Concrete Engineering and Technology
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Lecture - 2
Constituents of Concrete
(Part 1 of 2)

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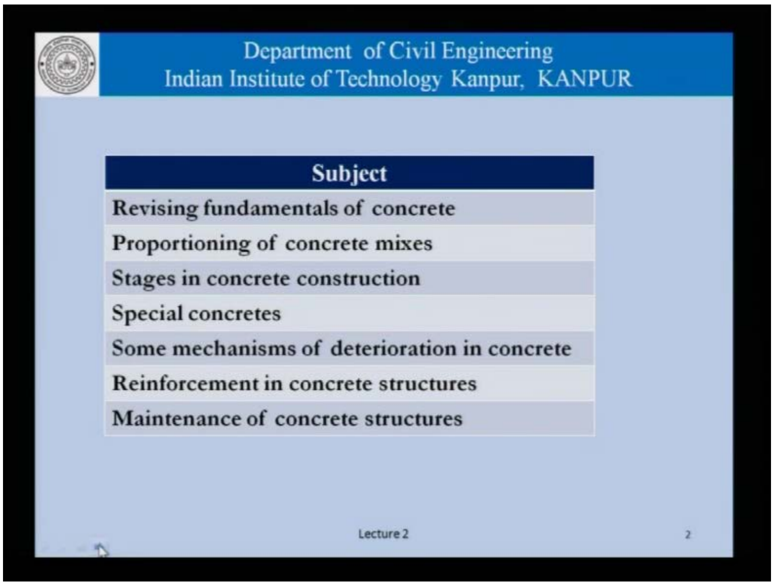

Welcome back to these lectures on concrete engineering technology. Beginning from where we left last time, this is the subject matter for this course revision of fundamentals, proportioning, stages in construction, special, mechanisms of deterioration, reinforcement, maintenance. We begin our discussion today with fundamentals of concrete.

Within this, we will be talking of introduction and overview which we completed last time, constituents of concrete, properties of fresh and hardened concrete, hydration of cement and strength development in concrete and, quality control in concrete construction. So, beginning with constituents of concrete.

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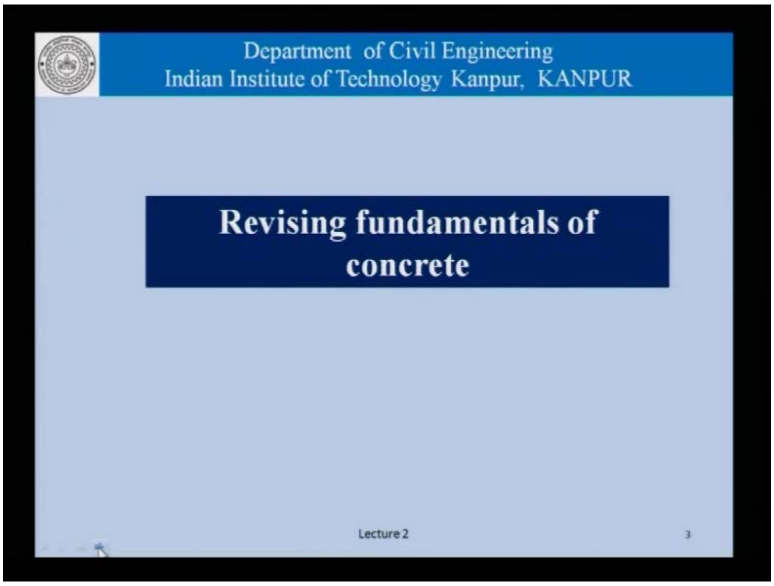

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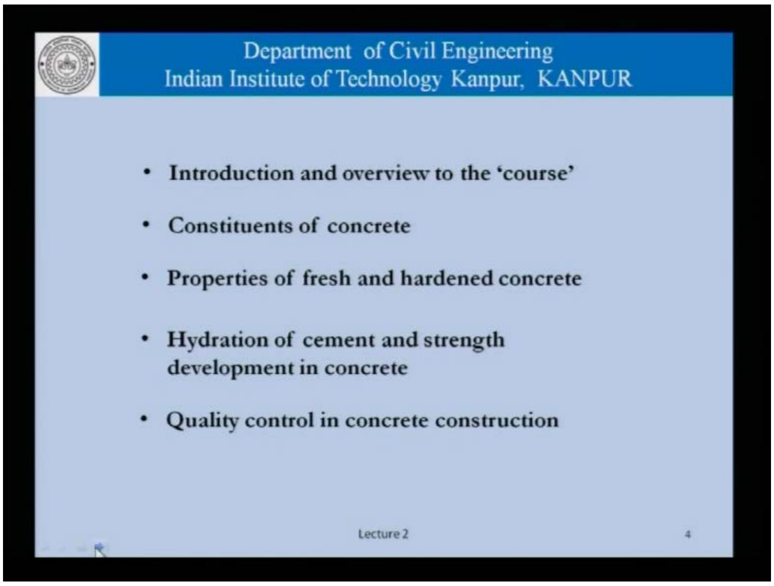

We have already seen that normal concrete contains coarse aggregate , fine aggregate, cement, which is ordinary Portland cement. For the time being unless we add some mineral admixtures, also unless we add some mineral admixtures and water other than mineral and chemical admixtures.

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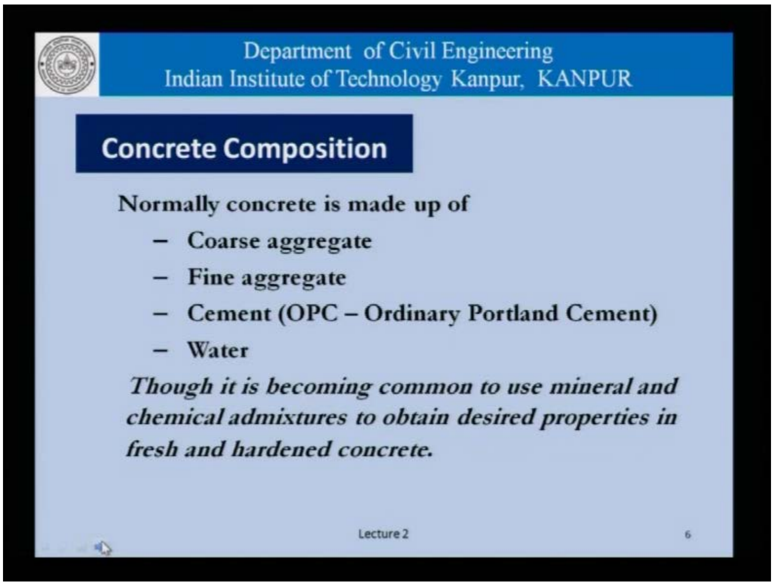

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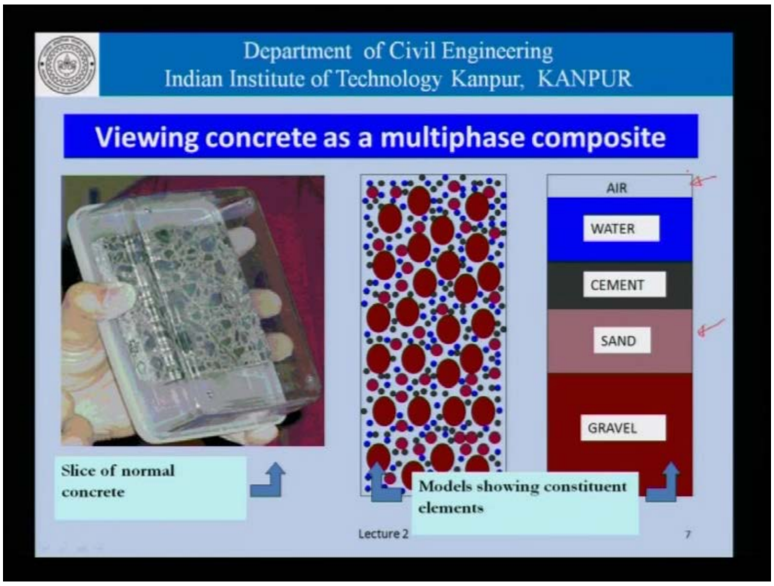

We had seen this picture as well, where we saw concrete as a multiphase material comprising of coarse aggregate s suspended in mortar, sand particles suspended in paste and cement particles suspended in water. That was our understanding. This picture here was the volumetrics of the concrete mix, where the coarse aggregate, sand, cement and water very importantly air had been discussed. These constituents are arranged in a concrete matrix.

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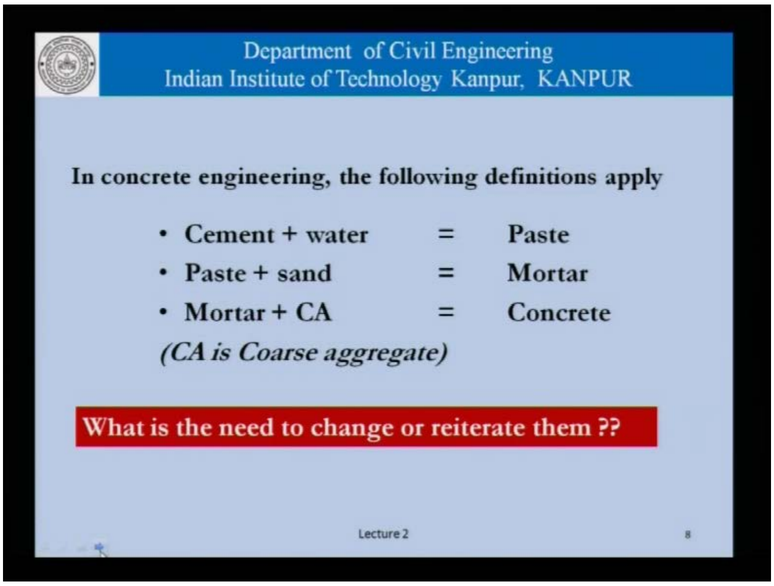

Continuing from this, we have defined the paste is cement and water, mortar is paste and sand and concrete is mortar and coarse aggregate.

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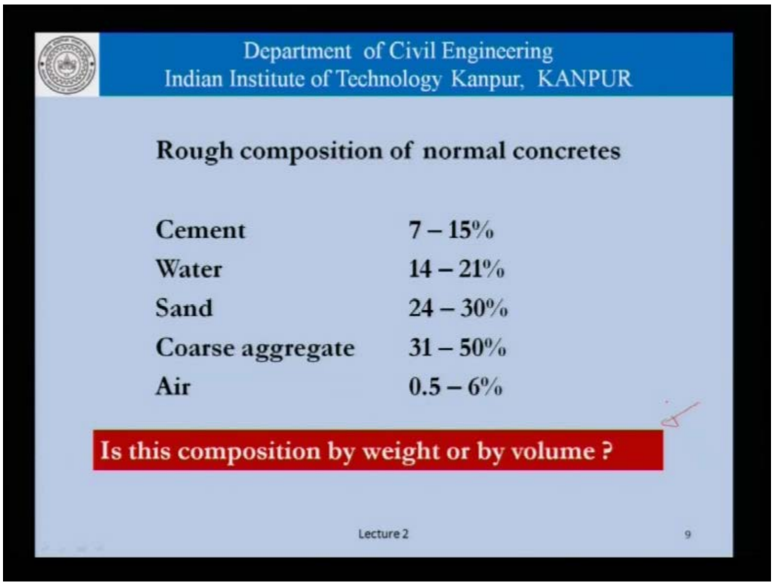

Now, roughly speaking, as far as normal concrete is concerned, cement is about 5 to 15 percent, Water is about 14 to 21 percent, Sand is about 24 to 30 percent, Coarse aggregate is about 31 to 50 percent. In other words Coarse and fine aggregate together could constitute as much as about 65, 70 and sometimes 75 percent of the overall volume of concrete. So, I have already given you the answer to this question here whether this composition is by weight or volume. Indeed, there is air which is about half a percent, may be 5,6 percent of concrete volume depending on whether we are talking of air entrained concrete or non air entrained concrete which we will talk about later.

