Industrial Inorganic Chemistry
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Lecture - 52
Ceramics and it is Manufacturing Processes

Welcome back.

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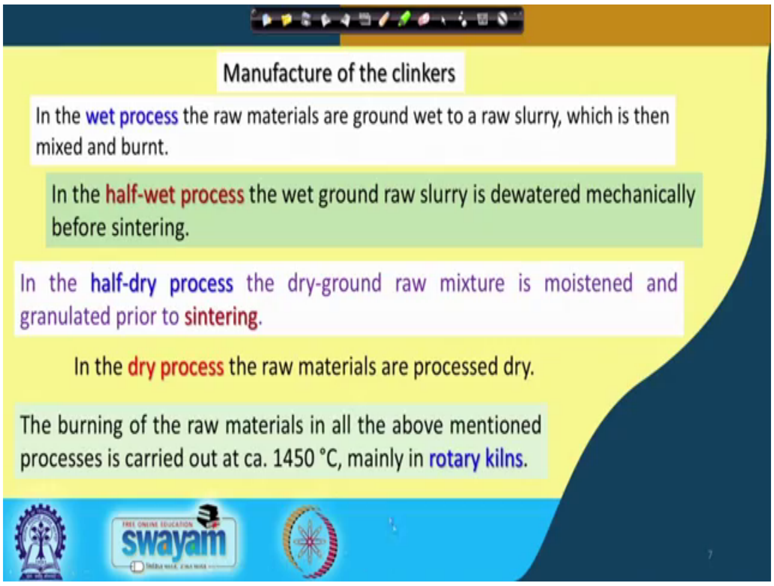

So, we are talking about these rotary kilns and these rotary kilns is the basic component for making cement in the industry.

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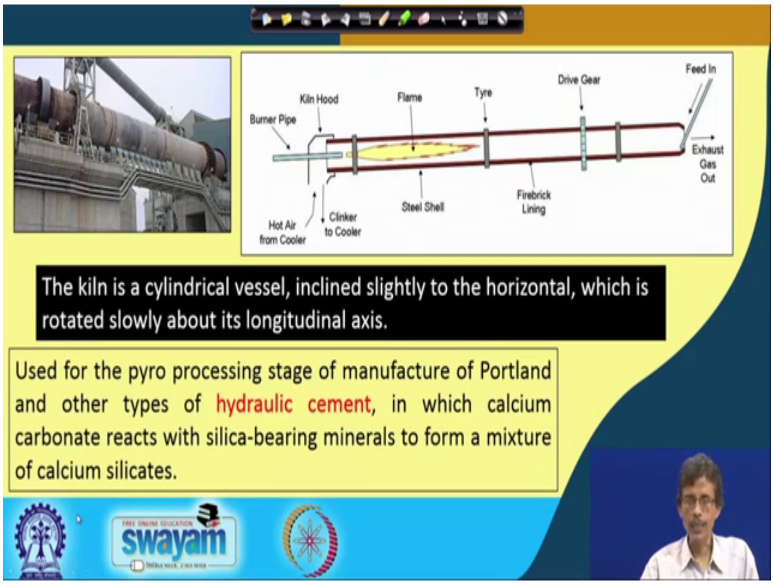

So, this is your corresponding figure for your rotary kilns, you see that a huge horizontal kiln type of arrangement, then basically jaws are there, the levers are there, and that will be utilized for making the cement. So, this kiln is a cylindrical vessel. So, you have basically a huge pipe you can consider as a huge long pipe type of thing, and definitely the structure is a cylindrical structure. So, it is a cylindrical vessel the reactor the reaction vessel we consider when we do some reaction in the laboratory or in industry and is also slightly inclined.

So, it is not a perfect horizontal disposition, it will have some slightly inclined position such that the material from one end to the other can move quite nicely. So, is slightly inclined to the horizontal which is rotated slowly about it is longitudinal axis. So, about it is longitudinal axis is sometimes it is a little bit inclined and then it is rotated with these all these particular junctions.

