Development and Applications of Special Concrete
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Lecture-25
Special Topics
Mixing of Concrete

Hello and welcome back to our series of lectures in development and applications of special concretes under this government of India's scheme of massive open online courses. Today we will start the 7th module in our discussion. And, we will begin with a special topic mixing of concrete that is something which we take for granted. And, we will try to understand some of the nuances associated with this topic. So let us begin our discussion with batching and mixing, let us take up batching first.

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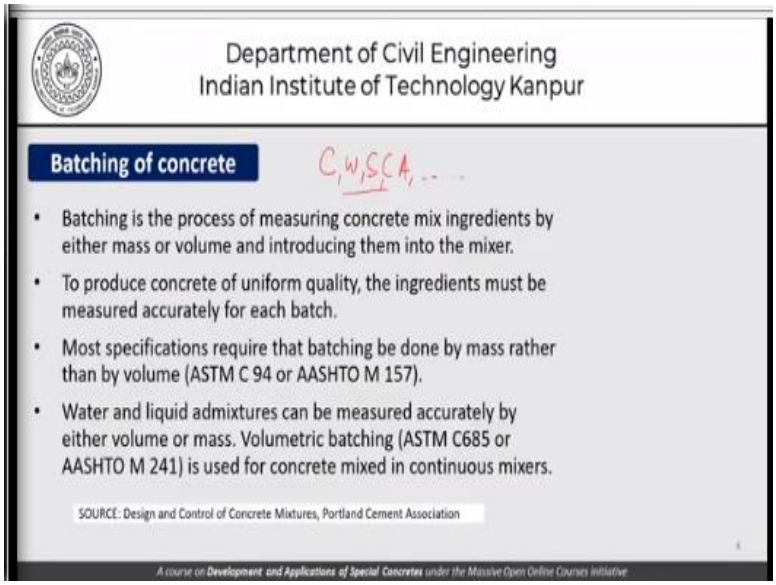

Batching of concrete is the process of measuring concrete mix ingredients by either mass or volume and introducing them to the mixer. We have talked about the mix ingredients when we are talking about proportioning. And we know that we need to proportion cement, water sand and coarse aggregate at least, and possibly other things like chemical admixtures or mineral admixtures and we have a specific mass associated with them.

For example, we may need 352 kg's of cement 186.3 kg's of water and so on. So, we need to measure all these concrete ingredients accurately and feed them into the mixer. So, as far as the accuracy is concerned, that is to produce concrete of uniform quality the ingredients must be measured accurately for each batch that is what we just said. And most specifications require that the batching is done by mass rather than by volume.

Water and liquid ingredients of course can be measured accurately by either mass or volume. And as far as concrete is concerned volumetric batching may be used in the case of continuous mixers.

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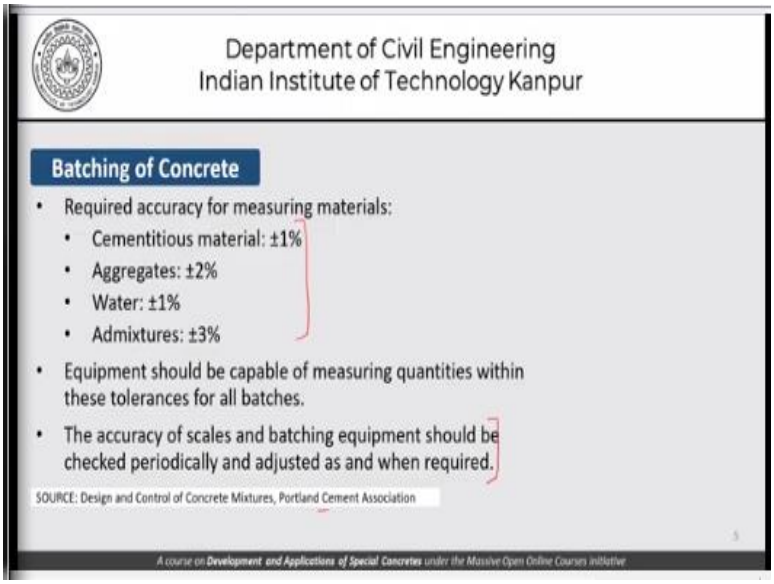

And things with our discussion of batching some of the benchmarks which are available to us are the required accuracy for measuring materials could be 1% for cementitious materials, 2% for aggregates, 1% for water and maybe 3% for admixtures. These numbers will obviously be different for different specifications and this is the source that we are using here. So, I will encourage you to take up some other source of information.

And find out what is the permitted range of variation as far as the batching of cementitious materials or aggregates or water admixtures is concerned. Equipment should be capable of measuring quantities within these tolerances for all the batches. The accuracy of scales and

batching equipment should be checked periodically and adjusted as and when required. So, this calibration is a periodic process.

And I would encourage you to find out what are the specifications that govern this calibration whether the calibration has to be done at regular intervals of time that is one way of looking at it. There is also another way of looking at it that the calibration should be done after producing a certain number of cubic meters of concrete regardless of the time it takes. So, whichever comes earlier that should govern the check as far as the plant is concerned for the equipment for it is accuracy.

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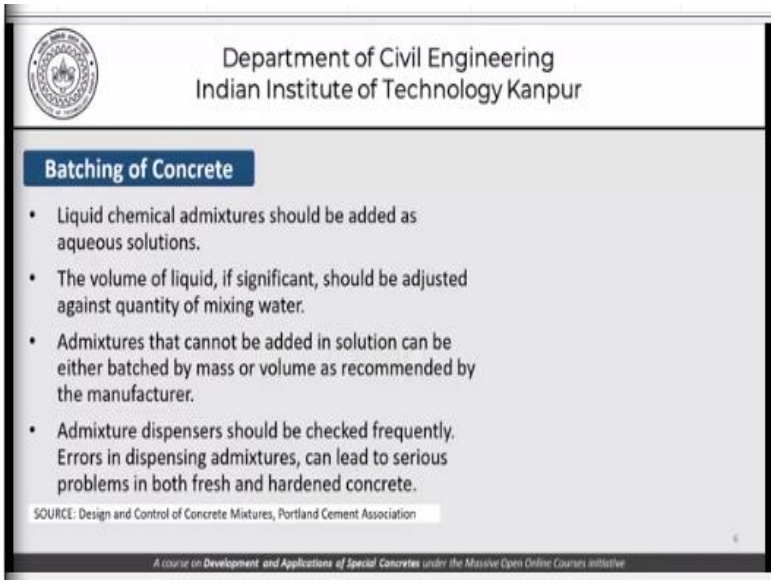

Liquid admixtures or liquid chemical admixture should be added as aqueous solutions. We can dilute them by using water which needs to be adjusted again with respect to the amount of total mixing water that we use the volume of liquid, if significance should be adjusted against the quantity of mixing water. Admixtures that cannot be added in solution can be batched by mass or volume as recommended by the manufacturer.

And the admixture dispensers should be checked frequently, errors in dispensing admixtures can lead to serious problems in both fresh and hardened concrete. One must remember that as far as batching is concerned especially for chemical admixtures and if they are being batched separately. There could be problems in the dispensing nozzle, and if that happens there has to be

a check, not only in terms of what is being fed into the mixer but also what is remaining in the bottles.

Because if something remains in the bottles it will not get known until a large amount of concrete has been mixed. So, these are things which as an operator we should have the necessary checks and balances in place to make sure that there is no problem as far as the dispensation of liquid admixtures is concerned. Because it is very difficult to find out from a given concrete whether or not it has the right dosage of the admixture, A slump of 10 centimeters could be 9 centimeters and we will not even know.

That it has 9 centimeters because of a problem in the addition of the super plasticizer. Therefore, we need to have checks and balances and rely not only on the properties of the fresh concrete but also the actual checking of the dispensing units.

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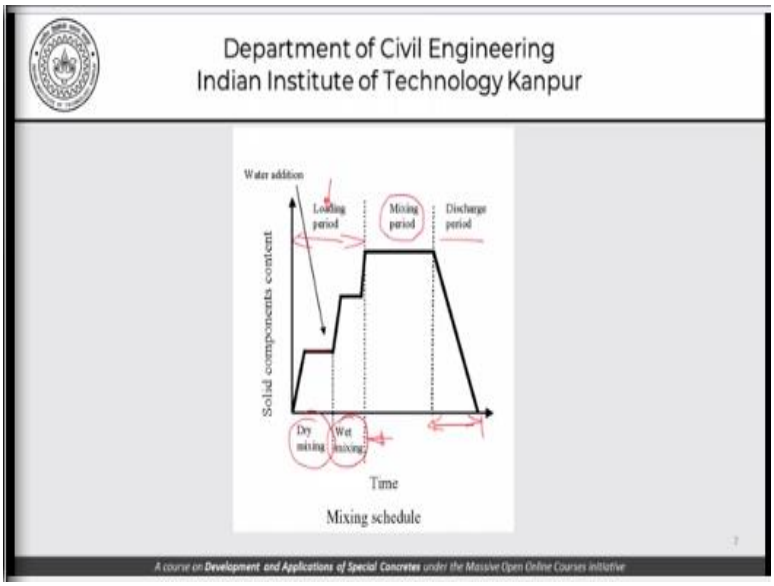

This picture shows a rough schematic diagram of the mixing schedule or the steps in the mixing process. So, we can see that these are the solid components that are being added gradually, there is a stage of dry mixing of concrete, there is wet mixing of concrete. Then we have the mixing period, this period overall is called the loading period. Then the mixing period and this is the discharge.