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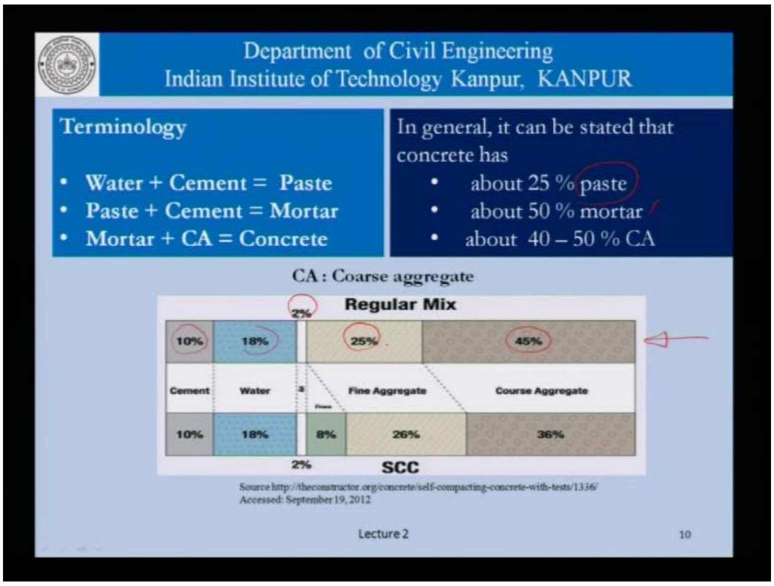

Now, if we look at a rough schematic of the relative volumes once again, this picture here shows regular concrete mix, where there is 10 percent of Cement, 18 percent water 2 percent I think is Air and there is a fine aggregate and coarse aggregate settled here. So, that is the rough volumes of a regular mix and that is pretty close to what we talked about last time.

Now, if we convert the volumes of these individual elements to the definition which we had talked about in terms of paste, mortar and concrete or coarse aggregate. Then it is about 25 percent paste, about 50 percent mortar and the balance 50 percent is coarse aggregate. So, coarse aggregate in other words just serves as inert filler, economical and cheap filler in the concrete matrix. That is a function which we must remember, when we carry out any detailed study of concrete proportions, concrete materials, concrete properties and so on.

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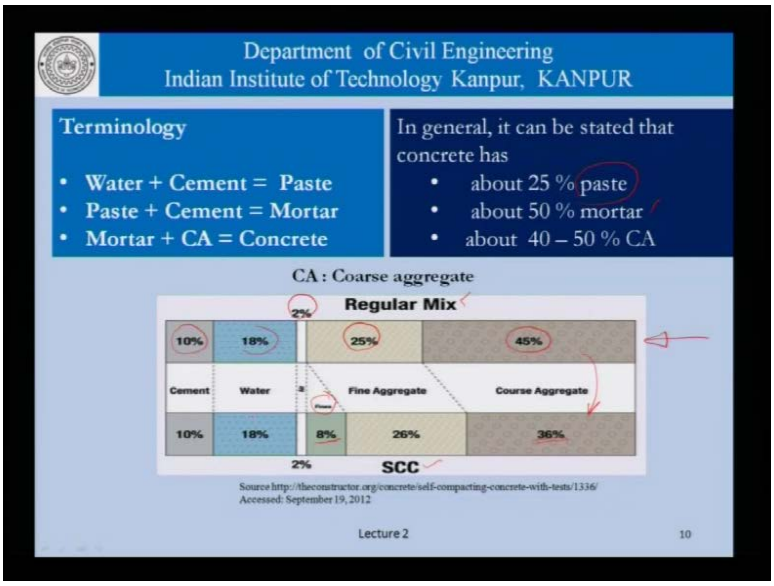

Compared to this what has been called a regular mix here, we will come back to this self compacting concrete later on, but if we look at this volumetric changes in self concrete or self compacting concrete, there is not much change. As far as the paste content itself is concerned of course, the properties of the paste are very different. What really happens is, that the coarse aggregate volume is reduced from about 45 percent to 36 percent and that additional volume, which is generate left behind, there are some fines which are added.

Now, it could be normal sand which is increased or some additional admixtures or the additional material which is used and serves the same purpose as sand. So, we must understand and this is their answer to the question in one of the previous slides. As to whether there is a need to change our definitions of paste and mortar because, paste is not only a mixture of cement and water in that sense and, particles which are added to the concrete, which have the same fineness as cement can qualify to be paste.

Similarly, any particles that qualify as sand as far characteristics are concerned, they would add to the sand content even though they are not normal sand. Therefore, we must understand that the definition that we have given to mortar as sand, water and cement needs to also include any other material, which qualifies as sand or which can be used as sand or a sand substitute.

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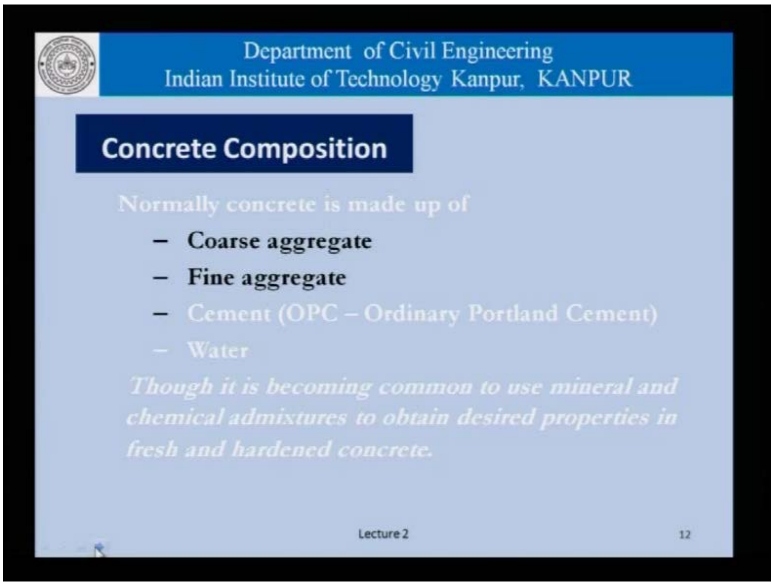

With this back ground, let us get started and study a little bit more about the properties of coarse and fine aggregate.

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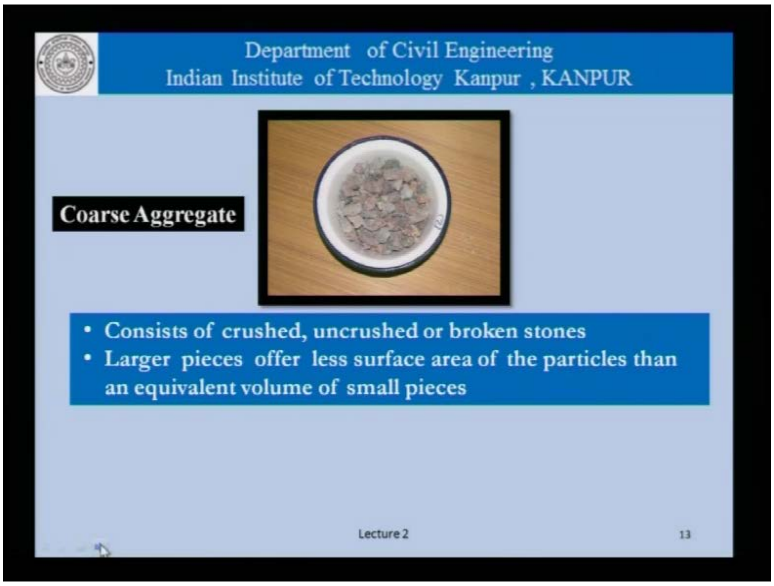

Let us start with coarse aggregate, this picture here shows some coarse aggregate, which consists of crushed, uncrushed or broken stones. The larger pieces of coarse aggregate offer less surface area when particles with an equivalent volume, but smaller in size now this has an important bearing on our treatment of concrete as we will see later on.

The hardened surface area of coarse aggregate, the more mortar you require to coat all the aggregate pieces. Therefore, the demand of mortar that is the volume of Mortar needs to be increased if we are working with finer aggregates, finer coarse aggregates or smaller coarse aggregates. Whereas, if we are using larger size of coarse aggregate particles, since the surface area is smaller, we can make do with a smaller volume of mortar.

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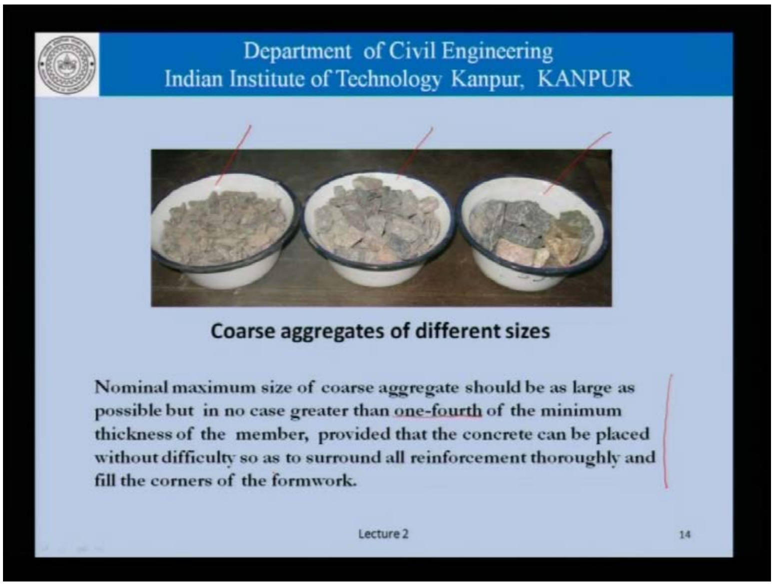

Now, here what we see is coarse aggregate of different sizes, there is coarse aggregate of this size which is very small, this size which is slightly bigger and relatively larger coarse aggregate particles. So, in a manner of speaking it make sense to use the largest possible aggregate size for a particular construction. Now, what governs the choice of the maximum size of the coarse aggregate? One of these considerations is given here, the nominal maximum size of coarse aggregate should be as large as possible, but in no case greater than one fourth the minimum thickness of the concrete member that we are talking about whether it is a column or a beam or a slag.

Provided that the concrete can be placed without difficulty so, as to surround all the reinforcement thoroughly and fill the volume fill all the corners of the form work. We must understand or remember that all these done provisions like one-fourth are a matter of convenience and different codes and specifications give different numbers. They give different values and this number one-fourth and the description here is based on Indian documents the Indian specifications.

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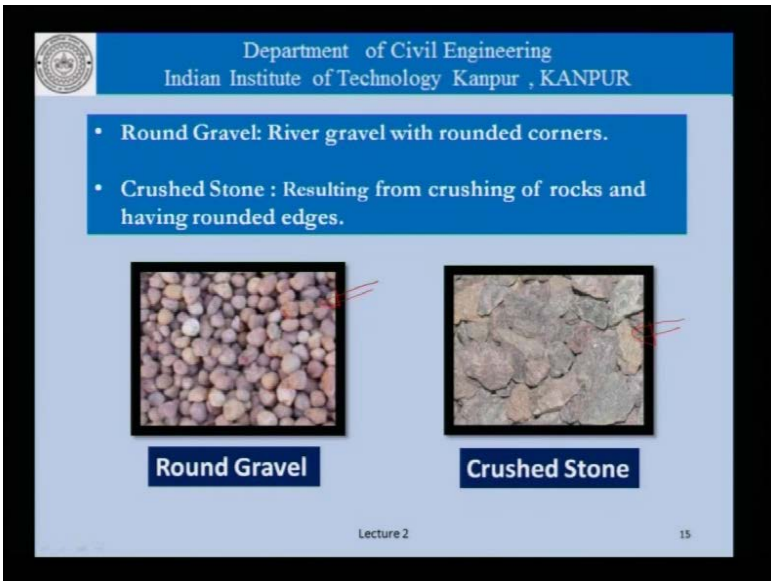

Another property of course aggregates be often seen is that we use round gravel or crushed stone. Now, round gravel is what is shown here and crushed stone is what is shown here. Round gravel is basically river gravel with rounded corners, crushed Stone is the result of crushing rocks and having angular edges.

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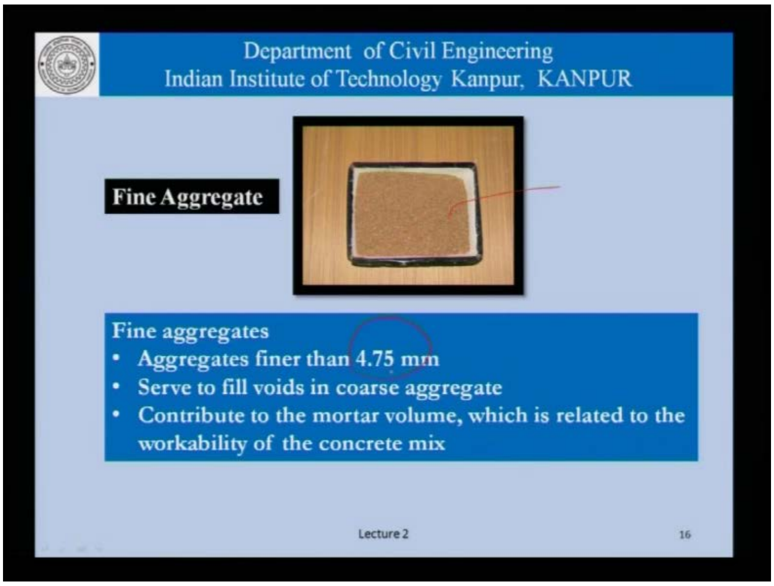

You will recall that the previous picture that is this one had all angular aggregates and Crushed Stone as the coarse aggregate s. Continue from here, what is Fine aggregate? Fine aggregate is what we see here is basically sand and it is an aggregate which is finer than 4.75 mille meter, serves to fill the voids in coarse aggregate and contributes to the volume of mortar, which is related to the workability of the concrete mix. Again 4.75 is only a universally accepted demarcation between coarse aggregate s and finer aggregates.