So, these junctions are utilized for rotating this particular cylindrical vessel. So, what should be the corresponding inside look of this particular one? So, inside look of this particular one is simply like this. So, you have this particular slide slanting. So, slight slanting is that so, the one end the end which is up basically is the feed in.

So, there is a feed inside and also this particular part that is the lower part is also this upper part is utilized for feeding the material, the raw material to the kiln, and the lower part is utilized for removing the exhaust gases, because we are burning. So, some other gases; that means, the typically the carbon monoxide and carbon dioxide because the carbonates we are taking out the moisture will also be removed, then if there are sulphur, material sulphur containing materials are there. So, the sulphur dioxide can also be produced, because it is a very high temperature reaction at the range of 1450 degree centigrade.

So, remember it at this particular temperature, everything what will be forming as the gas material will form there and will be taken out as your exhaust gas. Then these are your corresponding rotating part; that means the drive gear. So, these are the sets of gears are there, which can be there to rotate it, then the different tires these are the tires basically this is the fixing points, then another fixing point you can have. So, you have then at one end basically this particular end you have the corresponding kiln hood and then you have the burner pipe.

And the burner pipe is basically giving you the corresponding temperature for giving you the corresponding flame. So, basically directly we are using the flame inside the corresponding kiln and you have the steel cell and the frame is there. So, hot air is there the hot air from the cooler is utilized there.

So, the heated material then finally, cooled and through the use of this hot air from the cooler, basically is it require air at a lower temperature. And, then the clinker or the clinker material is basically passed to the cooler. So, during this particular processing; that means, it is used that the kiln is used the kiln is used for pyro processing stage.

The stage is known because it is the high temperature reaction. So, is the pyro processing stage or manufacturing the Portland and other types of hydraulic cement. So, any kind of hydraulic cement can be utilized for making using this thing and in which the calcium carbonate reacts with silica bearing minerals.

So, you have the typical lime, which is your calcium carbonate and that calcium carbonate will be reacting with the clay material or the kaolinite material to form a mixture of different types of calcium silicates. So, the product is your now calcium silicates in your hand.

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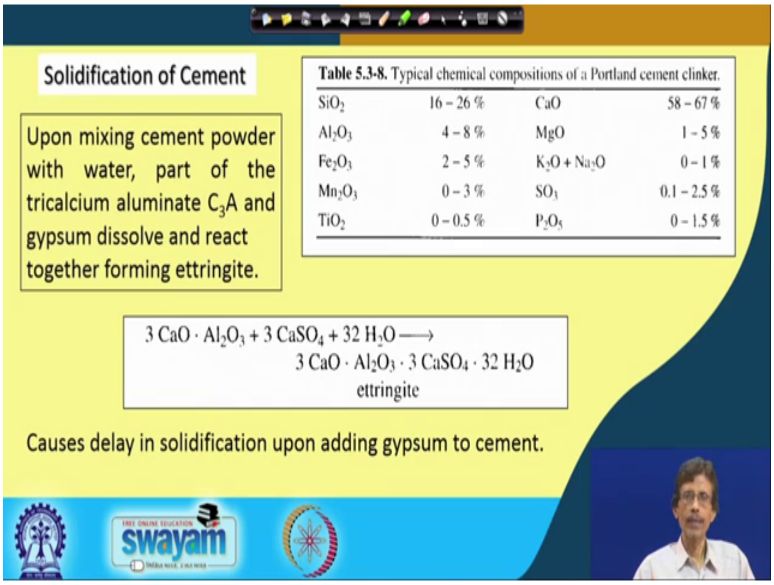

So, those calcium silicates then can be allowed for as a powdery material. So, what you get therefore, before talking in terms of either solidification of the cement is a very important reaction then we will consider, before that what we must consider over here is that, this particular one is that, that you get something as a very dry material and dry material when it is grounded. It gives you a powder material and that powder material will be very useful for making your cement material of desired choice.

So, is a anhydrous material because it is kept in the anhydrous condition it should not be allowed to react with water or the moist air. So, the packing is also something it will be isolated from the air and the moisture, such that you get a anhydrous powdery material, which is mineral like when it is reacting with water or the moisture such that you go for the hydration reaction. So, that hydration reaction will tell you that you can have the corresponding solidification process of the cement through the use of water or the moisture. So, let us see now how your solidification of the powder cement material.