So, these lengths are not necessarily to scale but they are indicating of the different processes involved. So, as far as mixing is concerned or as far as the engineering involved in mixing is concerned, we need to understand what are the processes that we design for dry mixing of the ingredients with the solids mix it for some time, add the water mix it for some time and then we get into a mixing period where all the ingredients are in place and we mix it.

Having said that there is also the issue of whether all the water is to be added all at one go or it could be done in 2 stages that is something which you will see.

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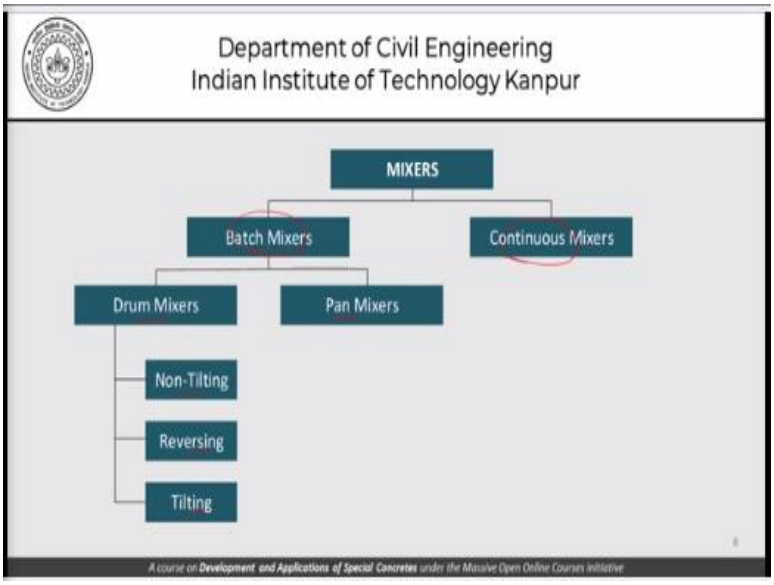

As far as mixers are concerned, there are basically two types of mixers batch mixers and continuous mixers. As far as batch mixers are concerned, there are two types the drum mixers and the pan mixers. And within the drum mixers there is a non-tilting, reversing and the tilting type of mixers. We will do a brief discussion about some of these mixers, but it will be important for you or it will be interesting for you to actually look at the pictures and also the performances of some of these mixers from the literature which is available on the internet.

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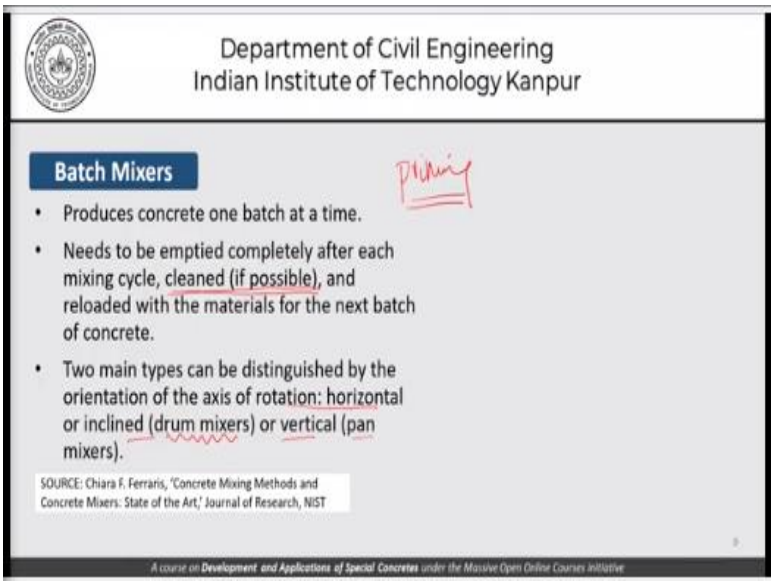

As far as batch mixers are concerned, as the name suggests they produce one batch of concrete at a time. That is if it is a 2 cubic meter batch mixer, you put the ingredients there for 2 cubic meters mix it and discharge it which gives us the 2 cubic meters of concrete. And then we add the next batch, so that is what is the principle of a batch mixer, it produces one batch at a time. A batch mixer needs to be completely emptied after each mixing cycle.

Cleaned if possible and reloaded with the materials for the next batch of concrete. So, this cleaning of the mixer is something which is interesting because whatever material remains in the concrete mixer gets added to the next batch. Except if you want to argue that well whatever is left in one batch will also be left at the end of the second batch and therefore the second batch will be truly the right batch, which then takes us to the discussion that what happens to the ingredients in the first batch?

Because in the ingredients of the first batch parts of it are left behind in the mixer, this typically happens in the case of mortar. A lot of mortar sometimes is left behind in the concrete mixer that takes us to the discussion of priming the equipment. That is, we make sure at the start of the mixing cycle that we mix a batch of concrete which is thrown away which is similar to the batch of concrete or the batches of concrete that we use subsequently.

And therefore, the batch we throw away leaves behind in the mixer some mortar or whatever it is. So, that for subsequent batches, the batches actually contain the kind of concrete ingredients that is designed for. Two main types can be distinguished by the orientation of the axis of rotation as far as batch mixers are concerned, the horizontal or inclined drum mixers and the vertical that is the pan mixers.

So, if the axis of rotation is horizontal or slightly inclined, they are typically called drum mixers. If the axis of rotation is vertical, they are typically called pan mixers as we shall see.

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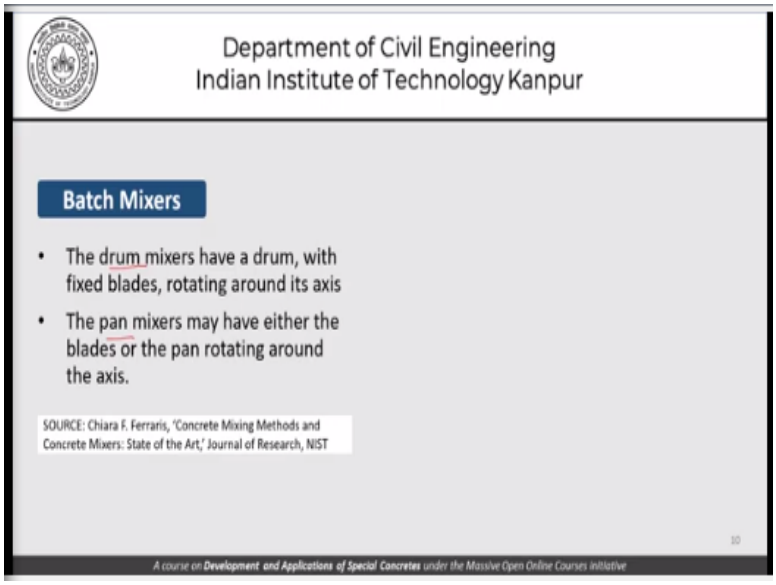

As far as the drum mixers are concerned, they have a drum with fixed blades and rotate around an axis. For pan mixers they may have either the blades or the pan rotating around this axis. So, that is the difference between a drum mixer and the pan mixer which is the basic classification of batch mixers.

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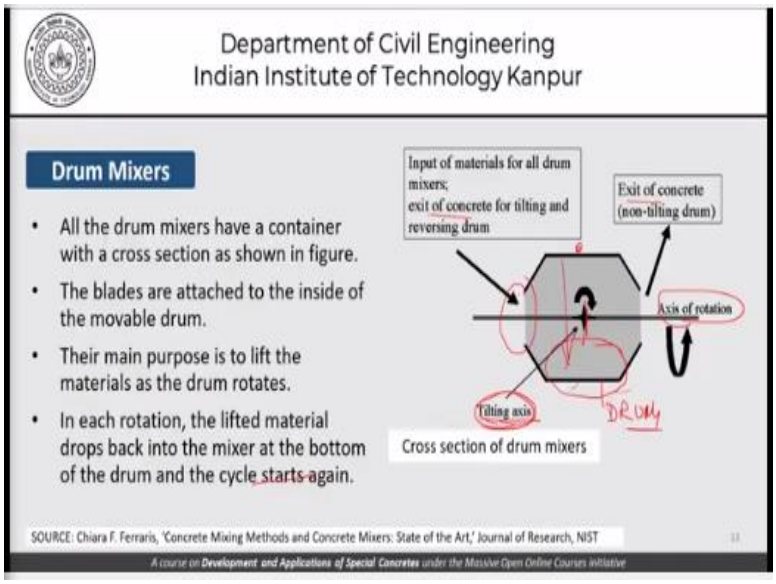

As far as drum mixes are concerned, this is a schematic representation of these mixers. We said that the axis of rotation is largely horizontal or slightly inclined. And we have input of materials for all drum mixers at one side here. And the exit of the concrete for tilting or reversing the drum at this end, sometimes in a non-tilting drum we have the exit of concrete on the other side. Whereas this largely remains the tilting axis and this axis is the tilting axis.

