Concrete Engineering and Technology
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Lecture - 3
Constituents of concrete (Part 2 of 2)

Welcome back to this series of lectures on Concrete Engineering and Technology.

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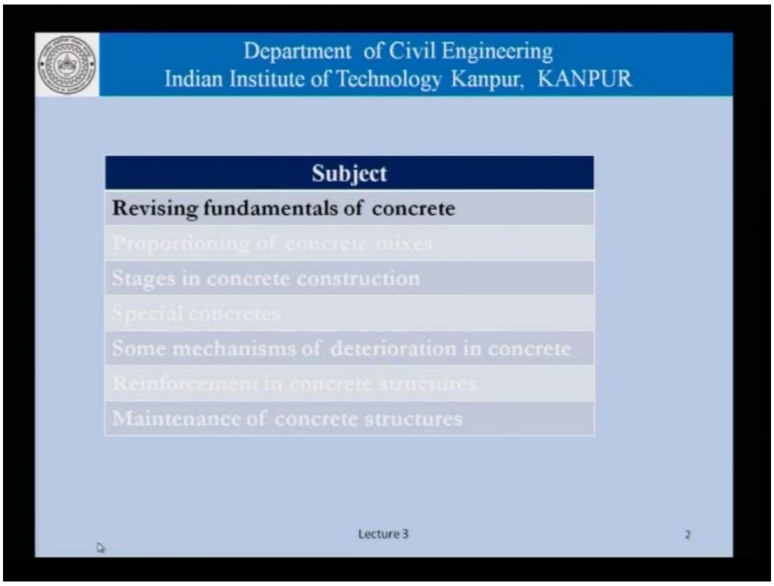

So far, we had looked at the different subjects that we will cover and we were trying to do a revision of the fundamentals of concrete. We were trying to study the constituents of concrete. In the last class, we had discussed that normal concrete consists of coarse aggregate, fine aggregate, cement and water. Discussions on mineral and chemical admixtures have been postponed to a later date. In the last class, we had discussed the properties of coarse and fine aggregate.

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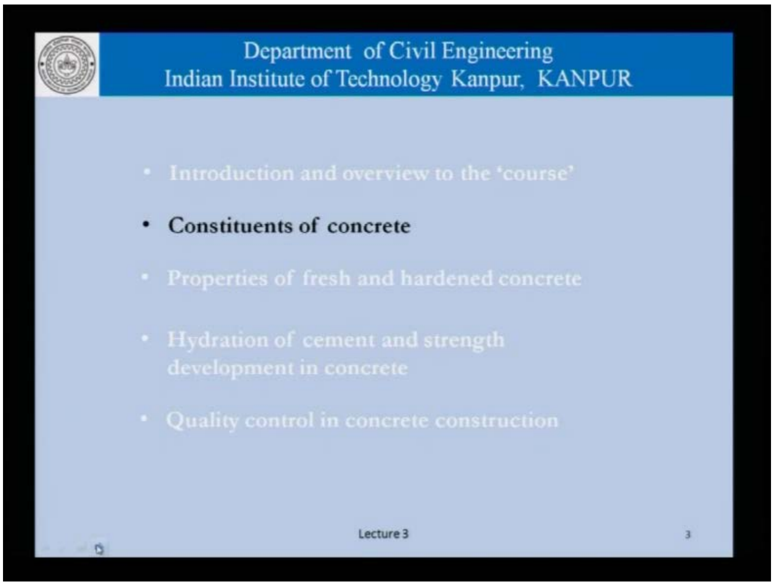

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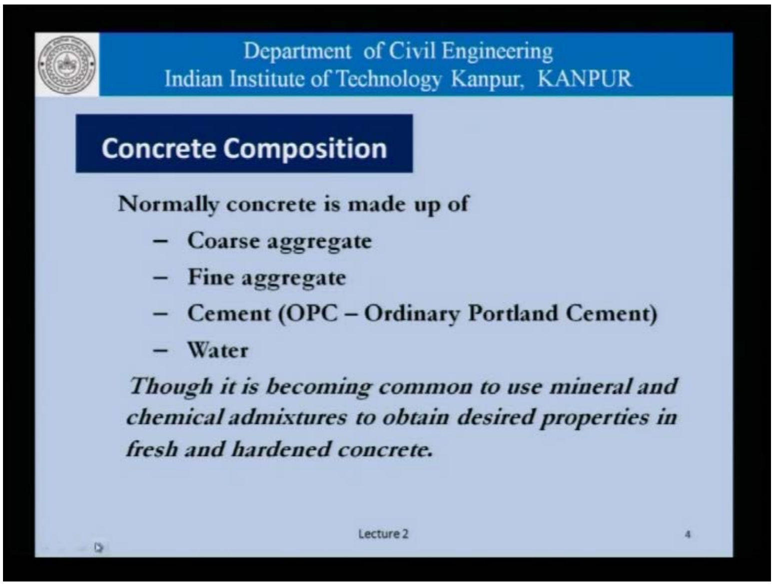

Moving on, we discuss the properties of ordinary Portland cement. Once again, let us take a look at this slide which we have seen in the previous lectures as well. We look at cement, which is the binder phase of the concrete mix. It is about it is so cement and water.

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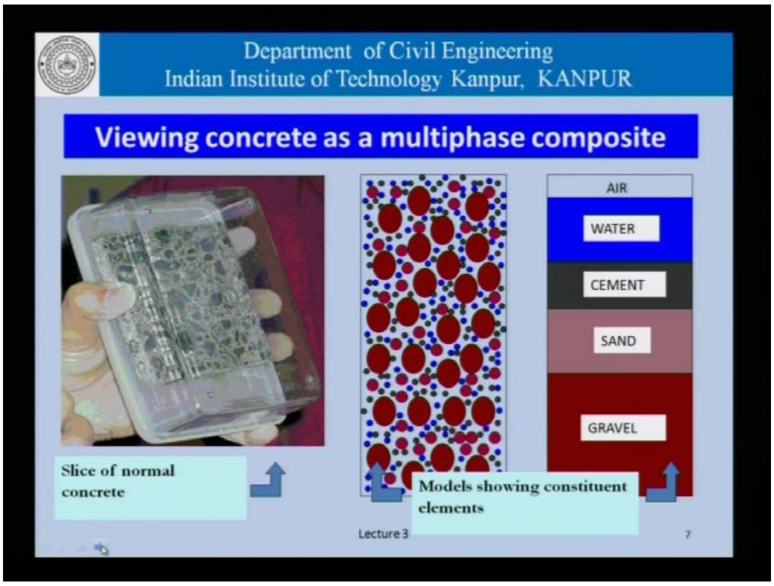

Let us look at this slide again, which shows a schematic of the concrete as a multiphase composite material and aggregates are embedded in a matrix of cement, water, paste, mortar whichever we want to look at it.

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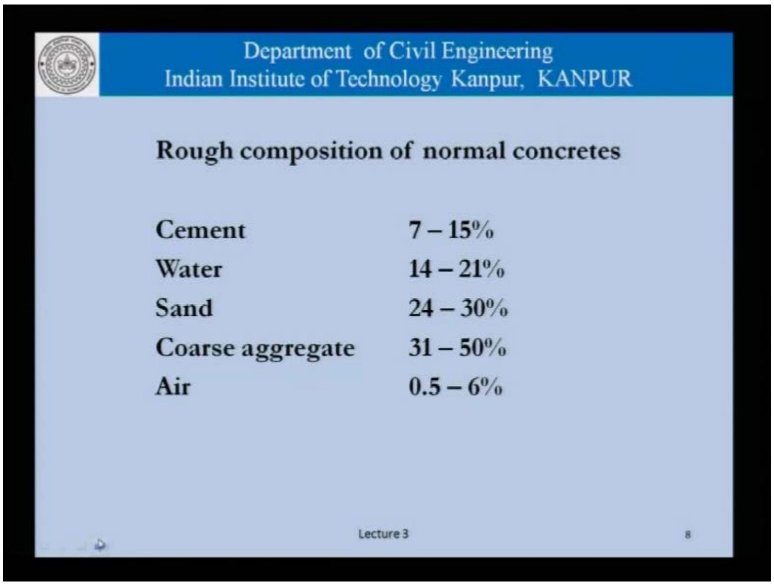

Roughly by volume, we has to see that the composition of concrete is basically about 7 to 15 percent of cement, 14 to 21 percent of water, 24 to 30 percent of sand and about 30 to 50 percent of coarse aggregate with a small amount of air in the concrete.

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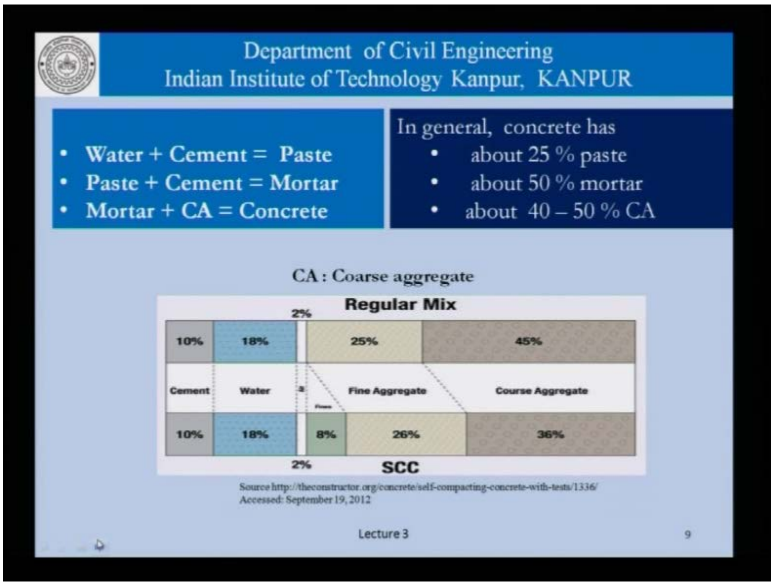

Now, if we look at it in a different way, paste constitutes about 25 percent, mortar constitutes about 50 percent and the coarse aggregate could be between 40 to 50 percent of a normal concrete, as the concrete becomes special. For example, if we are talking of self-compacting concretes, we have seen that the coarse aggregate content goes down even though the paste content more or less remains the same.

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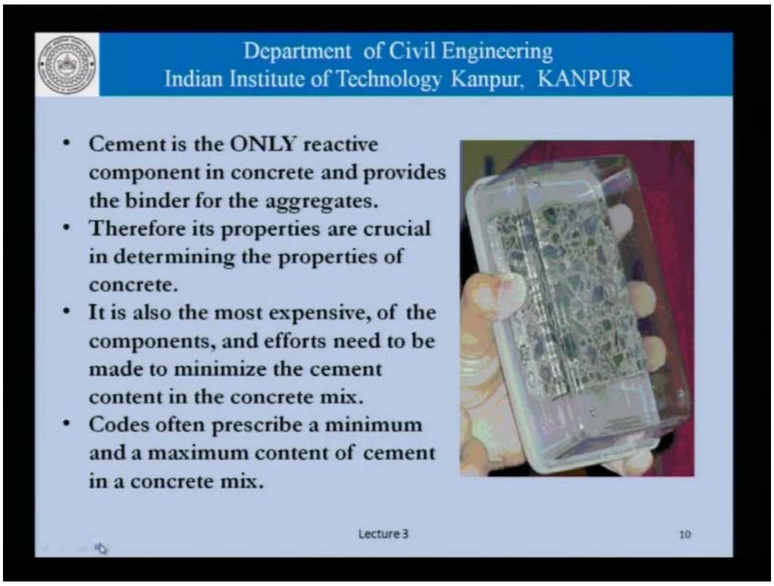

We should remember that cement is the only reactive component in concrete and provides the binder for the aggregates as can be once again seen in this picture here.

Therefore, the properties of cement are crucial in determining the properties of concrete. In other words, if we want concrete to have certain properties we should make sure or we need to make sure that the cement has certain properties. Further, cement is also the most expensive of the materials.

Therefore, for economic reasons and of course there are other reasons as well, efforts need to be made to minimize the cement content in a concrete mix. We should remember also the codes and specifications in different countries prescribe a minimum and a maximum content of cement in a concrete mix. The minimum is often prescribed from points of view of durability the maximum is prescribed from the points of view of shrinkage, heat of hydration and so on.