You see this material is very much similar to that of the naturally occurring other kind of material we talked as your talcum powder we use for our day to day use is nothing, but your hydrated magnesium silicate. So, talc we also get, but that is powder, but that will not absorb any moisture or any air or moist air, but it is always remain as a very dry condition.

So, hydrated magnesium silicate can have a very different property which will not absorb moisture or water, but this particular material which is formed at a very high temperature, but will definitely be hygroscopic in nature which can trap and which can attract moisture. So, if you put water definitely it will react with water and the process will then be quickly termed as your hydration reaction. So, if we have considered that what are the different composition which can be achieved through that of your tri calcium, di calcium, tri calcium aluminate and the calcium aluminium ferret or alumino ferret. So, when you have the alumino ferret.

So, the basic composition of these so, the main component is nothing, but your C a 3 S or C a 2 S the tri calcium or di calcium silicates. So, the main composition of your Portland cement clinker, which is used for making the cement is your these two top material. So, the chemical composition will tell you that your silicon dioxide can vary from 16 to 26 degree so, percentage whereas calcium oxide is from 56 to 67 percent so, huge amount of calcium. So, basically it is a calcium oxide material and when you consider silica, it is a calcium silicate material.

So, together these two the highest range of these two basically. So, 60 plus almost 90 plus percentage of these so, is 93 percent basically. So, 93 percent of this thing is basically you are getting from calcium oxide and S i O 2. So, remaining 7 percent will be the different other types of oxides, which can be there and which are also the very important component of the cement material, because these can improve the corresponding quality of the cement. So, like your sand, like your salt, the cement material should not be also very much costly one.

Because only thing, that what you are using is basically purity wise, or the chemical composition wise, is basically 93 percent of your calcium silicate. Then, we have 4 to 8 percent the next higher category of percentage because you are using calcium aluminate. So, calcium aluminate is there so, calcium component is rising so, with the use of your aluminate as alumina. So, it is 4 to 8 percent then your ferric oxide F e 2 O 3 as 2 to 5 percent, then as just now I told you the hydrated magnesium silicate, but magnesium as magnesium oxide in cement is also some kind of binding behavior.

So, magnesium oxide will also be there and it can range from 1 to 5 percent. So, large number of varieties different companies are making different varieties of this sort of cement material, by putting other types of things. So, you have also the manganese oxide, you can have also the titanium, titanium dioxide and the corresponding potassium and sodium oxides 0 to 1 percent.

So, below 1 percent you have these oxides of potassium and sodium. And sulphur trioxide and phosphorus pentoxide also you can have because you cannot avoid some time, but it will be very less is only below 2.5 percent and below 1.5 percent of your phosphorous and sulphur trioxide as the corresponding oxide. So, when we mix this with water, you can think of the corresponding process of solidification. So, part of the C a 3 a, which is your tri calcium aluminate and gypsum dissolve and react together forming ettringite. So, ettringite is a corresponding mineral terminology. So, mineral like terminology or the mineral like material you get.

So, ettringite will be obtained when only C 3 a will be reacting in presence of gypsum in water. So, the reaction what you get there that is why you have you write, typically the corresponding is the way we write as the corresponding dot formula, but you can also have the full formula of your calcium aluminate because you simply add this. So, it will be C a 3 a l 2 and O 6 C a 3 a l 2 O l 6 O 6. So, this you can convert and you can have the gypsum together and water. So, if you have the balanced amount of this thing, because the corresponding form of this amount of water that is 32 water molecules.

So, when you write a chemical formula of a compound we write as the dot thirty 2 H 2 O; that means, the water of hydration is very important to that particular cement material, because we will be adding water. So, amount of water is required to get this particular formula of a complex structure is that, you are writing dot dot dot something, but you get ultimately a very complex structure, where you can have the networking of your silicon oxygen silicon linear type of chain type of thing, and some of them will be modified by oxygen aluminum oxygen bond.