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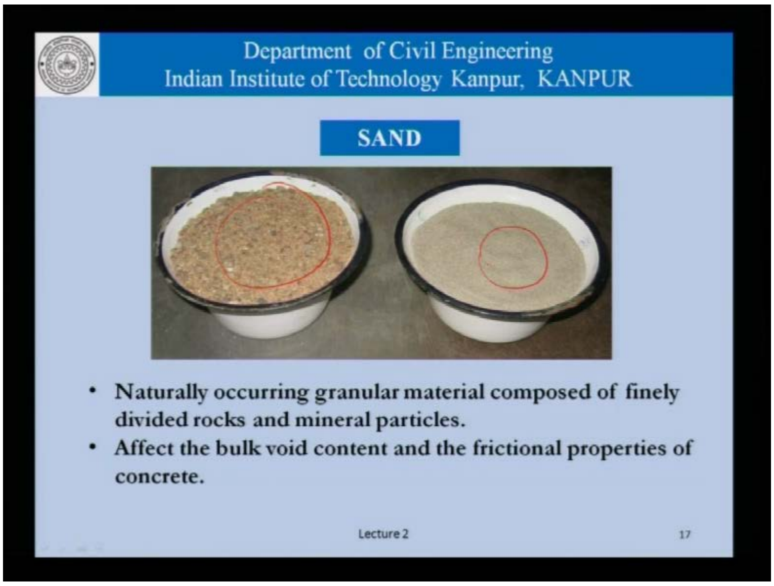

A little bit more about sand, this sand here is coarser than this sand here, because both of them are sand. That is they are very fine in nature, they have no reactive properties and therefore, do not quality a cement and therefore, they are fine aggregate depending on the requirement whether we are trying to plaster a wall or we are trying to mix it in concrete, we may use one sand or the other or at times we may try to blend different sands to get a particular size distribution and so on. Sand consists of naturally occurring granular particles, granular material, composed of finely divided rocks and mineral particles and affect the bulk void content and the frictional properties of the concrete.

Coming to the properties of coarse aggregate , we often talk of shape, the maximum size of aggregate, the particle distribution or the particle size distribution, density, porosity and strength. Now, I would only like to draw a rotation to porosity, porosity means the aggregates are porous, that means they have internal pores and these internal pores can be full of water or may be not full of water. When we are talking of dry aggregates we are talking of aggregates which do not have water in them. At times after a rain and so on the aggregates the volume of pores in the aggregate is fully saturated with water. And the porosity is related to strength. No porous aggregates will have lower strength aggregates with less porosity will have a higher strength. Density is another property which we will discuss in greater detail later on.

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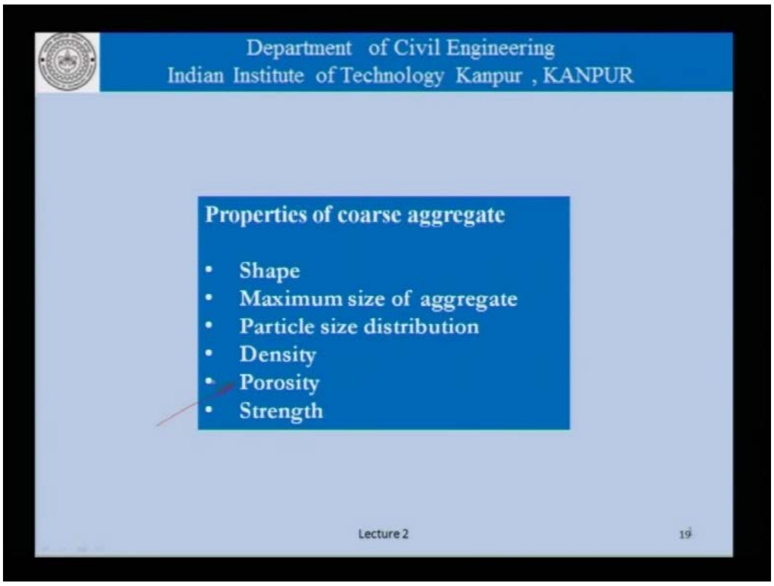

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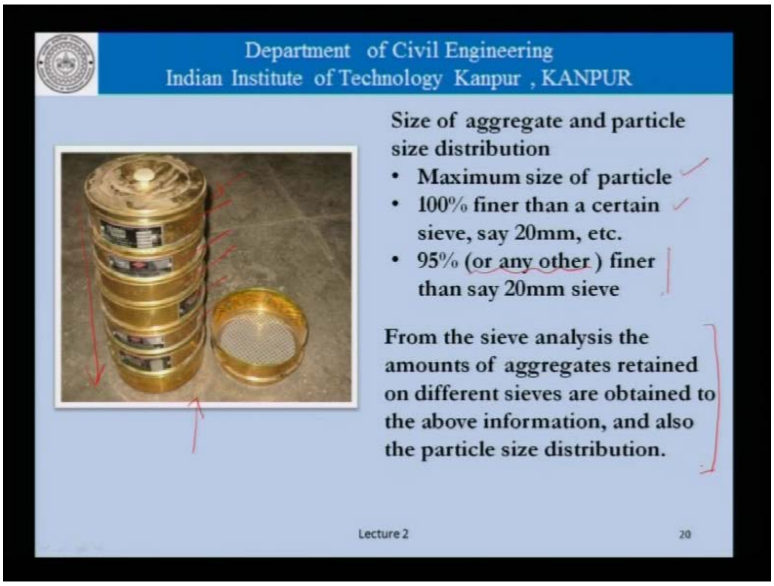

Now coming to the first of these important properties which basically deals with the size distribution and the size of aggregates, this here is a sieve set which is used to determine the particle size distribution. So, we have all these different sieves which are arranged in a certain manner and we put an aggregate sample at the top and shake the sieves. Once we shake the sieves, we have particles retained at different sieves and these particles which are retained at different levels.

We take up measure of that in terms of the weights and the relative weight retained at a particular sieve with respect to the total amount of aggregate taken and we get the amount of aggregate or the percentage of aggregates of that particular size. What this sieve analysis gives us is the maximum size of particles, a size compared to which hundred percent particles are finer, that is if we have a 20 mille meter sieve and everything, that is all the aggregates from the sample passed through the 20 mille meter sieve, we say that the aggregates are at most 20 mille meter in size.

And then there is information like 95 percent or any other number finer than the 20 mille meter sieve, maybe we have 5 percent retained on the 20 mille meter sieve and 95 percent passed through that. So, that gives us that 95 percent of the particles are finer than 20 mille meters. From this analysis as I have already talked to you, we get the amounts of aggregate retained on different sieves and that gives us the particle size distribution.

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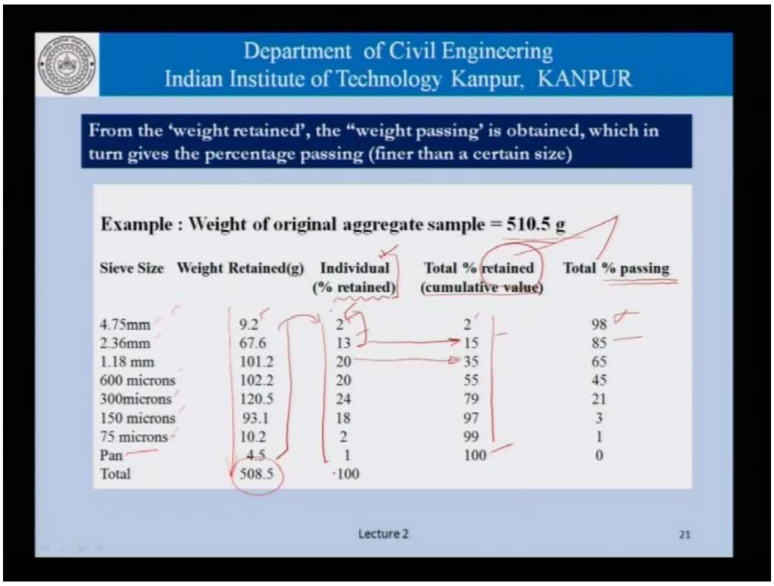

Let us look at an example of this, suppose we begin with an original sample of 510.5 grams and we have these different sieves, which are used which are set in that order and we have a pan at the bottom to collect particles, which are finer than 75 microns. Once we have all these particles which are placed here and we shake the sieve set and get these numbers, that 9.2 grams is retained, here 67.6 is retained, here and so on. And we get a total which is 508.5, which is different from the total of 510.

Let us take an example of particle size distribution as determined from sieve analysis, we can talk in terms of weight retained or we can talk in terms of weight passing, which in turn will give us the percentage passing which will give us the final term a certain size. Now, if we take aggregate sample which is 510 grams or 510.5 grams to be precise and pass it through a sieve set which starts with 4.75, 2.36 and so on and goes all the way to the pan, which collects the residue or which collects material, which is finer than the 75 micron. Sieve in this case and we should the sieves in a certain manner as required and we find out how much material has been retained on each of these sieves.

If we get this as the numbers, then what we can get from here is these numbers which are individual retentions at the different sieves. So, if 9.2 grams is retained, we can say that 2 percent of the aggregate taken is retained at the 4.75 mille meter sieve and so on. So, these are individual retentions. Another thing which is often very important or very interesting to note is the cumulative retention and cumulative retention means and cumulative retention is reflected here.

What it says is that 2 percent is retained at 4.75 and this 13 percent which is retained in 2.36 is also added to this and we get 15 here similarly, 20 gets added to this and we get 35 here and so on and so forth till we get this number 100 here. Now, this as I mentioned is the values for retained, the retention at that particular sieve, then we have percentage passing that is 98 percent because 2 percent were retained here, 98 percent of the particles passed through that sieve. Because 15 percent particles were retained here then 85 percent have passed through and so on. So this is two different ways of representing the sieve data which is given here.

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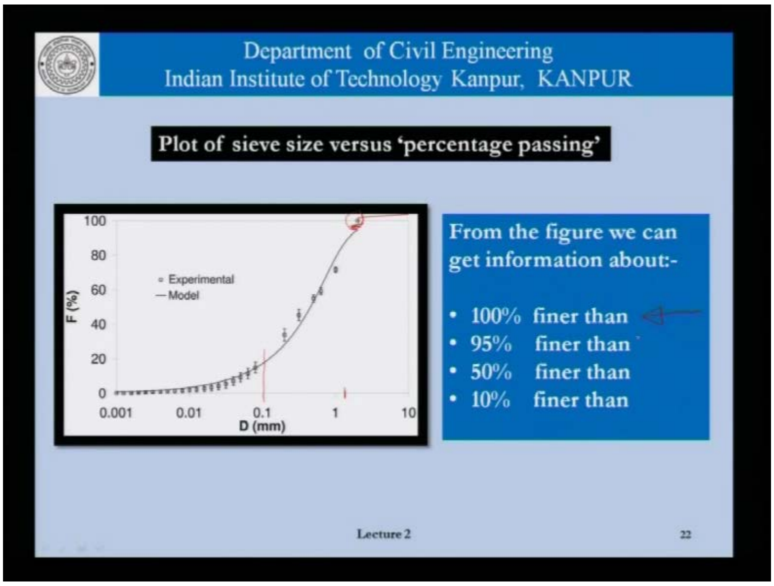

And this data, when it is plotted on a graph look something like this, that this is the particle sizes or the sieve sizes and F is the percentage finer than. So, basically what it says is that there will be a particular sieve size here and all the particles will be finer than that and that is nothing will be retained on those sieves. Similarly, if we come to any other number here, we get the percentage of particle which are finer than that number. So, this kind of a representation of the percentage finer than versus the sieve size can be used to get information about 100 percent finer than what number? 95 percent finer than what number? 50 percent finer than what number? 10 percent finer than what number? and so on.

