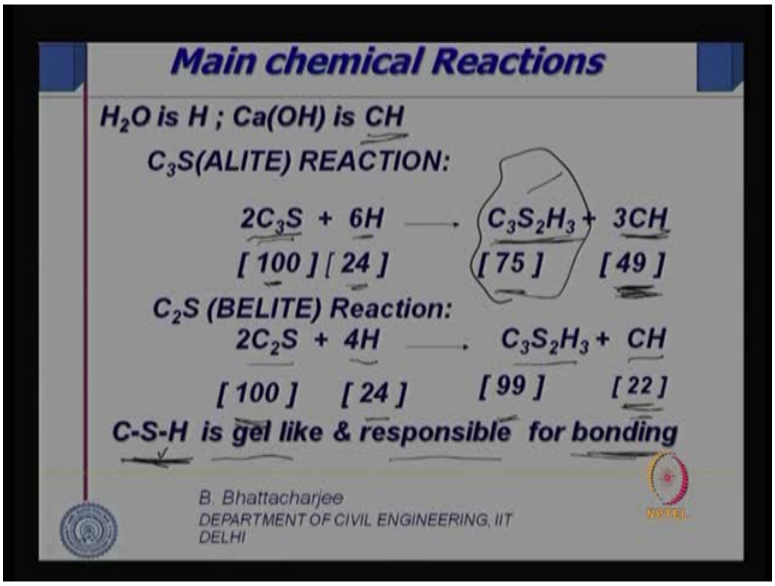

We obrierate like obrierate calcium oxide as C water, we obrierate H as we mentioned earlier water is obrierated H that is calcium hydroxide will be returned as CH, calcium hydroxide will be returned as CH. So, C 3 S reacts with 6 water to C 3 reacts with 6 water, this is the difficult reaction forming calcium silicate hydrate the water goes into the calcium silicate structure and calcium hydroxide.

So, its produces calcium hydroxide and the calcium hydroxide and the calcium silicate hydrate, similarly belite or C 2 S also reacts forming calcium silicate hydrate and calcium hydroxide. One can note, this that is produce us more more calcium hydroxide C 3 S produces more calcium hydroxide then C 2 S 100 grams C 3 S reacts with a approximately 24 grams of water to produce 75 grams of C S, you know C 3 S to H 3 and 49 grams of C H, 100 grams almost reacts with 24 grams producing 99 and 22 grams of calcium hydroxide. So, this is this are the 2 most important reaction.

Now this is we you know there is a why you call it as C H C S H rather than, you know compound complete formula will come to that shortly, this is got a gel like structure and this is responsible for bounding. So, this is got a gel like structure and responsible for bounding will come to that in more details.

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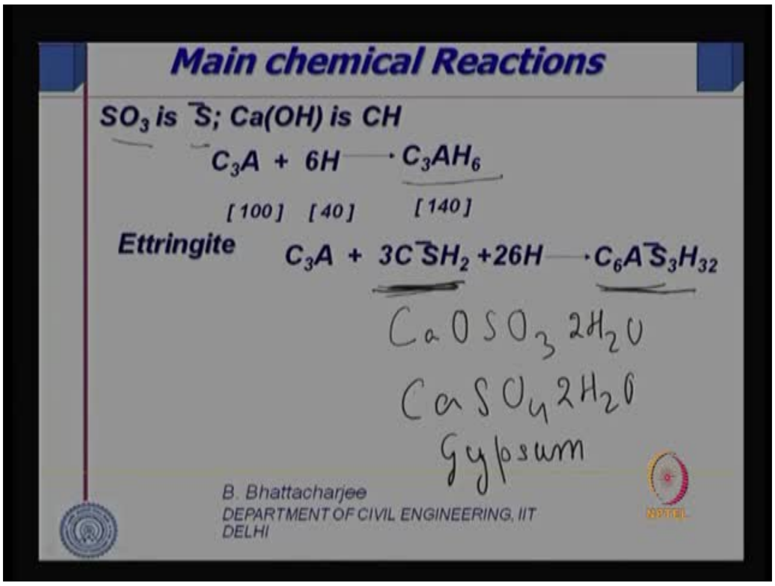

The next chemical reaction important one is off course, C 3 a reacting with 6 water forming calcium aluminate hydrate C 3 H 6. This is this are the difficult reaction, but one more, which is important is reaction of C 3 a with calcium sulfate with water of crystallization of what is this calcium oxide and S o 3, because S o 3 is abbreviate is part and then to H 2 O. So, this is nothing but, can C A S o 4 2 H 2 O zip some, this gypsum is added to the cement as we have mentioned dialed here, gypsum is added to the cement to control setting in the last lecture, we talked about that.

Now this calcium sulfate or gypsum, you know hydrated calcium sulfate reacts with C 3 A readily reacts with C 3 A and forms, it come compound of this kinds C 6 A alumina alumina oxide S 3 bar that is. So, 3 and H 32, so C 3 reacts C 3 reacts C 3 reacts with gypsum will presents of water to form this kind of a compound.