So, you will have a network of all these things; that means, you will have a network of silicon oxygen bond and network further modified by aluminum oxygen bonds. And you can have some time the corresponding sulphate as a sulphate material in it, because it is supplying calcium out of that, but the sulphate will be your component over there. So, that is why your sulphur trioxide can be a basic component or the chemical composition, it should have up to 2.5 percent.

So, 0.1 to 2.5 percent of sulphur trioxide can be there such that this can also be hydrated to give you the corresponding sulphate material, which can also impart some modification in your quality of the cement.

So, ettringite will be formed thus by taking 32 water molecules along with your gypsum by your C a 3 a. So, this particular one can causes delay in solidification upon adding gypsum to cement. So, if you add gypsum, you can basically reduce the time of solidification of the cement material; that means, the very slow hydration reaction the kinetic for that particular slow reaction can further be delayed with the addition of your calcium sulphate.

So, calcium sulphate addition will therefore, be very useful it will not compromise with the quality or the strength of the cement material the concrete what you will be obtain from out of that particular cement. But, the corresponding solidification process is different and compared to that, if your solidification is very fast the strength wise these will be definitely different.

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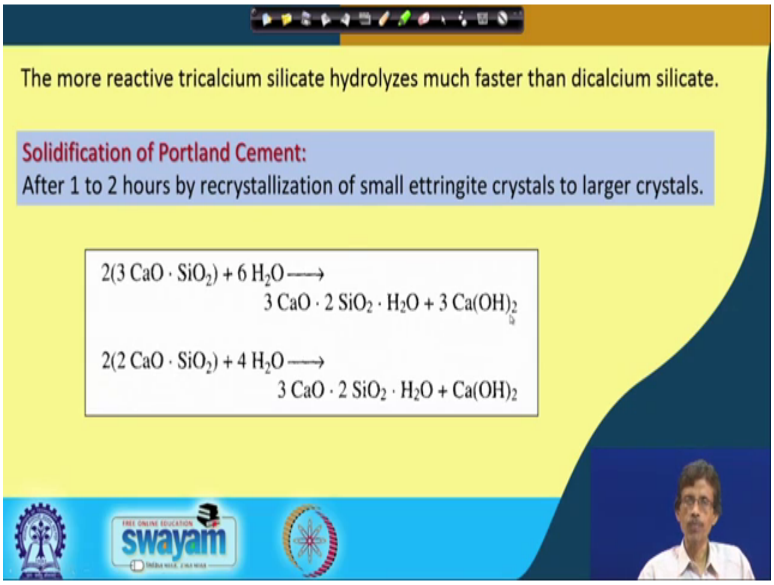

So, next we will find that if you have a tri calcium silicate, which is more reactive and hydrolyzes much faster than dicalcium silicate. So, the rate of the reaction so, these two material are; obviously, different the tri one.

The tri calcium one is showing very faster hydrolysis reaction compared to the di calcium one. So, what we find that in case of the solidification process after 1 to 2 hours, what we get that the recrystallization of small ettringite crystals are there. So, initially the small ettringite crystals are forming and within 2 hours, it will be forming the larger crystal.

So, the crystal size will be more and more. So, basically a nucleation point is there, where your ettringite crystals are forming that is basically the seed crystal. So, above that particular seed crystal you will be getting the growth of this crystalline structure for formation of your crystal of the concrete in the solid form.

So, that is why the time is also important and what we find that both these two; that means, the tri calcium and the di calcium one, that is the tri calcium silicate will react in a different form and the di calcium silicate will also react in a different form. And, but the product of these two are the same. Only the rate of the reaction are different and in both the two cases the amount of calcium hydroxide what is forming over there, that corresponding the line or the corresponding the select line we consider it as the calcium oxide plus water; that means, the calcium hydroxide what is forming.

So, the amount of calcium hydroxide formation will be different. So, you see that the type of this ettringite crystal formation from these two components will be completely different; that means, the growth of these crystals will also be different. So, if you allow more and more time and if you find, that your strength of the concrete or strength of the corresponding structure is different will also consider to makes the tri calcium with that of your di calcium. So, there must be some balance between these two component while you make the cement material.