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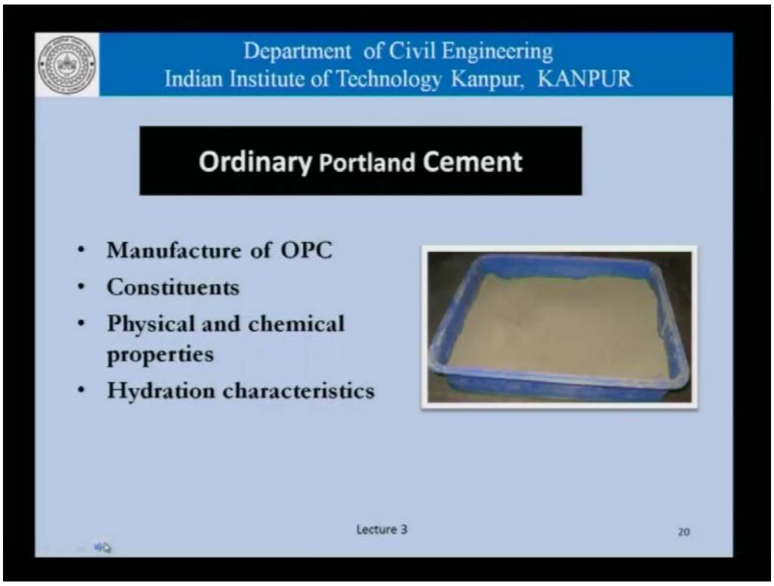

Now, let us take a look at this picture of ordinary Portland cement. It is a very fine powder usually grey in color. What we will do in the discussion today? We will talk about manufacture of material that is, manufacture of OPC. You will spend some time talking about the constitution, the components of the ordinary Portland cement and the physical and chemical properties. We will spend some time may be today or the next day on hydration characteristics of cement.

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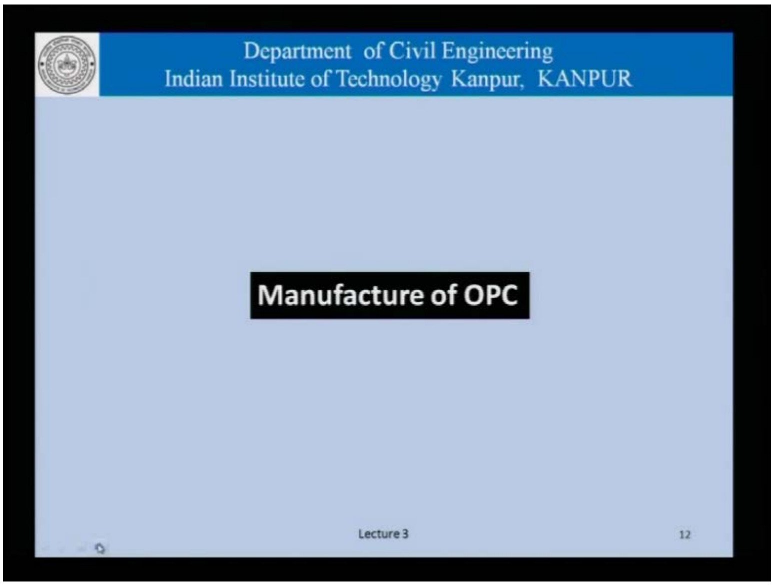

Now, coming to the manufacture of ordinary Portland cement.

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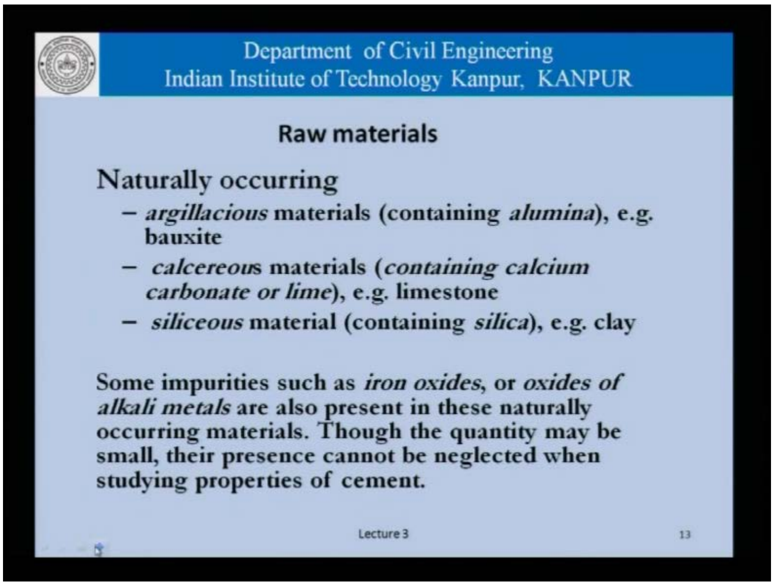

It consists of argillaceous materials containing alumina, and bauxite is a common source, calcareous materials containing calcium carbonate or lime, limestone is mostly used. Siliceous materials containing silica of which clay is the usual soaps. These constitute the bulk of the raw materials for ordinary portland cement. Now, in addition to these, there are impurities like the oxides of iron or oxides of alkali metals such as sodium or potassium, which are present in these naturally occurring materials. Though the quantity of these impurities is quite small, their presence cannot be neglected when studying the properties of cement as we will see later on in this discussion.

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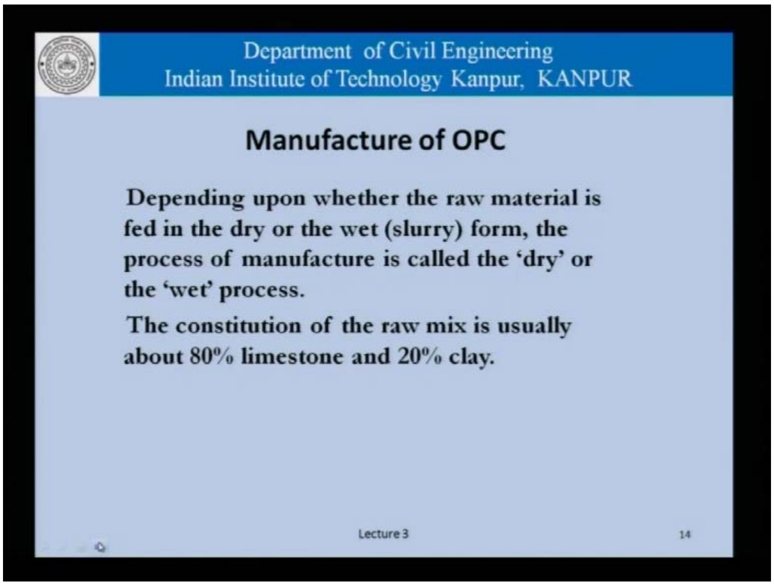

Continuing with our discussion on how cement is manufactured? Depending on whether the raw material is fed in this dry or the wet slurry form, the process of manufacture is called dry or wet. The constituents in the raw mix are usually about eighty percent is limestone and twenty percent clay.

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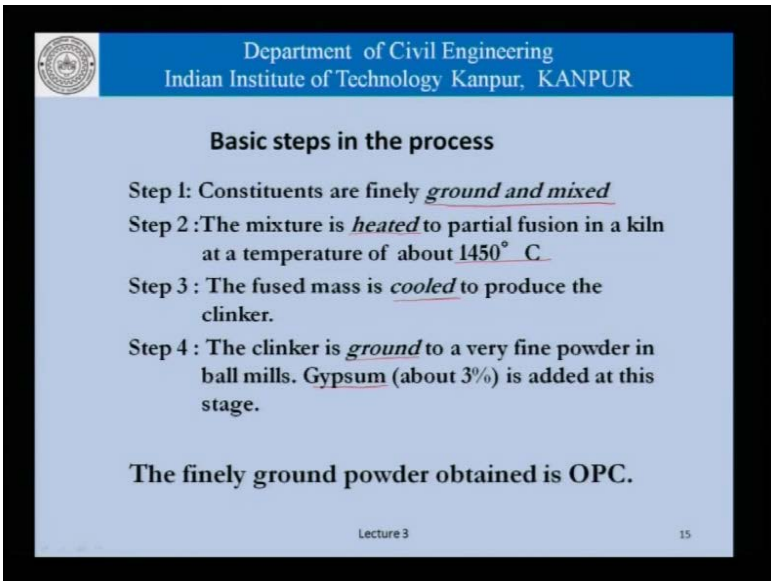

The basic steps in the process involved are, the constituents are finely ground and mixed. So we have the different constituents of cement coming in, they are ground and mixed. The mixture that we get now is heated to a state of partial fusion in a kiln in a temperature of about 1400 and 50s to 1500 degree centigrade. This fused mass is cooled to produce clinker. Clinker is the product of cooling of this mass. The last step is, the clinker is ground to a very fine powder in ball mills. At this stage, gypsum, which is about three percent by weight is added to the clinker and what we get is ordinary portland cement.

If we study the process of manufacture carefully, the different steps involved are grinding and mixing of the ingredients, heating of these ingredients, the temperature involved, cooling of the clinker, grinding of the clinker, addition of gypsum. Now, each of these processes has a major impact on the properties of cement that we get. One should be aware of that.

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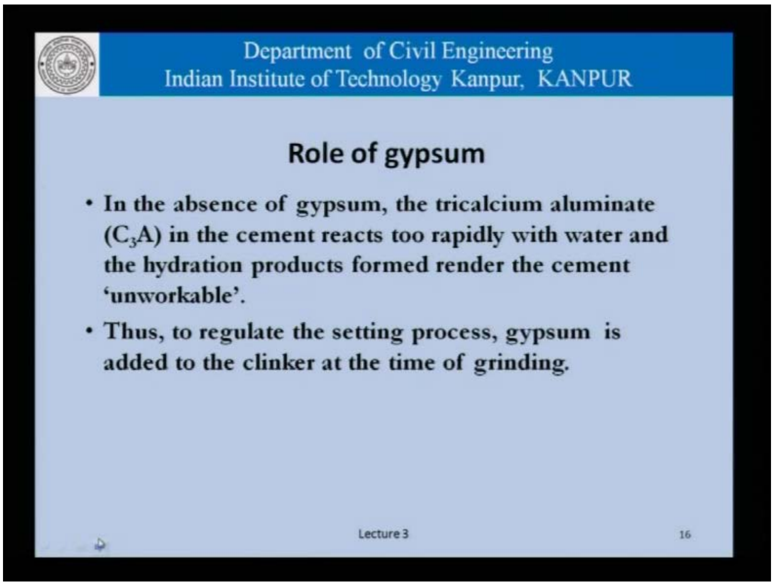

Now, why is gypsum added? If it is not added, the tri calcium aluminate that is C 3 A, which we will study later in the cement reacts too rapidly with water and the hydration products become very and the hydration products formed render the cement unworkable very quickly. So, it does not serve our purpose. Thus to regulate the setting process, gypsum is added to the clinker at the time of grinding.

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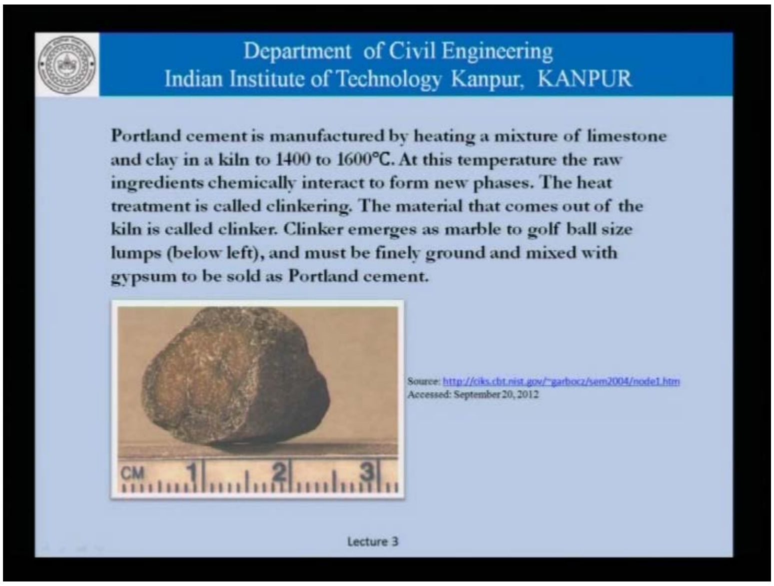

To recapitulate, portland cement is manufactured by heating a mixture of limestone and clay in a kiln, to about 1400 to 1600 degree centigrade. At this temperature, the raw ingredients chemically interact to form new phases, so the oxides of the different elements, the oxides of the different elements calcium, silica, aluminum and so on. They form new phases. The heat treatment is called clinkering, the material that comes out of the kiln is called clinker and it emerges as more or less golf size balls about 2 centimeters 2 and a half centimeters in diameter. That must be finely ground with gypsum and sold as ordinary portland cement. A picture of clinker is shown here now.