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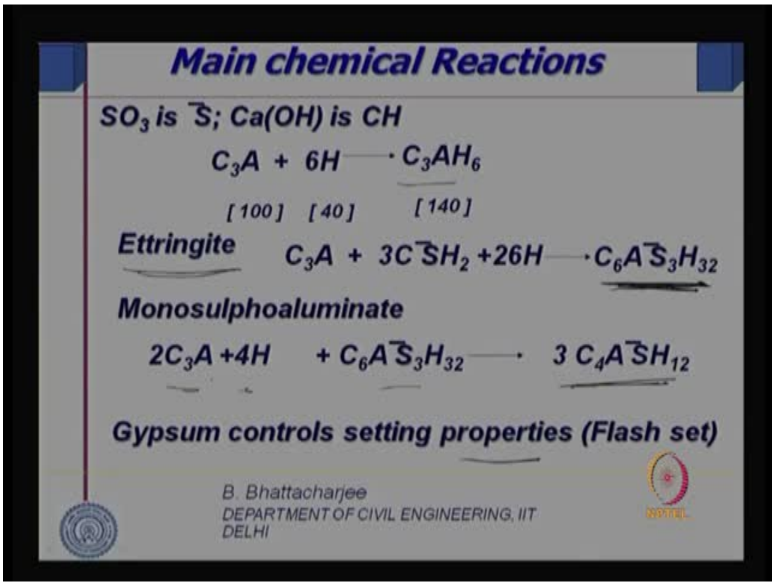

And this is quad emprinzime, this is called emprinzime, there is a name emprinzime, this is called emprinzime. So, this reaction forms but, this is not very stable compound and later on it changes in presents of C 3 and water to what is called mono sulfate to what is called mono sulfate S bar only not S 3. So, this is called mono sulfate.

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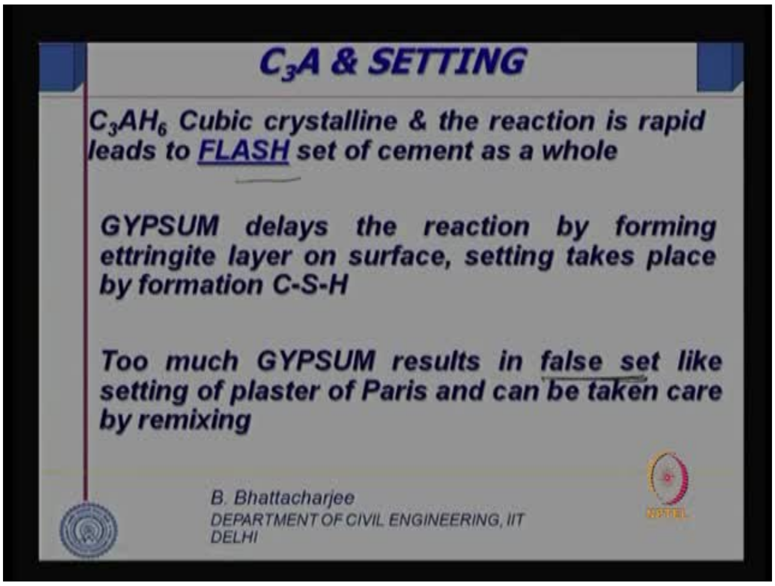

So, this 2 reactions are also important in case of hydration of cement aldyed 2 reactions and this a luminary reactions a luminary reactions, we have seen here. So, this is the main chemical reactions for cement with water gypsum controls setting properties will discuss the sometime later on what happen is if you do not up gypsum then C 3 A quickly reacts with water and can results in what is called plus shelve.

And 2 much of gypsum on the other hand can result in was known as false set come to that. So, C 3 A H 6 cubic crystalline and the reaction is rapidly it to flash of cement as a hole and do you it is not desirable, because this flash set do not allow C 3 S and C 2 S to react it quickly solve deface, you now kind of at a very short period and it is not desirable, because other directions do not continue.

So, flash set is not desirable and that is why you we add gypsum in the cement, now gypsum essentially, delays the reaction by forming a train a ettringite layer on surface setting takes place by formation of C H S later on. So, this is what it does gypsum it delays the reaction right well forming in ettringite will look into the somewhat in more details from time to time and setting takes place by formation of C H S.

To much to much gypsum is also not good to much gypsum is again not good, because it results in what is known as fall set, it results in what is known as fall set like plaster of the sets like plaster of pairis. Because, gypsum is selves will react with water and form hydrated gypsum, you know like plaster of pairis and therefore, this is also not desirable this called fall set, but you can actually you know remix it little bit and it will set again.

So, both optimal quantity of gypsum is important gypsum should be able to retired the reaction of C 3 A. So, this C H S, you y know what C 3 S C 2 S can react, but at the same time tow much of gypsum by solidified by reacting itself with water instead of C 3 alone and does by giving impression of a falls set.

So, anyway this is this again, we may look into this sometime later on. Lets come back to so, we have seen the chemical reaction or reaction product of the cement, this we have seen that silicate hydro calcium silicate hydrates lets look at there structure, because this structures have some role. In the property is and things like this in understanding there properties and you know hydration processes itself. So, lets look at structure of C H S.

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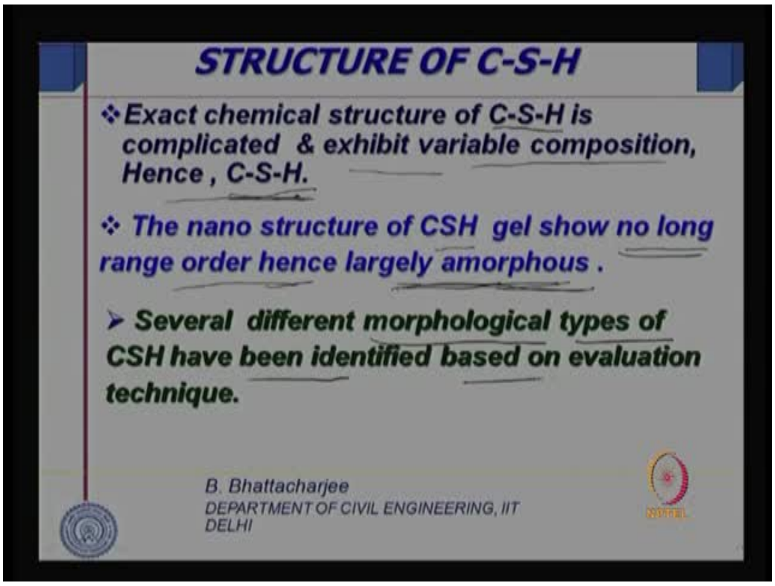

Exact chemical structure of C S C S H is complicated and exhibit very will composition hence, we call it C S H that is why there is a reason, you know there is a reason, we said that it has got general like structure it has got a zeletelian structure zeletelian structure. But, we said that you know denoted by the exact formula, because it has got variable formula.