So, this is the axis of rotation and this is the tilting axis. So, the tilting axis helps us load the material and take the concrete out of the drum mixer. So, all drum mixers have a container with the cross section as shown in the figure. So, the blades have not really been shown here, they are fixed to the inside of the movable drum, this here is the drum. The main purpose is to lift the materials as the drum rotates and at each rotation the lifted material drops back into the mixer at the bottom of the drum and the cycle starts all over again.

So, as this drum is being rotated the material gets collected here, gets lifted up to this point as it is moved up during rotation and then again falls to the bottom of the drum. So, that is the principle of mixing in drum mixers.

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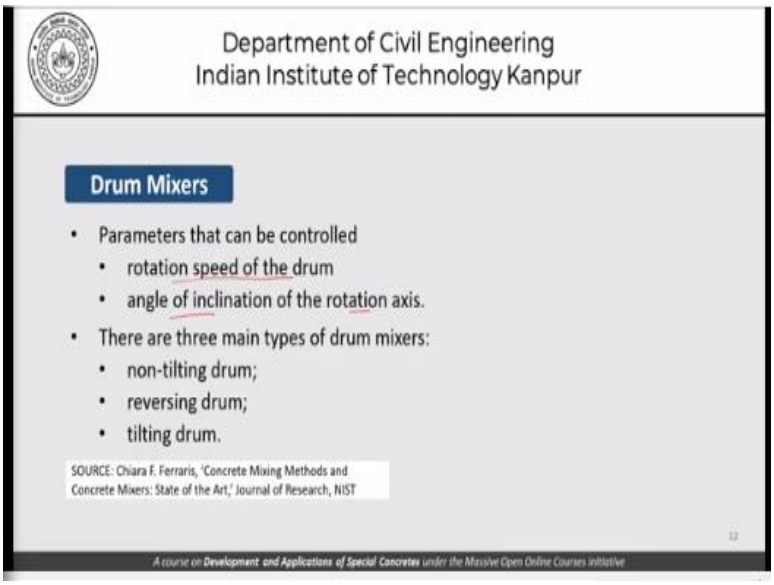

Continuing with our discussion on drum mixers, the parameters that can be controlled is the rotation speed of the drum and the angle of inclination of the rotation axis if any. There are three main types of drum mixers the non-tilting type, the reversing drum and the tilting drum.

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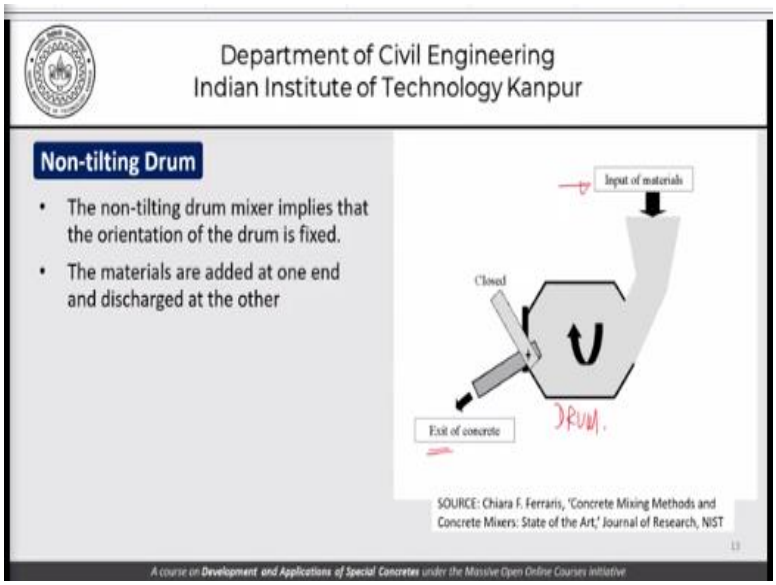

So, coming to the first part of our discussion the non tilting drum mixers, as we can see here this is the drum and we have the input of materials at one end of the drum and the exit of concrete at the other end. So, the non-tilting drum mixer implies that the orientation of the drum is essentially fixed. The material is added at one end of the drum and is discharged at the other.

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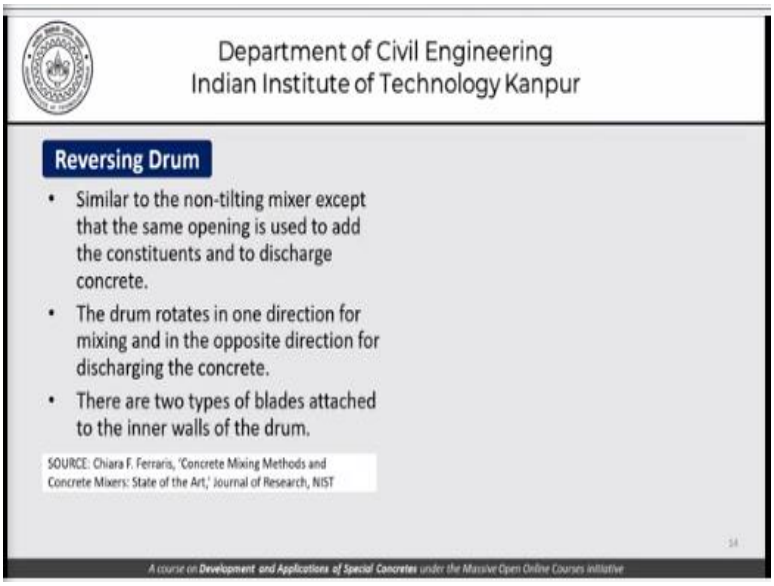

As far as a reversing drum mixer is concerned, it is similar to the non tilting mixer except for the fact that the same opening is used to add the constituents and to discharge the concrete. The drum rotates in one direction for mixing and the opposite direction for discharging of concrete. There are two types of blades attached to the inner walls of the drum as far as a reversing drum is concerned.

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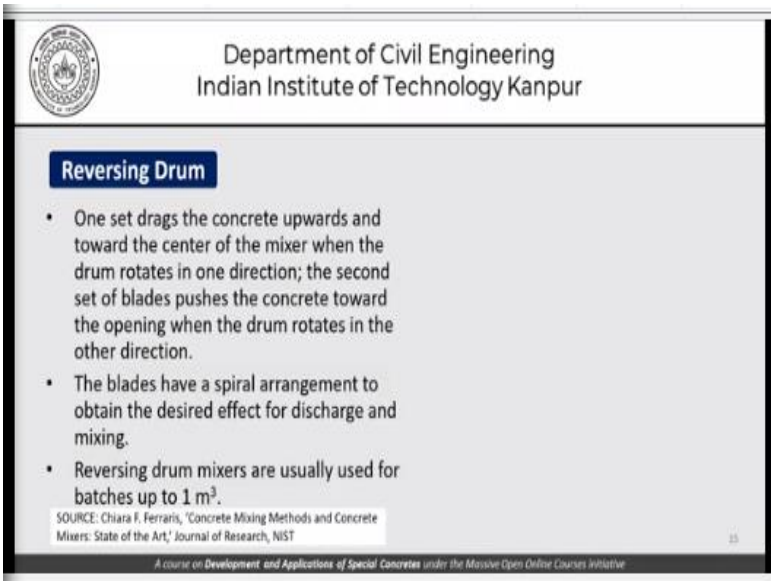

One set of blades drags the concrete upwards and towards the center of the mixer when the drum rotates in one direction. And the second set of blades pushes the concrete towards the opening when the drum rotates in the other direction at the time of discharge. The blades have a spiral

arrangement to obtain the desired effect for discharge and mixing. The reversing drum mixers are usually for batches up to about 1 cubic meter.

These things are very easy to read and listen, but I think it is the best understood if you are able to see some videos. Or able to visit a batching plant to see how the one set of blades help in the mixing and the other set of blades help in the discharge of the concrete from a reversing drum mixer.