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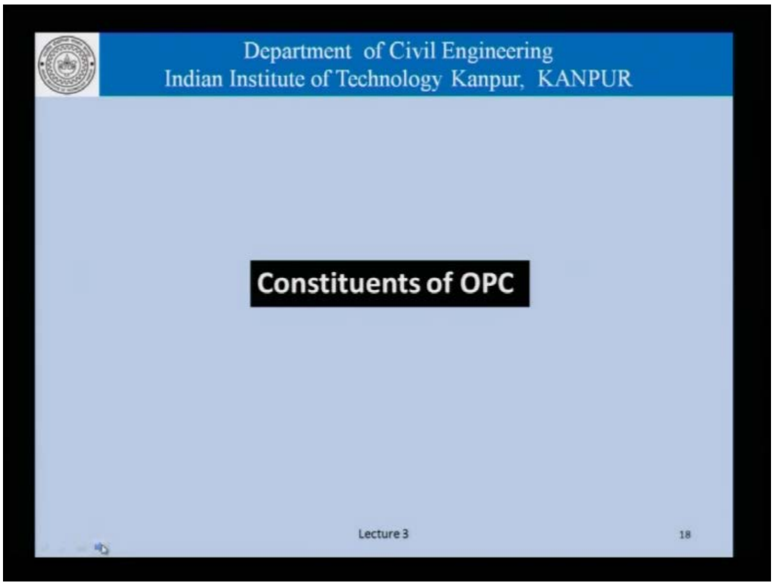

Now, coming to the constituents of ordinary Portland cement as the raw materials are oxides of calcium.

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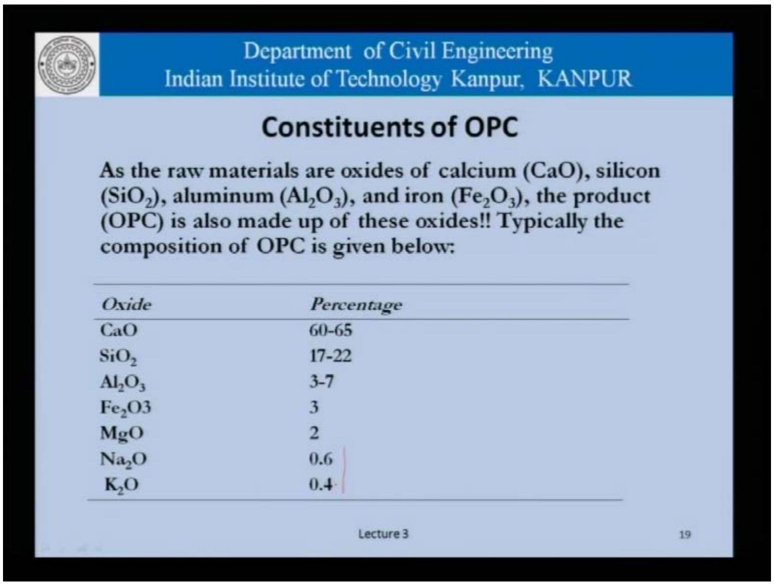

That is calcium oxide, silicon that is silicon oxide, aluminum that is Al 2 O 3 or aluminum oxide and iron that is Fe 2 O 3 the product, which is OPC is naturally made up of these oxides. Typically, the composition of OPC is expressed in terms of the percentage of these oxides and the table here gives some typical values. Calcium oxide is about 60 to 65 percent, silicon oxide is about 17 to 22 percent and so on.

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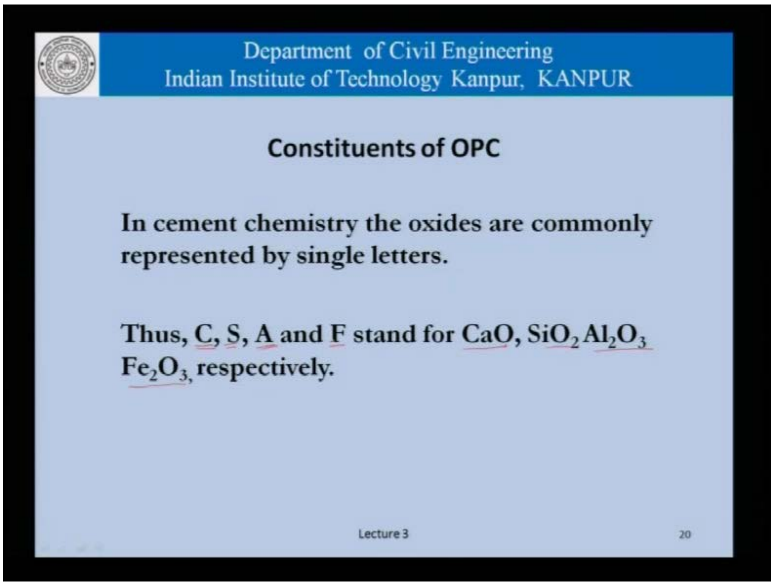

Notice here, the small presence of sodium and potassium oxides, which are the oxides of alkali metals that we talked about earlier in the discussion. I should point out that in cement chemistry, the oxides are commonly represented by single letters. It is a convention that calcium oxide Ca O is represented as a C, silicon oxide, which is Si O 2 is represented as S, Al 2 O 3 which is represented as Al 2 O 3 cement chemist call it A and Fe 2 O 3, the cement call it the cement chemists call it F.

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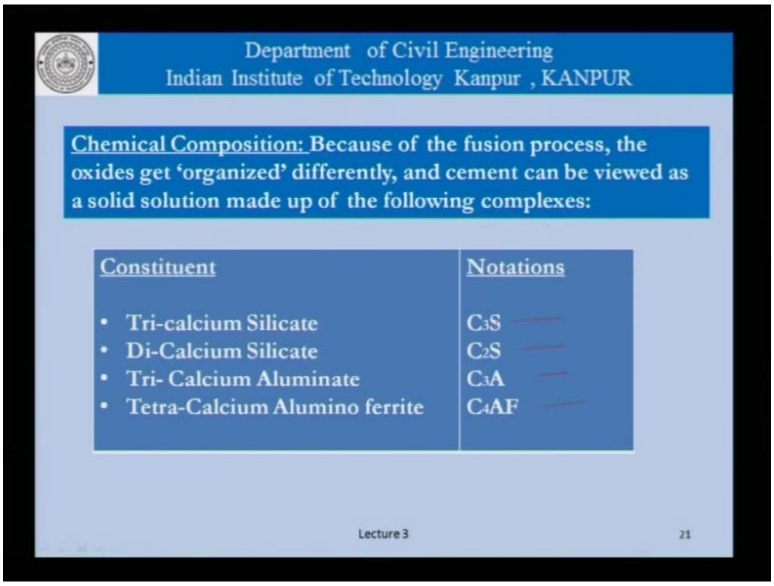

Now, because of the fusion process, the oxides of the different elements get organized differently and the cement is actually a solid solution made up of the following complexes. Tri calcium Silicate, di calcium silicate, tri calcium aluminate and tetra calcium, alumino ferrite, these complexes in cement chemist notation are written as C 3 S, C 2 S, C 3 A and C 4 AF. So, this is where you understand that when a cement chemist says C 3 S; the C refers to C A O and S refers to Si O 2. This does not mean that C 3 S comprises only of C A O and S I O 2 or C 3 A comprises only of C A O and Al 2 O 3. This part we will just study a little later, but these are the basic solid complexes of cement.

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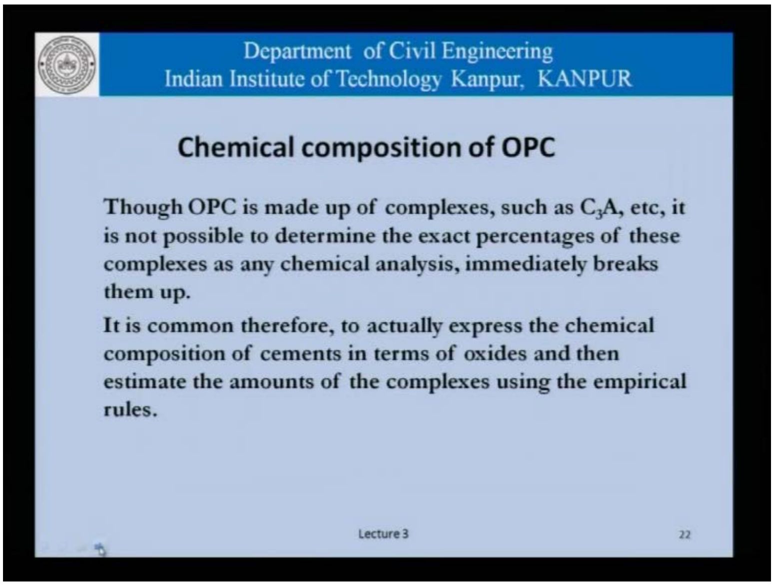

Now, the OPC is made of these complexes such as C 3 A etcetera. It is not possible to determine the exact percentage of these complexes in any chemical analysis because these complexes break up as we add any solvent like acids to it. Water cannot be added and used in the process, because there is a chemical reaction involved and hydration starts. It is common, therefore to actually express the chemical composition of cement in terms of oxides. Then try to estimate the amount of complexes using empirical relationships.

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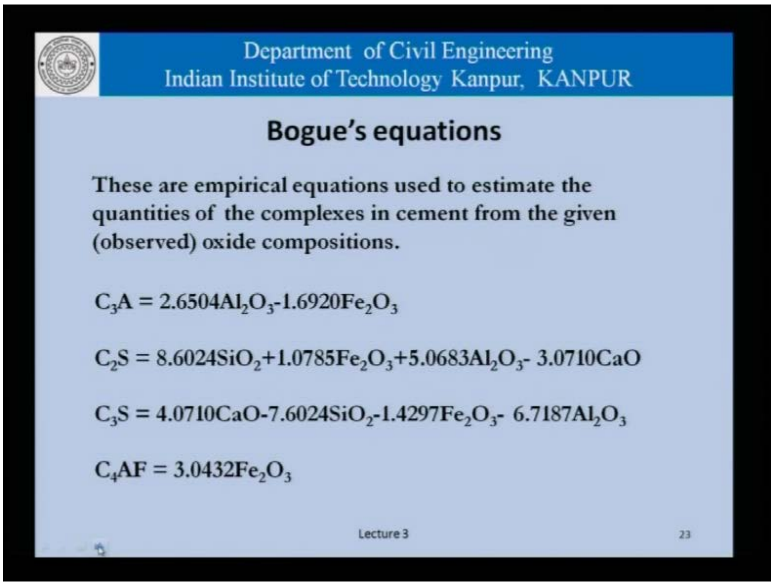

These empirical relationships are called the Bogue's equations and are used to estimate the quantities of complexes C 3 A, C 2 S, C 3 S and C 4 AF in a cement from the given or observed or measured oxide compositions. So, these are the complicated looking equations which a cement chemist uses to estimate the amount of C 3 A in a given cement. What he knows is the oxide composition that this particular cement has this particular calcium oxide silicon oxide Fe O 3 and so on. Based on that he makes an estimate using Bogue's equations and finds out how much of C 3 S, C 2 S, C 3 A and C 4 AF, which are the four principle components of ordinary portland cement. How much of these components is there?