So, we generally denoted by C S H denoted by C S H, the it is not a actually crystalline as usual see C S H is not crystalline as usual C S H is not is crystalline right, it is not crystalline, we look into a and therefore, the crystal structure of C S H is not really define instead, we talk of nano structure of C H S fine level. So, this C H S gel show on no long order, hence largely amount first.

This do not show no long range order, therefore amorphous a repetition of the structure is not there the therefore, it is largely amorphous. Several different morphological types of C H S has been identify based on evaluation technique. There are number of they have you know similarity to some of those calcium silicate hydrates pure calcium silicate hydrated produce, otherwise not from the cement namely marmite or similar once there are several minerals crystalline structure they have.

But, the C S H produce from cement, they do not have long range, you know crystalline structure therefore, they largely amorphous cannot be cannot be associated or cannot be assume to represent such crystals are to murmerite. So, there essentially amorphous right.

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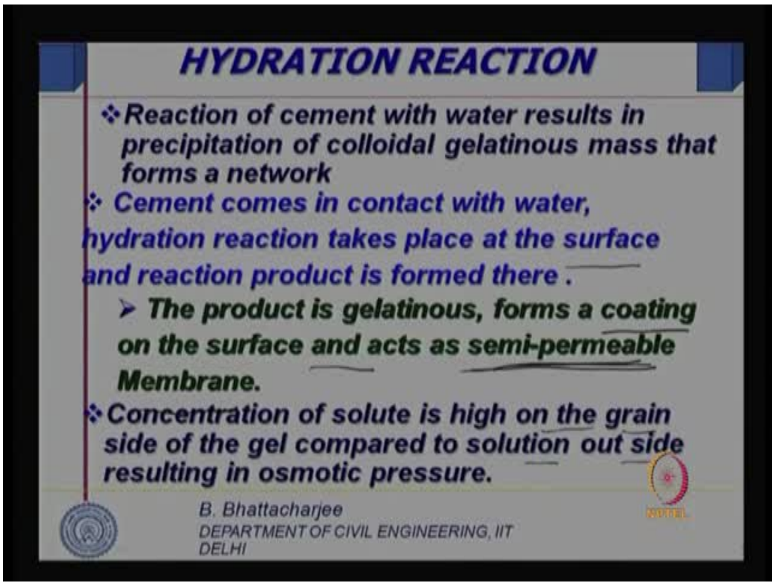

And the the product that, you know you find out the crystal structure, you determine, you usually depends upon the evaluation technique well, it actually reaction of cement with water result in specific repetition of cloudlet glutinous mass. And this forms a network this forms a network, this forms a network cement comes in contact with water hydration reaction takes places surface and reaction product is formed at the surface itself.

So, we have a diagram, we have cause diagram, which will I am come to what happen is the reaction takes place at the surface, cement particles well, they may be clog but, if you can dispose them, if they are separated from each other right. So, the water when it comes in contact with the water it surface that is the reaction takes place at the surface and products are deposited by the surface because water comes in.

Now, next what will happen the product off course is colloidal and gelatinous colloidal and gelatinous and it forms in the coating on the surface of the cement itself and this coating because semi permeable memoriam and next like semi permeable memoriam. Now on the grain size on the cement side of this semi permeable memoriam, there is more concentration of the solute, that is a cement itself and on the other side there is less concentration of the solute.

So, when you have difference in concentration, you know across a semi permeable memoriam, it gives rise to osmotic pressure will come to that some time later on will come to that some time later on when, we talk you know at appropriate time. We know that, if there is difference of concentration exist, across a semi permeable memoriam, you find that after some time concentration 10 to be same after concentration tan to be same, because a presser deferens exist between the higher concentration side and the lower concentration side.

And this presser is osmotic presser will toke about this, because we will be toke about defecation of chloride concrete so, on in the connection of durability. So, any were the moment, we are understand that they will be osmotic presser created on the grin size and that will result in rapture package of the seamy permeable membrane and water panic crate water cons, you know water will panic crate into the un hydrate position with the cement right.

It will panic crate un hydrate position with the cement and they are by hydration reaction would progress. So, concentration of solve it is high on the grin side of the jell compeer to solution out side resulting osmotic presser resulting osmotic presser.