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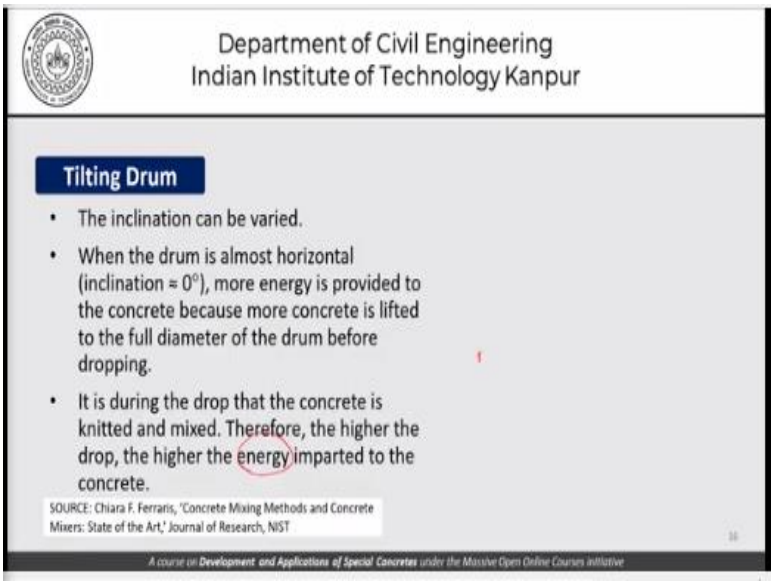

Coming to the tilting drum, the angle of inclination can be varied and when the drum is almost horizontal that is having no inclination 0 degrees. More energy is provided to the concrete because more concrete is lifted to the full diameter of the drum before dropping. And it is during the drop that the concrete is actually knitted and mixed. Therefore, the higher the drop, the higher the energy imparted to the concrete.

Now, here for the first time in our discussion today we have used the word energy. So, one of the very important concepts as far as mixing is concerned is the amount of energy which is used for mixing. So, you can imagine that as far as concrete is concerned especially stiffer concretes is concerned, it will require more energy for mixing. Now whether that mixing energy or the energy for mixing is coming from drops or from some other mechanisms is a different story.

This discussion or this concept was also alluded to when we talked about the rpm in case of the drum mixers. When we have a machine being rotated at a higher rpm versus at a lower rpm, that will have mixing effect to different degrees.

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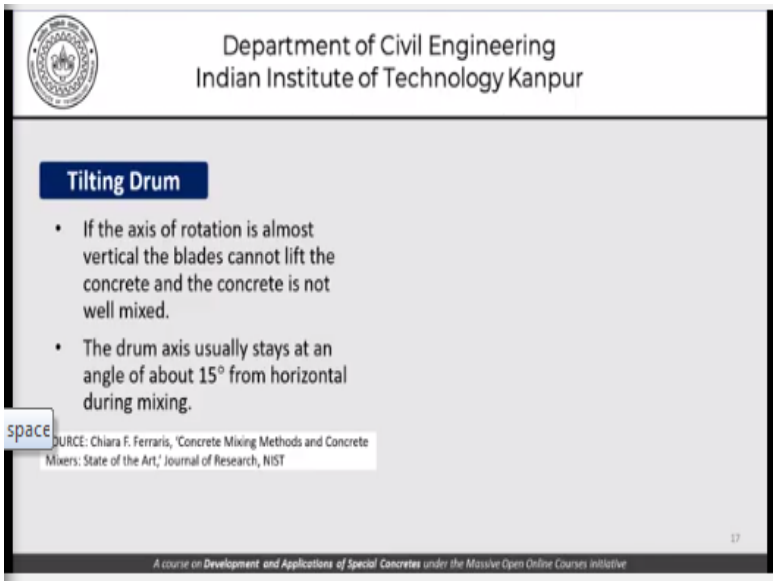

If the axis of rotation is almost vertical the blades cannot lift the concrete and the concrete is not mixed well. The drum axis usually stays at an angle of about 15 degrees from the horizontal during mixing.

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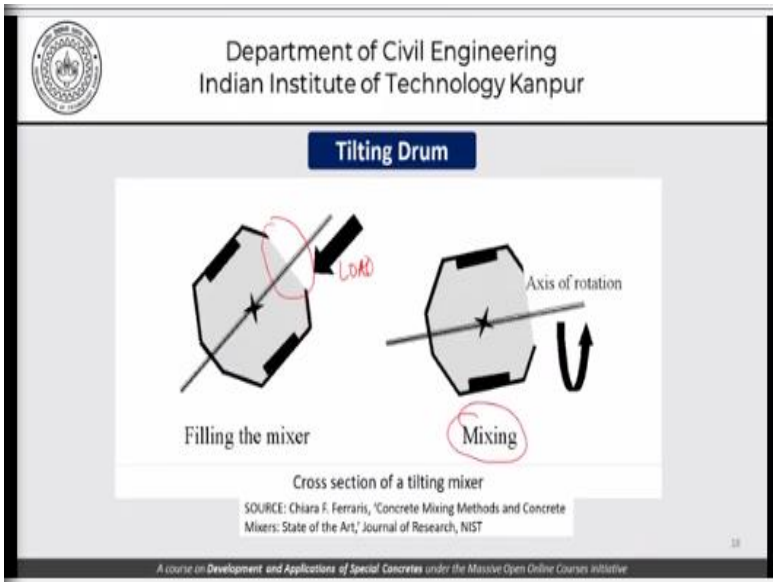

Here is a schematic representation of a tilting drum mixer with the cross section of this mixer shown here. So, we have this opening here which is used for the loading the mixer as well as

discharging it, so it is at this position that we load the mixer. Then we make it basically horizontal or just half horizontal rotate the mixer and mix the concrete. So, this is the mixing process that is going on as far as this mixer is concerned.

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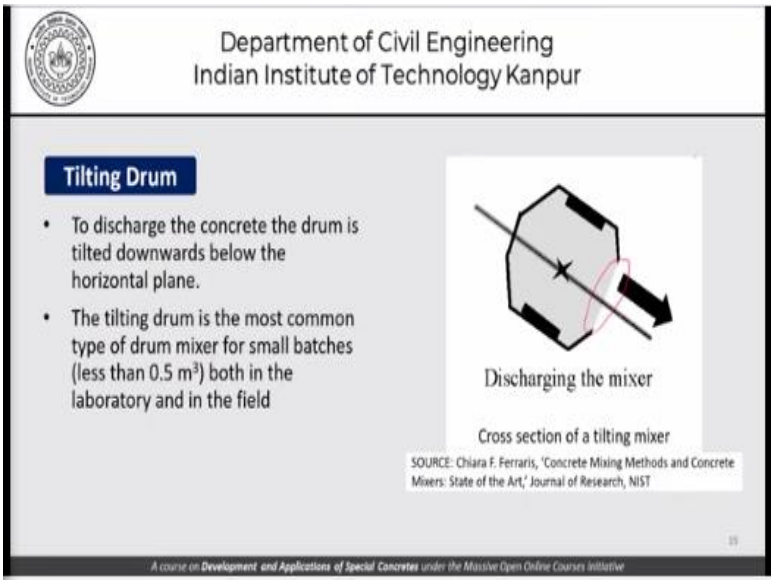

And finally, we tilt the drum, in this direction that is shown for discharging the concrete from the mixer. So, it is the same opening being used for loading as well as discharging the concrete. So, to discharge the concrete the drum is tilted downwards below the horizontal plane. The tilting drum is most common type of mixer for a small batches less than about 0.5 cubic meters, which is about 500 liters of concrete both in the laboratory and in the field.

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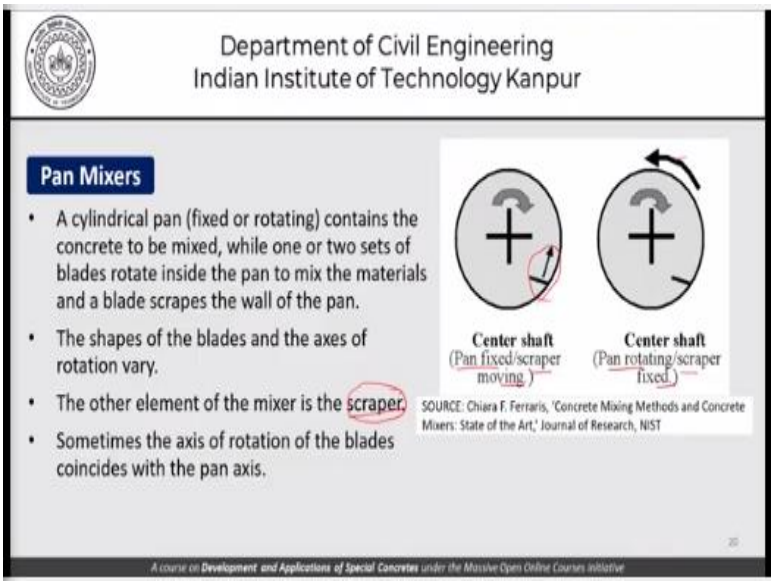

Now moving on to pan mixers, we have 2 essentially different types of pan mixes, one where the pan is fixed and the scraper is moving that is shown here. In another case the pan rotates and the scraper is fixed. So, we have a pan rotation here as shown here, and this scraper is fixed. Describing these pan mixers, a cylindrical pan which could be fixed or rotating contains the concrete to be mixed while one or two sets of plates rotate inside the pan to mix the materials and the blade scrapes the walls of the pan.

The shapes of the blade and the axes of rotation could vary. The other element of the mixer is this is scraper. So, this scraper plays a very important role in determining the efficiency or the efficacy of a band mixer. Sometimes the axis of rotation of the blades coincides with the axis of rotation of the pan.