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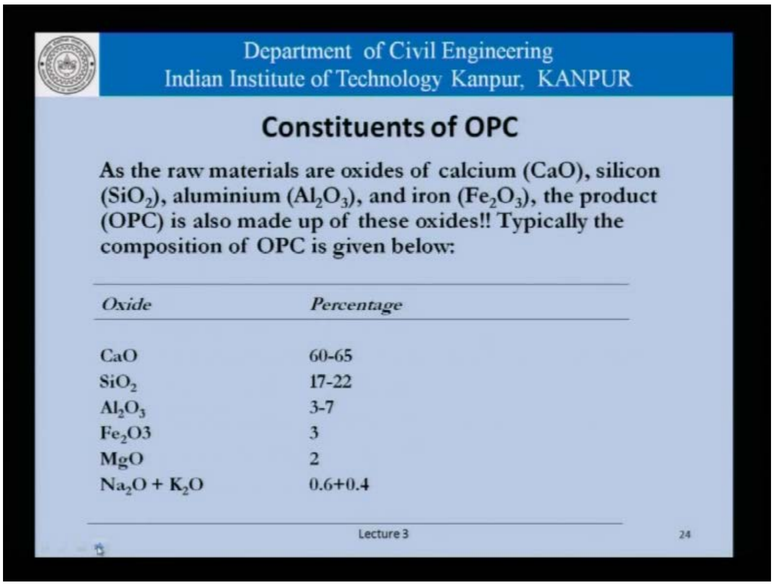

Now, this is just a repetition of the previous slide to give an idea of the oxide composition of a normal cement. Based on the Bogue's equations, the composition in terms of these complexes gives you the range of 8 10 percent C 3 A, 30 50 percent C 3 S, 20 45 percent C 2 S and 6 to 10 percent of C 4 AF. Depending on the different ways of manufacture, the kind of processes about which we talked about, the temperature at which the raw material is heated, the rate at which the clinker is cooled and so on, the kind of raw material that is used. We can try to have cements having different compositions of these solid complexes.

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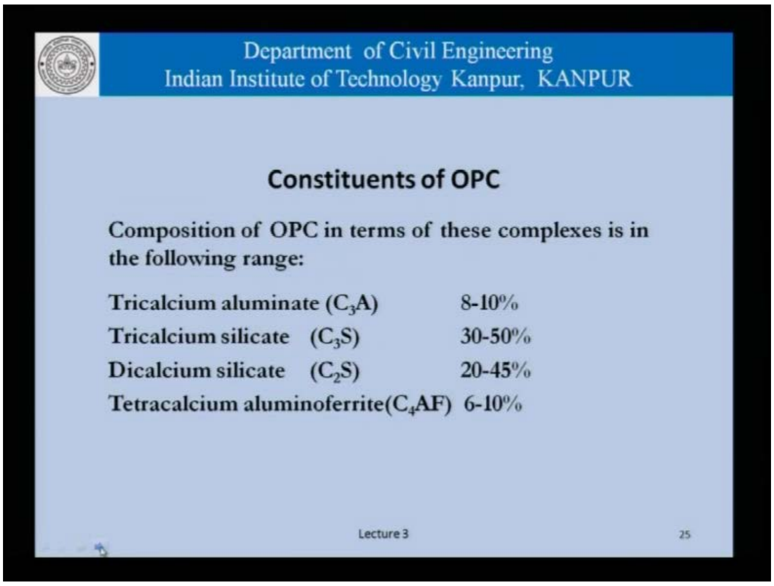

So if you look at these complexes alone, ordinary Portland cement comprises of roughly 50-70 percent of the dicalcium and the tricalcium silicates and the remaining is tri calcium aluminates and tetracalcium aluminoferrites, that is C 3 A and C 4 AF. A broad understanding of the rough composition of ordinary portland cement in terms of C 3 A, C 2 S, C 3 S and C 4 AF is very important for a concrete engineer to understand and predict the properties of concrete for a particular cement.

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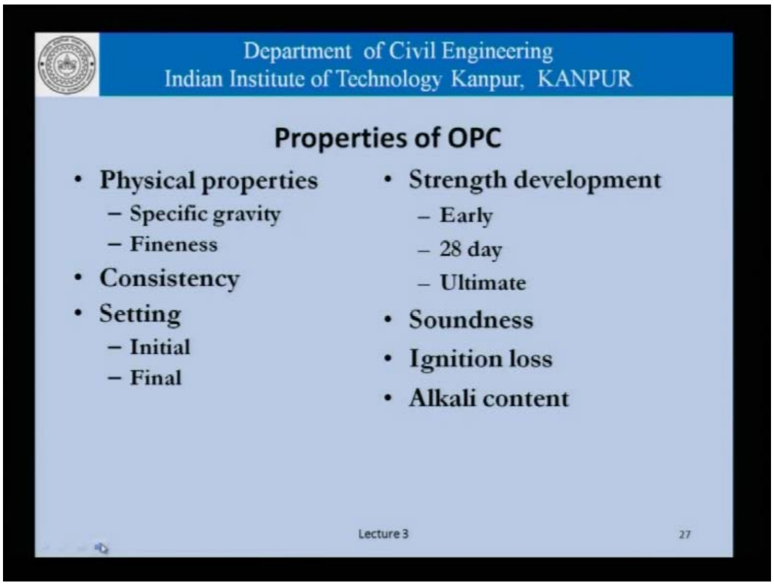

The other way around that is, for a particular concrete, what is the kind of cement that the concrete engineer needs to use. The cement chemistry need not be understood very deeply, but the fundamentals must be clearly understood. Now, coming to the properties of ordinary Portland cement, we can divide the discussion of the properties in terms of physical properties which could be specific gravity and fineness, consistency, setting time, initial and final strength, development which could be early 28 day or ultimate. I would only like to point out that strength development in cement or for that matter concrete continues for a long period of time. It is only a matter of convenience that we take 28 days as a basis for our quality control and other tests.

Otherwise, as far as the science is concerned, we can have the strength development going on for a much longer period of time depending on the kind of cement that we are using. Therefore, depending on the application we should be free. We should indeed understand what our requirement should be for early strength, 7 days strength, 3 days strength, 28 days and so on and so forth.

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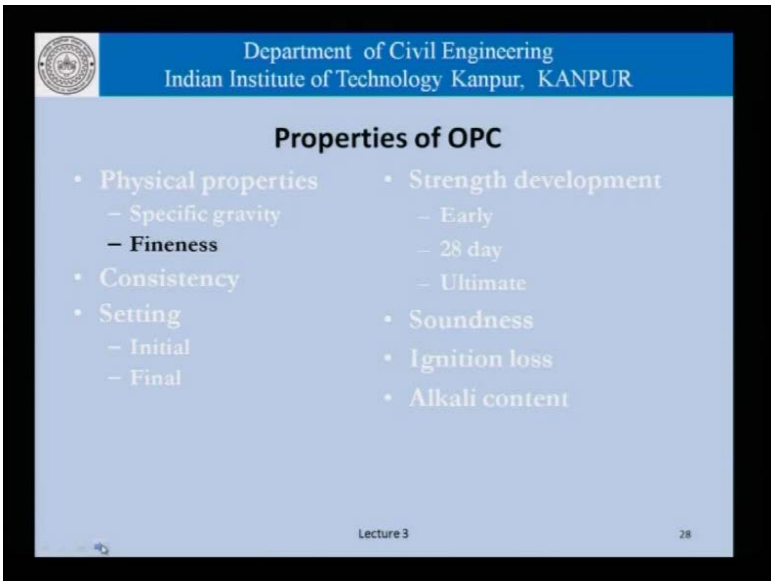

Then we have properties; which includes soundness, ignition loss and alkali content which have the role importance and the reasons for which we must study them. We will try to study some of these properties in our discussion today. Coming to the first part which we will take up is, the fineness of cement. Now, fineness is basically how fine the cement powder is and it is determined basically by the kind of process that has been followed in grinding the clinker.

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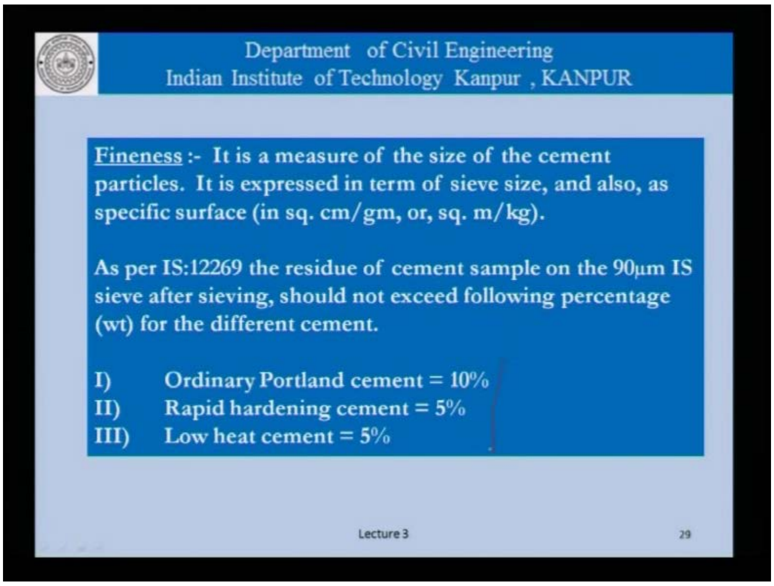

As I said, fineness is a measure of the size of the cement particles and is expressed either in terms of a sieve size because that is the most common, most easily understood method of trying to find out the size of a particle. We saw that in the discussion when we talking about aggregates, coarse aggregates and fine aggregates and also as a specific surface area that is in terms of square centimeters per gram or square meters per kilogram. Remember that, it is not possible to sieve very fine particles, because if the particles become very fine, then the sieve size has also to become equally finer and physically that has its limitations.

Therefore, instead of only you relying on sieve size analysis, we often try to work with other methods and try to get a measure of the fineness of cement in terms of square kilogram in terms of square meters per kilogram and so on. As far as Indian standards is concerned, the residue of cement sample on a 90 micro meter sieve after sieving should not exceed the following percentages by weight and certain numbers are given. That is what we say in a code is that the cement should have at least a certain fineness. This numbers basically indicate that the amount of particles coarser than this particular sieve size should not exceed a certain number.

We should remember that in the last 30 to 40 years a lot of development has taken place in the grinding technology as far as cement industry is concerned. Therefore, the fineness of cements over the time has increased. It is become so much more possible now to have cements which are very, very fine. Now how much that very fine is is precisely? What is a measurement here and usually, we do it in terms of square meters per kilogram.

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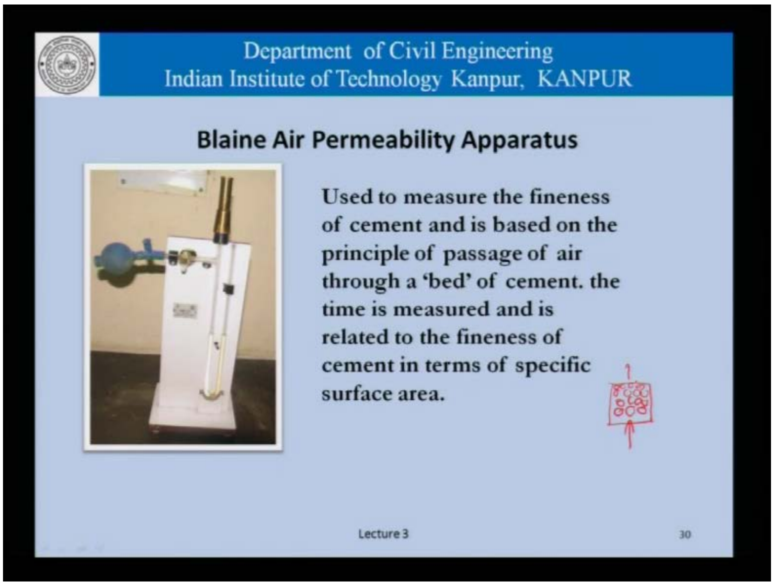

This is one of the most simple apparatus that is used to measure the fineness of cement called the Blaine Air Permeability Apparatus and is based on the principle of passage of air through a bed of cement. The time is measured and this time is related to the fineness of cement in terms of a specific surface area. Intuitively, it is clear that if we have a box where we pack small particles and we have air to pass through this bed. If these particles are very fine and are very heavily compacted it will become more difficult for the passage of air. That is, it will take a longer time for a certain volume of air to pass through a densely compacted mass of fine particles.

If the particles were coarser or the particles were less compacted the passage of air would be a lot easier and that is what we do in this test. We have the air passed through such a bed, this is what is called the bed, we have the air passing through this bed and the time it takes is recorded. This time is related to the fineness of this particles that we use. There is a calibration curve we use in standard powders and is used to estimate the fineness of cement. There are other methods as well. I am leaving that out as a self study project.