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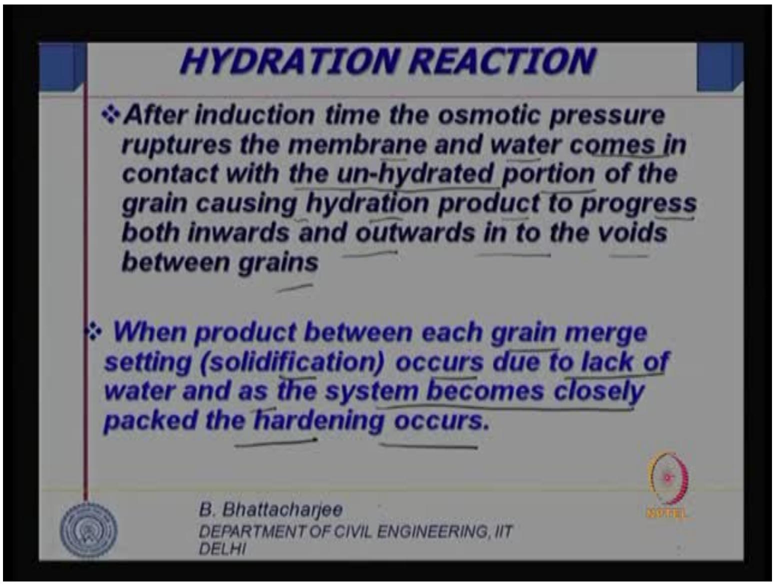

An after induction time osmotic pressure ruptures the membrane that what I am saying and water comes in contact with the un hydrated portion of the grain causing hydration product to progress both inwards and outwards in to the void between grains. So, this osmotic presser that is higher on the grain side coses rapture of the membrane and they are water can enter to the you know inside chose the membrane to un hydrate cement and reaction product will be from inside both inside some of it will go outside. And actually get the posited in to the weaken space, that is a available and also within the space were original cement grin outer peripheral of the original cement grain itself.

When product between each grin merge, so when the merge to gather, you know they will tech each other the setting would it will from a solid skeleton what we called setting, we occurs you know this product will will diagrammatical will explain this again.

So, when this product, they come in tech each other they from solid network, you know tech each other, they will from solid network with of course, bovid space inside and that time when the solid network is from it is actually, we call it setting is cored, because setting is the process solidification of cement water plastic mix.

So, thus due to the reaction solid sot from, they would tech each other and they are by the solid network could from and that setting would occurs. Further then process of more generation of solids my take place, more hydration product may from and felly know the that is you know is available within the space right. So, when product between each grain merge setting occurs give to lack of water as the system become closely packed and the then hardening occurs.

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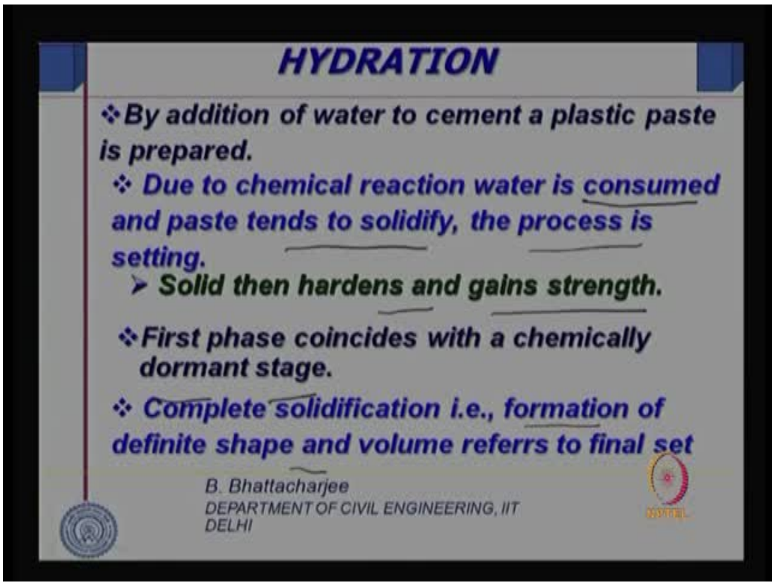

By addition of water to cement a plastic paste is prepared that we set, due to chemical reaction water is consumed. And paste tends to solidify the process is setting solid then hardens and gains strength, setting is solidification, it does not get strength sufficient strength that moment. And then gradually, it will grin strength as well it, we again as well what, we call first phase of first phase of the solidification, we call it side with chemically dormant pride, we call it chemically dormant stage chemically dormant stage.

And complete solidification on formation definite shape and volume refers to final set that means, solid as got as definite shape and volume. So, when cement and water mix when, you mix cement and water it is from plastic kind if a paste. This gradually solidifies an were it attends definite volume shape fully solid, we call it final setting as occurs final setting as occurs.

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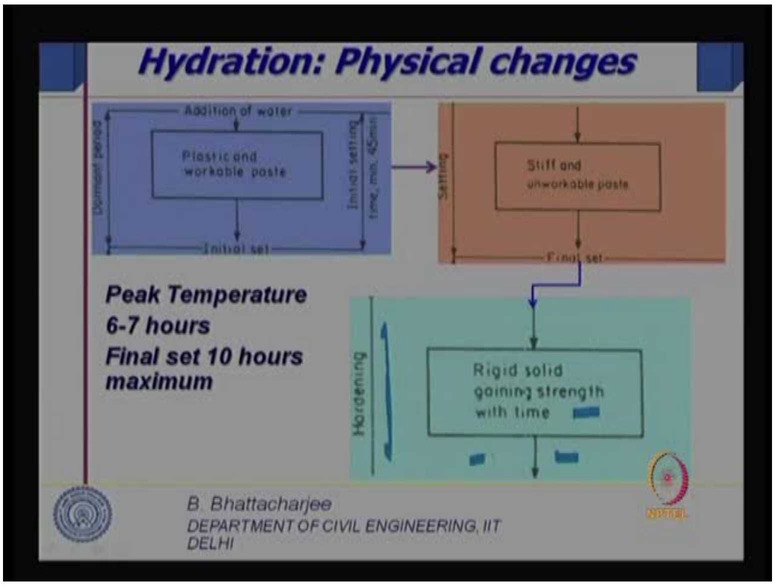

Well fiscal changes as you can see addition of water, we can plastic and workable paste, this is chemically, we call it as dormant stage an it then solidify such that, if deistrive it farther this stage after this stage then it use some of property. So, that state, we call as initial seat, you know solidify in a such manner still soft not fully solid, you can impress possible, you can a make small dank.