So, if we are looking (( )) if we want to know in a particular application, that given a sample of aggregates whether it is fine or coarse, what is the sieve size corresponding to which 95 percent particles are finer than that number, we just go here go all the way to this point and try to find out what is that number. So, that is how we try to determine 95 percent, 50 percent, and 10 percent and so on and so forth. Please note that this scale usually is a log scale it is not plotted on a linear scale.

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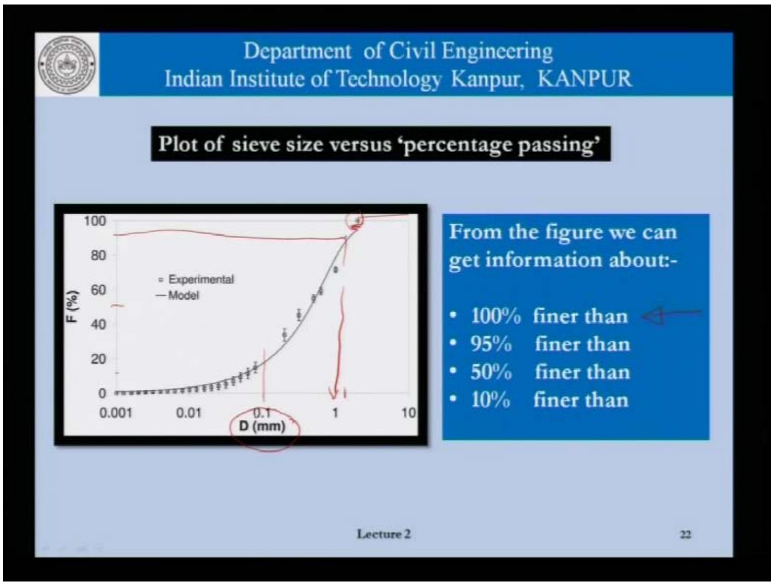

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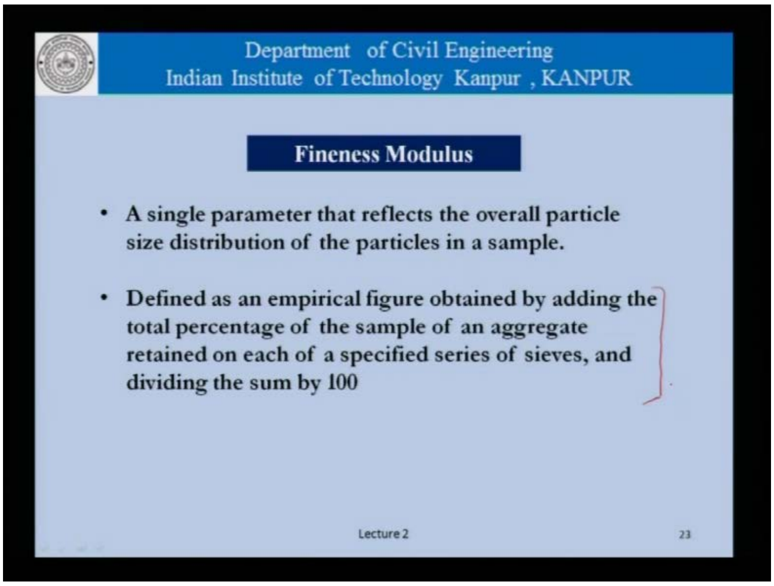

Another parameter that we use to represent the particle sizes of aggregates is the so called fineness modulus. It is a single parameter that reflects the overall particle size distribution of particles in a sample. It is defined as an empirical figure obtained by adding the total percentage of the samples in an aggregate which is retained on each of the specified series of sieves and dividing the sum by 100. This is a very difficult text to read and to understand.

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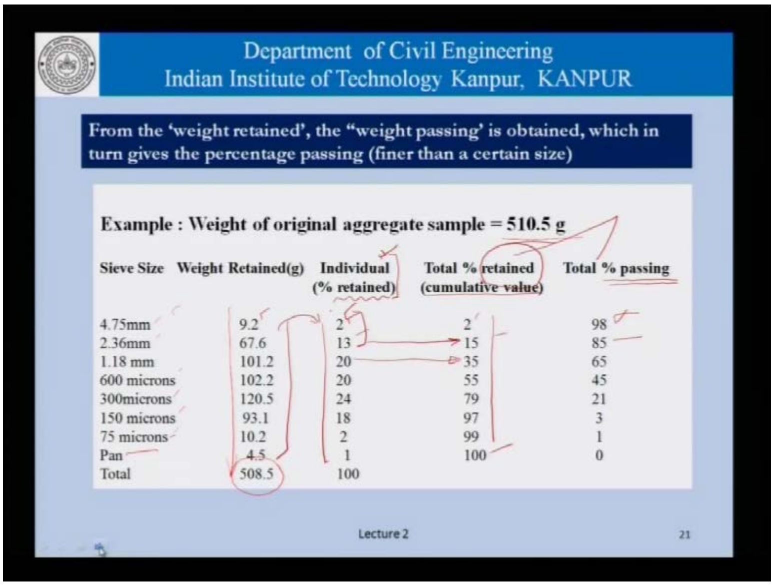

My suggestion to you would be to actually see how the fineness modulus is calculated for a given particle size distribution, which is basically this kind of a data, which is determined from the lab. How we determine the fineness modulus from here is one exercise, which I am leaving for you to do. We will probably give the answer in some later presentation?

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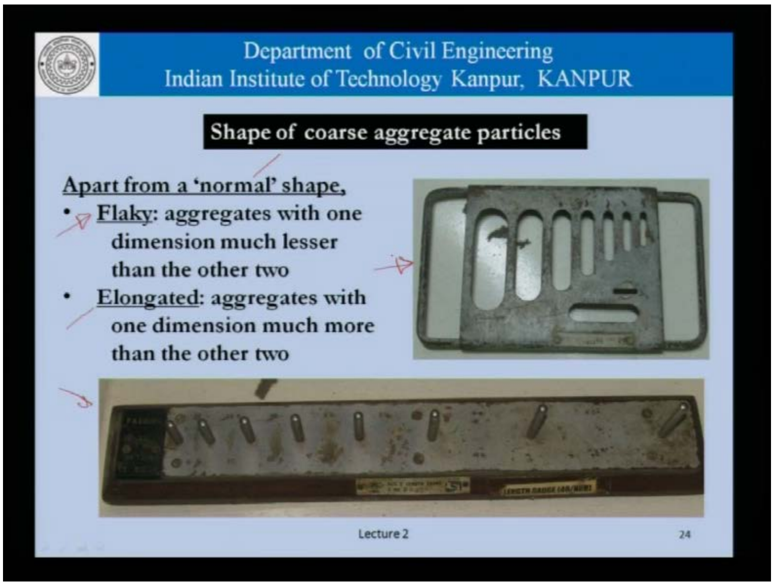

Coming to the shape of coarse aggregate particles, we do not talk of shape of fine aggregate particles. For coarse aggregate particles apart from the normal shape, we sometimes use the term flaky aggregates. We use the term elongated aggregates. Now, what does flaky mean? Flaky means the aggregates with one dimension much less than the other two so, a notebook for that matter is a flaky object elongated aggregates are those where one dimension is more than the other two.

So, this pen for example, is a elongated object and we do not want too many flaky or elongated particles in our sample of aggregates which we are going to use in concrete. For various reasons now, how do we determine the amount of flaky particles or the elongated particles? So, there are these standard gauges which are used and we are not getting into the details of how to use these gauges, but you should know that yes there are standard methods of determining; what particles or what percentage of particles are flaky, what percentage of particles are elongated and what should be the maximum amount of elongated or flaky particles that are permitted in an aggregate sample for use in concrete. And those specifications are all machine dependent, application dependent, client dependent and so on and so forth.

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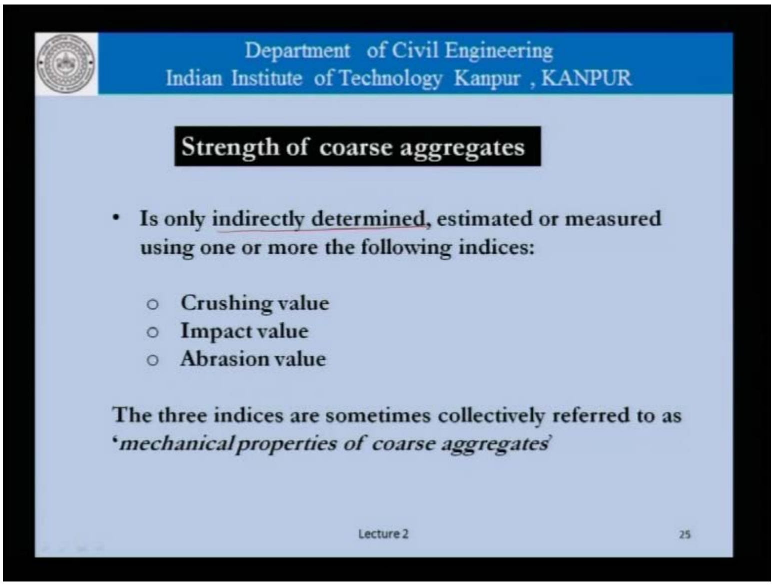

Coming to the strength of coarse aggregate s, it is only indirectly determined estimated or measured using one of the following indices, which is crushing value, impact value, abrasion value and these 3 indices are sometimes collectively referred to as mechanical properties of coarse aggregates. When I say that they are indirectly determined, what does that mean? Strength if we understand normally would mean we should take aggregate sample and crush it till it fails.

Now, that normally is very very difficult to do and is not so much required as far as civil engineering applications are concerned or normal civil engineering applications are concerned. Therefore, we may do with these 3 parameters crushing value, impact value and the abrasion value which are good enough for our purposes. Let us try to understand how they are determined.

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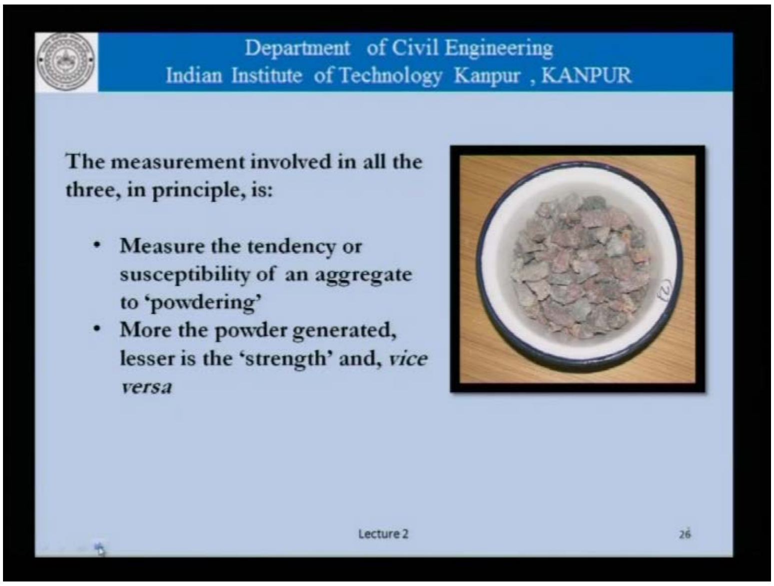

In principle, the measurement in all the 3 cases involves the following we just measure the tendency of an aggregate or it is susceptibility to powdering that is how much powder gets generated. More powders generated lesser is the strength and vice versa that is if we take an aggregate do something to it and a lot of powder is generated, then we say that the aggregate is weaker. Whereas, if we take the aggregate, do the same things to it apply the same load and so on and no powder is generated. Then of course, the aggregate is very strong. How is the powder generated? The powder is generated by the fracture of the edges, the angular edges of the aggregate and that is what we get tendency of an aggregate to powder.