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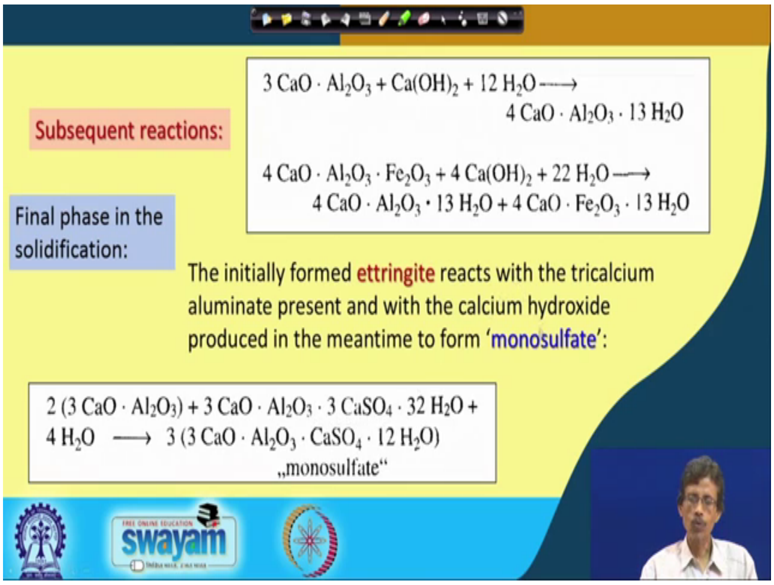

Then, we see that, there will be some subsequent reaction; that means, the further reactions can take place once your tri calcium silicate and di calcium silicate are reacting with the water molecules. So, what are those for the reaction because already we are producing some amount of calcium hydroxide out of that. So, if your now your tri calcium aluminate.

So now, tri why you have the tri calcium aluminate in the cement matrix or the cement powder? So, now, your tri calcium aluminate will come into the picture, which will be reacting with the formed calcium hydroxide in the previous reaction. So, in the previous step what we have seen in the previous step we have produced calcium hydroxide.

So, that calcium hydroxide will now react with the available calcium aluminate in the powder form or the in the mixture. Along with again the sufficient number of water molecules forming a particular species of a particular formula of calcium oxide A l 2 O 3 and 13 H 2 O, because always try to remember it the number of water molecules available.

Because these water of hydration is always very important as we all know, that simple inorganic compound like that of inorganic metal and salt like your copper sulphate, like your copper acetate all will have some water of crystallization. And those water of crystallizations are required for your crystallization process. So, when you have this you do not think that these are only the water of crystallization. So, if you heat it these will be removed, but these will be the corresponding material what is there; that means, the all these oxides and these are in the anhydrous form. If, you take out this water it will be hydrated through more number of O H bonds will be there.

So, more number of O H bonds which can further be linked through a clipping arrangement of the hydroxides. So, hydroxides can clip 2 aluminum centers or 2 sulphur centers or further, you can have the silicon oxygen silicon structure or the aluminum oxygen aluminum structure within the concrete. Then, if you have the corresponding the see that the two other component; that means, the tri calcium aluminate and the calcium alumino ferret; so, the calcium alumino ferret again it will be reacting with calcium hydroxide and 22 water molecules.

Giving the same compound of the same formula, but also some other material where you have the instead of alumina you can have also F e 2 O 3 in a similar fashion; that means, the position of those aluminum; that means, the aluminum oxygen bonds or the oxygen aluminum oxygen network linking will be substituted by oxygen r and oxygen network such that your quality of the corresponding concrete material will be different.

So, you have the initial reactions, you have the subsequent reactions and you have the final phase of solidification. In the final phase of solidification what has been formed at the initial stage, we have already seen that ettringite was formed this ettringite will be reacting with your calcium aluminate present in. So, the formed ettringite will now be reacting with the tri calcium aluminate the tri calcium aluminate will also reacting with calcium hydroxide with the calcium hydroxide produced over there and forming the monosulfate.