It is not fully solid, but if you try to distrive it, farther you know nearly solid, if you try to distrive it farther it is properties will be effected. So, that what initial set generally around minimum should be half an hour and usually could be 45 minutes right could be 45 mints source.

So, fallow from this is a stiff and unworkable paste stiff and unworkable paste that means become fully solid. So, it is stiff and unworkable paste, you know and that corresponds to final set as saying, now it has got at definite shape and the volume and there farther final set, so there final set.

So, it got a definite shape and volume and it is final set followed by them is rigid solid gaining strength with time and this process, we call as hardening. So, it will gradually gain strength, it will become hard solid is there, it was soft initially not very strong, but with time then, it will gain strength an will become stronger that process, we call as hardening.

This is the physical changes in case of hydration well peak of temperature occurs 6 to 7 hours mixing the water and final set generally, this time corresponds about 10 hours. So, not more then 10 hour that most cod will specify most of the cod will specify not more then 10 hour.

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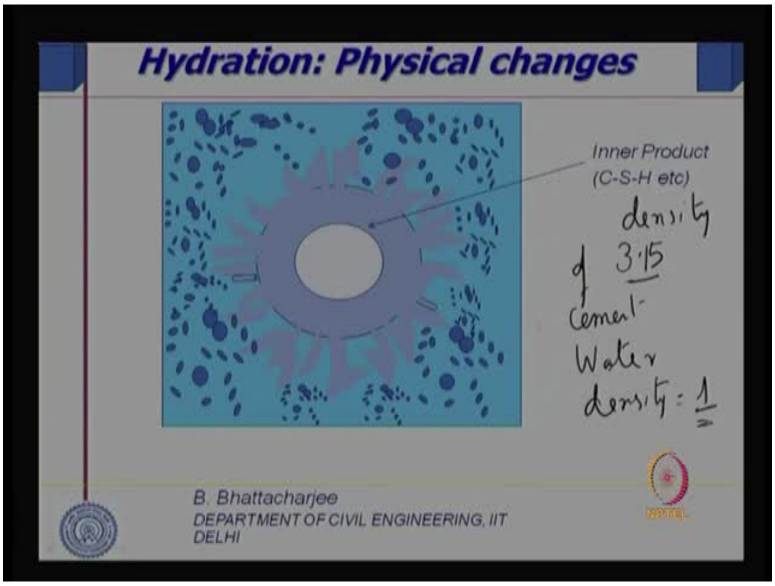

If you look at hydration process of you can consider small position of water like this, you know water like this an lets this is cement grain, cement grain as you know cross product is grinded. Therefore it will not have a rounded shape, it will have some sore irregular shape as we can see. So, it will have some sore irregular shape I can idealize this as a circle something like this right. So, cement shape was something like this idealize circle, now let say hydration proceeds.

So, as a hydration proceeds, you see the product that will be from, this position has been actually, this cement has been consumed the water comes from out side, the hydration process means water is reacted the cement from outer surface. Now as we know the product hydration acutely as got a density lower then density lower then it has got density you know density of cement is 3.15 density of cement cement, we shall see that product water has got one water density.

Now it has reacted and from the product, this will have a density more then you know less then 3.15 more then 1 some are in between. So, it occupies more volume then the volume that was occupies by the cement. So, there 4, you fine that this spaces are also filly solid some water as reacted and you know the product as gone out side the periphery. The 1, which is ream within the original boundary, we call it has inner products, we call it has inner products inner products we call it has inner products.

So, inner products is that product, which is produce within the original grin boundary inner products is that hydration product, which is produce within the original grin boundary let me repeat cement has got a specific gravity 3.15, water has got specific gravity 1, the product form as a specific gravity some out les then 3.15 smaller then 3.15, but more then 1.

So, the new solid that is from occupies more volume then the original volume of the cement some product will be produced within that zone were, original cement was there and water is inter and produce the hydration products that products call as inner products.

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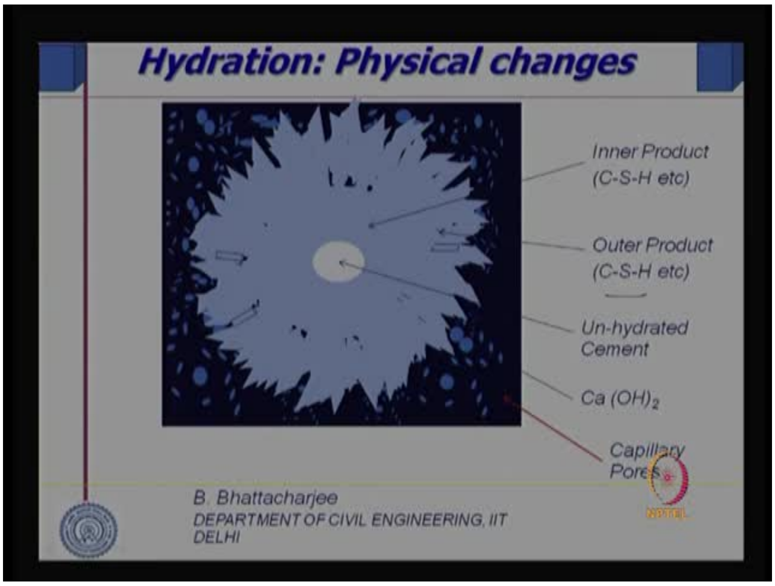

And some products that will be from out side this and we call it outer products. Now outer products abyssal, we have C H S, but it will also have some calcium hydroxide, it will have also calcium this one, this once you know precipitated precipitated are calcium hydroxide.