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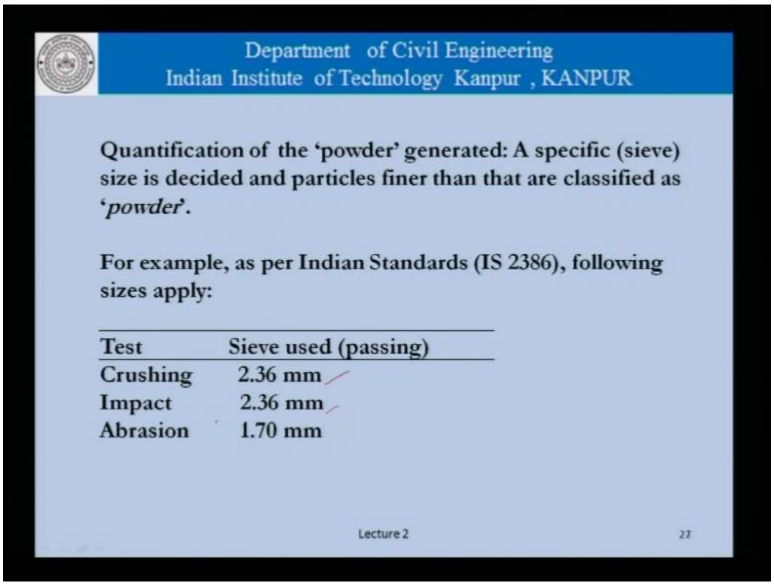

Quantification of the powder generated and how do we determine? How much powder has been generated? That requires a specific sieve size, which should be decided and particles finer than that are classified as powder. For example, as far as Indian standards are concerned, they say that for crushing value particles finer than 2.36 mille meter. And the same value of 2.36 mille meter is used for impact value as well, particles finer than 2.36 mille meter are powder. Whereas, for the abrasion test particles finer than 1.7 mille meter are considered as powder.

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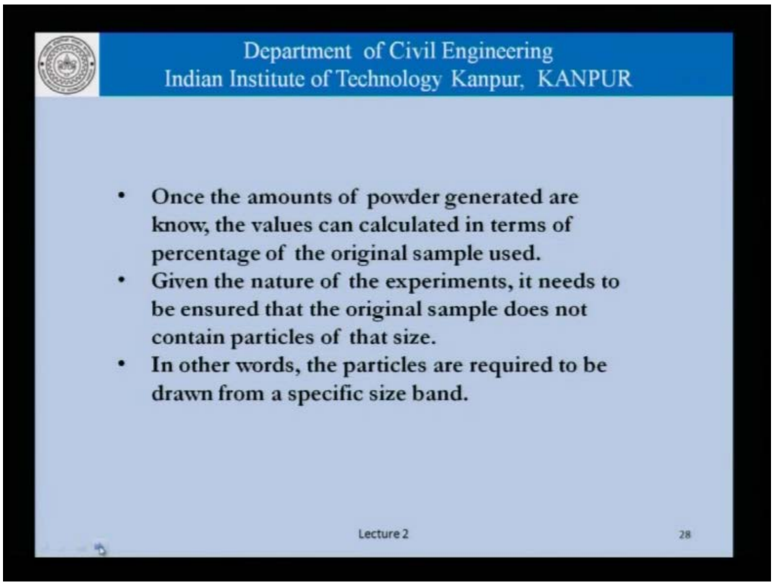

Naturally, what that means is that once the amounts of powder generated are known, the values can be calculated in terms of the percentage of the original sample used and given the nature of the experiments it needs to be ensured, that the original size or the original sample does not contain particles of that size. We cannot have fine particles or powder originally present in the sample. Because that will interfere with our measurement of the impact value or the crushing value and so on. And therefore, the particles which we use as samples for testing are required to be drawn from only a specific size band.

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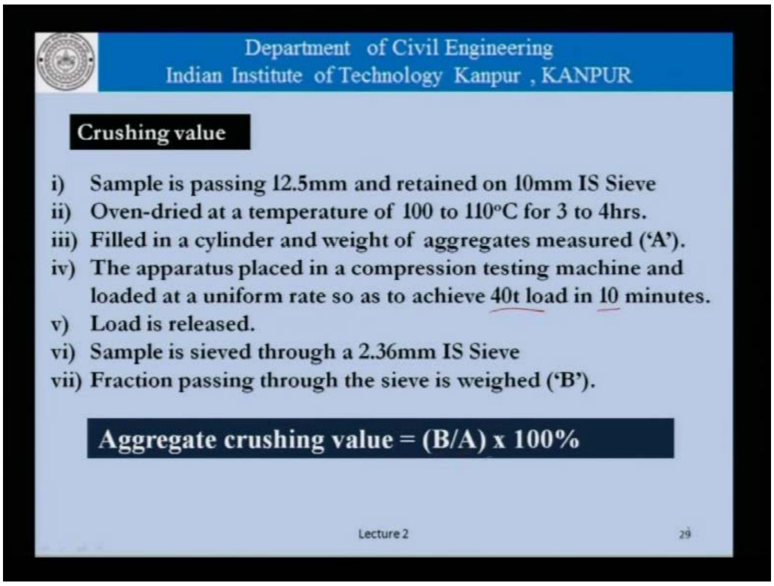

Now, let us quickly look at some of the tests that are carried out for crushing value the aggregate passing through 12.5 mille meter and retained on 10 mille meter sieve are used. They are oven-dried at a temperature of 100 to 110 degrees for 3 to 4 hours and then they are filled in a cylinder and the weight of the aggregates is measured. That is we now, know how much aggregate have we taken, the apparatus which is this cylinder is now, placed in a compression testing machine and loaded at a uniform rate so as to achieve a load of 40 tonnes in 10 minutes. So, the rate of load is also specified, the load is released and the sample is sieved throughout 2.36 mille meter I have seen sieve and the fraction passing through that sieve is measured and that is how we get the crushing value of the aggregates as B divided by A into 100.

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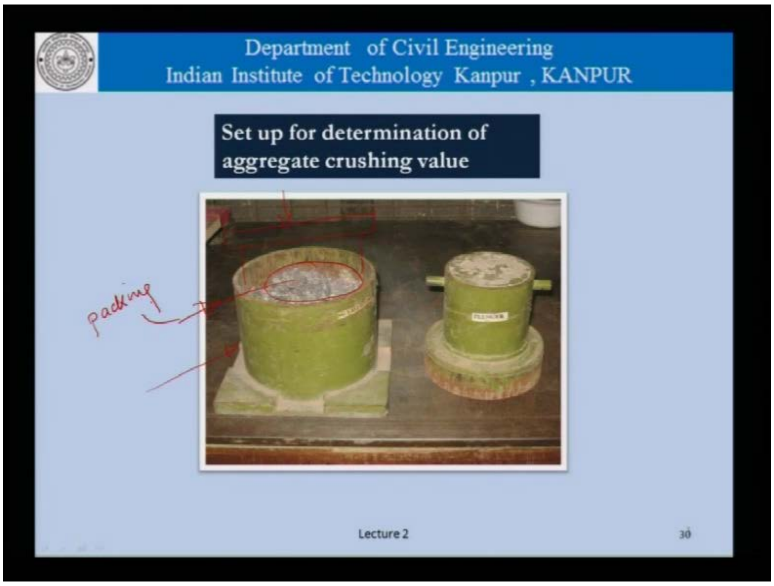

And this is the set up which is used for determining the crushing value, this is the cylinder where the aggregates are filled, this is the plunger which is used over this cylinder at the time of load application.

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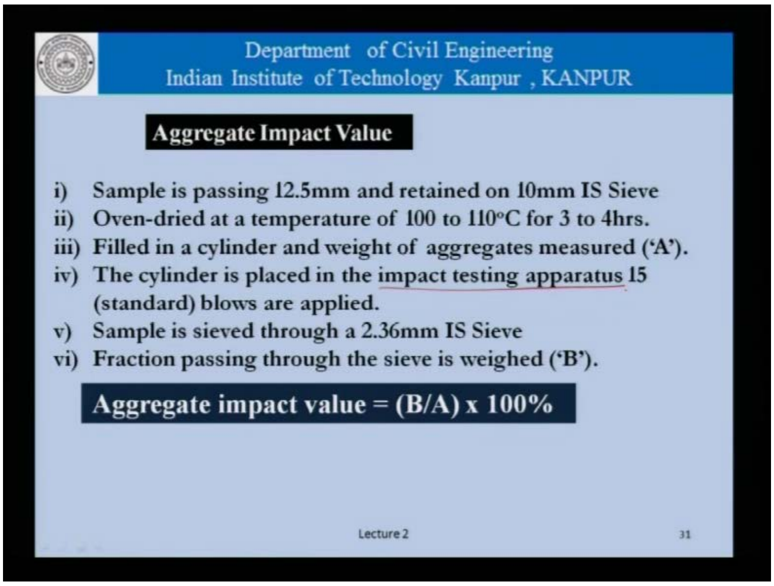

Naturally, now the crushing value that we get that is the amount of powder that is generated at the end of the test, will depend also on how the packing has been done, that is how densely we have packed the aggregates in this cylinder. And therefore, test methods very often must specify how exactly the samples has to be taken as far as filling the cylinder is concerned.

Now, coming to the aggregate impact value here, this is another test where again the sample is similar passing through 12.5 mille meter and retained on 10 mille meter. It is over-dried, filled in a cylinder and weight of this aggregate taken as measured and the cylinder is placed in an impact testing apparatus. So, now we are talking of a impact testing apparatus, which we will show in a later slide and 15 standard blows are applied the sample is sieved through a 2.36 mm sieve and we determine how much is the fraction of the aggregates that pass through the sieve.

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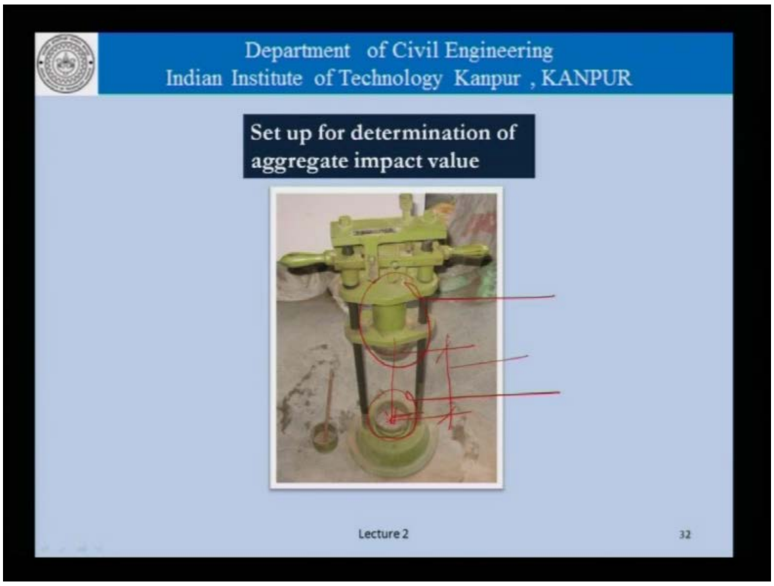

And we get the aggregate impact value in terms of v by a, this is the apparatus here for the aggregate impact value. This part here shows the cylinder where the aggregates are placed for determination of the aggregate impact value and this set up here has a certain mass and it falls through a certain height and constitutes one standard blow. So, once were release this plunger here it comes and impacts the aggregates in this box or in this cylinder and we take it back using these handles and, drop the weight again and that is what is repeated 15 times and we try to powder the aggregates which are here. All the aggregates which are powdered break they are that amount of powder generated is measured.

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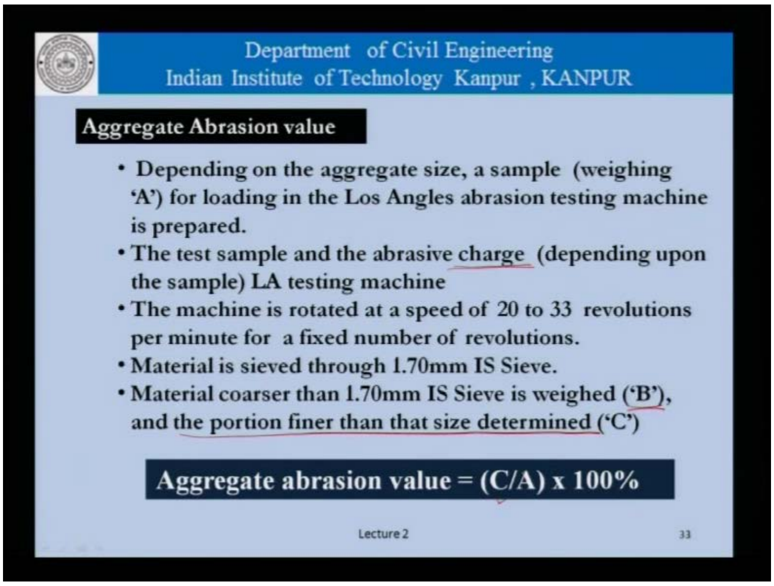

And we get the aggregate impact value. Coming to the aggregate abrasion value, this test is carried out slightly differently and how we do it is we take a certain sample weighing let us say A for loading in a Los Angles abrasion testing machine.