So, this is the corresponding final phase of reaction where we will get that. So, far we are reacting this with calcium hydroxide. So, you have now the formed thing; that means, the alumina based compound; that means, C a O; that means, the tri calcium aluminate S. Then the formed which is that earlier formed that 32 water molecules which is formed over there in the earlier stage not in these two stages.

So, this particular one; that means, the tri calcium aluminate with that of your thing what is formed out of that your calcium hydroxide. So, what do you get in the previous stage, that will be formed and giving you again a calcium oxide alumina. Now, calcium sulphate will be entrapped earlier you have seen that A l 2 O 3 has been trapped, this one you have the corresponding F e 2 O 3 has been now your calcium sulphate is being trapped.

So, you get a species or a product which is known as monosulfate, because calcium sulphate has been trapped in it. So, a monosulfate material as at the final stage of solidification process is obtained over there.

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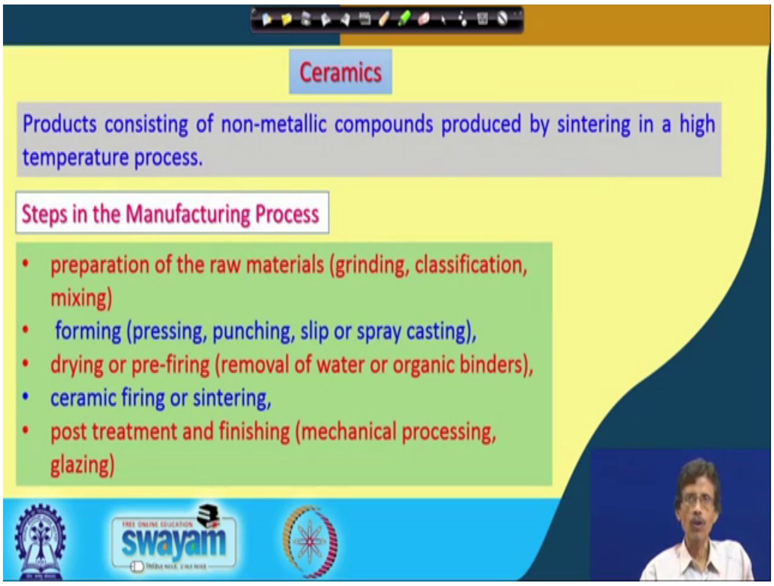

Now, with this we can move to the material, which is known as your ceramic material. So, the ceramics what how with that the difference? So, another important building material or industrially very important material is our ceramics. So, the ceramic industry we have then ceramic engineering we study also so, what are the corresponding basic inorganic chemistry involved in it.

On how the inorganic chemistry can help in understanding ceramic in a different way, from a inorganic chemists point of view, how you understand ceramics are also the ceramic engineering, or the ceramic as your material science. Because, the material science in the material science the ceramic is the most important area of research and development; so, these are the corresponding products, which will be termed as the ceramic material and this ceramic material are nothing, but nonmetallic compounds. So, you do not have the metallic part over here.

You can have some amount of metallic part after you have the corresponding compound form which is produced by sintering in a high temperature process. So, like that of our cement making process. So, this is also a very high temperature reaction. So, at high temperature some new material is forming from the very cheaply available low cost naturally occurring material. So, that is why is a very old industry people are trying for several thousand years for making this ceramics, but we are modifying, year after year and will be utilizing for some other good purposes. So, what are the basic steps basically?

So, the fundamentally how you get, how you make these all these things? So, what are the chemical reactions or the inorganic chemistry happening over there, during the process of this manufacturing of the ceramic material. So, quickly we see or we summarize these processes. So, these are the 5 different or the distinct steps you can have the first step is compromising of the preparation of the raw material always in any industrial processes. This is the most fundamental process of understanding or learning, that how you know how you get those raw materials. And these raw materials are available naturally or sometimes it is processed a little bit.