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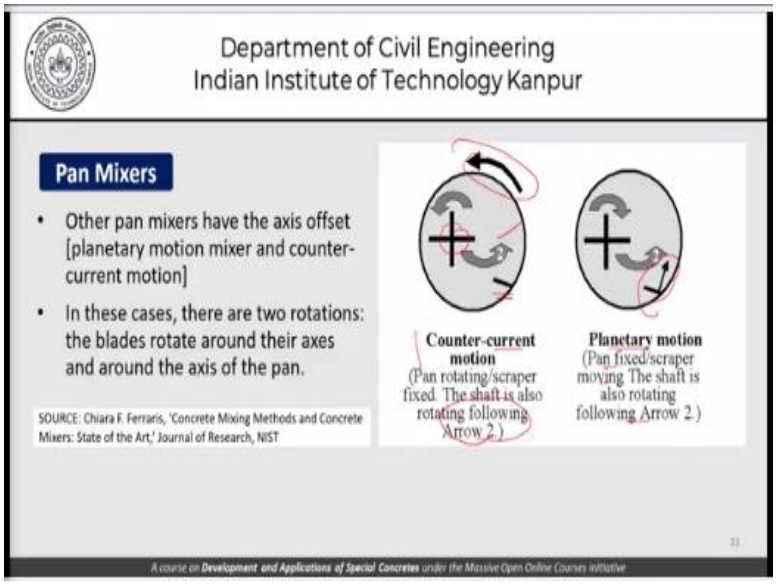

Continue our discussion with pan mixers, another type of pan mixers is one where the axis offset, that is planetary motion mixer and the counter motion mixer as is shown here. So, in this case we have a planetary motion mixer and a counter current motion. In this case in the counter current motion the pan rotating, scraper is fixed and the shaft is also rotating following this arrow 2, so this shaft rotates following this arrow here.

As far as the planetary motion is concerned the pan is fixed, the scraper is moving, the shaft is also rotating following the arrow 2, so this is the rotation here but this is the rotation here. So,

this is also something which is more easily understood if you see a video of these mixers being operated. And I am sure there are sites that you will be able to see and you will be able to understand for yourself, what is the importance of this scraper and how different mixers as far as a pan mixer is concerned?

Or for that matter the drum mixer what is the mixer mechanism? Or what is the mechanism of mixing the different ingredients? That is sand coarse aggregate, water and cement.

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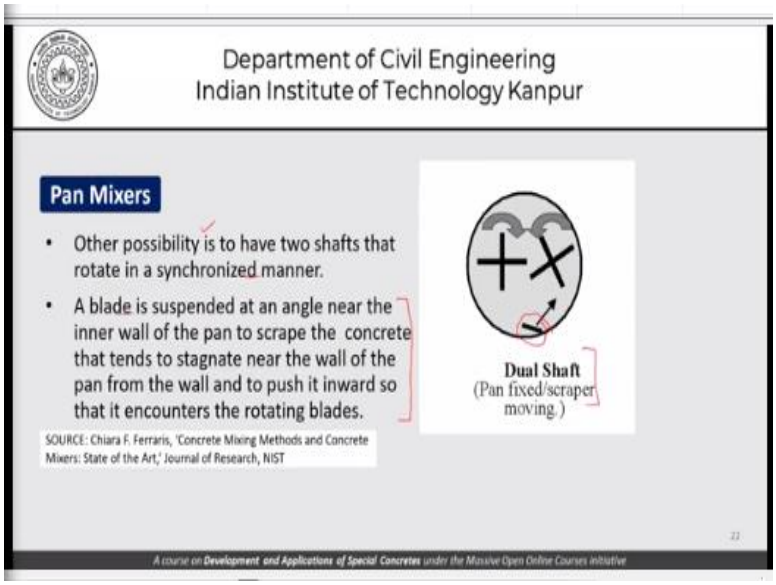

This one is another type of a pan mixer where we have a dual shaft that is we have two shafts. The other possibility as is listed here is to have two shafts that rotate in a synchronized manner. A blade is suspended at an angle near the inner wall of the pan to scrape the concrete that tends to stagnate near the walls of the pan from the wall and to push it inwards, so that it encounters the rotating plates.

Now, what this discussion is telling us or sensitizing us towards is the importance of this scraper or this what is called a blade here. And sometimes we may find as far as maintenance of the equipment is concerned that the scraper is not working properly or there is some difficulty as far as the movement of these shafts is concerned. We may not see it as far as the properties of concrete are concerned.

But if the civil engineer or the concrete engineer in charge of the operations is sensitive towards the need to maintain the mixers, these things will come handy.

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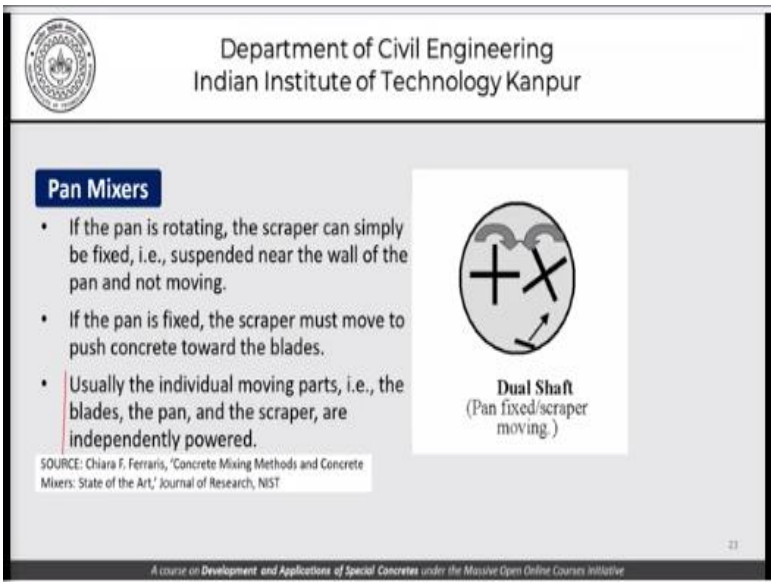

Now continuing our discussion of pan mixers, if the pan is rotating, the scraper can simply be fixed. That is, it can be suspended near the wall of the pan and not moving, if the pan is fixed however the scraper must move to push the concrete towards the blades. And usually, the individual moving part that is the plates, the pan and the scraper are independently powered, that is something which we must bear in mind.

That the individual moving parts whether that is the blades or the pan or the scraper they are all independently powered. Now so far, our concentration had been on batch mixers whether it was pan or drum type.

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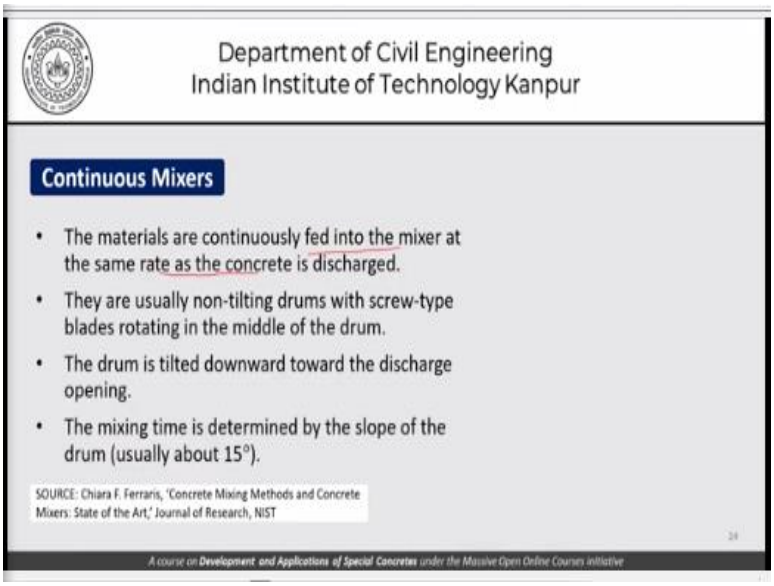

Now coming to continuous mixers, in this the material is continuously fed into the mixer at the same rate as the concrete is discharged. This balance of the rate of concrete discharge and the rate of feed into the mixer has obviously to be maintained. In order that the concrete of a certain consistency as far as the constitution is concerned can still be obtained. Now they are usually non tilting drums with screw type blades rotating in the middle of the drum.

The drum is tilted towards the discharge opening which facilitates the discharge and the mixing time is determined by the slope of the drum which is usually about 15 degrees.