So, this are this precipitated calcium hydroxide calcium hydroxide. So, calcium hydroxide precipitated as because is sparingly soluble it is sparingly soluble you know so, it remain as precipitated non sealing precipitated non sealing does not seal any thing non sealing precipitated were is outer products C H S will be something like this, you know in the periphery of the original grin boundary.

So, they will exchange out side right and calcium hydroxide precipitated outside, un hydrated cement still reams in side, lets say farther reaction starts occurring. So, un hydrated cement not get reduce and C H S outer product, now increases to a large skill an you will still have.

This once this calcium hydroxide precipitates outside, but the black position, if it is not stop hydration was stop black position represent blank space, which are nothing but, they will remain 4 blank space, which will remain 4. So, black you know there become from the blue water, final is water evaporated and that is become force right. So, that is what we call as capillary force, there is size are large and there, we call them as capillary 4.

So, this diagram explains you the process of hydration taking from idealize cement particle taking considering idealize cement particle surrounded by water. When the solids as we have seen all the solid touch, each other at some corner solid skeleton is from touch, each other from the other side another particle and so on.

Solid skeleton is from but, remember, there we large 4 large quantity of force remaining at the initial state un less, you have less water very little, water less space field by the solid products of hydration and the continue reaction progresses long pride of time, we look into this in some more details latter on right.

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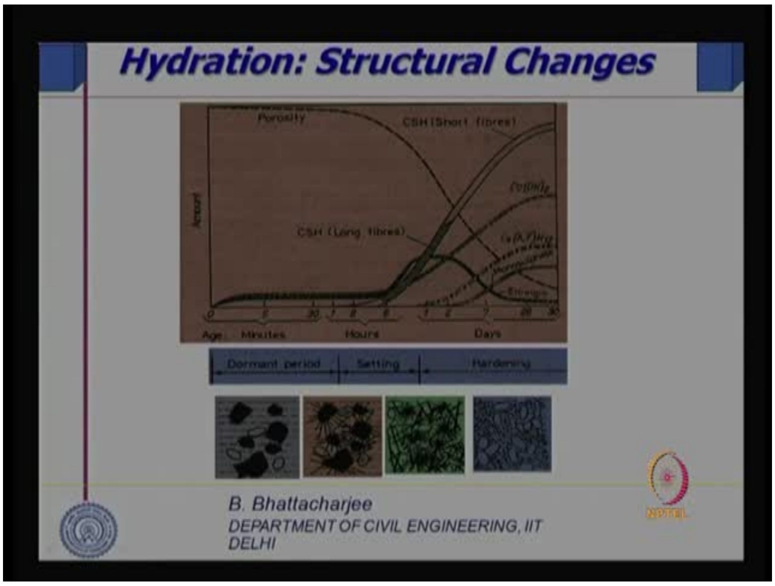

So, if I look at now the look at now the structure changes that occurs in case of hydration y excess, I have quantities of material from the y excess, I have quantity on this side and x excess time initial, it is seconds and mints extra extra, initial mints then it is avers then it is in days.

Now there are deferent products forming as you can see for example, this products, if you look at it, it is etrin join, you know this is etrin join. So, etrin join formation occurs. So, etrin join is first 1 to be produce.

It is produce, but if you remember, I seed that it is not very stable. So, etrin join it is a first one, which is from but, it not very stable. So, after certain pride of time it is get commandeering into it get commanding into mono sulfide, it is get commandeering into mono sulfide. So, this is the mono sulfide its get commandeering into mono sulfide.

So, first thing that is formed is etrin join C H S start forming from about 1 2 hours, you know sorry, 7 to 8 hours, I mean sorry not 1 2 3 hours extra, extra not 6 7 6 7 hours is hear. So, it is start felling after some pride of time and then C H S would be produce in this manner deferent types structural changes occurs from long fibers to be know to fibers are from long fibers to shot formation locker. And calcium hydroxide is also produced.

So, excess is volume or amount an you can see calcium hydroxide volume or quantity increases with time hydration progress C H S long fiber initial from then the short for by they will sterilize short fiber. Calcium hydroxide is from, but etrin join it is from in the beginning it attends big, but then it is concentration starts coming down because, they get commandeering into mono sulfide. It is not stable commandeering into mono sulfide and C 4 A F hydrate formed, there which is not very important.

So, we can see that products those a from is first is a etrin join then C H S and etrin join gets commandeering into mono sulfide, calcium hydroxide produces to gather with C H S and mono sulfide concentration increases. Simultaneously volume of fore will go on reducing initially, most of large quantity will be larger and thus will go on reducing water and this will go on reducing because, this solids will occupies, the spaces that was originally field by water.

So, dormant pride as a mansion chemically dormant pride is actually etrin join reaction setting occurs C H S starts forming right. And then hardening is this pride of time in days setting is in hours hardening is days and if you go back to the initially it was something like this particles and water.

Next stage at this stage between dormant stage setting the fibers of C H S extra started forming prospected calcium hydroxide is would started coming outer of that and hear the lot of this fiber shot a from, lot of solid would a from and lastly as hardened structure would something like this 100 structure would something like this.

So, this is the hydration products, you know structure with changes that occurs in cement when it is mixes with water, when we jest it comes contact with water, we have seen the chemical reaction. And physically, how the hydration process occurs that, we have seen and jest have seen the you know with the time how deferent products are from how deferent products are from. So, that what the hydration process.

