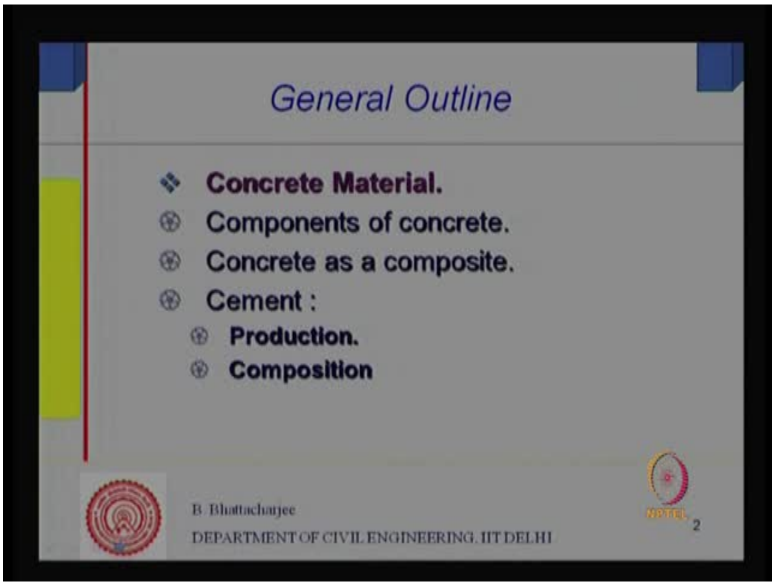
Concrete Technology
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Science, Delhi

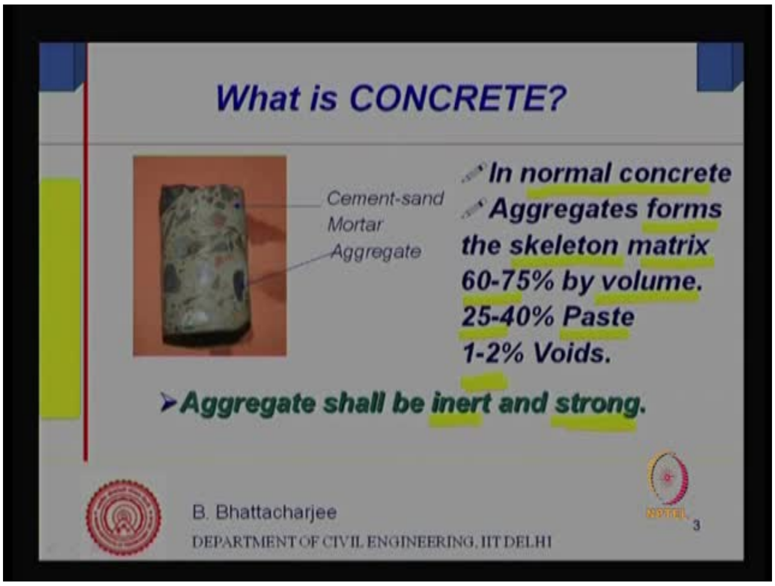
Lecture - 1
Cement Production and Composition

Welcome to concrete technology, module 1 lecture 1. We shall be discussing about cement production and composition in this lecture. Of course, we start with, we will just introduce concrete as a material, because is a coition concrete technology.

(Refer Slide Time: 00:49)



(Refer Slide Time: 01:19)

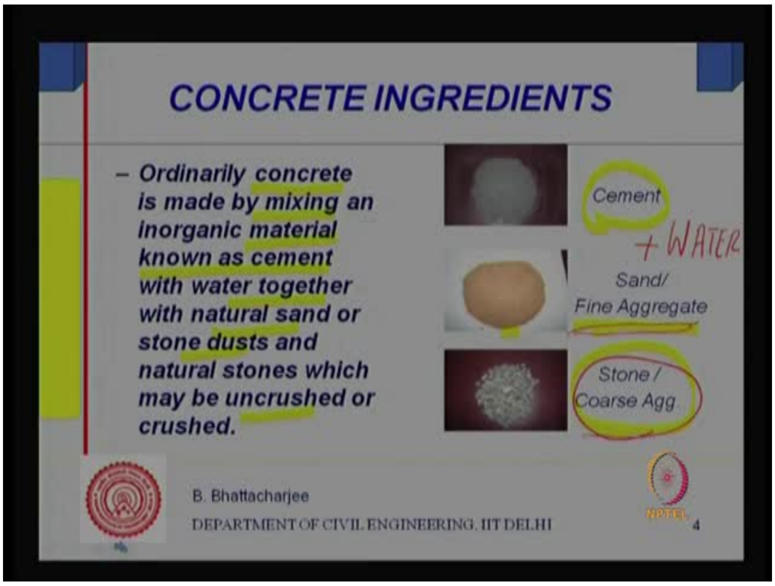


So, general outline of our discussion will be concrete material, components of concrete and also we will just mention concrete as a component. At the end, we will talk about cement, the production process and its composition.

Now, what is concrete? Perhaps you would have seen concrete or also studied about it. Concrete is made up of components sachets, aggregation of stones, which we called as aggregate embedded in cement mortar that is cement-sand mortar, in his hardened state concrete is aggregation of stones or similar hard material embedded in what we call cement-sand mortar. The aggregates, aggregates in normal concrete forms this skeleton matrix; it is about 60 to 65 percent by volume and rest all is 25 percent is a paste; now paste means cement and water, that combines to paste.

So, this aggregate when we talking of it is the large aggregation of stones, sand etcetera etcetera put together. 1 to 2 percent words are usually there in normal concrete. It is required that the aggregate shall be inert and strong, inert means should not be reacting with anything and it should be strong. It should strong, so that it can carry the load. So, that it can carry the loads, so that it can carry the concrete can which ten forces.

(Refer Slide Time: 03:15)

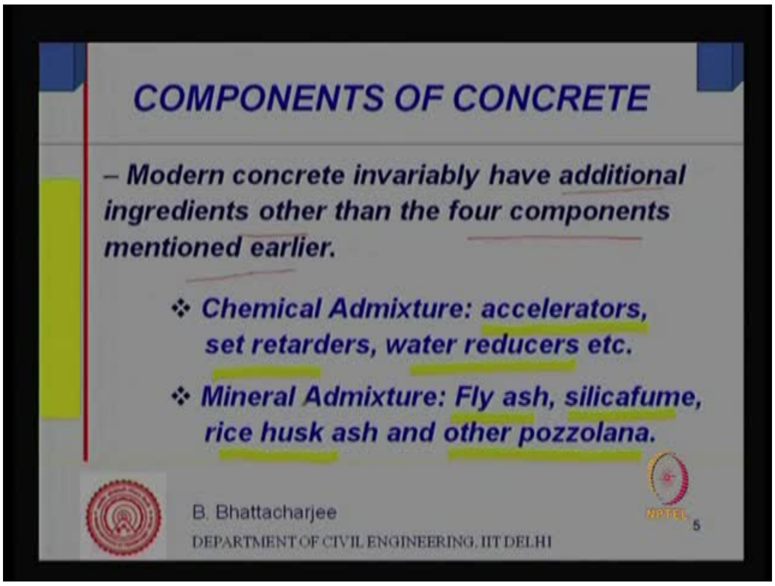


Ingredients of concrete, therefore if you look at the ordinary concrete or normal concrete it is made up by mixing inorganic material known as cement. I said cements and water, so this is cement is one other component, water together with cement forms what is called paste and the naturals sand or stone dust like something like this as we can see.

Stone dust or naturals sand and you know, in addition to that will have course aggregate which quite often could be coarse stone or natural uncrushed stones themselves.

So, there for concrete is generally normal concrete or very conventional concrete is made up of cement plus water plus water, this two makes paste, sand which are, which we called as fine aggregate, could be sand or crushed stone powder. Then stones which forms are course aggregates. So, that is generally the concrete normal concrete, generally the normal concrete.

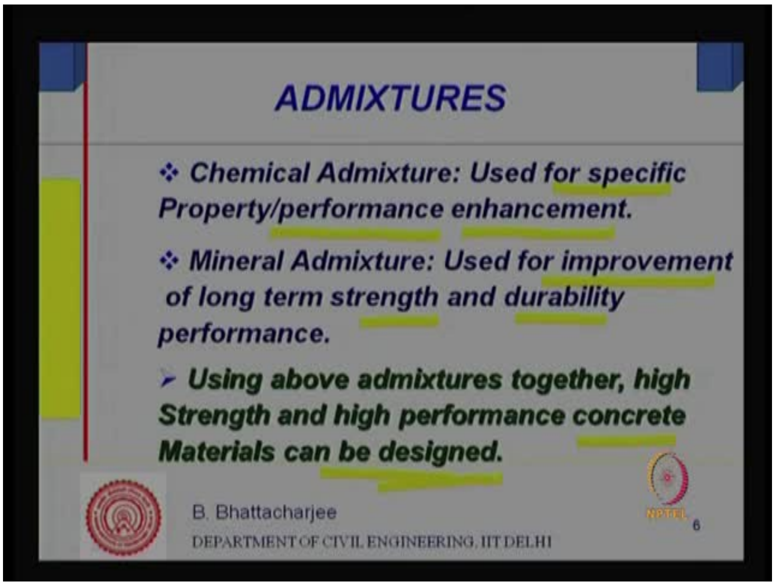
(Refer Slide Time: 04:45)



But modern concretes if you look at it, it is not only this four components, but it has definitely two more components. So, modern engineered concrete has additional ingredients other than the four components just mention, right? These are chemical admixtures, these are chemical admixtures like they some of them are called accelerator, set retarders, water reducers etcetera. This ones are added to the concrete system during production, in order to improve the performance of concrete, either in frustrate or in hardened state.