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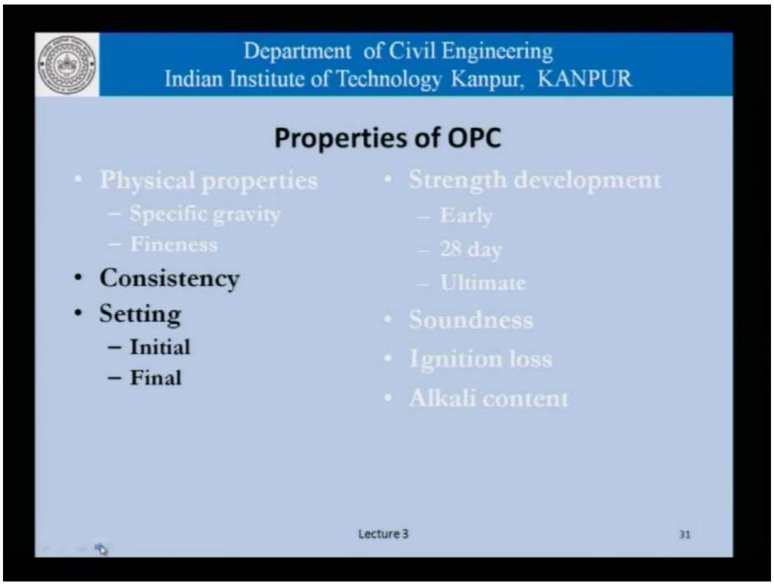

Now, coming to the consistency and the initial and final setting times, which is also an important property of the Cement.

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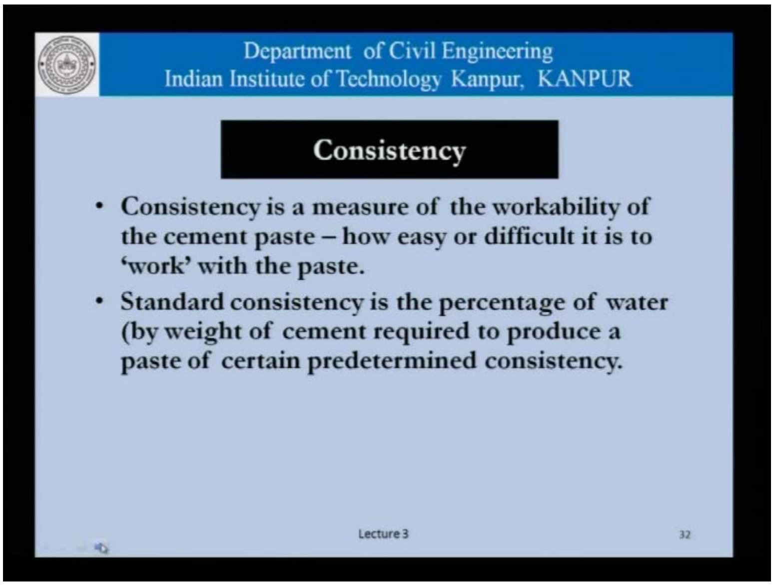

What is consistency? Consistency is a measure of the workability of the cement paste. Workability means, how easy or how difficult it is to work with the paste. What does it mean, how do we relate to it? If we mix very little water with cement it will be very difficult for the paste to take the shape that we wanted to take. For example, filling a circular form work and so, on passing through the reinforcing bars and that is what happens in a concrete. If we add more water to it, then the paste becomes more workable and it is easy for the paste, or for that matter than the concrete to be worked with, that is it moves through the reinforcement more easily. It occupies the nooks and corners or form work more easily and so on.

So that is the intuitive, qualitative picture of consistency. It is a measure of the workability of the cement paste, that is, how easy or how difficult it is to work with the paste. There is a term standard consistency, and that refers to the percentage of water by weight of cement required to produce a paste of a certain predetermined consistency. So if we have a predetermined consistency and a method to determinate it. Then we can say that okay, there can be different cements.

Therefore, for different cements what is the amount of water that is required to produce a cement paste of that particular consistency and that can actually be different. It could vary with the particle shapes of cement or the shapes of cement particles, it will vary with the fineness of the cement particles and so on. So for the same cement depending on fineness and other things we could have different standard consistencies. That is something which concrete engineers must be aware of.

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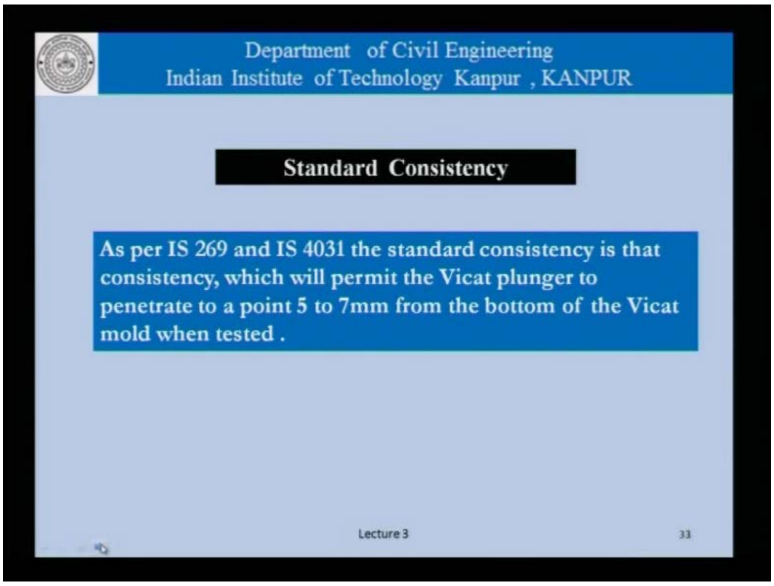

As a matter of definition, standard consistency as per as Indian standards is concerned, is defined as that consistency which will permit the Vicat plunger to penetrate to a point five to 7 millimeter from the bottom of the Vicat mold when tested. We will look at the Vicat mold and the test in a few slides. We will look at the Vicat mold and the testing procedure a little later.

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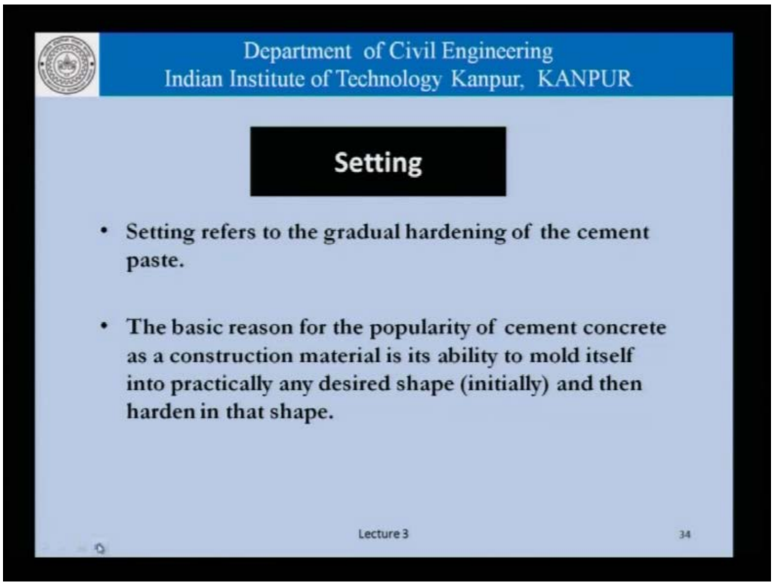

Now, coming to setting; setting refers to the gradual hardening of the cement paste. We should remember that the basic reason for popularity of cement concrete as a construction material is its ability to mold itself into practically any desired shape initially and then harden in that shape. As water is added to cement, the initial reactions will cause the cement to set. Then there will be hardening and then there will be strength development. So, we can on the time axis look at the whole process in these three different steps setting, hardening and strength development. The strength development could continue for several days. Setting and hardening are much shorter processes.

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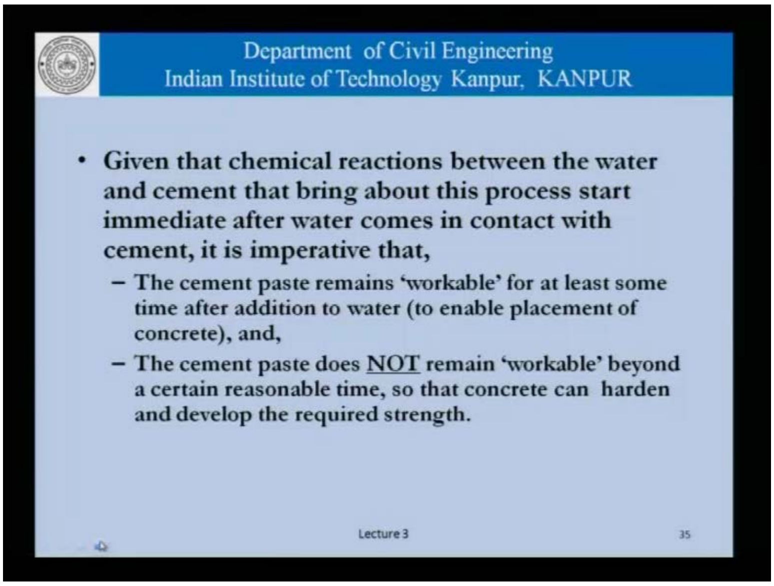

Now, given that the chemical reactions between water and cement that bring about this process, which could be setting, start immediately after water comes in contact with cement. It is imperative that the cement paste remains workable for at least some time after addition of water to enable placement of the concrete. Concrete is mixed at a particular location, whether it is a mixer at site or a ready mix concrete plant which could be several kilometers from the site. Then needs to be transported to the site of placement and therefore, the cement paste or the concrete should remain workable for this period.

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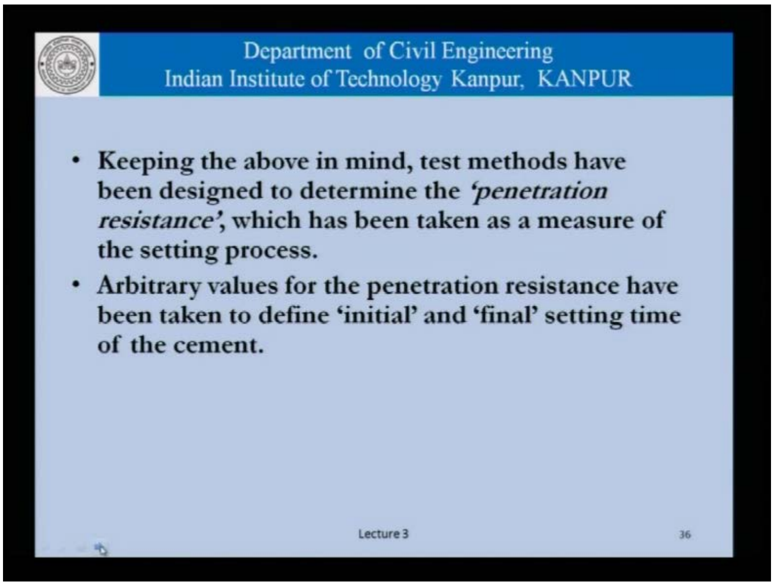

However, the cement paste does not or should not remain workable beyond the certain. point so that concrete can harden and develop the required strength. So as engineers we would like the concrete to remain workable so long as it is being transported from the mixing site to the site of placing. But once the concrete has been placed, we will like the concrete to harden and gain strength so that further work can be carried out.

Now, keeping the above in mind, test methods have been designed to determine the penetration resistance, which has been taken as a measure of the setting process. So, if there is a paste which offers a certain penetration resistance, we take a needle and try to pears it with that needle. Then if the needle goes through very easily, the material is offering very, very penetration resistance and in the case of cement paste. We will say that the setting has not occurred. Whereas, if the needle is offered stiff resistance and we are not able to penetrate the needle, we are not able to push that needle into the cement paste. Then we say that the cement past has set or the setting has reached a certain level. Arbitrary values for this penetration resistance have been taken to define initial and final setting times of cement.