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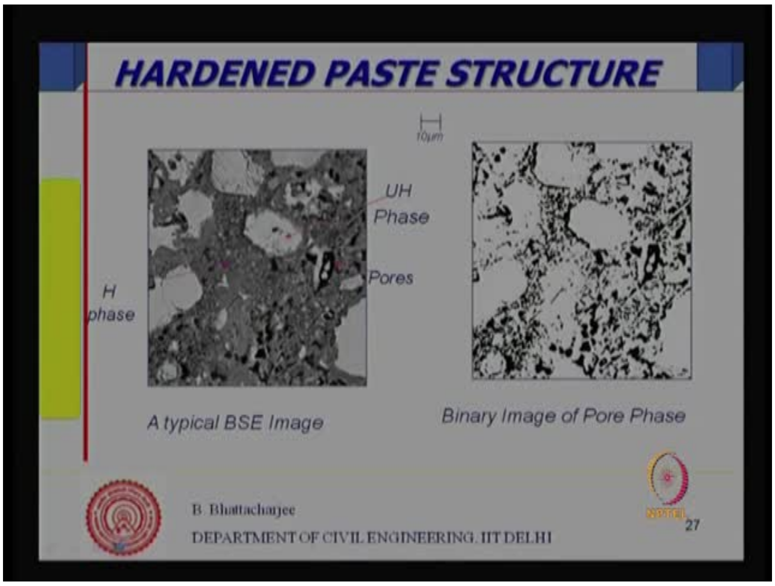

Well the 100 structure, if we look from backs ten electron microscopic becksten electron microscopic image un hydrated phase, you can see that, you can see the un hydrated phase hear right. And force on the black one infect, this all are force, because we separated out by binary separation all the black once from rest of the color.

So, this are the structure of the force by binary separation and the grey coaler the white one is a un hydrated cement, in fact calcium hydroxide is also whit largely white color and gray color is hydrated is phase hydrated phase that is you hydration product extra extra. Calcium hydroxide of course, cements is prospected surrounding aggregates or summer, they will remain non selling prospected.

So, backs ten electron microscopic confirms as the you know the process that, I was talking about infect it is from this ideas of electron microscopic and backs ten electron microscopic, the process of hydration model that is show actually as been develop actually as been develop this kind of ideas.

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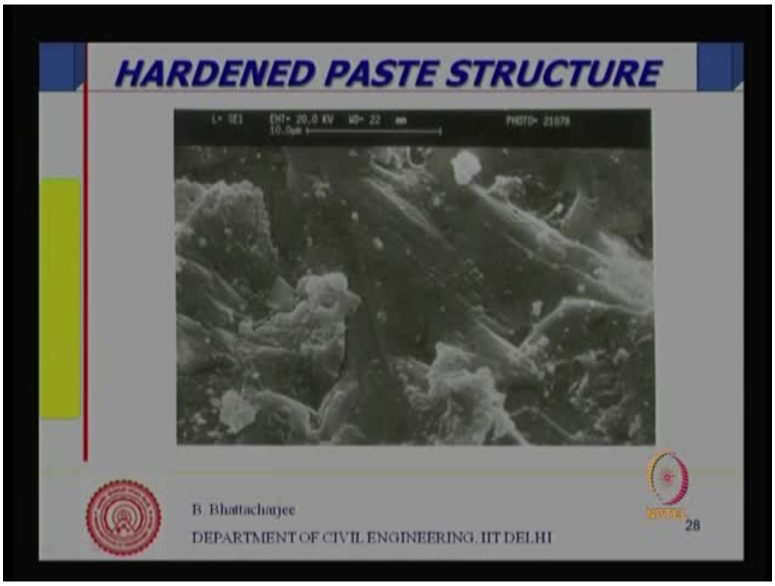

For example, we look at electron microscopic right. This they look this is the possibly calcium hydroxide, the hydration hydrated products would be something like this un hydrated products whit look something like this right.

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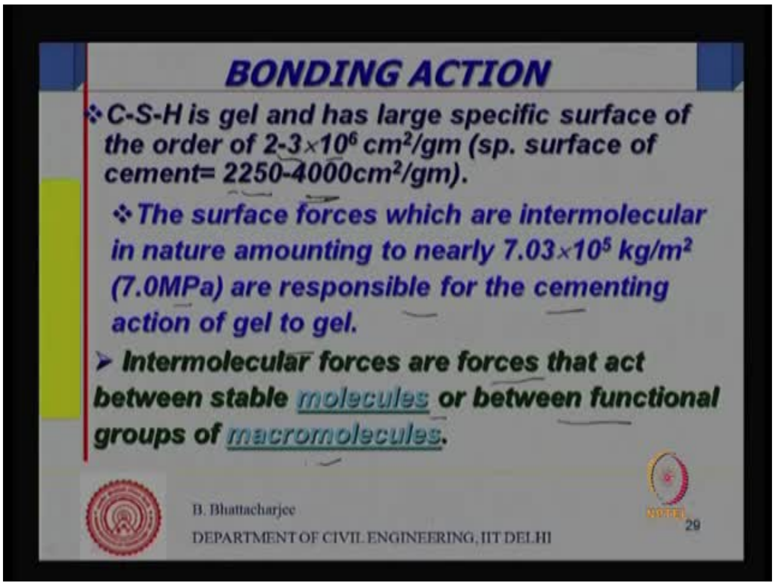

Now, have seen the structure, we can come to the bonding action will repeat of course, bonding action will initial, today but, will content do with the next class again. Is C H S gel is large specific surface and it is the order of 2 2 3 into 10 to the per 6 centimeter per gram, I am not define the specific surface as get, will actually tell, you how to major specific surface of cement.