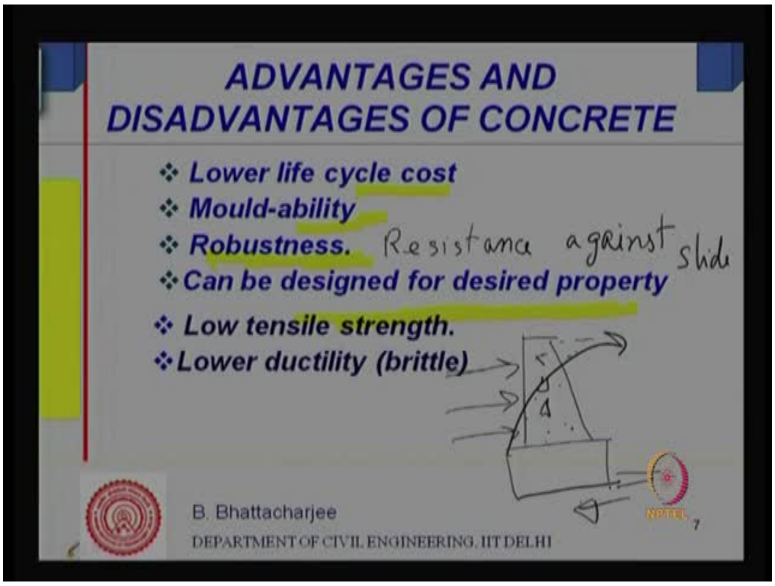
We will discuss about them later on in details. Mineral admixtures, this is the other kind of material which goes into the concrete, sometimes even in cement making and this are fly ash, silica fume, rice husk ash and other pozzolana or similar other material. So, as we can see modern concrete is not four component material, but six components material. So, a modern engineered concrete is actually six components material rather than four component material, rather then four component material, all right, okay?

(Refer Slide Time: 06:27)



Chemical admixture admixtures as I mention, therefore specific property performance enhancement. Specific property of performance an enhancement and mineral admixtures they do improve long term strength and durability performance. So, therefore these two admixtures are must in modern engineered concrete. Of course, manually produced concrete, non engineered concrete may not include this, but an engineered concrete definitely includes this two item as well. Using this admixtures it has become possible to obtained high strength materials, you know modern high strength and high performance concrete, right? You can design the concrete as you like, so this is what the concrete is, this is what the concrete is.

(Refer Slide Time: 07:33)



Now, there are lot of advantages and disadvantages of concrete a few, the advantages are lower life cycle cost. It is relatively achieve material, right? I mean cheap, relatively cheap and you know a material it is use for construction purpose is used in very huge quantity. Therefore it is a requirement that a construction material be cheap and concrete of course is cheap. It has what we call, low life cycle cost. Now, life cycle cost means not only that initial cost capital cost is low, initial production cost is low, but its maintenance future, maintenance cost during service life period is also low.

It can be molded, you can mold into any shape that you like. Concrete can be mold it, it can be molded to any shape that you like. It is robust it is robust what it means is that, what we means mean is that, robustness, what we mean is that, were I need emissivity it can provide that emissivity. For example, if I have a structure if I have a structure let us say I have a structures like this and them already training wall. Now, horizontal forces if acting is acting in to 8, then it must have sufficient resistance again sliding. It should not slide, it should not slide you know, it should not slide along this directions. It should not slide or it should not avoid of turn because this forces will have a tendency to causes it to overturn.

So, it must have a sufficient resistance against sliding, so resistance against sliding sliding and over turning, that must be there. This you can get from concrete, this you can get from concrete not for let us say, it is very difficult to make a retaining or dam out of plastic. Let us say even steel you steel you can, but steel is it is not very common. But concrete can provide this kind of concrete, can provide this kind of robustness, concrete can provide robustness. You can design it for desire property, you can design it for desire property whatever property you want, you can design it for that, it is a, it is a composite.

Now, a composite is a material as you know, is made up of number of material or ingradience, which were combined together you know, when they are final material produce. It has a property different than the original material use in his production. So, concrete is also a composite and composite concrete you can design by braiding the proportion of ingradience or changing the ingradience themselves. You can design for desire property, not of course very well versatiled but, quite well versatiled because it has got two weaknesses, it has got two weaknesses. One it has got lower tensile strength and other it had got lower ductility.

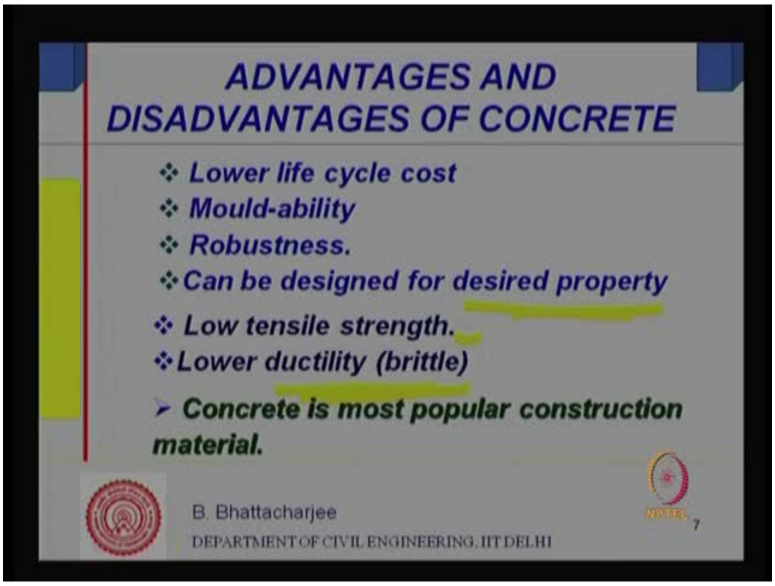
Now ductility is a property by virtue of which the material exhibits a large amount of deformation proir to failure and such large deformation ensures warning, prior to failure, it does not fail suddenly. But particular system bounded by cementing material as in case of cement as we have seen. That it was aggregates, which are bound together in a mortar matrix and if you go further the mortar itself is made of cement paste in which we have sand, so concrete is a composite. First aggregates are and better then mortar matrix and in mortar sand is embittered cement paste. If you go further down to final sizes, you will find cement paste itself, has got different solid components as well as force etcetera etcetera.

So, is a composite and its actually particulate system bounded together. So, one can call concrete as a chemically combined ceramics also, chemically combined ceramic. A composite is composite you know, and its actually composite if you look at it its composite form vary scale to scale. The scale of structure it is almost a we quite an often assume it to be macro homogenizes. But if we go to slightly finer scale you will find aggregate a mortar. You go to steel finer scale, you will find its is paste and sand, hardened concrete I am talking of. In the paste itself there are different solids which will discuss some time later on.

So, it is composite and each scale its composite nature of the composite varies. And you know, It becomes more and one complex as we go to the fines. Properties of the final products actually is dependent on the micro level composite as well. Any way will talk about this sometime later on, but what we on the stand, this is a particle its system bounded by the cementing material, such material do not show exhibit, do not exhibit large ductility. They feel suddenly, so it is brittle. So, this are the two disadvantages, but it is quite at but advantages from other point of view.

Now, to take care of this accepts, we actually put in steel rain for cement. You use rain force concreters a composite or pressured the concrete. Therefore when we use concrete as a structural material, we really use it alone, accept for ingrabidi dam or massive structure, were we use mass concrete. Rain force concrete or pressured concrete, which are again another form of composite, they are quite versatile and there we can design them almost for whatever property we desire.

(Refer Slide Time: 14:39)



So, that is why the statement and that is why concrete is a most popular material in you know, in the are… In fact it is water, the human being consumes possibly water and next material is concrete. In fact cement is next to water consumed by human being, right? So, this are the very popular material just because it has got all this advantages.

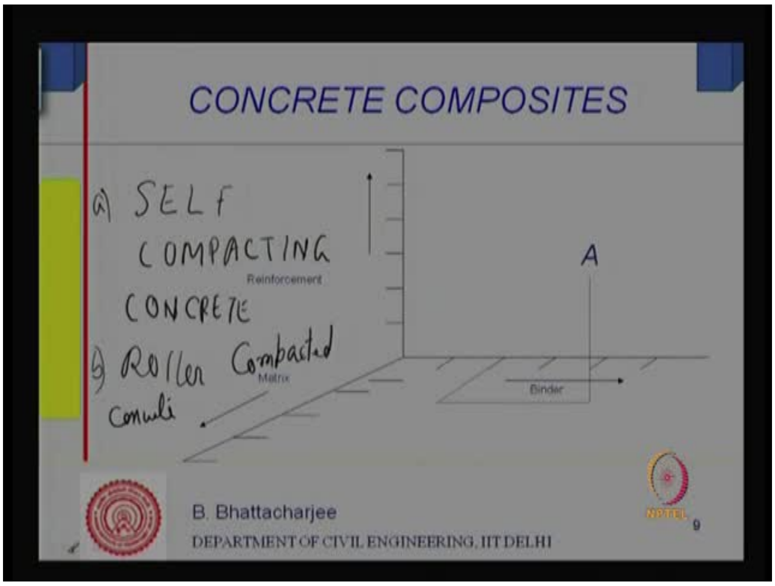
(Refer Slide Time: 15:11)

So, concrete and concrete composite system, some of which we will be discussing. Like it is not only one type of material, it is verity of material today. Modern concrete there are verities and we can classify them something like this normal strength concrete, high strength or high performance concrete, ultra high strength concrete or some composite special composite very high strength will discuss. Some of them at the end of our you know, in the last module.