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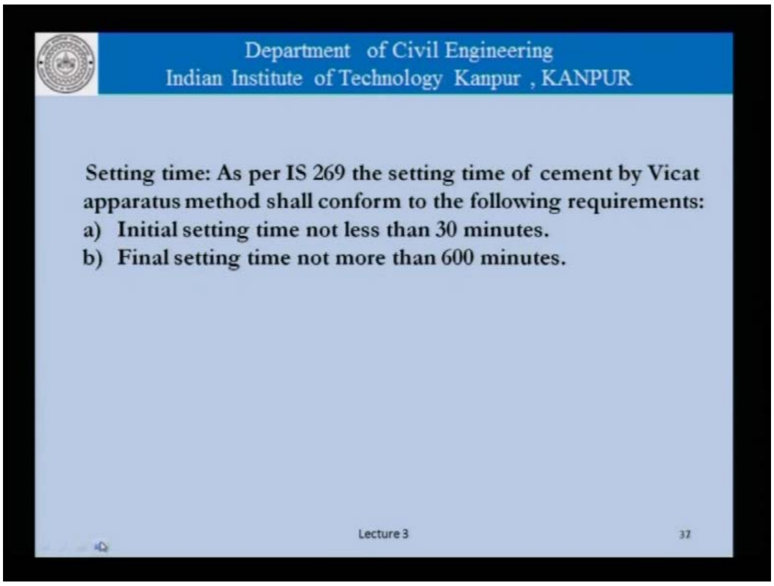

Now, as far as the Indian standards is concerned, the setting time of cement by Vicat apparatus, needs to conform to the following requirements. The initial setting time should not be less than 30 minutes and that enables the concrete to be transported and placed and the final setting time should not be more than 600 minutes. That is 10 hours and that means that beyond 10 hours, we would expect the concrete to have at least reach the certain level of setting. We must remember that, the initial and final setting time of cement or the standard consistency of the cement does not really reflect, how the concrete will behave?

Cement paste or cement is just one of the constituents of concrete. Therefore, all these tests are really quality control parameters that define the cement as a constituent material. The setting times in the consistencies of concrete are a completely different ball game and need to be discussed at a separate pointing time which we will take up for discussion in subsequent lectures. Here we are talking of the constituents of concrete and discussing the properties of cement. However, in order to put the properties of cement in perspective. I have been taking examples of how this cement is used in concrete and how the properties of cement would change the properties of concrete?

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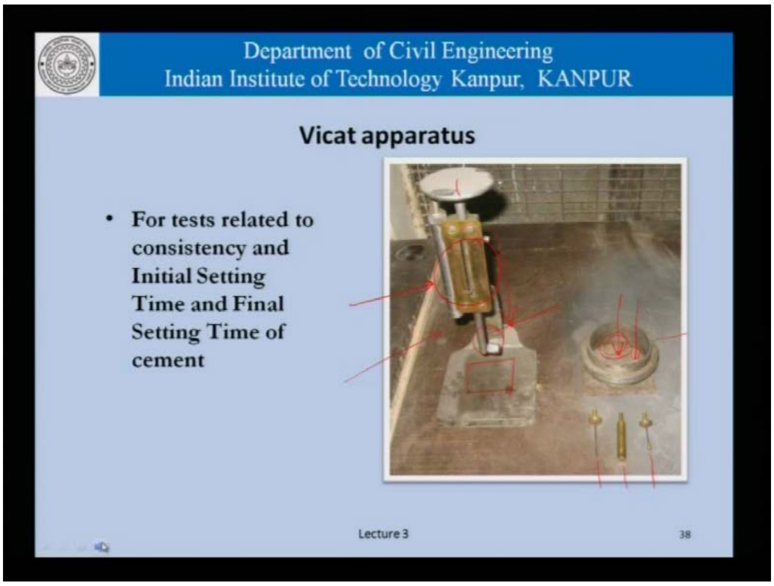

So, with this background, let us try to quickly look at the Vicat apparatus and how it works? So this here is the Vicat apparatus. This is the mold in which the cement paste is prepared and filled and these are the needles which are used to determine the penetration resistance. So, this mold is filled up and placed below here on this platform and these needles become part of this plunger here. Once we lift it from here and allow it to drop. These needles penetrate into the cement paste to different degrees and depending on the degree of penetration, which is measured using a scale. Here we try to find out the standard consistency of cement, we try to find out the initial and the final setting time of cement and so on.

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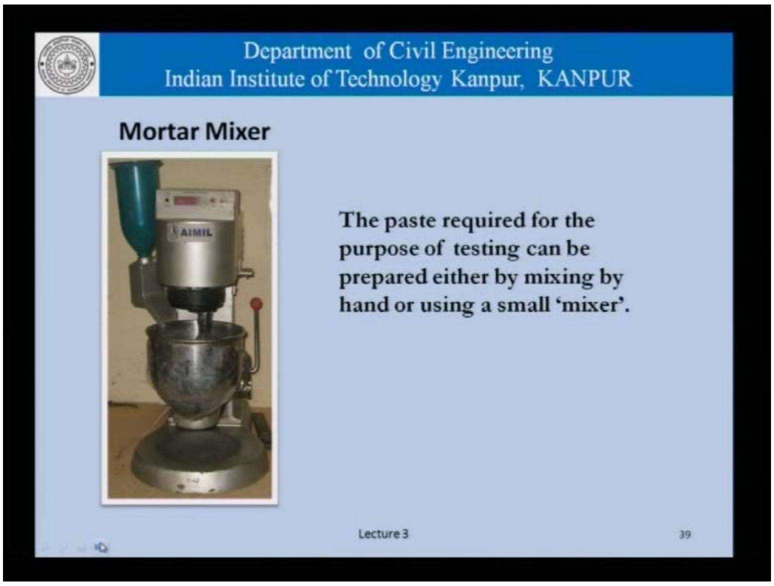

As far as preparing the paste is concerned, which is to be placed in order to determine the standard consistency of a certain times of cement, the paste can be prepared either by mixing by hand or using a small mixture as just shown in this picture.

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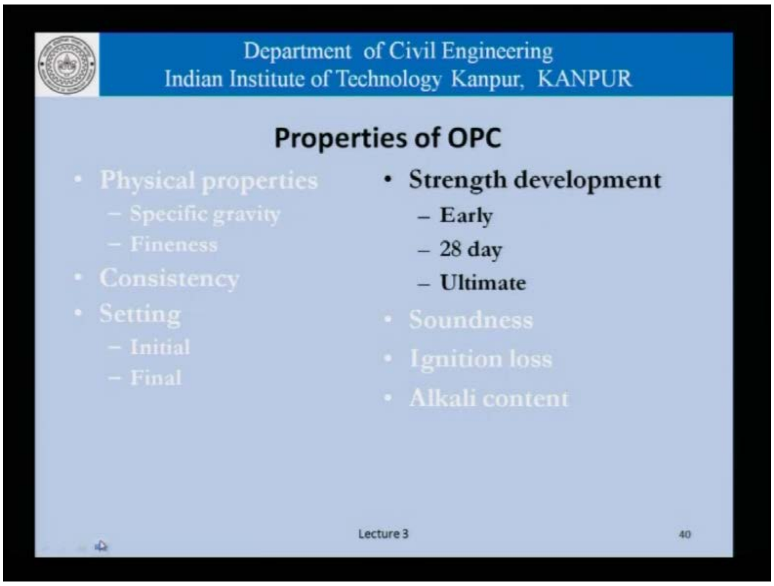

Coming to the other property of cement, which is strength development. Let us talk on terms of how this property is determined.

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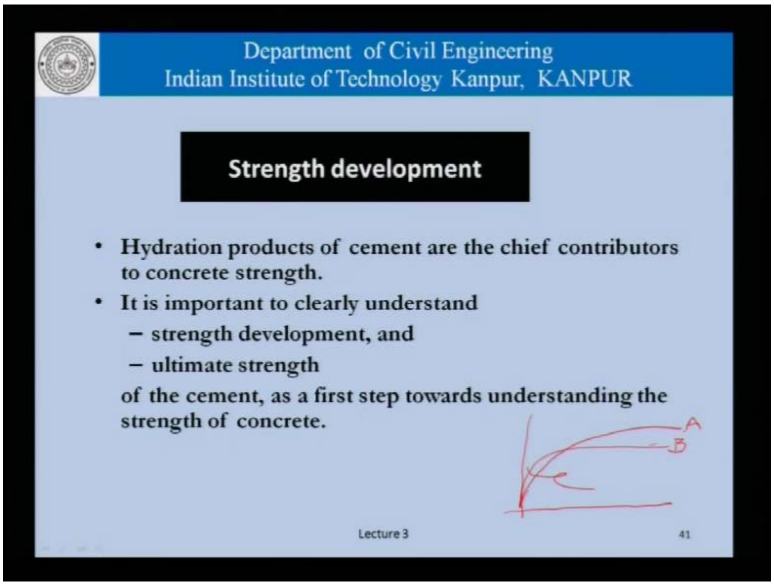

We must remember that the hydration products of cement are the chief contributors to the concrete strength. So, this cement and water when they react they form hydration products and those hydration products which act as winders to the concrete are a very important element of the strength of the concrete. It is also important to clearly understand that strength development and the ultimate strength of the cement is a first step towards understanding the strength of concrete.

So, we can have different cements which will have different curves for strength development. So in a particular cement, may be the strength development goes like this in another cement may be the strength development goes on like this. So, if we have a cement, which has this characteristic and a cement b which has this characteristic cement b is a rapid strength development. Cement b shows rapid initial strength development but, a lower ultimate strength. Cement a comparatively shows lower strength development initially, but a higher ultimate strength, and so on. So, once we understand this characteristic rising out of this cement and cement paste studies or cement mortars studies we can better understand the properties of concrete.

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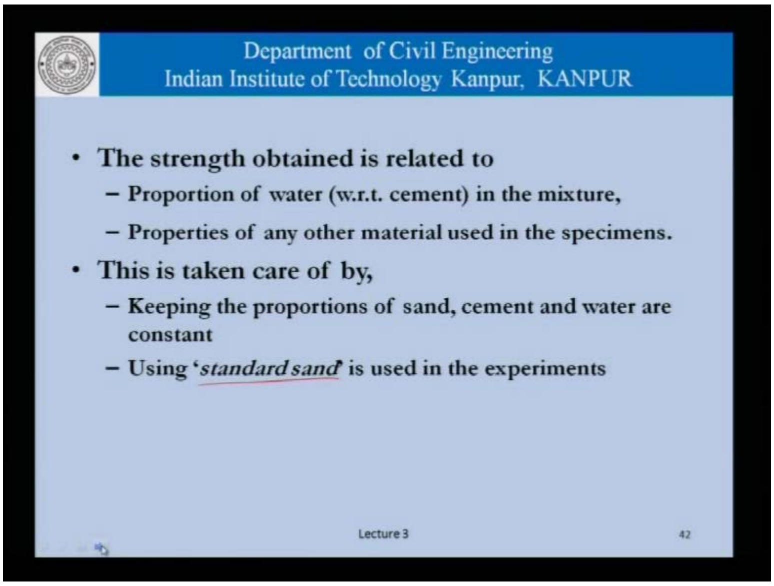

The strength obtained, we will discuss this later is related to the proportion of water with respect to cement that is the water cement ratio, which we know in the mixture and the properties of any other materials that are used in the specimen. Now, when we are talking of cement standards or methods to control the properties of cement or specified them in a certain manner, strength is one property. We want to determine the strength, we do not usually determine the strength using cement paste that is just cement and water is not normally used.