It is the surface area parvenus mass of course, major it carton manner by certain techniques. Now, specific surface of C H S gel is very very hard and it about you know you can see that it is possibly about 1000 times more then then of cement, because it is 2 2 3 into 10 power 6 centimeter square and were it is 2.2 into 10 to power 3 to 4 into 10 power 3.

So, this 10 to the power 3, this 10 to the power 3, this 10 to the power 6. So, order is 1000 times. So, there 4 you know particles size have colvedy size, very small particles size, if you thing items of particles.

They very fine size as and therefore surface forces starts acting or dominating surface force starts acting and dominating and the surface force, which are intermolecular in nature of the order of around 7 M P A are responsible for cementing action of gel to gel. So, gel to gel cementing action is because of intermediate molecular forces, what is called Pender wolves forces will come to that so, intermolecular forces, those that between stables molecules between functional groups between micro molecules or between molecules.

So, they are called intermolecular forces within the molecule, it is covalent electable bounds but, between molecules there are carton intermolecular forces and gel to gel bound attraction is intermolecular imager this not chemical bound gel to gel. Because, gel is C H S another C H S. There are intermolecular forces between C H S gel system right.

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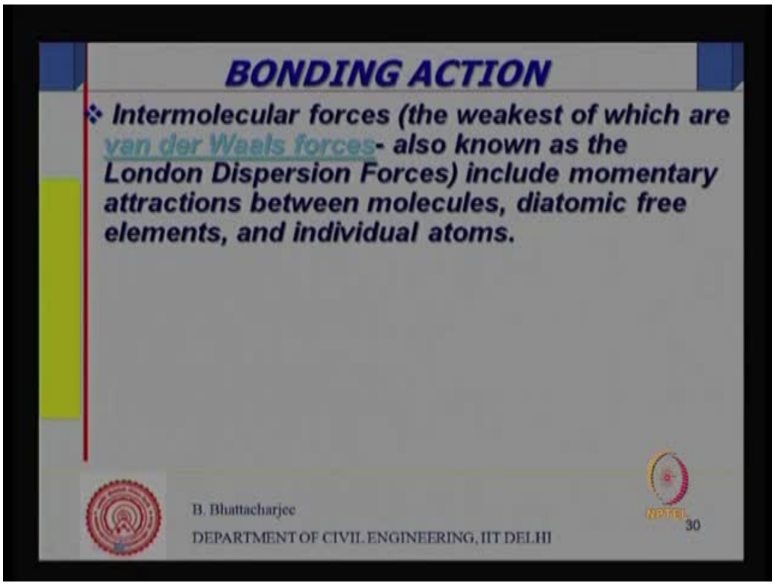

So, bounding action of this intermolecular forces, they are generally week not chemical bound not very strong you have seen that it is about 7 M P on the order of this, but actual bound could be possible more then that. Well a cement to cement bound is because of this. Now, will understand this little bit more in the next class by you know by understanding the nature of this kind of intermolecular forces little bit more, you will go into the fundamental, this little bit more what causes, this forces in material and then we fallow it afar bounding action of cement. So, we fallow it upper bounding, so I thing we should summaries it right. Now, will summaries aver discussion at this stage rest of the bounding will discuss in the next class, summarizing this what to do discussion would be.

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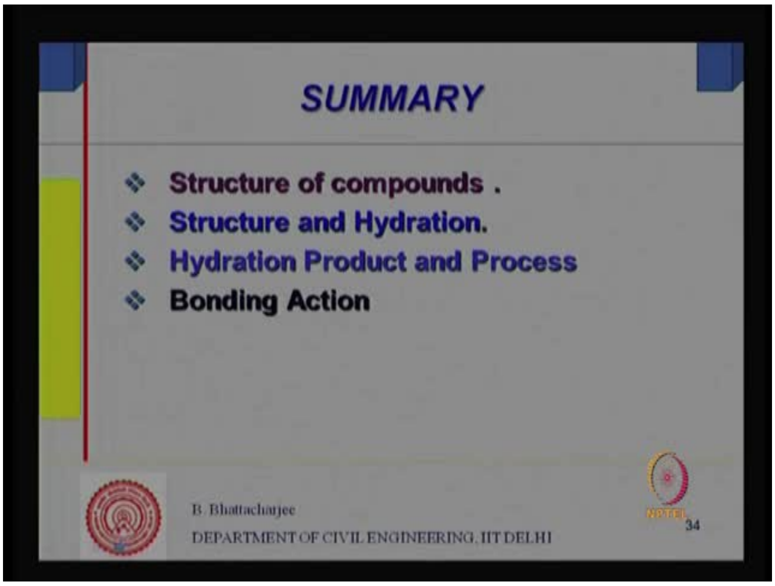

We have looked into structure of structure of we have looked into structure of compounds structure and hydration process, structure of hydration process and sum what we looked into hydration product and the process involve. And we also introduced, you bounding action bounding action right.

So, what we have look they for you, first looked into structure of the cement compounds one thing, we have identify that there are large anions, which small cations. So, therefore are not stable and can you know stable crystalline structure is not stable, because packing density is not stable packing density, therefore like many others compounds are slots actually, react with water or take water around the cation to foremost kind of stable structure.

Cement is similar kind and that is way they react with water. Basic structure of the cement compounds come from silica structure S i O 4 and that way absorbed water, we looked into the hydration process and the products that is from that mean very fine surface forces demeaning. And that way, you have bounding between gel to gel, which is not very strong, but someone strong in the next class look into this bounding action and more to fiscal structure of the cement hydration.

Thank you.