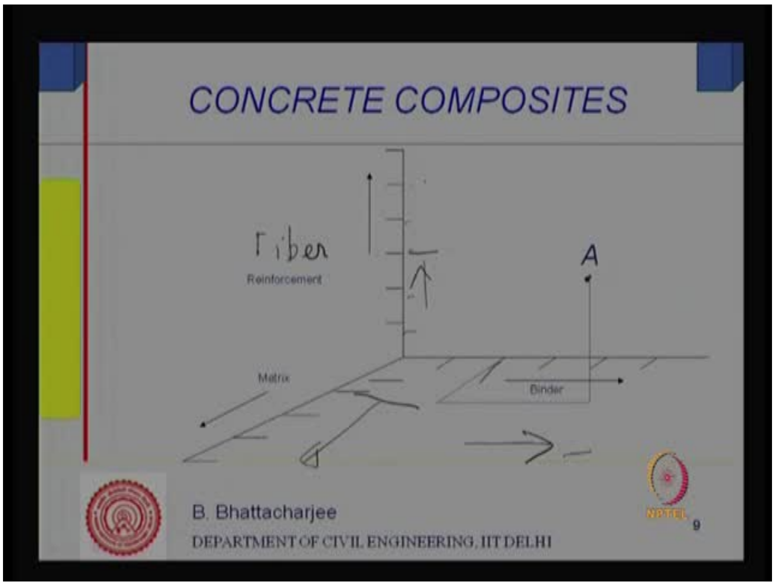
Then fiber reinforced concrete, then they something called densified with small particle, which will possible come into ultra high strength system. Macro defect free matrix, which is again in ultra high strength system and reactive powder concrete which are again ultra high strength system. All this will discuss in details, at the movement time I am just introducing to you the name of this concrete or cement based components, will discuss about them at length sometime at appropriate time.

Then there are something called polymer concrete, polymer modified concrete or polymer cement concrete, self-compacting concrete and some more self-compacting concrete, roller compacting concrete, some more more additional additional, once are self-compacting concrete, roller compacted concrete etcetera.

(Refer Slide Time: 16:42)



(Refer Slide Time: 17:34)

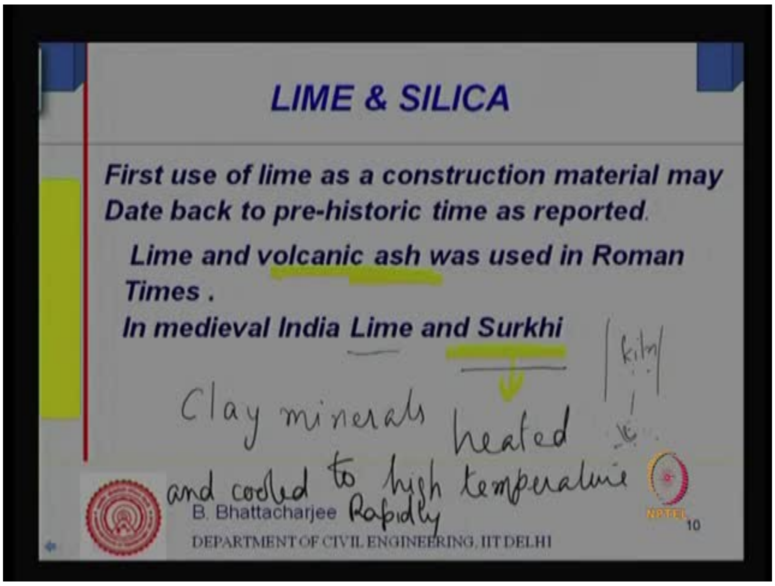


We will discuss them at a proper time, in fact in generally we look, in generally we look at concrete, the binder scan be them in our many binders like I said polymer concrete. So, therefore it as also a not cement base composite, but its concrete of some type or polymer cement concrete were polymeric material is added in almost like a admixture. So, you can have a difference type of binders because you can have a varieties of cement as well the matrix is skeleton.

I am talking of here it is a matrix is skeleton, that can also vary and I can put varities of fiber reinforcement to obtain the composite. So, therefore concrete, there are lot of choices, choice are available to me in terms of the binder, in terms of the matrix, in terms of the fiber. Like a is a material, which has got this binder, this matrix and may be some here is a reinforcement because I can use varities of fibers in the system.

Will discuss about this special concrete some time later on I mention. So, this is the just give an oval view of the concrete, before we start with the actual discussion of cement, right? So, let us look at now cement. A little bit of history you see mankind use lime and silica for quite some time.

(Refer Slide Time: 19:15)

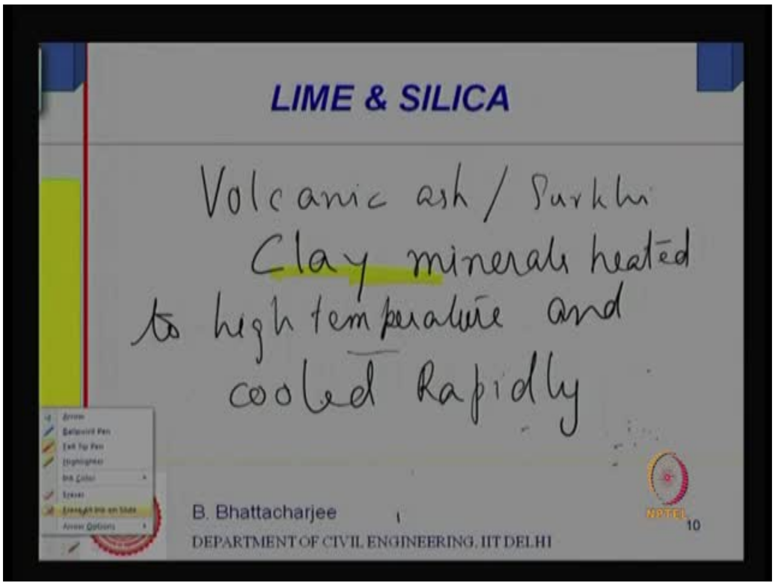


In fact, first use of lime as a construction material as reportedly in literature. You know, they actually found out one of the, one of the article professor Iron Benthur, you know, there, some were some of the people from Israel, they could craze. The first use of lime something to pre historic time possible 7000 years from now, lime was used as a construction material, right? If you look at roman civilization, they used lime and volcanic ash, right? Because Italy there are volcanic cases available there and they used them.

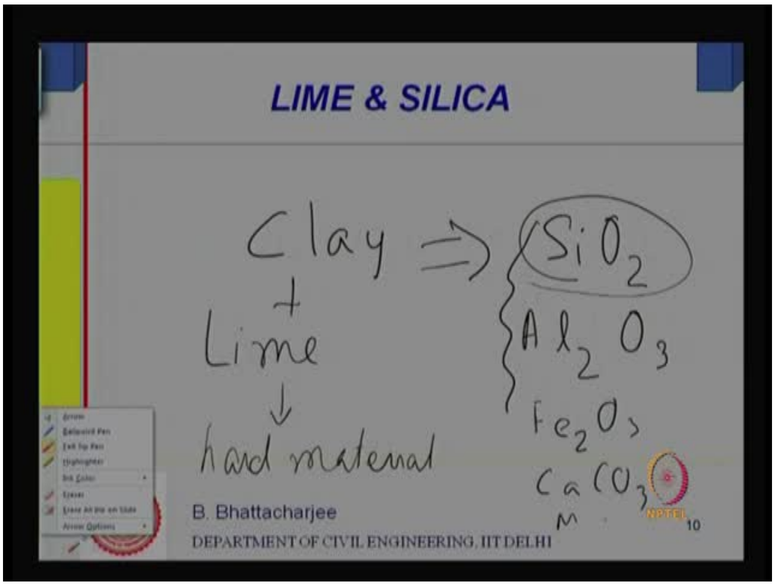
So, lime an volcanic ash in medieval India people are use lime and surkhi, lime and surkhi. Surkhi is a material which comes out from (( )), when you burn the brake then there are fine dust which settle downs below. You know, when you burn the brake, when you burn the brake when you burn the brake in a kiln, so there is will be a fine dust, if this is the brake kiln let us say and find dust will settle down at the bottom, this is called surkhi.

Then, lime and surkhi was using India also largely as a binding material of stones to produce concrete like, concrete is a artificial stone. So, mesmery in mesmery contractors or something of similar kind, so bind the stone, stone missionary lime will gives us use. Now, what is surkhi or volcanic ash? If you look at if you look at volcanic ash or surkhi, they are nothing but clay I can say, clay mineral heated to high temperature and cooled rapidly, right?