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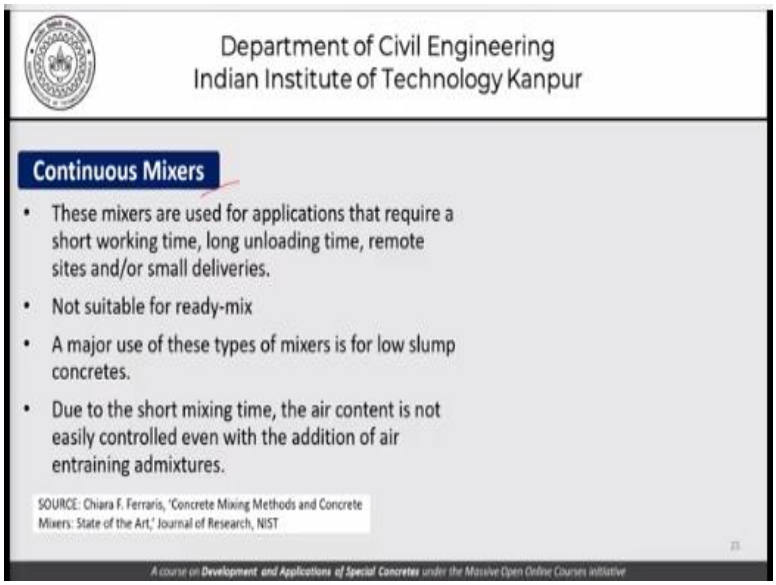

Continuing our discussion about continuous mixers, these mixers are used for applications that require a short working time, long unloading times, remote sites and or small deliveries. They are not particularly suitable for large volumes of concrete to be mixed or delivered. They are not suitable for ready mixed operations and a major use of these types of mixers is for low slump concretes, high slump concretes are difficult to get out of these continuous mixers.

Due to the short mixing time, the air content is not easily controlled even with the addition of air entraining at mixtures. So, use of continuous mixers is rather limited in it is scope as we can see from the brief description that has been given here.

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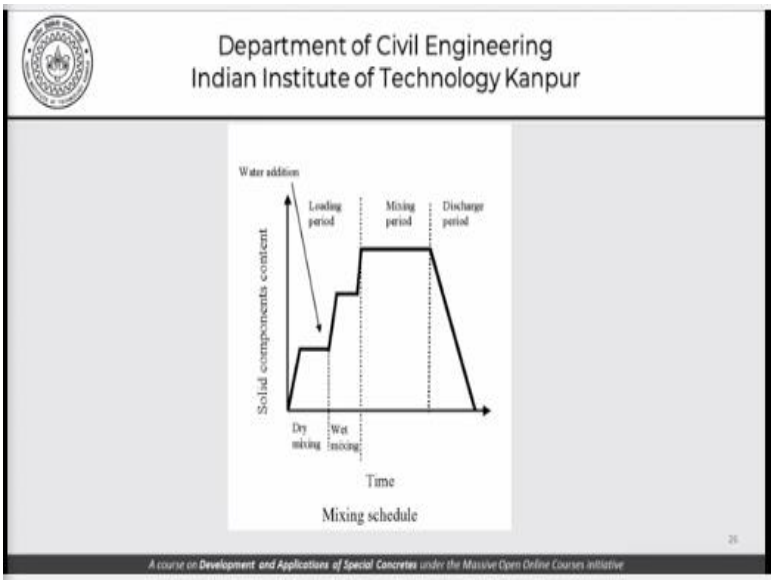

Once again, I show you this schematic representation of the mixing process. The dry mixing, the wet mixing, the real mixing period and the discharge on a schematic diagram.

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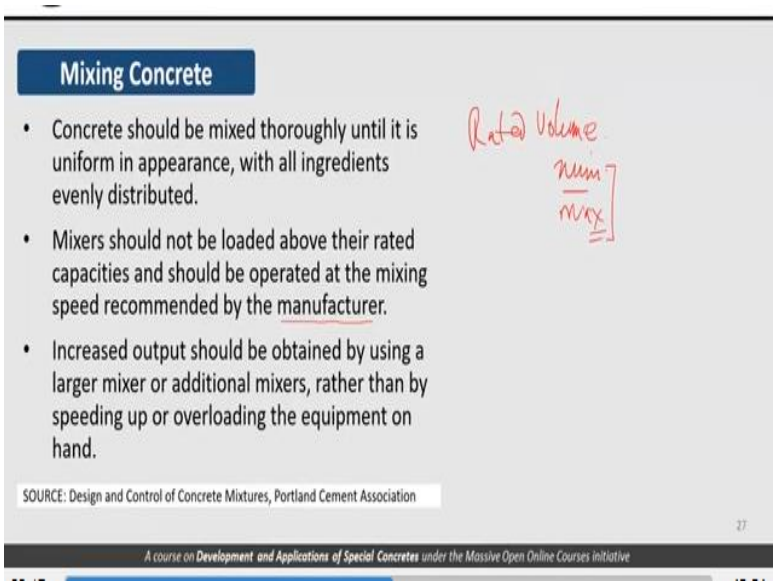

And we try to come to the discussion on mixing concrete, the concrete should obviously be mixed thoroughly until it is uniform in appearance with all it is ingredients uniformly distributed, that is the essence of the mixing process. The mixers should not be loaded above their rated capacities and should be operated at the mixing speed recommended by the manufacturer. So, there is manufacturer involved who tells the operator as to what is the mixing speed that is recommended.

And also, that for a given rated volume of the mixer, what is the minimum amount of concrete that should be placed in it and what is the maximum? And in any case this maximum should not be higher than the rated capacity. Increased output should be obtained by using a larger mixer or additional mixers rather than by speeding up or overloading the equipment on hand. This is something which we must remember that overloading the mixers or trying to obtain a higher output by speeding up the mixing operation that is actually counterproductive and it should not be resorted to.

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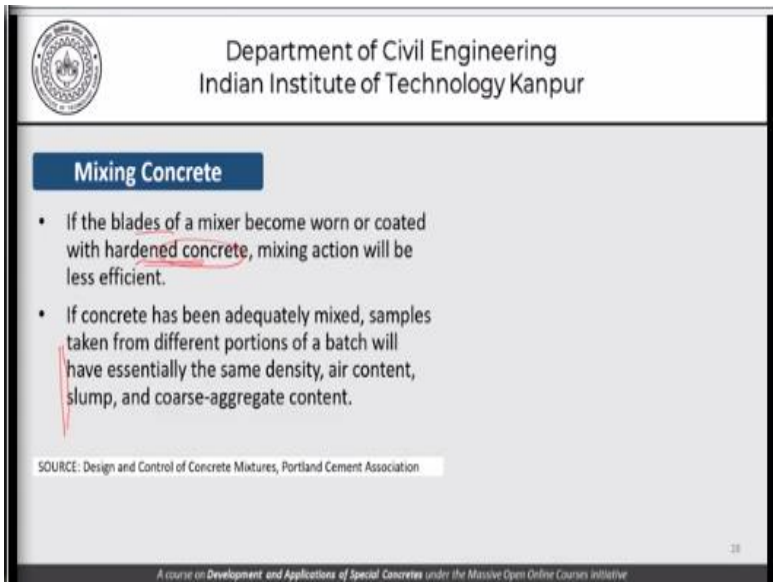

If the blades of a mixer become worn or coated with hardened concrete, the mixing action will be inefficient. So, we have to make sure that the blades of the mixture are not worn out and they are not coated with hardened concrete. Now in order to ensure that they are not coated with hardened concrete it is important to ensure that at the end of a mixing operation, the mixers are thoroughly washed.

And it is ensured that no cement or concrete adheres to the mixing blades or the scrapers or the sides of the mixer. If the concrete has been adequately mixed, samples taken from different portions of batch will have essentially the same density air content slump and coarse aggregate content. So, this is again the essence of a properly mixed concrete, that it should have the same density, air content, slump and coarse aggregate content in the different parts of the mixer.

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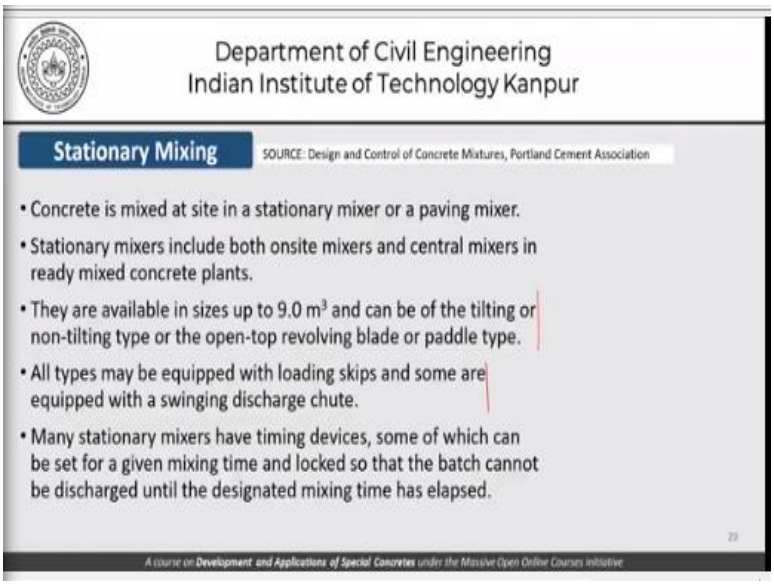

Now let me introduce to you the concept of stationary mixing. In this case concrete is mixed at site in a stationary mixer or a paving mixer. A Stationary mixers include both on-site mixers and central mixers in the ready mixed concrete plants. They are available in sizes up to 9 cubic meters and can be of the tilting or non-tilting type or the open top revolving blade or paddle type. The best way to learn about these different types of mixers would be to actually visit some of the batching plants or try to watch some of the movies relating to these construction equipments.