So, one of them is that how you make thus the nature of the material, whether you get it as a huge stone or a lump of the material. So, the grinding is there, then classification; that means, that separating out of all this thing and then again mixing of this individual component to get a mixture of these raw materials. In the second step is the forming step the name is itself is the forming how you form these things. So, is the processing or pressing of this particular mixing material, then punching, slip or the spray casting. So, is the casting process.

So, you get that. So, you have some mold and you get that the molding material and you get something as a casting material. Then in the third step you go for drying or pre firing, either you dry at air or you go for firing process; that means, not the final firing, but is the pre firing. So, initial drying process, which will remove the water; that means, the water vapor which basically we know that which can remove at a temperature of 120 to 150 degree centigrade. So, at that particular preheating temperature, you can remove water. Then some other organic binders, if already added those organic molecules, you can burn those organic additives in the fourth step what we get the actual firing process.

So, actual firing process is the ceramic firing process and then the sintering. Sintering basically when we heat it the gas molecules are coming out through that particular bulk material. So, you get a fluffy material. So, when all these glassy that gas molecules are coming out which it is escaped completely from that mixture, your material will basically then settling down, and it is in the sintered phase, and well it is centering it is forming sometimes a glassy type of material. So, we get a sintered bed also within the crucible if we heat everything within a crucible.

Then in the last step we have the post treatment; that means the finishing step and the finishing process. So, is basically a mechanical processing and finally, the glazing, how you improve the corresponding phases or corresponding surfaces of the ceramic material.

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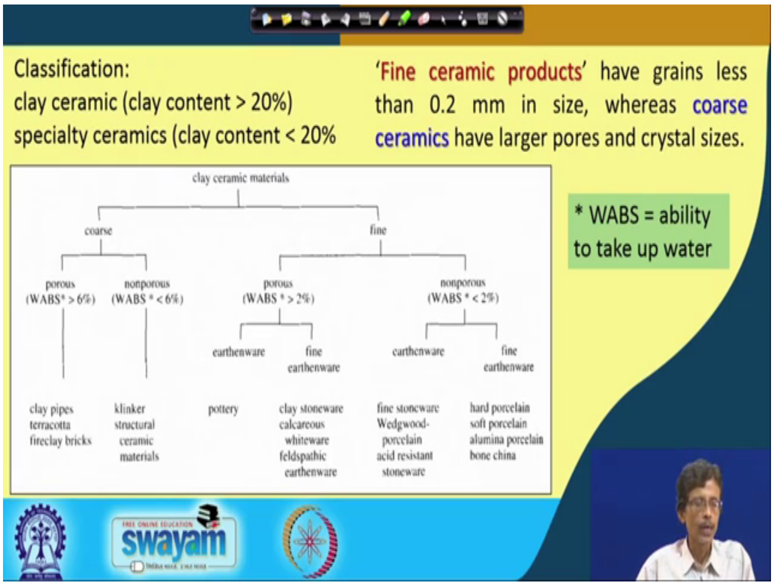

Then, if we classify these materials in terms of two types; one is your clay ceramic which can be considered as the corresponding component as the clay component, we all know this is also a very cheap component. So, when the clay component is above 20 percent, we consider this as only the ceramic made of clay material; that means, is that clay ceramics.

So, the clay ceramic material can be obtained by looking at the corresponding composition, but if we move from there; that means, if we try to have a speciality ceramics for special purposes or special use, that will see the large number of ceramic materials nowadays industrially very useful and very importantly we use in different sectors.

So, if your clay content is less than 20 percent we consider this as the speciality ceramic material. Then, we can have something which we considered as the fine ceramic products. So, the speciality ceramics the material wise, then the physical characteristics of that material will also tell you that you can have a fine particles of those ceramic materials.

So, the fine ceramic products you can have where the grain sizes are very small. So, if your grain sizes are less than 0.2 millimeter or so, we can consider them as the fine ceramic products, but if it is above the particular size of 0.2 millimeter, you can consider as the coarse ceramic. So, the coarse ceramic have the larger pores as a result and have the bigger crystal sizes.