This test sample and an abrasive charge now, this charge is nothing but a steel balls of a certain diameter having a certain weight and a certain number of those balls constitute what is called the abrasive charge. They are placed in the Los Angles testing machine and the machine is rotated at a speed of 20 to 33 revolutions per minute for a fixed number of revolutions. The aggregates now, are sieved through a 1.7 mille meter IS sieve and material coarser than 1.7 IS sieve is weighed. And from this value here which is the amount retain on the 1.7 mille meter sieve, we work out the portion finer than the 1.7 mille meter sieve. So, in this case even though the aggregate abrasion value is exactly the same that means the percentage of particles which are finer than 1.7 mille meter with respect to the original size, we do not measure the percentage finer than directly what we measure is the weight retained at the 1.7 mille meter level and then try to determine how much has been how much is passing through.

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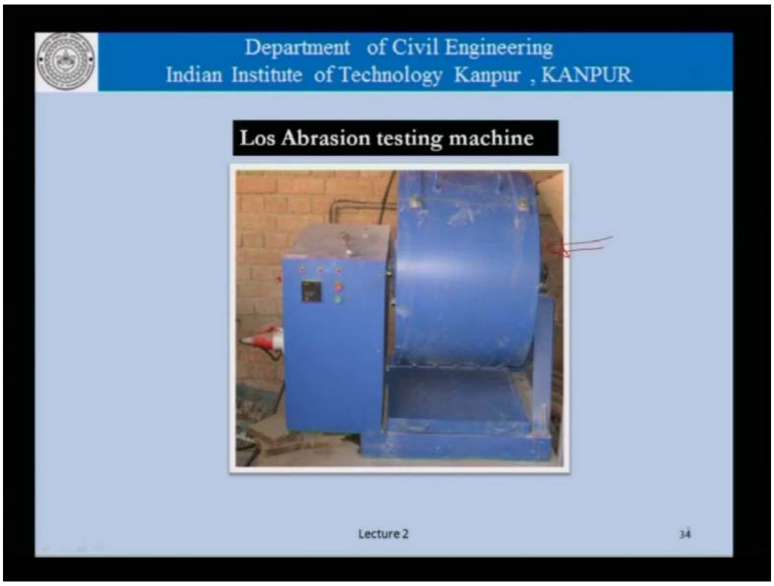

That is because, some of the powder that is generated is often left in the machines which is like this, the Los Angles testing machine is shown here and within this we have the charge and the aggregate particles which are moved in a rotary motion and some of the powder or the finer particles get left behind in the Los Angles abrasion testing machine. And therefore, it is better that we measure the percentage retained on the 1.7 mille meter sieve and then calculate the percentage finer than which helps us in turn calculate the abrasion value of the aggregates.

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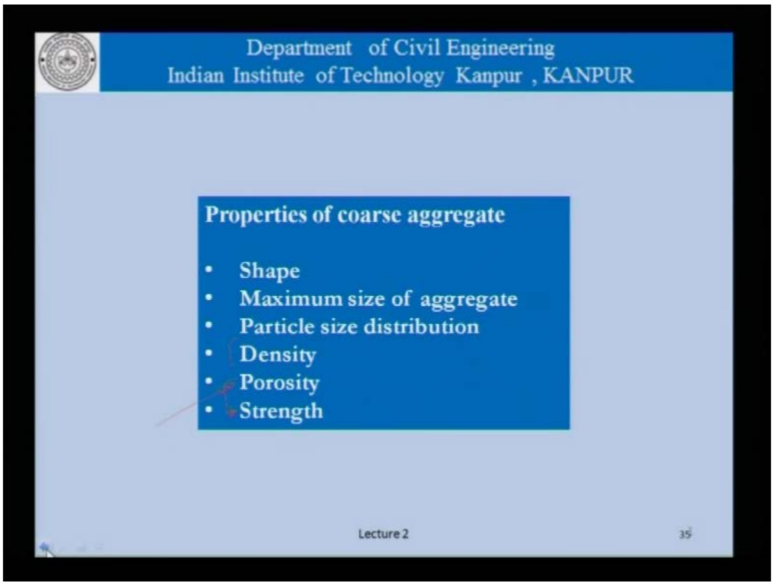

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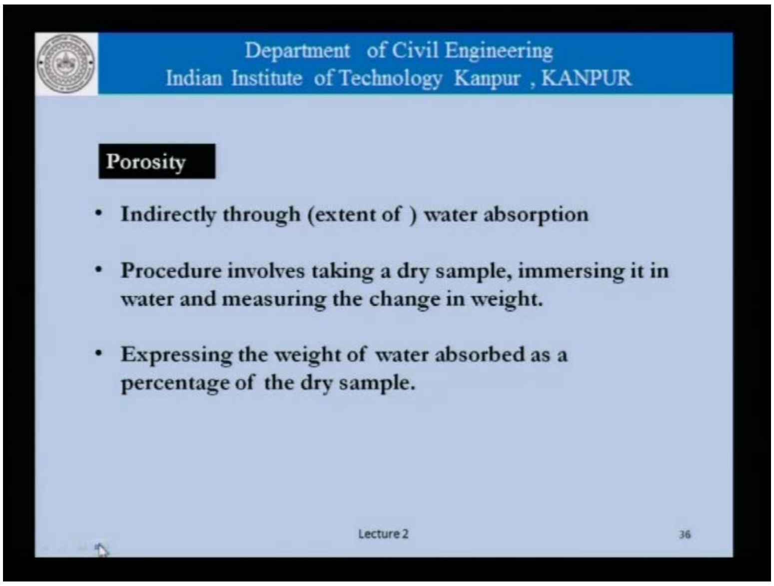

Now, after the mechanical properties have been discussed. Now, let us look at density, porosity and strength of coarse aggregates. Porosity again is indirectly measured through the extent of water absorption. The procedure involves taking a dry sample, immersing it in water and measuring the change in weight expressing the weight of water absorbed as a percentage of the dry sample. Strictly speaking, porosity should be giving us an idea of the size of the course within the coarse aggregate.

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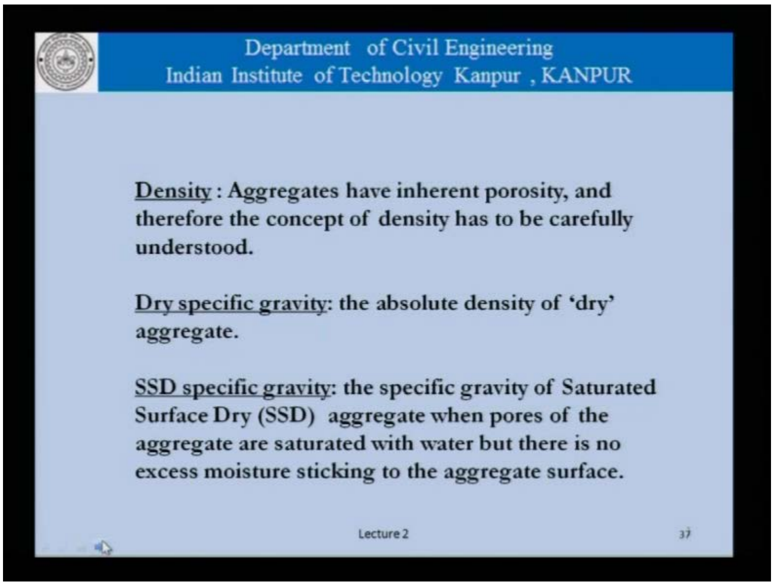

Now, those are very very fine and techniques such as poro-symmetry and so on which we will see later on in the course or specialized techniques, which for normal civil engineering construction and normal evolution of aggregates are not required. Therefore, civil engineering practice has the wide reasonably, well I should say based on simple measurement of porosity as determined from water absorption alone. Now, other terms like density and specific gravity. We all know the density is mass per unit volume, but let us try to understand this in the context of coarse aggregate s a little more vigorously.

Density basically means aggregates have inherent porosity. And therefore, the concept of density should be cared here. Now, let us understand the concept of density and specific gravity more rigorously in the context of aggregates. Since, they have inherent porosity these concepts have to be carefully understood. The dry specific gravity is the absolute density of dry aggregate, that is there is no water in the aggregates and we determine somehow the volume of the solids in the aggregate, we determine the mass and we determine the dry specific gravity. SSD specific gravity is the saturated surface dry specific gravity and that means the specific gravity of SSD aggregates that is those aggregates were water saturates the pores within the aggregate, but does not wet the surface.

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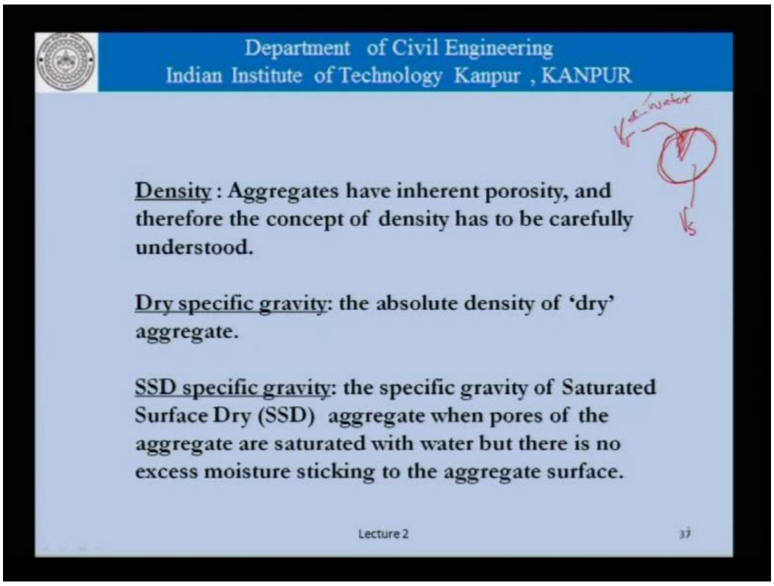

So, what we are looking at really is an aggregate particle which may have an inherent volume of pores like shown here. This is the volume of solids in the aggregate particle this is the volume of voids in the aggregate particle and this is the total volume. So, dry specific gravity means this volume is not filled with water and the total volume that is taken could be simply v s or if it is impossible to determine v s it could be v s plus v p because v v that is the volume of pores that is the volume of voids. In the coarse aggregate is really very small in the case of SSD this is saturated with water and we get the mass and the volume and we determine the SSD specific gravity.

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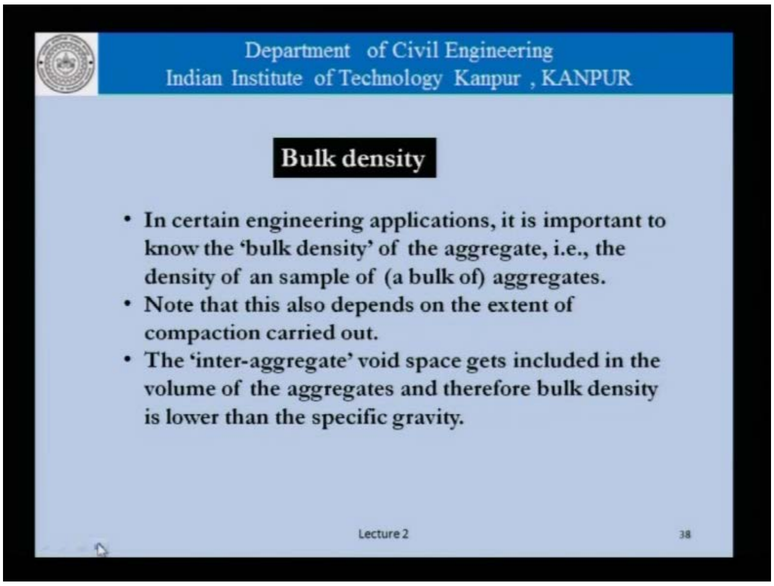

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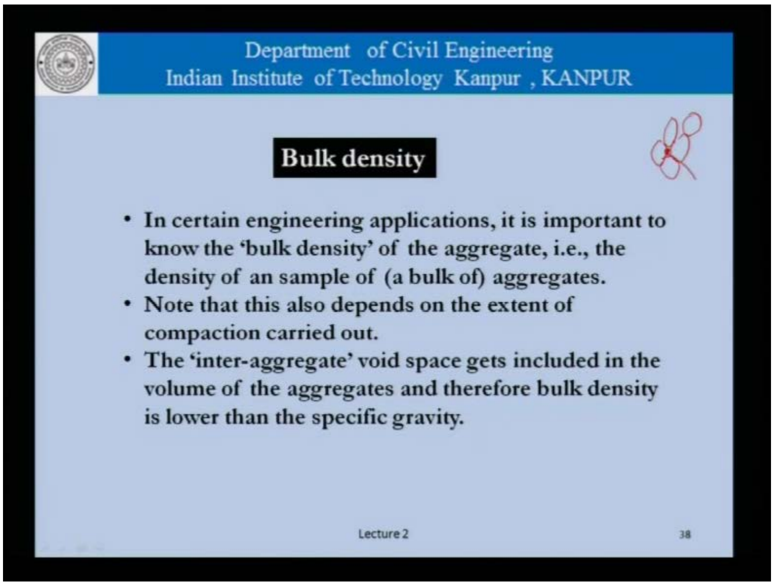

Then, there is a concept of bulk density in certain engineering applications it is important to know the bulk density of the aggregate. That is the density often sampled of a bulk of aggregates. That is we have these aggregates all over the place and we want to find out the bulk density that is all these void spaces in between these aggregates will get included in the volume.