All types of these mixers may be equipped with loading skips, and some are equipped with a swinging discharge chute. So, these are the kind of additions that we have in stationary mixing plants. Many stationary mixers have timing devices some of which can be set for a given mixing time and locked, so that the batch cannot be discharged until the designated mixing time has elapsed.

Several codes in fact tell us that the minimum mixing time for a particular concrete should be 2 minutes or 3 minutes or whatever it is. And that is where the timing devices help because that prevent the operator from being tempted to reduce the mixing time and try to improve or increase the productivity in the short term.

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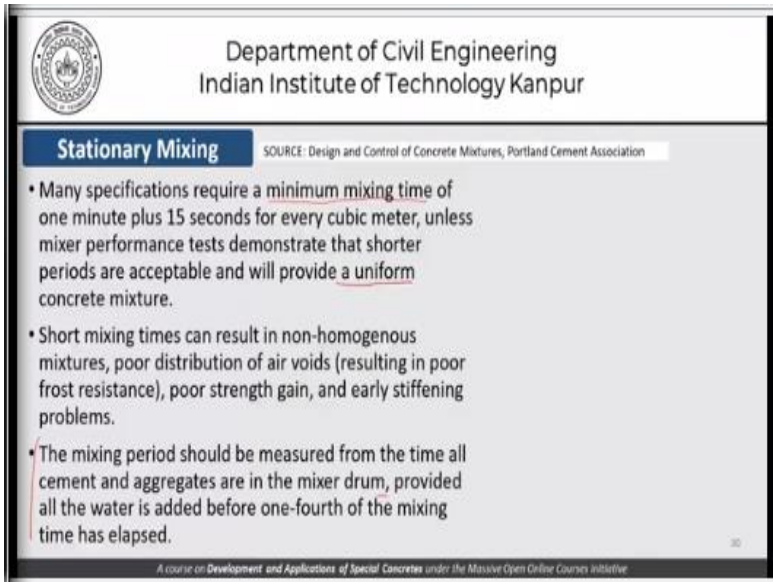

Many specifications require a minimum mixing time as I mentioned to you of course I told you 2 minutes, what is mentioned here is 1 minute 15 seconds for every cubic meter of concrete unless the mixer performance tests. Demonstrate that shorter periods of time are acceptable and will provide a uniform concrete mixture. The characteristics of a uniform concrete mixture have already been discussed in terms of having a concrete which has the same aggregate content or slump or air content in the different parts of the concrete.

I would encourage you to look up documents, specifications or codes which give you the minimum mixing time which is required. Please also note that in our discussion of special concretes it is very easy to conclude that the mixing time would be related to the type of concrete being cast or the type of concrete being mixed. Obviously if you are talking of a harsh concrete or a fibre reinforced concrete or a concrete in which a lot of viscosity modifying agents have been used.

The kind of mixer in terms of it is power or the mixing time which is required that could be very different. So, that is why in fact I chose to spend some time with you on this topic of mixing of concrete because of it is relevance as far as delivering special types of concrete is concerned. Short mixing times can result in non-homogenous mixtures, poor distribution of air voids resulting in poor frost resistance, poor strength gain, and early stiffening kind of problems.

The mixing period should be measured from the time all cement and aggregate are in the mixer drum provided all the water is added before one-fourth of the mixing time has elapsed. So, this is a matter of convention that how should we measure the mixing period, one way of looking at it is this.

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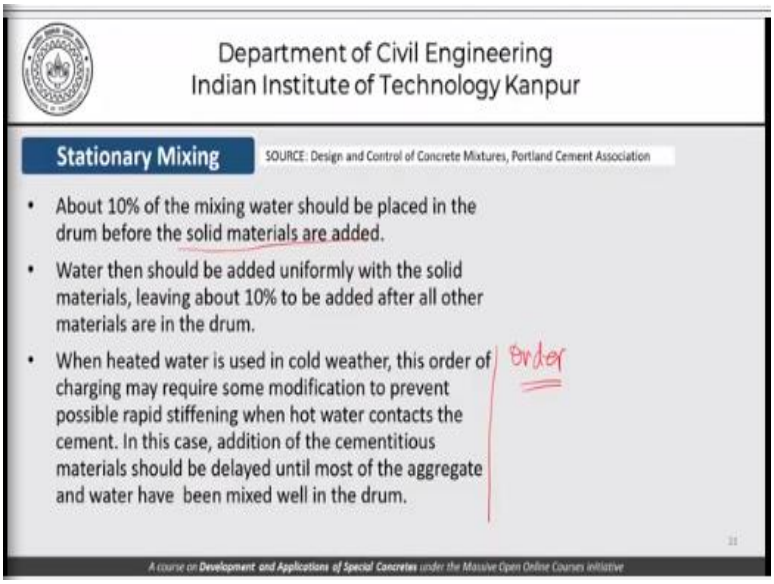

Moving forward with stationary mixing about 10% of the mixing water should be placed in the drum before solid materials are added. So, this is a characteristic or this is a suggestion or a guideline as far as stationary mixing is concerned. That is 10% of the mixing water should be placed in the drum before solid materials are added. Water should then be added uniformly with the solid materials leaving about 10% to be added after all the other material is in the drum.

When heated water is used in cold weather conditions, this order of charging may require some modification to prevent possible rapid stiffening when hot water comes in contact with the cement. In this case addition of the cementitious material should be delayed until most of the aggregate and water have been mixed well in the drum. So, here we are raising this concept or this issue of what is the order in which the material should be charged?

What is being suggested here is that you add 10% of mixing water to begin with, then add the solid material along with the water leaving about 10% of it to be added after all the material is in the drum. In the case when you are trying to do hot weather or cold weather concretings the

order may need to be re-looked at. So, to that extent nothing is really written in stone and depending on the kind of conditions that you are working with or the concrete that you are working with the order and so on can and should be changed. Provided, the bottom line is very clearly understood, that is uniform concrete has to be achieved.

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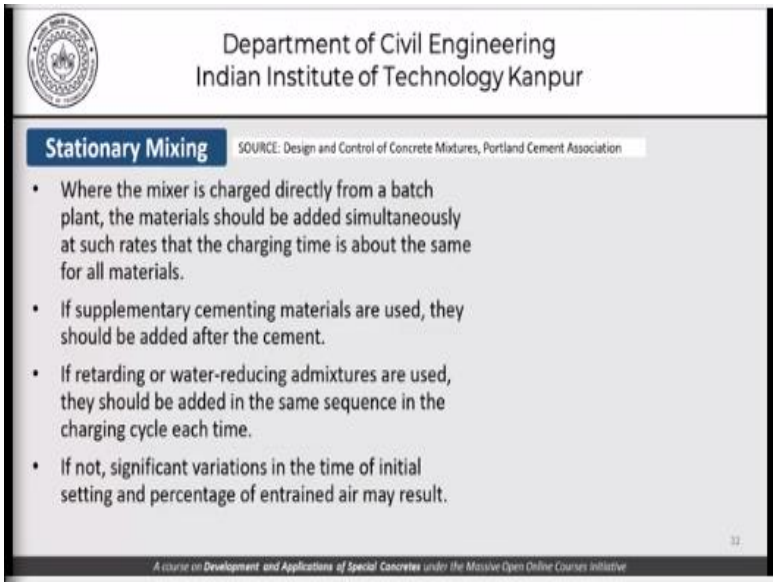

Where the mixer is charged directly from a batching plant, the material should be added simultaneously at such rates that the charging time is about the same for all the materials. And if supplementary cementing materials are used, they should be added after the cement. If retarding or water reducing admixtures are used, they should be added in the same sequence in the charging cycle each time.

So, it should not happen that water reducing agents or the retarding agents are charged into the concrete first in some batches and later on in some other batches. So, the process is not really and a + b = b + a process. We should have a certain amount of consistency when it comes to charging the materials and mixers. If not, significant variation in the time of initial setting and percentage of entrained air may result. So, these are the kind of things that we need to keep in mind when it comes to mixing the concrete.

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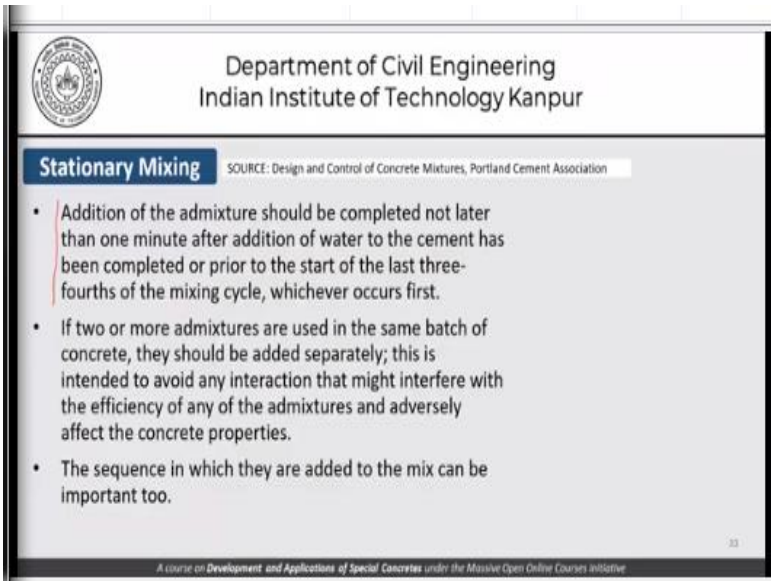

Addition of the admixture should be completed not later than 1 minute after the addition of water to the cement has been completed. Or prior to the start of the last three-fourths of the mixing cycle whichever occurs first. Say you can see that a lot of detailed guidelines such as these have been laid out. So, it is not really the fact you just put all the material together and mix it somehow for some amount of time, so as to ensure that you have the concrete which looks uniform, no, that will not work.