(Refer Slide Time: 21:52)



(Refer Slide Time: 22:58)

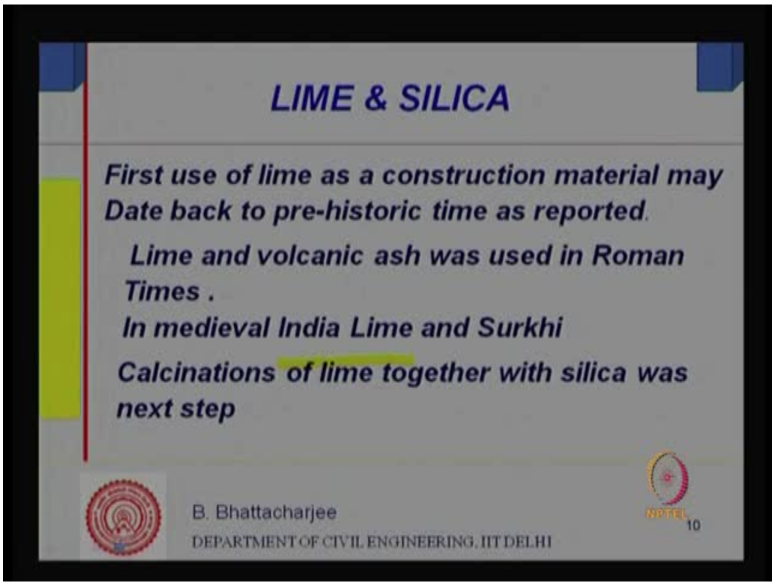


In fact cay you no volcanic ash or surkhi and nothing but clay minerals heated to high temperature and cooled rapidly cooled rapidly cooled rapidly. Now, what is ash chemically or clay minerals?

Essentially this are, essentially clay is essentially clay is silica alumina, some amount of iron etcetera etcetera magnesium all this, but main compounds are silica alumina. So, what we are doing? You are heating up silica and alumina and then cooling rapidly is is also same formation of a more for silica amaphor silica not crystalline amaphor silica and in amaphor material in crystalline material atoms are arranging regular order. So, there at low ward potential energy, they are electively stable.

Amaphor material on the other hand atoms are all haphazardly arranged and it is resettable can react. Provided physically this material is this material is fine, so that large surface area is available for reaction. So, when it comes to surkhi or volcanic ash this are clay material heated up and they cooled rapidly. In fact they will some amount of emerged trade into it chemical energy trab into it. It forms a ore fast material and if it fine and conduce of condition it can react and dissipate that chemical energy. So, amaphor silica fine a more for silica can react with lime and can give you hard material, hard material solid hard solid like stone.

(Refer Slide Time: 25:13)



And this is what was absorbs by you know this is was utilized in Roman time or even in India, even in India. Now calcinations of lime together with silica obviously was next step. So, in case of the earlier once, this this material volcanic ash were known as posalans, will come to that again sometime later on. Now, this material together with lime in presence of water forms are hard mass, you know almost like stone. Say wards a surkhi with lime and water forms hard mass, now this are reactive silica basically.

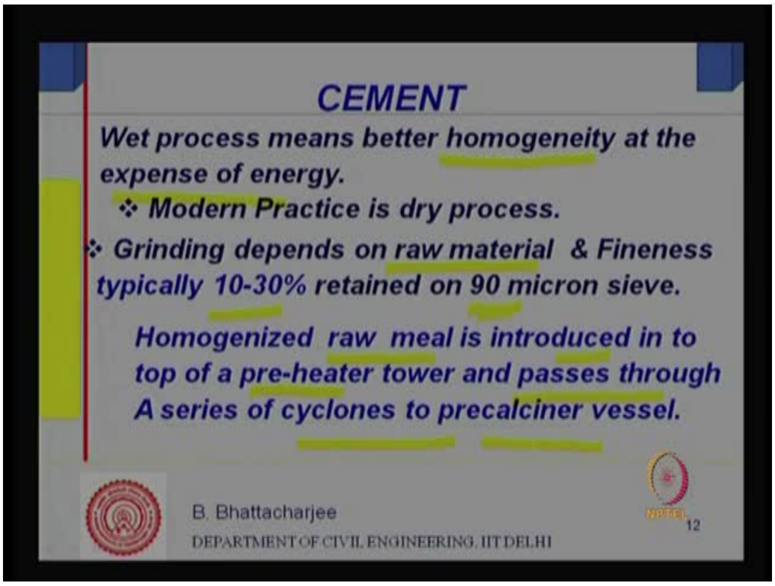
The surkhi or the pozolone are the volcanic ash, so the reactive silica can react with lime in ordinary temperature. But lime an silica if you combined them together and burn it, then you know, that could give lies to a product, which can react with water itself because in lime surkhi reactions your lime surkhi and water. Now, lime an surkhi put together heat them up and form into a compound, that can react with water to give you seminal hard mass. So, that is the idea of cement.

(Refer Slide Time: 26:40)

Actually the most commonly used cement is called Portland cement patented by Joseph as paten in England in 19, 1824 and this when mixed with water hardens. Since, it s mixed with water, it hardens we call it hydraulic cement. You know Portland died is a stone name and from that it got the name of Portland cement, right? So, this is what? This is a cement, so therefore in this one basic raw material used in this manufacture is calcium carbonate. The lime and the lime you know, the calcium carbonate which you can find in lime stone or chalk and silica and alumina and iron found oxide found in clay or shale.

So, the difference here is you are putting them together and heating it up and do you of course, some more is just a little bit of processing for the process will come to that and in case of lime and surkhi or lime or pozolona lime and volcanic ash, you are actually used, using a reactive silica together with lime get similar of products. So, Portland cement is this, ordinary Portland cement as we call it. It is actually produced from lime and clay or shale. So, basically essentially you are using the silica alumina an iron present in clay or shale to get the cement.

(Refer Slide Time: 28:25)

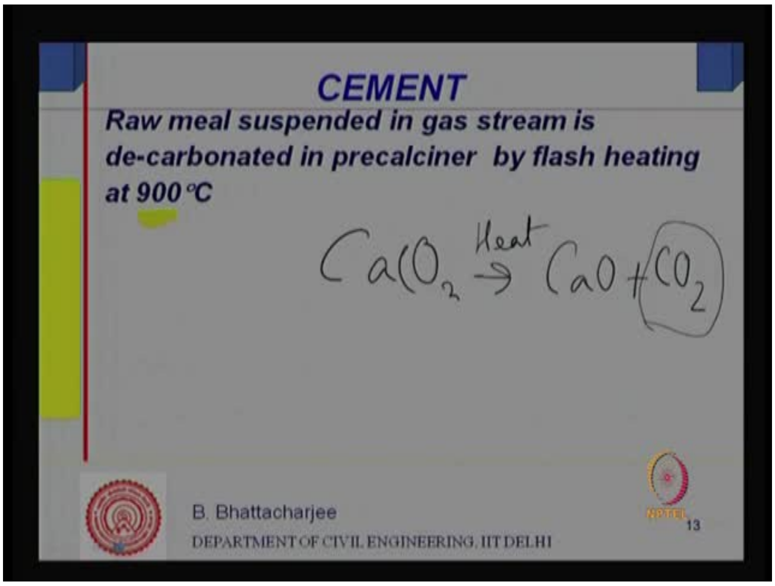


There are two processes, well there are iron say, there were they were one process called weight process, which is now not use much. So, you have to essentially mix up lime and silica in a appropriate proportion and weight process was used were they were made into slurry and you know you get homogeny mix of the two. So, in the wet process one would have got better homogeneity about 40 percent would have been the water, in this slurry but then when you heated you have to drive over that water there for energy used his more.

In drive process in the technology improved in the second half of last century and there for 90 and 80, so onwards you do not find in were process any more it is mostly the dry process. So, modern practice is dry process, essentially what we got to do? You got to mix lime and silica or clay and glam stone in an appropriate proportion and you got to grin them to fine size, grined them to fine size and amount of grinding will of course, depend upon the raw material. Generally granite up to 10 to 30 percent retained on 90 micron, sieve 10 to 30 percent retained on 90 micron, sieve 10 to 30 percent retained on 90 micron, sieve and this homogenized then, then you mix them up grinned.

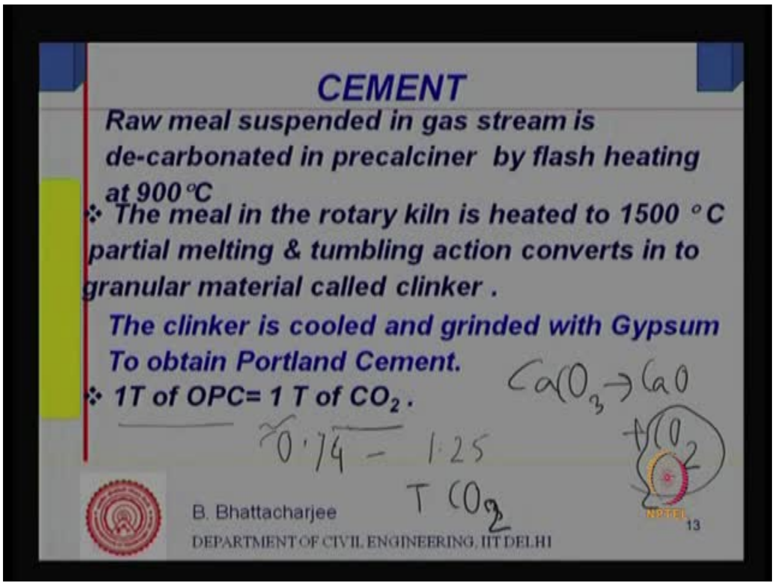
Then this is called row meal and this homogenized raw meal is introduced into the top of a pre heater tower. This passes through a series of cyclones to precalciner as it is called, passes through cyclone separator, cyclone sapper series of cyclone separators to precaciner vessel.