So, we talk of two types of voids in an aggregate system; one is the intra aggregate void that is, the void that we showed in the previous slide, which is the voids present within aggregate particles. Then, there is inter aggregate voids that is the void, which which are present between aggregate particles. So, when we pack the aggregates more or less let us say by damping them by vibrating them and so on, the intra aggregate voids do not change because that is an inherent property of the aggregates. Whereas, the inter aggregate voids are the ones that change. If we pack an aggregate mode thoroughly then the volume of inter aggregate particles goes down if we do not pack them thoroughly there is more inter aggregate voids. So, the bulk density includes all the inter aggregate voids as is indicated on this slide.

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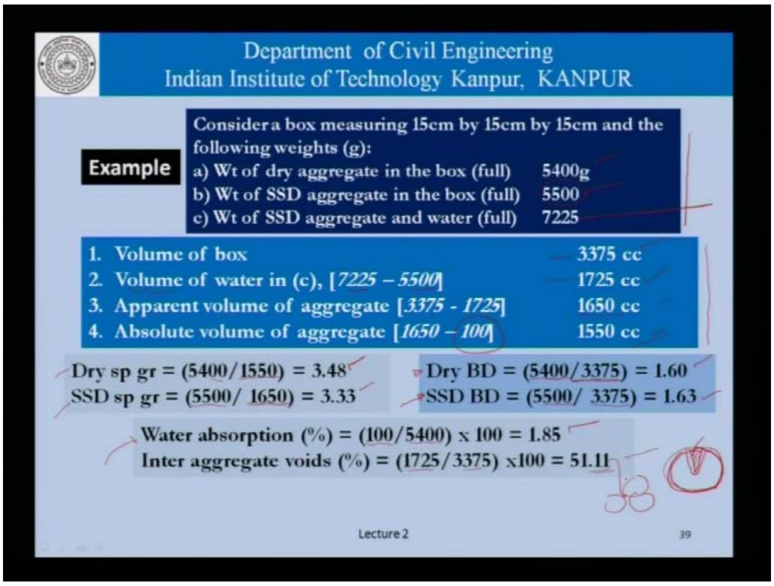

Now, let us look at a example of this calculation consider a box measuring 15 cm by 15 cm by 15 cm. In the next experiment, we fill the same box with SSD aggregate that is those aggregates where the intra aggregate voids are saturated with water and now, since the weight of water will get included that number will be slightly higher. Let us say is

5500 g and then, we have water poured into that box the weight of the SSD aggregates and water is 7225g. So, we have an experiment where, we have a box we have filled with dry aggregate then, we try to fill it with SSD aggregates and finally, we pour water in that box to fill all the inter aggregate voids with water and get a weight of 7225g. Now, based on this information here, we carry out these simple calculations we calculate the volume of the box which is 15 into 15 into 15 and turns out to be 3375.

Then, we calculate the volume of water, in this part here, and there what we get is 7225 minus 5550 because that is the mass of the or volume of the assuming. The density of water to be 1 the volume of water which is there in the inter aggregate voids is 7225 minus 5550 and we get this number 1725. The apparent volume of the aggregates is 3375 which is the volume of the box minus 1725, which is the volume of water and we get 1650 as, the volume of the aggregates. The absolute volume of the aggregates is 1650 minus another 100 which is 1550 so, this 100 here is the total amount of intra aggregate voids and that is what is getting filled with water when we are using SSD samples.

So, the apparent volume which includes the volume of the voids this total volume is 1650 and if we remove this volume and we just consider this volume then, we have a volume of 1550. Now, we can calculate the dry specific gravity of the aggregate sample as 50400 which is the mass of the coarse aggregate. Dry coarse aggregate divided by 1550, which is the absolute volume of solids as far as aggregates are concerned and we get this number SSD specific gravity is 5500, which is the mass here, divided by 1650 which is the volume here, which is this total volume and we get this number as far as bulk density is concerned. We can talk in terms of a dry bulk density where the total mass will remain the same 5400g, but the volume that we use is the volume of the box 1333375 and we get this number.

Similarly, with the SSD bulk density can be calculated as, 5500 divided by 3375 and we get 1.63 water absorption which is a measure of the porosity of the aggregates is basically 100 grams of water absorbed by 5400g of aggregates and we get a water absorption of 1 point 85 as far as the inter aggregate voids the percentage or the total volume of inter aggregate voids is concerned. We get 1725 divided by 3375 into 100 which is 51. So, these numbers tell us a lot of very important lessons one is the relationship between specific gravity and bulk density. So, specific gravities which are 3.48 and 3.33 are almost twice, the bulk density, which are only 1.6 and 1.63. When we pack these aggregates the weight as the numbers are arranged there is as much as 50 percent 51 percent of the voids within the aggregates.

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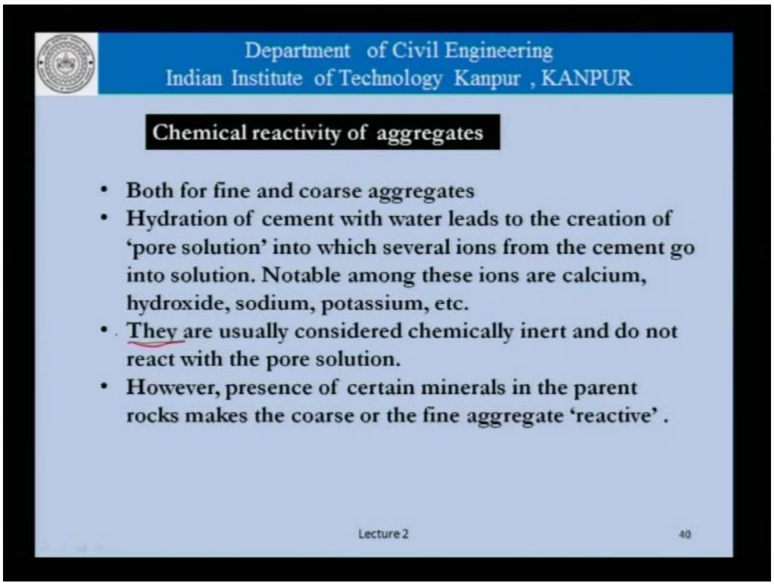

Now, coming to a very different kind of property of the aggregates which is chemical reactivity and this is true for both fine and coarse aggregate s. We know that hydration of cement with water leads to the creation of pore solution into which several ions from cement go into solution notable among them are ions of calcium, hydroxide or the hydroxyl ions sodium and potassium. They are usually considered chemically inert and do not react with the pore solution, this is the coarse and fine aggregates, they are the inert part of the concrete mix usually. However, in the presence of certain minerals in the parent rock the aggregates become reactive and when it comes to the evaluation of aggregates whether it is coarse aggregate s or fine aggregates.

We must also ascertain make sure that the aggregates are chemically inert. So, let us recall this picture where, we now could have reactive particles whether it is the coarse particles or it is the finer particles. They are surrounded by an alkaline solution which could be rich in sodium or potassium ions or hydroxyl ions calcium ions and so on, so as far as alkali aggregate reaction or the reactivity of these aggregates is concerned. It has been found that usually it is the sodium and the potassium ions which are the potential culprits of cause in this reaction, and they are coming into the pore solution from cement.

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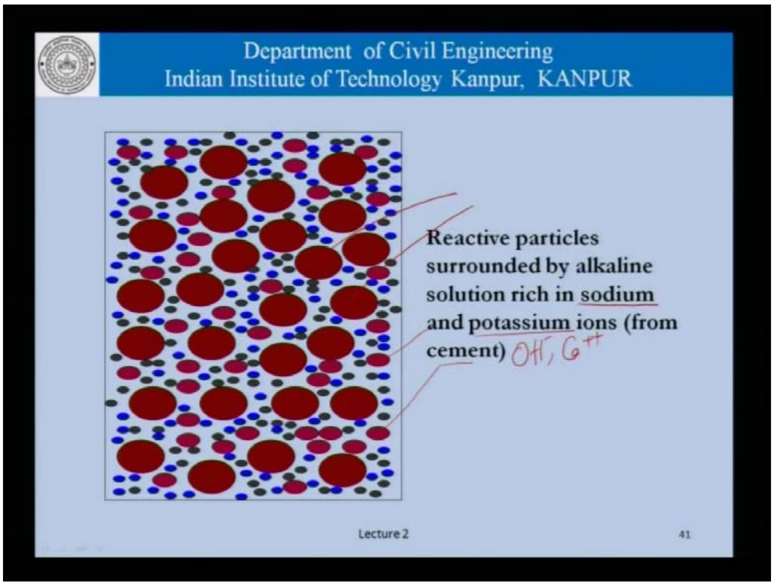

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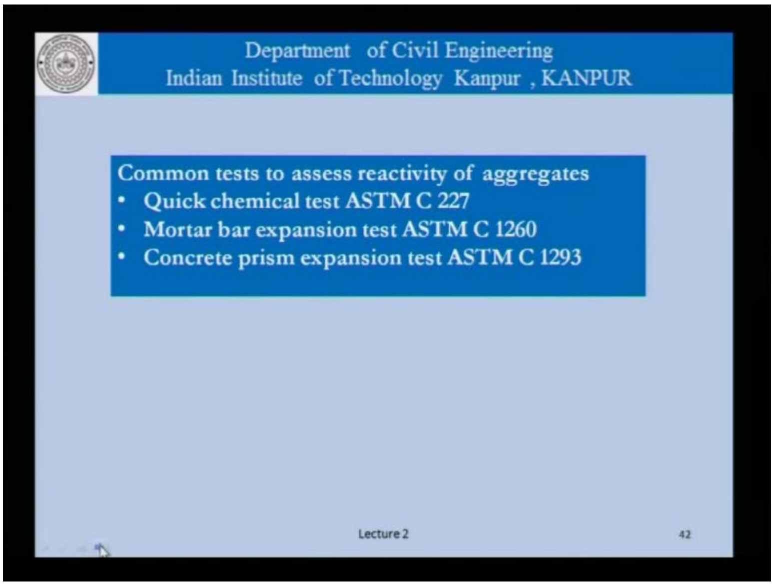

There are several tests that, we can use and some of them are listed here, there is a quick chemical test or mortar bar expansion test or the concrete prism expansion test and there are appropriate or corresponding, ASTM numbers for that the principles are just outlined here, as far as the quick chemical test is concerned, the method involves aggregate samples reacting with alkali solutions at an elevated temperature of 80 degrees centigrade.

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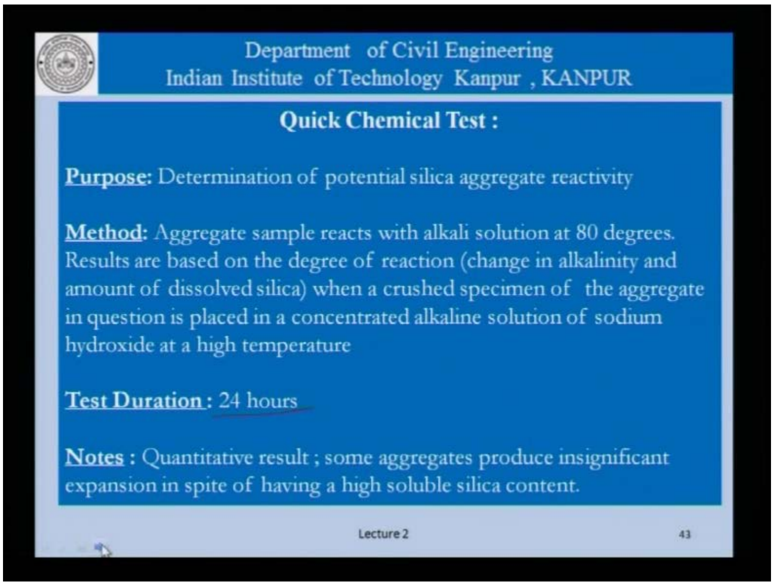

And, the evaluation is based on the degree of reaction which is measured in terms of the change in alkalinity of the solution and the amount of dissolved silica. When a crushed specimen of the aggregate is placed in a concentrated alkaline solution of sodium hydroxide. A sodium hydroxide is used as a substitute for the pore solution and the aggregates are powdered to a certain size and allowed to stand in that solution at higher temperature. So, it is and so it is an accelerative test and is completed within 24 hours and we must understand that the result is qualitative and some aggregates produce insignificant expansion, in spite of having a high alkali soluble content in spite of having a high soluble silica content.