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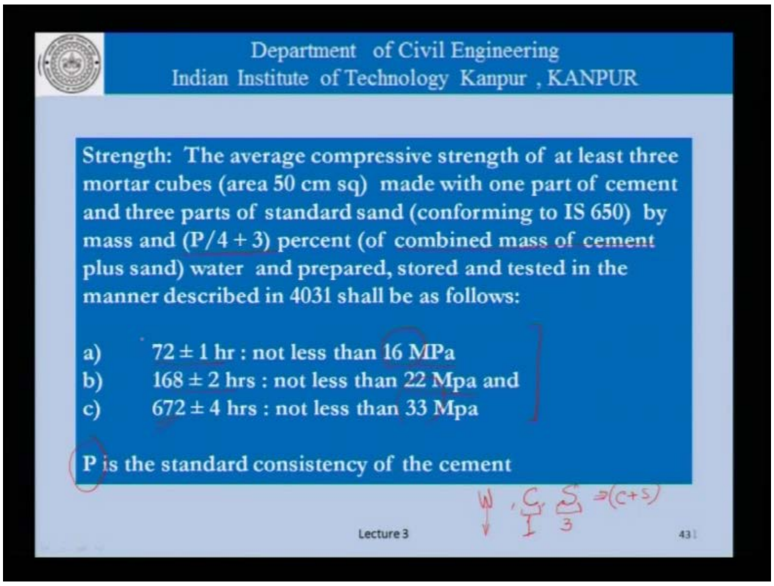

What we use is modern, that is we use sand as an added constituent to a mixture to determine the strength of cement. If we use different sands at different times or different places, it will be impossible to compare one cement with the other. Therefore, what we do is we use standard sand in the experiments and keep the proportions of sand cement and water at the same level.

As far as standards are concerned, or the way it is written is, the weight the average compressive strength of at least 3 mortar cubes measuring say 50 centimeter square made with one part of cement and 3 parts of standard sand conforming to IS 650 by mass. P by 4 plus 3 percent of the combined mass of cement and sand of water and prepared stored and tested in the manner described in a certain standard shall be as follows. So, what it says is that you mix water cement and sand. We use three parts of sand to one part of cement and the amount of water to be added is P by 4 plus 3 percent of cement plus sand.

That is the combined mass of cement and sand, and once we do that then we try to mix those, we try to prepare those specimens and have them tested at different points of time. The standards could be 16 m p a of strength in 3 days, 22 m p a of strength in a certain amount of 168 hours 160 m p a, 16 m p a strength in 72 hours, 22 m p a in 168 hours and 33 m p a for 672 hours, where you must remember that P is the standard consistency of that particular cement. These numbers are of course, for a given cement, different cements will have different requirements.

So, cement which is supposed to be used in repair work where we want high early strength these numbers can be much higher. We may not so much depend on how much is the strength at a later point in time. However, a cement where we want a strength development to be later, there we may not be concerned so much with what is the strength development initially we are only concerned with the strength development much later at different or a later point in hydration.

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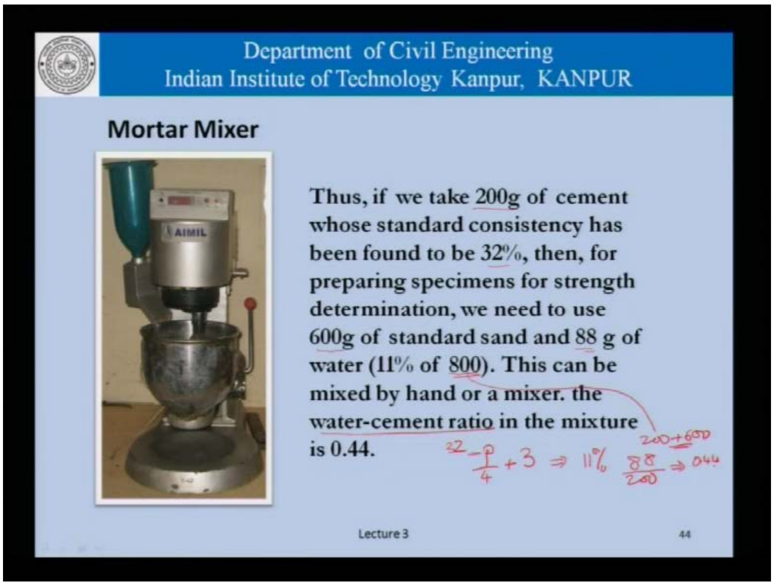

So, again if we take 200 now as an example, if we take 200 grams of cement whose standard consistency has been found to be 32 percent, then for preparing the specimens for strength determination, you need to use 600 grams of standard sand because that is 1 is to 3 and 88 grams of water. Now, 88 comes from P by 4 plus 3 and given the fact that P is equal to 32, we have this as 11 percent of 800 which is nothing but 200 plus 600. So, we are using 11 percent that is 88 grams of water and this mixture can be mixed by hand or using a mixer.

Here, please remember that if this is the mix that we are using then the water cement ratio of that mortar is 88 grams of water divided by 200 grams of cement, which is 0.44 or 44 percent. Now, this is the very important thing because, for the same cement if the standard consistency is different that is if the fineness was different or something else was to happen. Then the amount of water that we used will be different and therefore, the strengths are likely to change.

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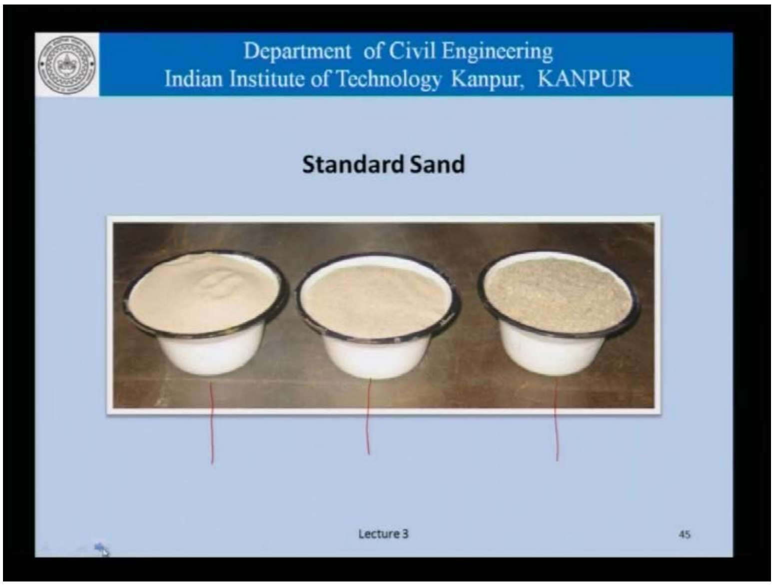

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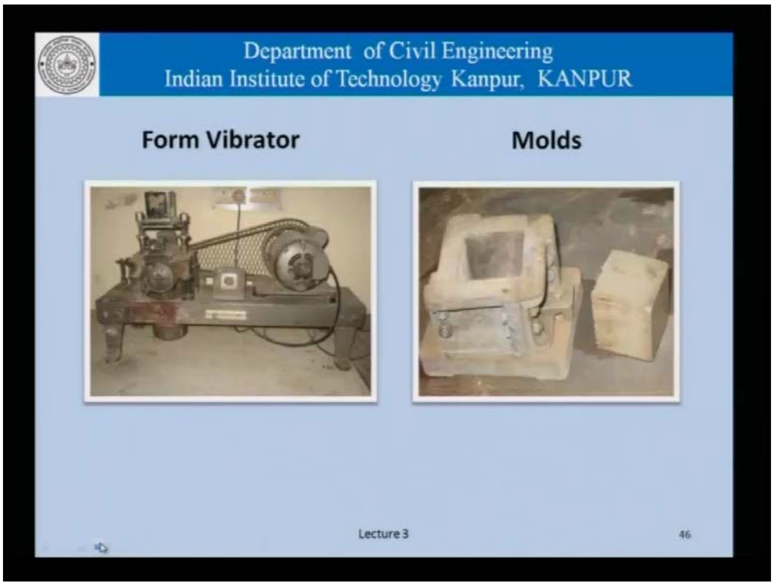

This picture only shows, this pictures, the two pictures here show the molds that are used for casting the cement specimens or the mortar specimens for strength determination and the form vibrator which is used. So, there is this mold which is fitted on to the vibrator which when switched on compact the mold.

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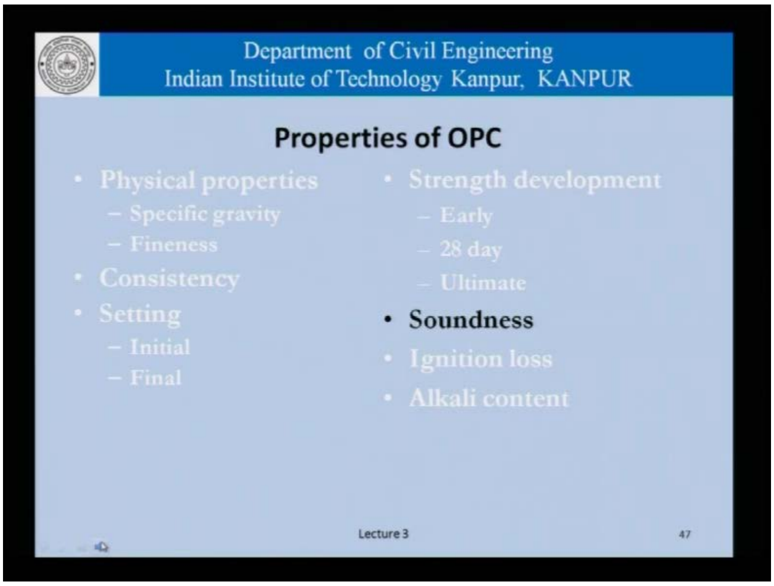

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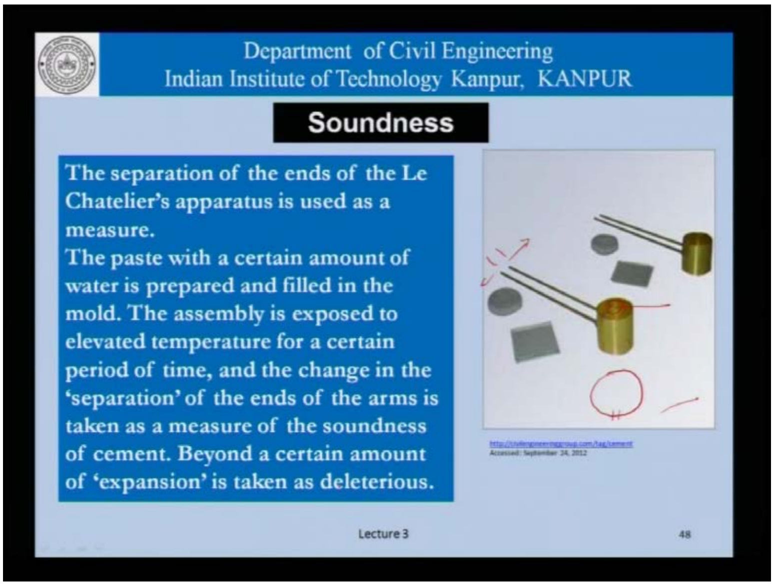

Now, coming to the next property that we need to talk about the, soundness of cement. This is usually measured using what is called a Le Chatelier's apparatus, which is shown in this picture here. The paste with a certain amount of water that is the water cement ratio of the paste is determined based on the standard consistency of the cement and that paste is filled in the mold. The assembly is then exposed to an elevated temperature for a certain period of time and the change in the separation of the ends of the arms is taken as a measure of the soundness of cement.

So, what is basically happens is that this mold is filled with the cement paste that we prepare, we measure the distance between these two ends of the tong and covered this mold with a glass plate and so on. Expose it to a certain temperature for a certain length of time and there is a slit here between the this this cylindrical mold has a split here. Therefore, this cylindrical mold has a small slit at one end and as the cement is exposed to elevated temperature and the reactions are accelerated.