(Refer Slide Time: 30:48)



There it is subjected to flash heat, sudden temperature rise of 900 degree centigrade in gas stream and some other carbon dioxide from the lime is given out because you know, you know calcium carbonate is lime, which you heat to result in calcium oxide carbon dioxide. So, calcium carbonate some of the carbon dioxide measured good lot of carbon dioxide is given of here.

(Refer Slide Time: 31:34)

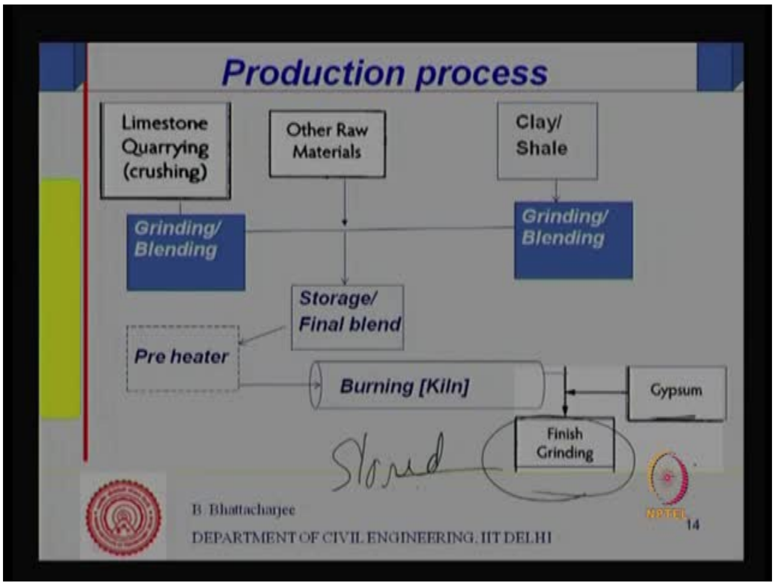


And this material then is allowed to entire into a rotary kiln and then heated to 1500 degree centigrade which causes partial melting. The tumbling action of the kiln converts into to granular material called clinker. So, this clinker because you know, it well melt. When you heat this material it will melt form solids solutions and because of the tumbling action the form into granular material and this is called clinkers. So, this is called OPC clinkers. The clinker in then cooled, so ground grinded with gypsum to obtained ordinary Portland cement or portland cement, portland cement. One issue is important write at the beginning, just let me introduced here.

Since, carbon dioxide is you no calcium carbonate brings down to calcium oxide pus carbon dioxide, therefore you are producing carbon dioxide, in addition you are using energy or heating. And when you use an energy for heating you might be using fossil fuel in some form other and people are actually calculated there about point 7.4 to 1.25 or 26 turn of carbon dioxide which is produced, carbon dioxide is produce from one turn of ordinary Portland cement production.

So, that but on an average you can say that one turn of OPC produces one turn of carbon dioxide, which will be an important points of discussions sometimes later on. Because with the concerns of global warming and green house gas emission, carbon dioxide is one of the green house gases along with water vapor and methane etcetera etcetera.

(Refer Slide Time: 34:17)

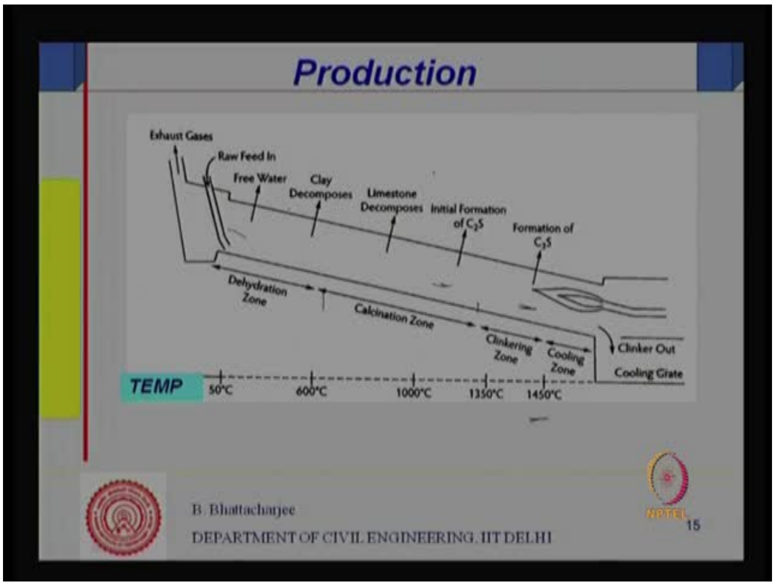


This issue has become very very important that cement produces carbon dioxide, a greenhouse gas. therefore OPC clinker consumption should be minimize or it should be use as judicially as possible. So, that so at the beginning itself I just one point out here, which will be discussing sometime later at some appropriate of time, right?

Diagrammatically look at this product process diagrammatically if we look at this production process you will have lime stone coring may be some other raw material you might be adding as flaxes things like that to control the clinker formation temperature clay or shale this is the other one and this together both of will be grinded and bended to get in an uniform mix of the two. All this are mix together to get a final blend, which I can stored somewhere, have I raw meal, raw meal which I can feed now to the pre heater or pre calsyner, were I have like slices cyclones, it will get heated.

Followed by some other carbon dioxide, we removed. After the pre heater, pre heating then it will go to the kiln kiln burning kiln were once the product is form this will mixed with gypsum and grinded by you no finish by grinding. So, this is what the production process of cement clinker looks like, right? This can be then stored, this can be then stored in a proper ate manner.

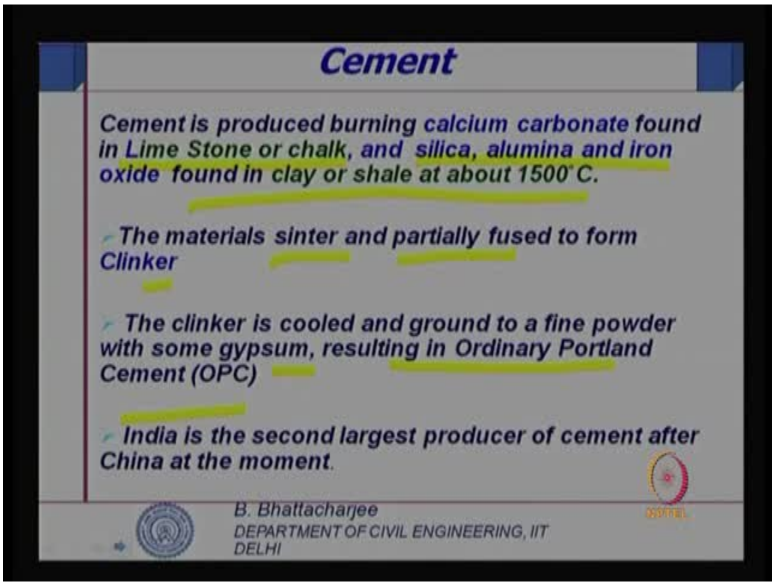
(Refer Slide Time: 51:56)



If we look at the kiln where, you know, the feed enters this is d hydrations zone ,were water will move out if there is in free water at 50 degree to 100 degree centigrade. At 600 centigrade clay decomposes, right? All exist gasesgo out through this, so therefore water vapor will move out along this directions. The heat is supplied from here through by warning process, you know? There the burner, so through you actually supply the heat. This zone is summer here is 1500 degree centigrade, this in clam a little bit, so that an this rotor nickel.

So, its rotate at 600 centigrade clay will the compose, then lime stone d composes. This is the calcinations of lime stone will take place in this zone of 600 to about 1200 1300 degree centigrade and this decomposition of lime stone results in carbon dioxide, w hich will go a with the exhaust gas. Then formation of C 2 S or another compound in the cement clinker that take place. C 3 s forms at somewhat higher temperature. This is called clinkering zone and then you cool it, the clinker goes out cool to about 60 degree centigrade also. Then later on you can mix up with gypsum very amount of gypsum and grind it, grind it.

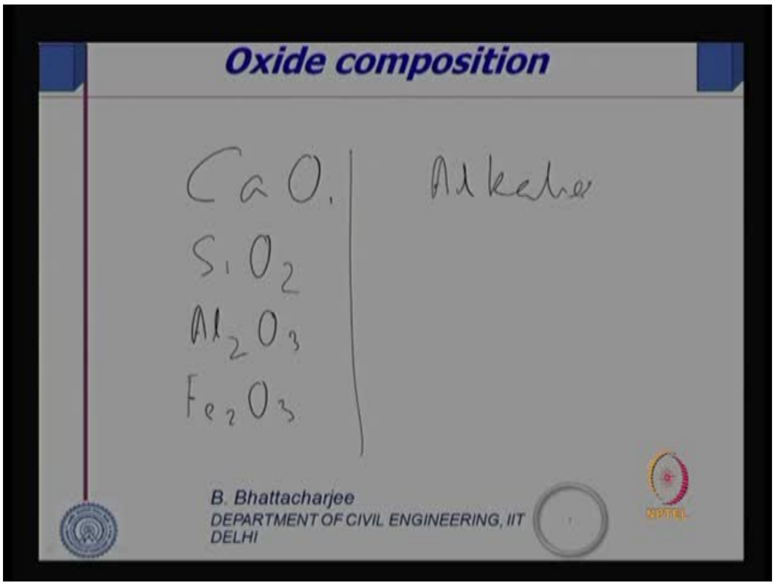
(Refer Slide Time: 37:36)



So, therefore if I summaries the cement production process, cement is produce by burning calcium carbonate form found in lime stone or chalk, right? Found in lime stone or chalk and silica alumina and iron oxide found in clay or shale at about 1500 degree centigrade 14, 1500 degree centigrade. The material centers and partial refuse to form clinkers. The clinker is cooled and ground to a fine powder with some gypsum, resulting in ordinary Portland cement.