Mortar bar expansion test involves producing mortar bars cured over water at 37.8 degree centigrade at a high RH that is a high relative humidity. And bars that expand in this harsh environment by more than 0.2 percent after 14 days are considered to be made with aggregates that are potentially reactive bars, that expand between 0.1 and 0.2 percent are known to produce deleterious expansions sometimes. Sometimes not the test duration in this case ranges from 14 days and subsequent measurements are often taken at 1,2,3,4,6,9 or 12 months and so on.

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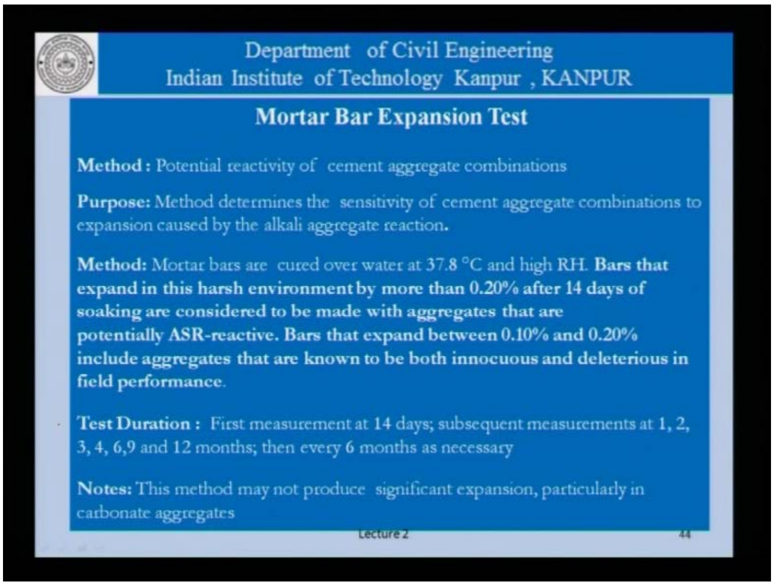

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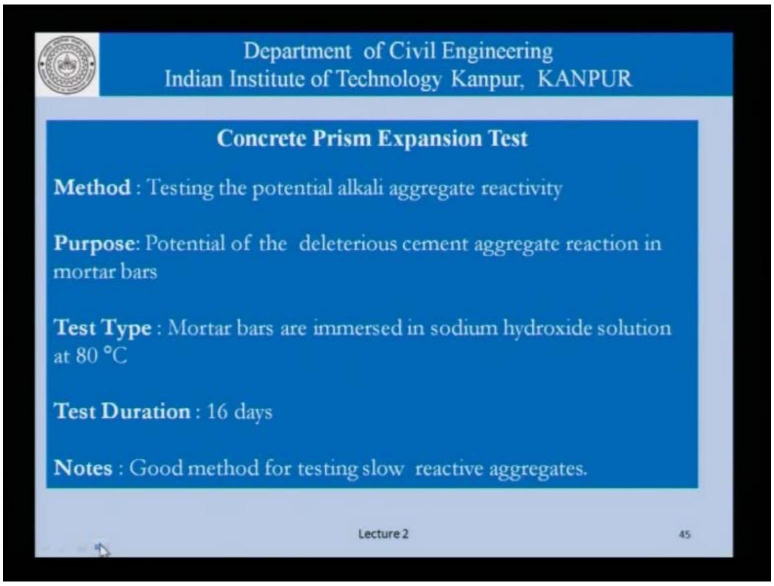

Concrete prism test includes using concrete prisms instead of mortar samples and the test duration as far as the test method standard test method is concerned is 16 days. Before we end the lecture today, let us leave a few questions for you to think about and we will answer them in the at some other point in time. We talked about the shape of coarse aggregate particles and we talked of flaky and elongated particles

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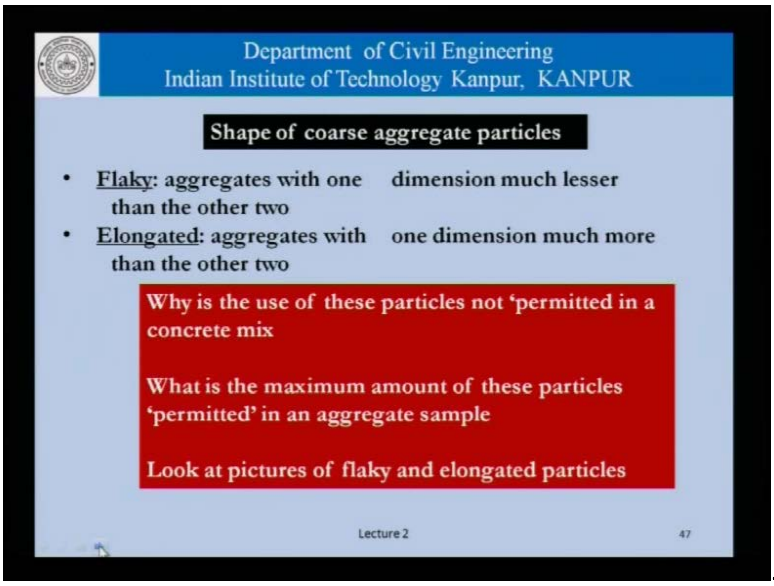

The questions I would like you to think about are, why is the use of these particles not permitted in a concrete mix what is the maximum amount of these particles permitted in an aggregate sample. I would also encourage you to look at pictures or look at the aggregates themselves. In terms of the flakiness and elongated nature we must remember that aggregates are naturally occurring material and it is not possible for us. As civil engineers to simply say that we will not use aggregate samples, which have elongated particles or flaky particles and as engineers therefore. We are allowed to use aggregate samples provided the amount of flaky particles and the amount of elongated particles do not exceed. A certain maximum and this is the maximum that I want you to determine from different specifications as far as the answer in this question is concerned.

Then, we talked in terms of a particle size distribution and we discussed this graph in reasonable detail, as to how to obtain this graph and so on, the question to you. Is if we have a particle size distribution that is we have a set of particles, we have a sample of aggregates and the particle size distribution looks something like this. What conclusion can you drawn about the nature of the sample that we are talking about?

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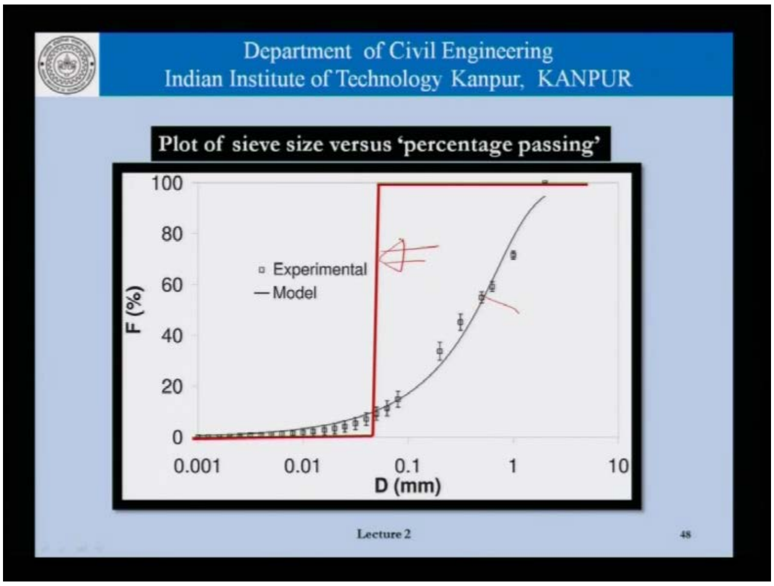

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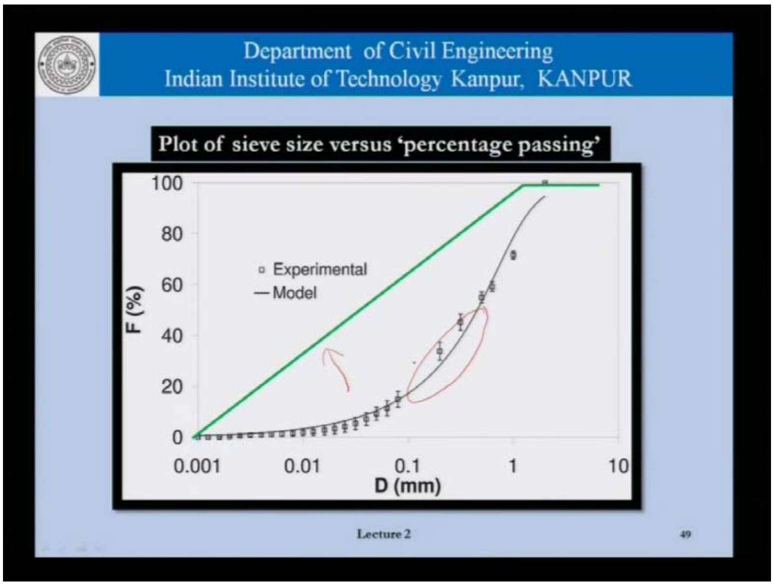

Similarly, if the particle size distribution plot looks something like this, then what is the conclusion that you draw as far as that particular sample is concerned. Remember that this graph here is basically a representation of the particle size distribution of the sample that, we are testing and the shape is a very very important indicator of the nature of the sample that we are talking about. And this line here and the previous line that we talked about here they should be also they give us very important clues, as to what the nature of the particles is.

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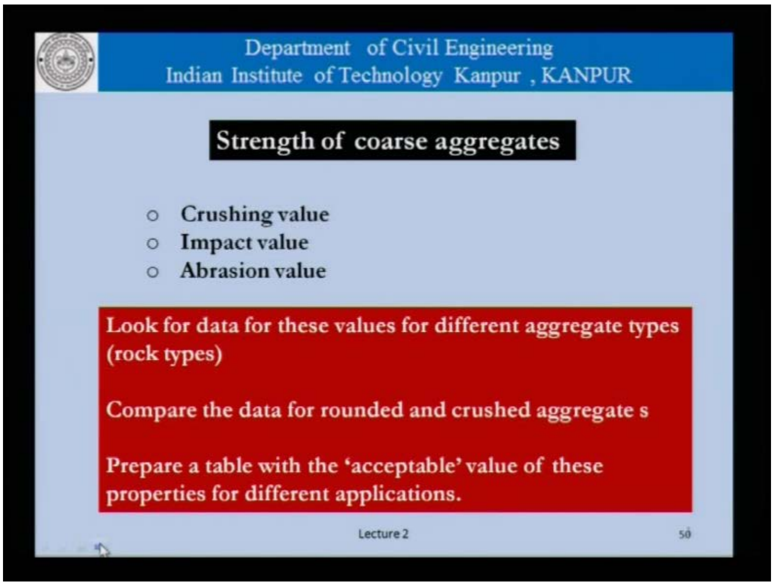

And then we talked in terms of the strength of aggregates in terms of the crushing value impact value and the abrasion values. Now, I request to you would be to look up the data for these values for different aggregate types. Different aggregates types means different rock types, because aggregates are coming from different rocks; and different rocks have different strengths, they have different porosities. And therefore, it stands to a reason that depending on the rock type, the crushing value, the impact value and the abrasion value of aggregates as determined by the test that we have just described will be different and I would encourage you to find out if you can find information about these values for the different rock types.

Compare this data for rounded and crushed aggregates, if we can find that data that will be helpful for you to understand, how different rounded particles and crushed particles or crushed aggregate are as far as the strength is concerned as determined by this parameters. The strength could be the same in principle, but depending on the shape of the particle, the measurement we are carrying out would give us different values; and that something, which I would like you to appreciate based on data.

Then I would like you to prepare a table with the acceptable values of these properties for different applications. See concrete is used in different applications; it is used in roads runways bridges dams and so on. Now, in each of these different applications, we do not really require aggregates, which have the same amount of strength. As you can imagine different concrete applications may require different strengths of aggregate. Therefore, different specifications may lay down different values as far as impact strength or crushing strength or abrasion strength is concerned as acceptable for that particular application. So, comparing that in a tabular form would help you and enhance your understanding of the subject. And with that we come to an end of a discussion today.

Thank you.