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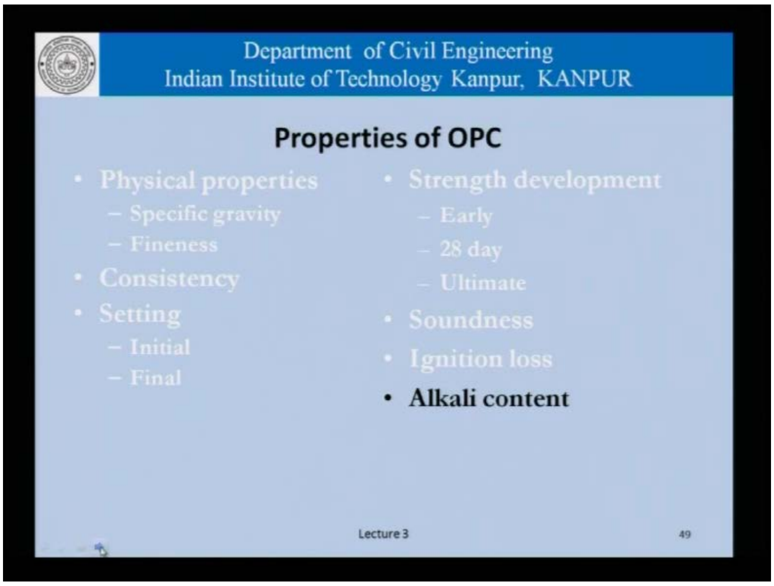

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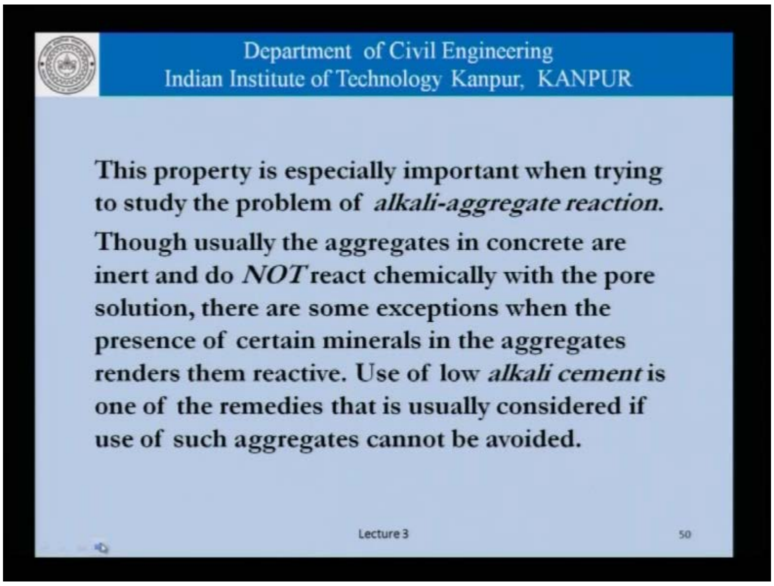

This distance tends to increase because, if the cement is unsound it tends to expand in this mold and beyond a certain amount the expansion is taken be deleterious. That is the cement is supposed to be unsound or is declared unsound. Coming to the alkali content of the cement. The property is especially important when trying to study the problem of alkali aggregate reaction. Though usually the aggregates in concrete are inert and do not react chemically with the pore solution, there are some exceptions when the presence of certain minerals in the aggregate renders them reactive. Use of low alkali cement is one of the remedies that is usually considered if the use of such aggregates cannot be avoided. So how do we determine the alkali content.

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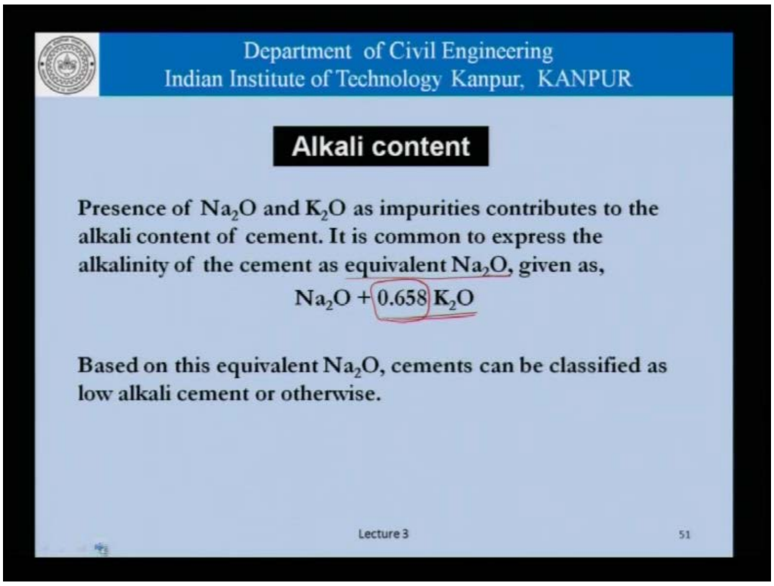

There is a chemical process which gives us the oxide composition of the cements and the alkali content itself is represented in terms of the N A 2 O and K 2 O that is the sodium and potassium oxides. These are basically impurities in the original raw materials of the cement and it is common to express the alkalinity, it is common to express the alkalinity of the cement as equivalent N A 2 O. What we do is to convert the amount of K 2 O that is present in the cement to an N A 2 O equivalent by using a factor of 0.658. Now, what is the basis of this factor, I am leaving it out as a self-study based on this equivalent of equivalent N A 2 O cements can be classified as low alkali or otherwise.

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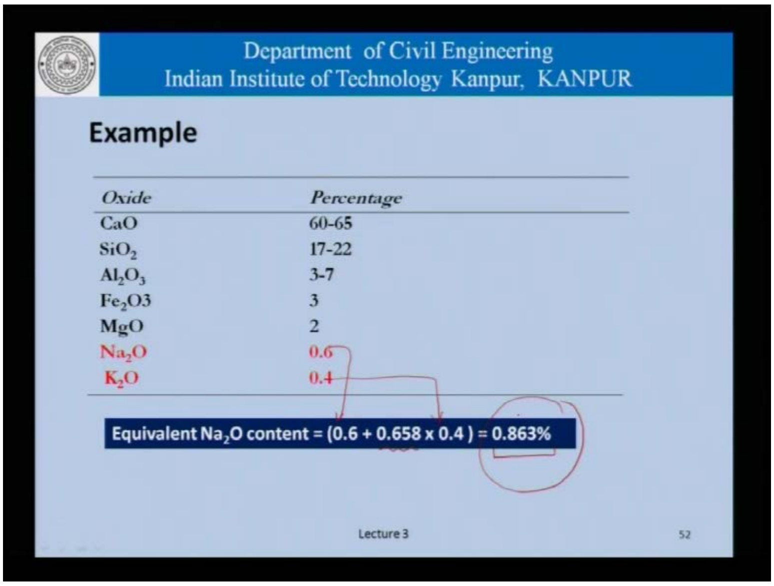

If we go back to the picture that we had seen earlier, where the N A 2 O and K 2 O in the cement composition were given to be 0.6 and 0.4 percent by mass. Then the N A 2 O equivalent of this cement is 0.6 which is this number and 0.65 8 times 0.4 ,which gives us a total alkali content or a equivalent N A 2 O content of 0.863 percent. So, that is the base.

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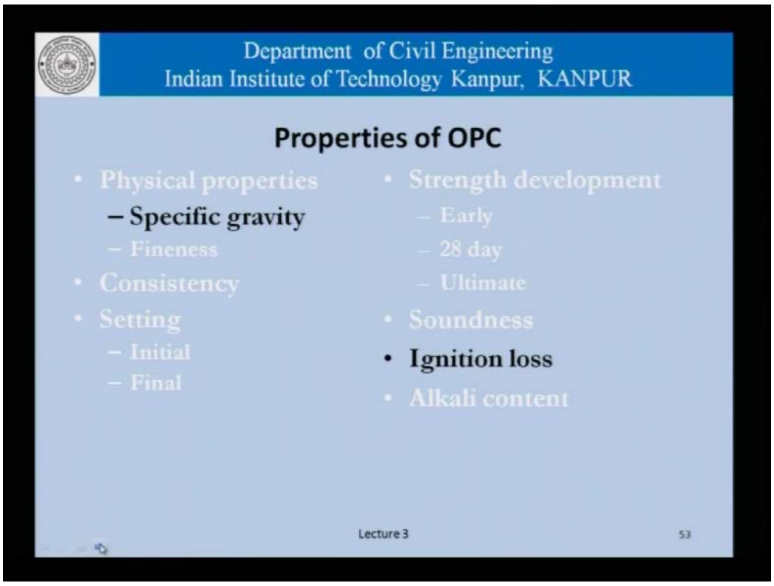

Based on this number the cement can be classified as high alkali or low alkali different specifications can put a number the 0.4 or 0.6 anything above that is high alkali cements.

As was mentioned in the previous slide, if we are forced to use reactive aggregates, then we should try to make sure that at least the cement that is used in low alkali that is at least one of the ingredients required for alkali aggregate reaction is minimized. Now, there are two properties which are left in this discussion from the list that we had started with specific gravity on any specific gravity and ignition loss. These two properties again I am leaving as a self-study assignment to you and you can look up standards which are available to determine them.

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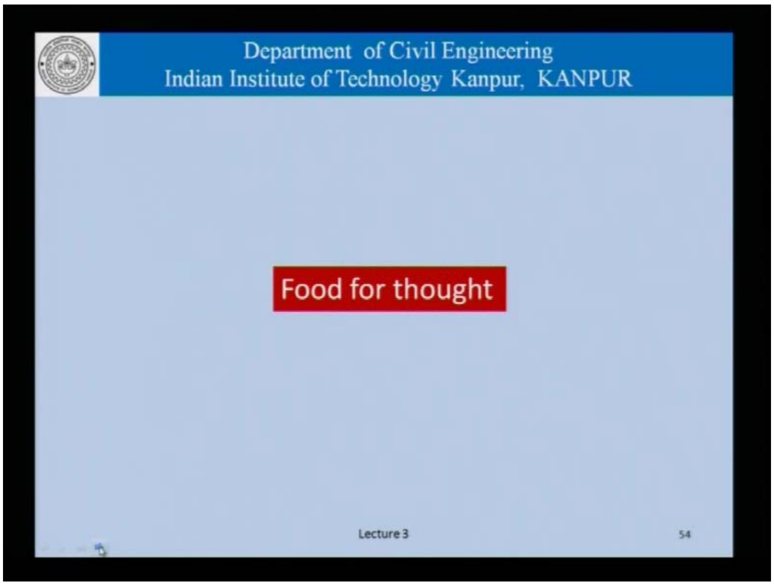

Now, the food for thought, that is recapitulate what we did in this discussion today. We went over the manufacturing of cement and its properties. The methods that are used to determine some of those properties setting time consistency and setting time consistency, strength fineness and so on. These are some of the questions which will help you better understand the subject that we discussed today.

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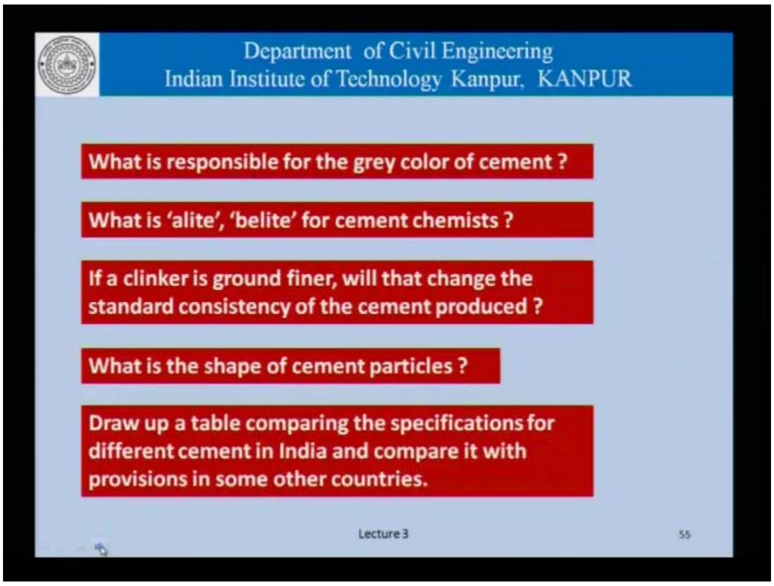

What is responsible for the grey color of cement? We all know that cement is usually grey in color. What is the ingredient of the cement, which gives this color to the material? Cement chemists often talk in terms of alite belite ferrite and so on. What are these minerals? What are these compounds? Now the third question is, if a clinker is ground finer, what if the clinker is ground finer? Will that change the standard consistency of the cement produced? The clinker is the base material that is to be ground and we get ordinary portland cement. Now, if we grind it in a method that the clinker is ground finer, how will that part effect the standard consistency of the cement that is to say how does fineness of the cement effect the standard consistency?

What is the shape of a cement particle? Is the next question are they spherical, are the angular, what is the size of each particle? That is something, which one must know. Finally, I think if you draw up a table comparing the specifications for different cements in India, and compare it with provisions in some of the other countries. You have a better idea as to what specifications say about what is the minimum fineness? For example, what is the strength development? What is the strengths that we talk about? What are the grades of cement? How are cements classified? With this, we come to the end of the discussion today.

Thank you.