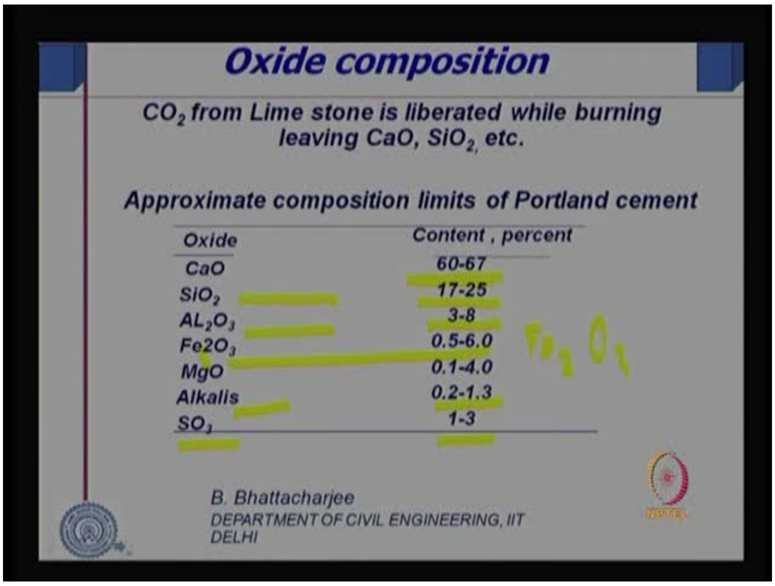
Well, one important point is at a India is the second largest producer of cement after China at the moment. In fact we we you know, we have being second large producers cement for quite some time, lot of infra structure you know, construction going on. All across China and India producing the maximum amount of cement now. In fact cement is again I said next material after water which is consume by human being and of course, India contributes to a large chunk in this production of cement. So, what is that the production process is all about cement productions, let us see the composition. Now, if you if you we can quickly understand, that there will be calcium oxide calcium oxide because calcium carbonate bound to form to calcium oxide.

(Refer Slide Time: 39:15)



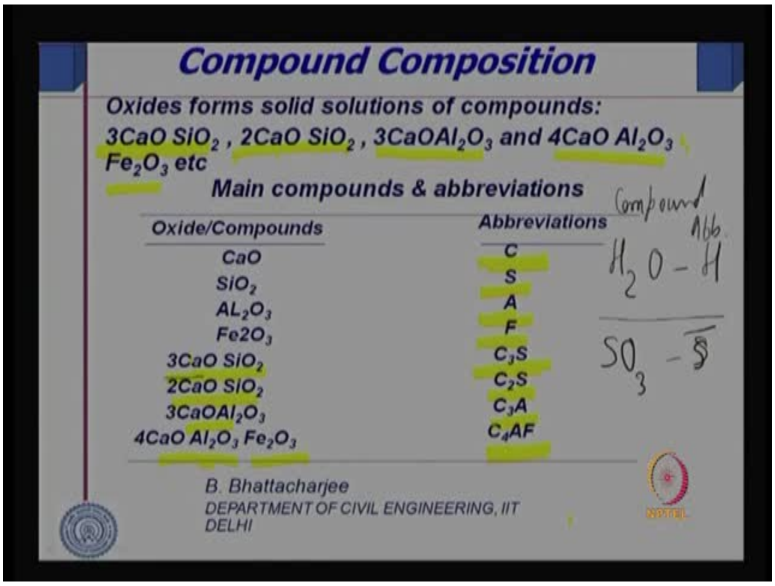
Obviously I will have Si O 2 and other materials available in clay, right? Fe 2 O 3 and some fluxes, which are added, so they will also be there. So, the oxide main oxides composition, it would be alkenes of course, alkenes. Then other impurity etcetera that will be there are magnesium oxide. That it usually then they controlled some of them come from the ingradience raw materials and some come through the process and then the oxide composition oxide composition are controlled depending upon the performance of the cement that you desire, right?

(Refer Slide Time: 40:09)



So, carbon dioxide from the lime stone is liberated while burning, therefore calcium oxide and Si O 2 would be there and approximate composition limits of the ordinary Portland cement if you look at it. Generally calcium oxide it would be, calcium oxide would be 60 to 67 percent. Silicon oxide Si O 2 is 17 to 25 percent aluminum oxide is 3 to 8 percent. Iron oxide is should be Fe 2 O 3 or Fe 2 O 3, the 3 should be subscript 0.5 to 0.5 to 6.

(Refer Slide Time: 41:19)



This is controlled, alkalis 0.2 to 1.3 percent. S O 3 is 1 to 3 percents. This are the oxide compositions of cements, this are limits actually given typical limits of oxides given you know, when most of the codes all over the world the ordinary Portland cement will have this kind of limits of oxides.

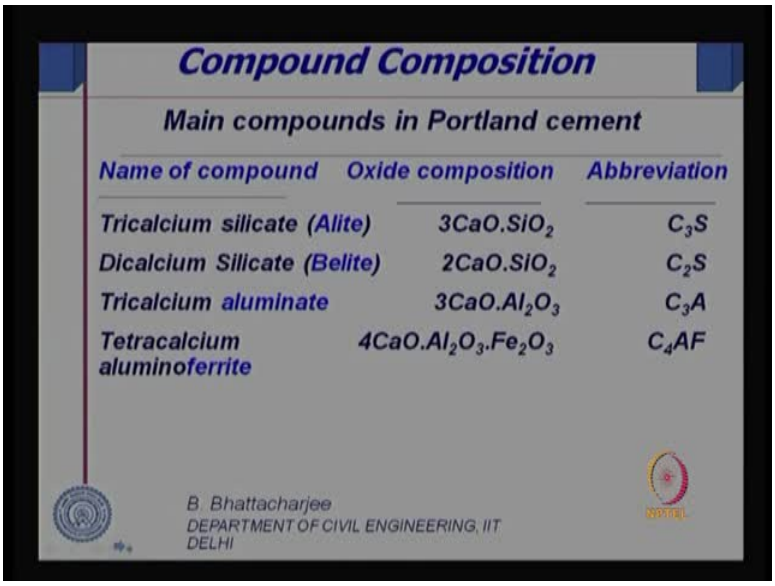
Now, this oxides actually found in solid solution forms and compound while you no clinkers formation occurred within the kiln, because they are partially melt, the compound main compounds, those are present in cement are recognized as you know this are the solid solutions, they are this compound 3 Ca O Si O 2 2 Ca O Si O 2, 3 Ca O l 2 O 3 and 4 Ca O Al 2 O 3, Fe 2 O 3 etcetera, etcetera. 4 Ca O Al 2 O 3 Fe 2 O 3, this is combined, this together etcetera. These compounds we, the names will come to them, but before that since this are the compounds and you can see their complex compound actually, complex oxides. So, therefore we do not write instrument chemistry we write do not write them, time an again. 2 Ca O Si O 2.

We abbreviate them, so oxides are actually abbreviated in cement, chemistry or in discussion with us to cement and Ca O abbreviate as C, Si O 2 we abbreviate as S, Al 2 we abbreviate as A and Fe 2 O 3 are abbreviates as F. Well some more abbreviations are something like this, all those is retained here, but sometimes it might be using it H 2 O, we abbreviate as H, H 2 O we abbreviate as H. So, the compound water abbreviations. Similarly, S O 3 we abbreviate as abbreviate as S bar because S is already there, so we abbreviate as S bar. So, this will comes sometimes later on, right?

Now, if I use this abbreviations, then this compound this compound can be a retain, this compound can be retain as C 3 S, this compound can be written as C 3 S, this compound can be written as C 2 S. So C 3 3 3Ca O tri calcium silicate, tri calcium silicate we call it. Di calcium we call it, d icalcium silicate I will come to the name, name I have not really mention to you.

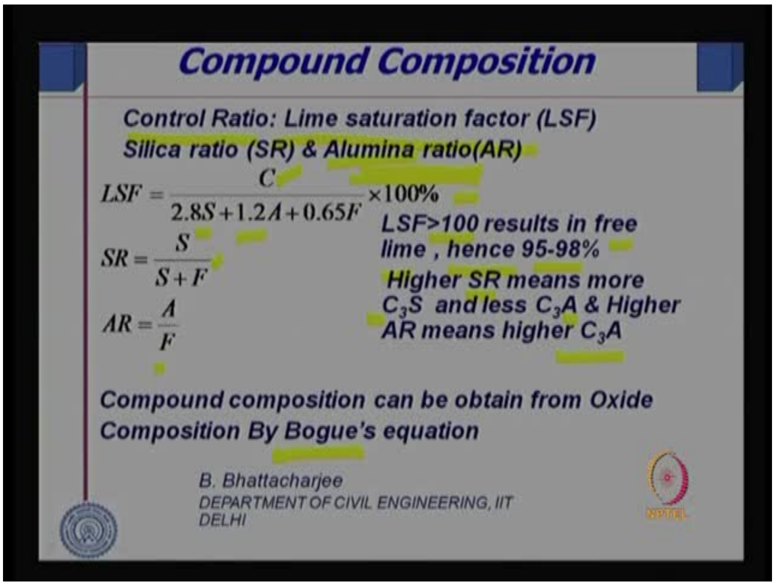
Tri calcium aluminates, we call it C 3 A and this is called tetra calcium aluminous ferried C 4 AF tetra calcium aluminous ferried and that is C 4 AF, all right? So, this is the abbreviated form of the compounds and now on words will be using mostly this and surly not this kind of compound functions this.