So, these are the basic quality; that means, the component wise as well the size wise; that means, the component wise if we considered as the corresponding composition, chemical composition of the ceramic material and the physical characteristics of this ceramic material will tell us the corresponding huge classification. So, you take some time basically at this point to remember it very nicely, that you can have the first category; that means, the clay ceramic material. So, we will have two types; one is your clay ceramic material and another is the speciality ceramic material.

So, when we have this first type you divide quickly by these two types, that one is the fine type and another is the coarse type, as we have defined it as a size category. So, when you have the coarse type coarse type is will be porous and non-porous. So, porous and nonporous type can also be obtained with that when one particular parameter is leveled with that which is W A S B. So, W A B S; what is W A B S? W is the ability to take up water, that how much water it can be it can trap.

So, the amount of water that particular material can trap. So, that will tell you that it has a highly porous structure. So, if it is above 6 percent; that means, the ability to take up water is above 6 percent.

So, 6 percent by weight it can take up that water molecules, you can consider as the porous material or otherwise it will be a nonporous material, though the size of the particles are about 0.2 millimeter, which we have defined as the coarse clay ceramic material. So, the first category the porous materials are used as the clay pipes, only very rough category of these clay pipes, terracotta material we know that different types of terracotta material we can have and fire clay bricks.

Because, the fire clay bricks are all of porous type, because where we use these fire clay bricks for making the industry furnace, even the blast furnace, so, any type heat resistant furnaces high temperature with stand we use these fire clay bricks. So, is the special type of bricks we always know earlier we are used these fire clay bricks for making roads also.

So, the terra cotta is also there then the clay pipes is, but the basic thing is that these are all porous; that means, it can take up huge amount of water vapor or the moisture. So, it can also a good absorber for the moisture, but for the nonporous material we can have the clinker structural material, we have seen that how we get the cement kiln for the clinker material. So, clinker structural material then for making the ceramic material also, we can have the one of the component is that your clay ceramic materials. So, that basically gives us that idea, that we can have this. So, for the fine category basically, for this fine category of this thing again we can have to do division porous and nonporous.

But porous can further be divided into two depending upon it is use one is for the earthenware and another is the fine earthenware. So, fine earthenware is basically more sophisticated one, but the typical earthenware we know that is the corresponding industry is the pottery industry. The clay based industry the pottery based industry this. So, basically all the pottery material the pottery industries are very huge industry we all know that most of the time we use as the pottery material. So, the earthenware we use so, the pottery material, but when you go to the fine material the fine earthenware, we get the stoneware, the clay base stoneware we get.

The calcareous whiteware the color is typically very white and feldspathic earthenware. So, you have more and more of the feldspar material that is why it is the feldspathic earthenware. So, still we are with the earthenware material; one is of the rough category and another is of the fine category. So, the fine category you can have more divisions and we can use for the different purposes. Then, lastly with this clay ceramic material we can have the fine earthenware material of nonporous type, where your water absorbing ability is less than 2 percent. Because in case of the coarse type it is 6 below 6 and above 6 and in the fine category it is above 2 and below 2.

So, that is the only difference with the parameter of W A B S. W A B S parameter will tell you all these classification of this clay ceramic material. So, you have this then earthenware the fine stoneware Wedgwood porcelain, then acid resistant stoneware also, acid will not attack. Because is a nonporous and very fine category, then lastly we have the finest one that is the fine earthenware of nonporous type.

So, fine earthenware of nonporous type will be the hard porcelain type, hard porcelain material, as well as the soft porcelain type if the porosities are only the mattering, the matter of concern, then alumina porcelain you can have more and more amount of alumina 18 and the bone China we know, the cups the (Refer Time: 32:14) and all these the fine bone china we know, the pottery industry is very much benefited through this particular knowledge that which particular thing can be your bone China.

So, what is bone China if you are asked you should be able to define it in terms of this family tree, then bone china is basically a type of fine earthenware of nonporous type and it is a fine category of it is belongs to a fine category of clay ceramic material. So, clay ceramic material of fine type have non-porous type and giving us the earthenware, which is your bone China.

So, in your next class we will be talking about the other variety; that means, your speciality ceramics, then will further continue how we make and how we use all these materials ok

Thank you very much.