(Refer Slide Time: 44:01)



So, let us see the name nomenclature, main compound in Portland cement tri calcium silicate this is this, then we abbreviate as C 3 S. We also the mineral name is alite. So, it is a mineral logical name is alite. D I calcium silicate it is a mineral logical name is belite and it is 2 Ca O Si O 2 or C 2 S, so alite and belite. Tricalcium aluminate is 3 Ca O, Al 2 O 3 or 3 Ca.

(Refer Slide Time: 45:07)



It is mineral name is aluminate, the bue colour signifies the mineral name, but its compound name is tri calcium aluminate. Tetracalcium aluminoferrite, so tetracalcium alumino ferrite C 4 AF is abbreviation and is mineral name is ferrite. So, alite and belite of the two compound, which has got silica and aluminate and ferrite of the compounds were there are alumina and iron present iron an alumina present.

Well, it is important. Then you control the properties of the cement because there are performance will depend upon, I mean properties of the control the composition of the cement because performance depend upon the compound composition. We will see that, each compound actually behaves differently than the others. Although it is possible is very difficult to actually identify directly C 3 S, C 2 S etcetera in cement if you take cement identifying directly other microscope or something or separating usually it is not easy. Although, you can identify them through, lets us say techniques analytical chemical techniques.

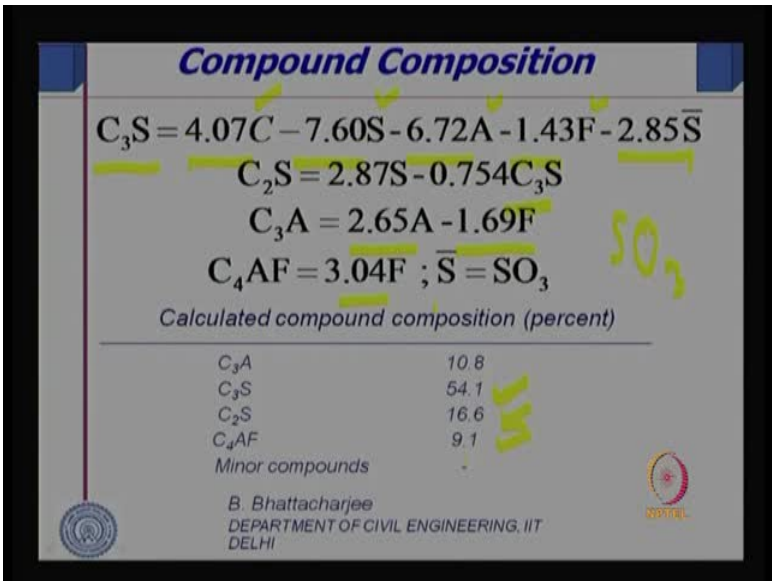
Now, there properties would be governed by the the properties are governed by properties are governed by composition of C 3 S, C 2 S etcetera, etcetera. Now, therefore there are some control ratios lime saturation factor is one of them, lime saturation is factor is one of them, silica ratio and alumina ratio are the two others. So, we shall see that how they control? Lime saturation factor is defined in this manner. This is the calcium oxide, divided by 2.8 S Si O 2 1.2 A 0.65 F expressed usually as percentage. So, lime saturation factor is nothing but the ratio of calcium two some factor multiply you know, some 2.8 multiple by the silica content 1.2 multiple by alumina and n 0.65 by multiply by the iron Fe 2 O 3 expressed at percentage.

Silica ratio is divided by S plus F plus F and alumina ratio is a by F. Now, how do that matter? If the lime saturation factor is greater than 100, you have some lime which will remain un combined free lime. So, it is more than 100 percent, right? This lime saturation factor more than 100 percent, then it results in free lime, un combined lime will be there; calcium oxide, because there now too much lime in this system and it cannot react.

So, they will remain as un reacted, so therefore the you no compound composition of oxide that is present proportion of oxide is various oxide, there is are very, very important. Now, generally it is maintain from 95 to 98 percent, lime saturation factor it is maintain 95 to 98 percent. Higher silica ratio means more C 3 S, so higher this means more C 3 S less C 3, C 2 S and obviously C 3 A. So, if you have high silica by you no silica ratio you will get more of this compound less of C 3 A and obviously less of C 2 S as well as you shall see.

Higher alumino ratio means higher C 3 A. So, higher supposing I control this proportions then I can control this oxide composition, I should be able to control the compound composition in cement and that would result in different performance. So, depending upon performance or type of cement I want to obtained, I can control this controlling, control ratios, in order to get appropriate compound composition also compound composition also is cement calculated. From oxide composition by and equation called Bogue's equations. Bogue's equations this is an empirical, we have determining.

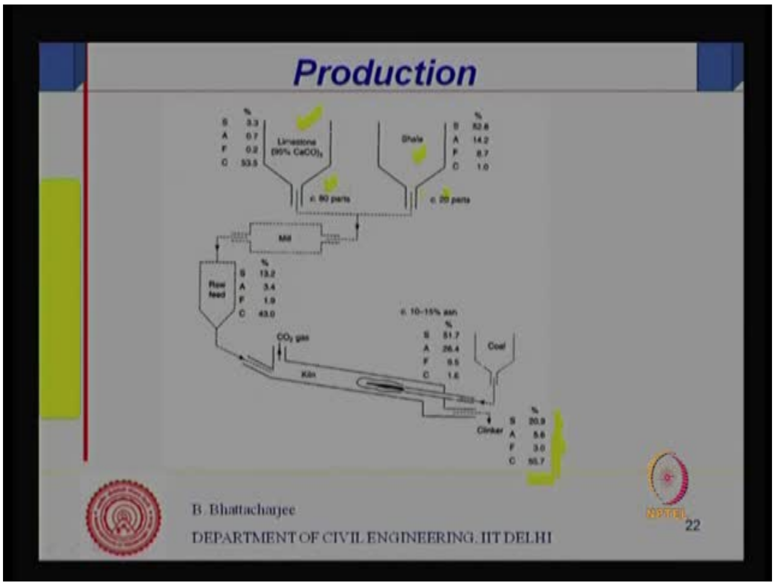
(Refer Slide Time: 49:09)



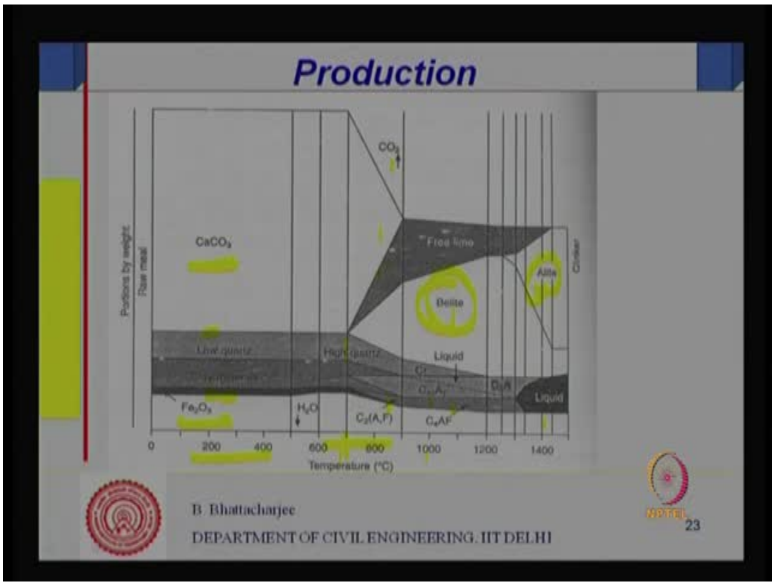
This is what it is C 3 S amount is given as 4.07 C minus 7.60 S minus 6.72 A, 1.43 F and 2.85 this is S O 3, A bar S O 3, this is S O 3 this is S O 3, so from this you can find out how much you will be the… So, if you no oxide composition, then you can find out the C 3 S composition and approximately, approximately using this are Bogue's empirical equation. C 2 S is obtain as 2.87 S that Si O 2 content minus 0.754 C 3 S. So, if you first calculate this, then from the C 2 S. C 3 A quantity you can find out from 2.65 aluminum oxide and 1.69 higher oxide.

C 4 A F is found order 3.04 S. S of course, is S O 3 as I mention. So, if you calculate the compound composition from oxide composition, then C 3 S typical something like 54.1 percent. Generally this is observes C 3 S, 10.8 percent. If you take 60, if you know, 65 percent from the oxide composition, which I have given earlier, earlier I have given from that, if you calculate out you can calculate out to find the C 3 S miht come around 54.1 C 3 S might come were there C 4 AF will be there. Then minor compounds etcetera etcetera. So, you can obtained the compound composition from oxide composition, using Bogue's equations.

(Refer Slide Time: 51:15)



(Refer Slide Time: 52:01)

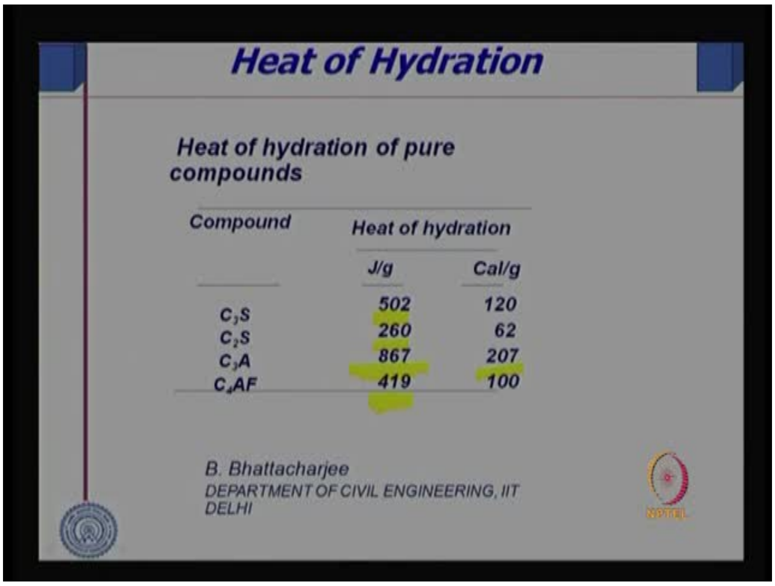


This diagram shows you at different stages what are the Si O 2 AF etcetera, like this is lime stone. then the shale. They mix together as 80 20 proportion that comes to the meal, then the raw feat to the pre heater and to the kiln final product is the opposite of 65 percent of calcium oxide, 3 percent alumina 5.6 and S 20.9 percent. So, this shows the stages, have various stages the composition of the oxide composition mixture at various stages.

This is a face diagram, in fact if we see with temperature the proportion by weight, then to start with I got lime here. This is low quartz right and the clay minerals iron oxide. Now, S by temperature increases the water has gone out 600, 800 centigrade, carbon dioxide as gone up. So, mass would have reduced, total mass would have reduced and C 4 A formation would have started here, C 4 A formation would at started here. This low quartz changes to high quartz and here free lime started producing from about 700 degree or 600 you no below 700 some were close to 700 because lime would have broken down, calcium carbonate had broken down, carbon dioxide have gone, so free lime would have gone.

As I go further C 4 A formation could occur around 1000, 1100 or 1200 degree centigrade. C 2 this this would be this is quartz they will change, this are in some liquid states which will solid if I later on. Belite forms here and alite finally, forms around 1400 degree centigrade, which we showed earlier also. That about 1400 degree centigrade C 3 S is formed. That is alite is form, the alite forms earlier and C 4 A forms much earlier at around 700 800 centigrade. So, this is the production and composition of cement.

(Refer Slide Time: 53:46)



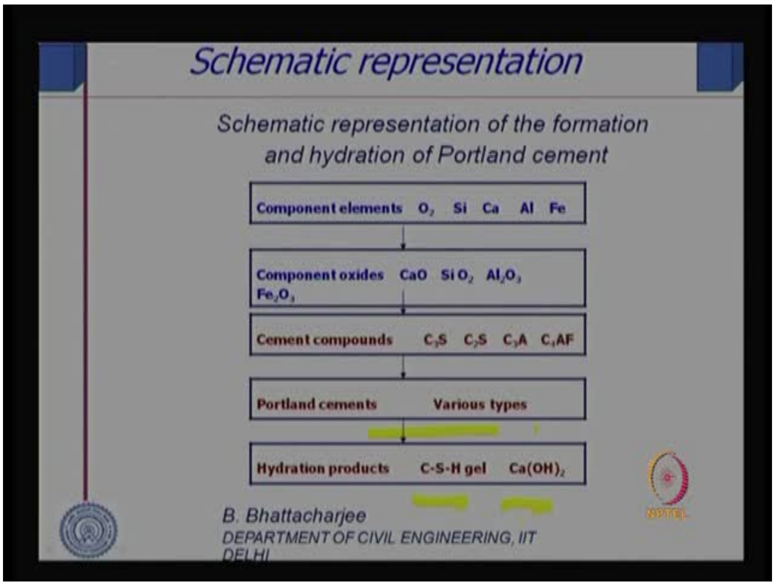
Next is, you see when cement reacts water it produces heat. It is in exothermic reactions because philosophically, we can understand this will occur we have heated this material up lime and silica I mean clay and you know, lime stone. Therefore, finally the product that is form, it is heated and produce high temperature. Now, this product will have some chemical energy logged up in to it because we have given energy to it. Therefore it will have tendency to react and it reacts with water, because that is we have seen that lime and surkhi, you know reacts with water.

Similarly, now we have producing for the raw material of lime and silica and this material the clinker grinded together with gypsum y gypsum. I will come to that some time later on, it will react with water, readily react with water it will readily with water, right? So, because it has got some chemically energy logged up its chemical potentially high, it will readily react with water and give a those energy, so the reaction is exothermic. Reaction of exothermic and the process, the reaction process we call it hydration process because you know, hydration because it at if water. Simply it have the water, so it is a hydration in chemistry.

We call it hydration process were water simple is reacting, right, getting added, so this hydration. Now, in the process of hydration of cement, hydration of cement heat is, heat ambulation takes place. So, heat of hydration occurs and if you see heat of hydration of this pure compound C 2 S C 3 S etcetera, we will find that C 4 C 3 A has got does highest value Jules per gram 867 or in calorie per gram is 207. C 4 C 3 A has got next highest as 502 Jules per gram and this is got 419 this has got least.

So, the one which is which gives out maximum heat, will have a tendency to react in the beginning, earlier. It will react, because it has a highest tendency to react. So, C 3 A has got highest tendency to react with water, C 3 S will have next highest tendency to react with water. This is a small compound, but this has a next tendency and this is the compound which will have list tendency to react with water. So, this is what it is, so heat of hydration is important from that point of view.

(Refer Slide Time: 56:37)

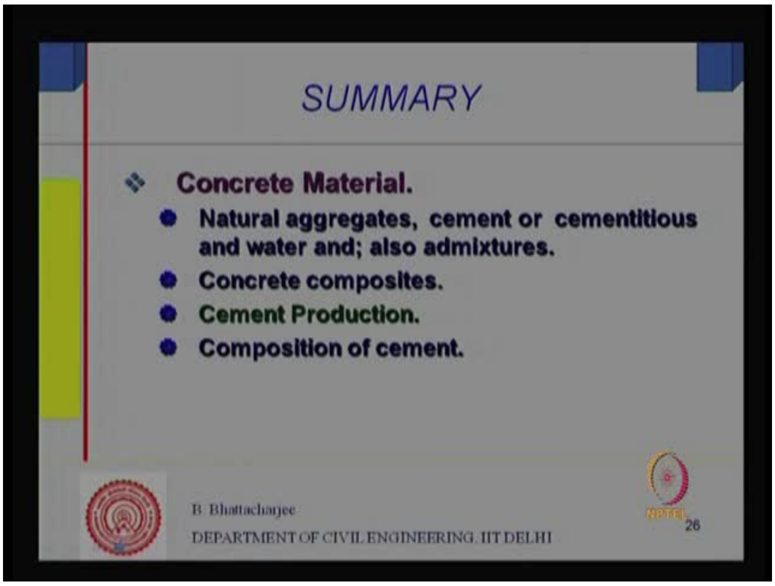


And we will use this quickly if we look now cement, the elements those are presents are oxygen, silica, calcium, aluminum and iron. Components oxides are calcium oxide Si O 2 Al 2 Fe 2 O 3 alkalis etcetera, etcetera. Then cement compounds is a form from next stages C 3 S, c 2 S, C 3 A C 4 A F and from this by combination of this, we formed various kind of Portland cements. Then this reacts and from some products which will discuss in a next lecture, right?

So, summaries this, what we have discuss today. First of all we actually introduced concrete as a material and of course, together with it cement based composites. Because concrete is one material, but today concrete is very, very versatile with cement based composite. There are many of them, many varieties as I mention earlier. So, we actually summaries them, you no introduced them by name only not gone into the details.

We also explain we also looked into that concrete is a composite made up of difference material and the properties of final product, is different than that. Also, we stayed that it is composite and depends upon the level at which you doing. So, multi level composite it is at the highest level of course, micro homogenizes, as we go should becomes a composite next level final level it still becomes composite etcetera, etcetera. Then we looked into the cement production process.

(Refer Slide Time: 58:31)



We looked into the concrete material looked into the cement a production process, right? So, we looked into components of the concrete as well natural aggregates cements and cements is you know, other, other material and water and mixtures. Then we looked into a cement production process, and then we looked into composition of cement. We will next follow, will next follow up, in the next lecture we look into the process of reaction of cement with water, which we call it as hydration products, hydration process. That products its form both in physical changes that occurs, because that cement and water when in whet together it forms of plastic paste and when its solidifies as the reaction progresses, and then we look into the product that is form hidden products in the next class, right?

So, thank you very much.