There are issues involved and these guidelines come in handy to make sure that the quality of concrete is not compromised and it is consistently the same as far as proportions is concerned. So, the proportions can be maintained but the concrete quality is also very strongly a function of the mixing process, and that is what we are discussing here in some detail. If two or more admixtures are used in the same batch of concrete they should be added separately.

This is intended to avoid any interaction that might interfere with the efficiency of any one of the admixtures and adversely affect the concrete properties. The sequence in which they are added to the mix can be important too. So, what happens is that when we are trying to finalize the mixing process, we should carry out some experiments and actually come to a conclusion and lay down very clearly the SOP to be followed as far as the mixing process is concerned.

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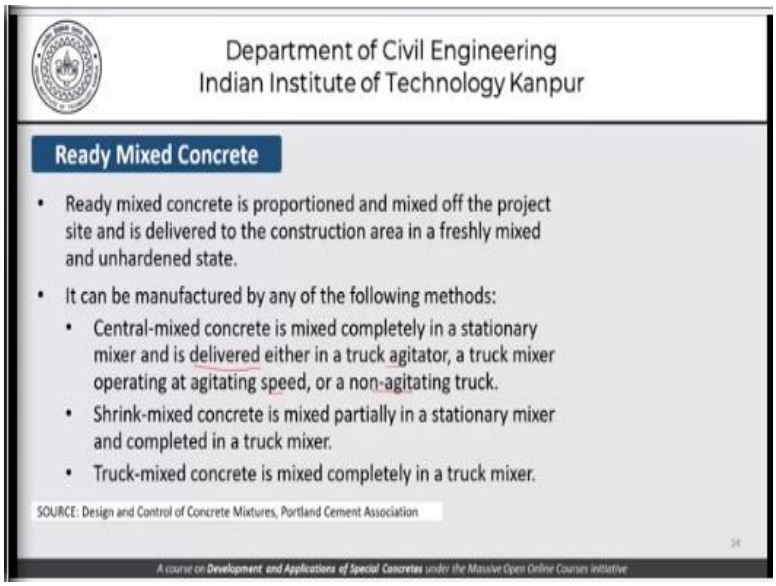

As far as the ready mixed concrete is concerned, this concrete is proportioned and mixed off the project site and is delivered to the construction area in a freshly mixed and unhardened state. That is something which we need to ensure that the concrete is delivered to the construction site from the ready mixed concrete plant, it should be freshly mixed and obviously unhardened. It can be manufactured by any one of the following methods.

Central mixed concrete is mixed completely in a stationary mixer, and is delivered either in a truck agitator, a truck mixer, operating at an agitating speed or a non-agitating truck. What is being suggested is that there is a delivery component involved and there is a manufacture component involved. The manufacturing happens in the ready mixed concrete plant which could be a central mixing plant.

And then the delivery could happen in an agitator truck or a truck operating at an agitating speed or in a non-agitating truck. Shrink mixed concrete is mixed partially in a stationary mixer and the mixing is completed in the truck mixer. And truck mixed concrete is mixed completely in a truck mixer. So, these are the methods that are available to us in order to use ready mixed concrete in a ()) (33:45).

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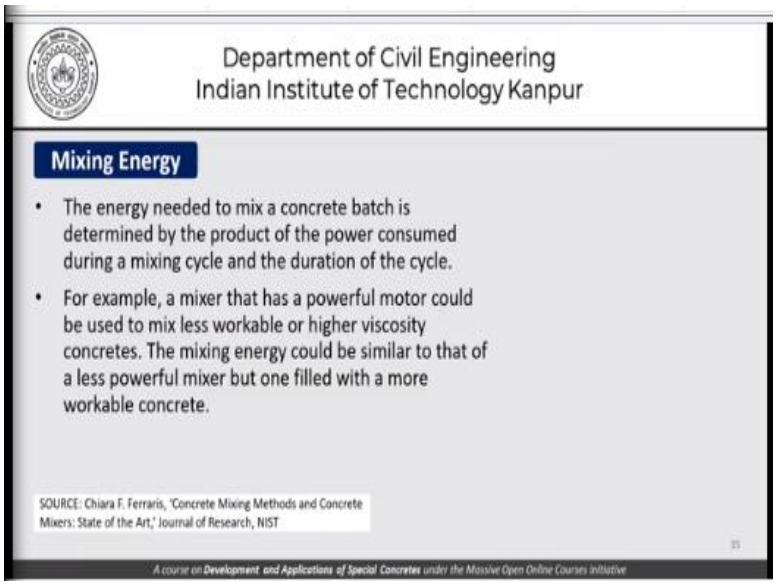

Let us go back to our discussion on the mixing energy. So, the energy needed to mix a concrete batch is determined by the product of the power consumed during a mixing cycle and the duration of the cycle. So, it is really the power times the duration that gives you the energy. As far as research is concerned, you could be talking in terms of the energy required per cubic meter of concrete.

And that could vary from one type of concrete to another of concrete containing viscosity modifiers versus a concrete which is low slump. So, for example a mixer that has a powerful motor could be used to mix less workable or higher viscosity concretes. The mixing energy could be similar to that of a less powerful mixer but one filled with more workable concrete. So, these are some things which we have to understand when we are trying to work with special concretes.

That the normal mixers or the normal mixing times may not necessarily be very suitable for the kind of concrete that we are using. So, that is one of the reasons as I have mentioned before of highlighting some of these issues in our discussion today.

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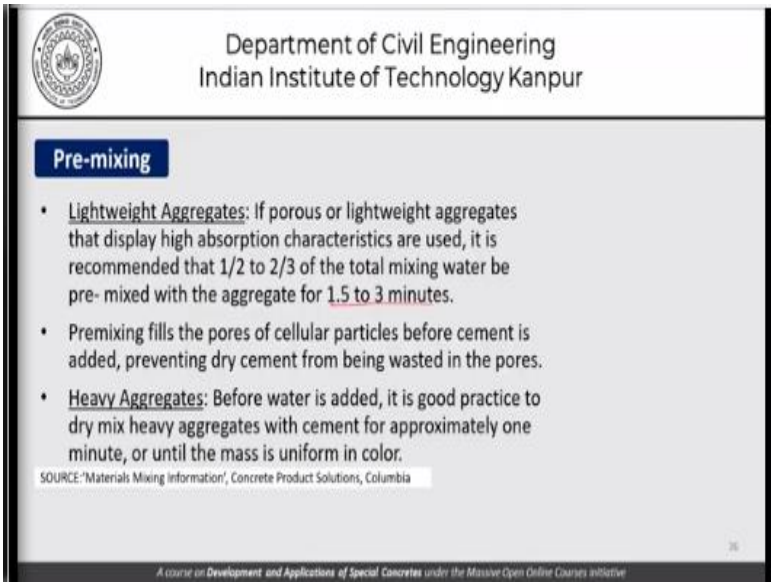

As far as pre-mixing is concerned, that is something which we shall remove all this. Now coming to pre-mixing as far as lightweight aggregates are concerned, they need to be pre-mixed. If porous or lightweight aggregates that display high absorption characteristics are used, it is recommended that half to two-thirds of the total mixing water be pre-mixed with the aggregates for about one and a half to 3 minutes.

This ensures that the absorption in the aggregates happens before the other ingredients are added. And if all the ingredients are added together the absorption in all the aggregates may not happen uniformly or it may not happen to the same extent, resulting in the concrete not being homogeneous. Pre-mixing fills the force of the cellular particles before cement is added, preventing dry cement from being wasted in these pores.

Similarly, when it comes to heavy aggregates before the water is added it is a good practice to dry the heavy aggregates with cement for approximately 1 minute or until the color of the mass becomes uniform. So, these are some of the tips, some of the issues that are being highlighted along with some kind of guidelines being given. So, of course this 1 minute or one and a half to 3 minutes, that should be taken with a pinch of salt.

Because those numbers will depend on the kind of aggregates involved the kind of mixing process that you are using. But please keep in mind the principle of what is been said, if you are

talking of aggregates which tend to absorb water is concerned, it is better to pre-mix them with water. As far as heavy aggregates are concerned before water is added, they should be mixed with cement or pre-mixed with cement.

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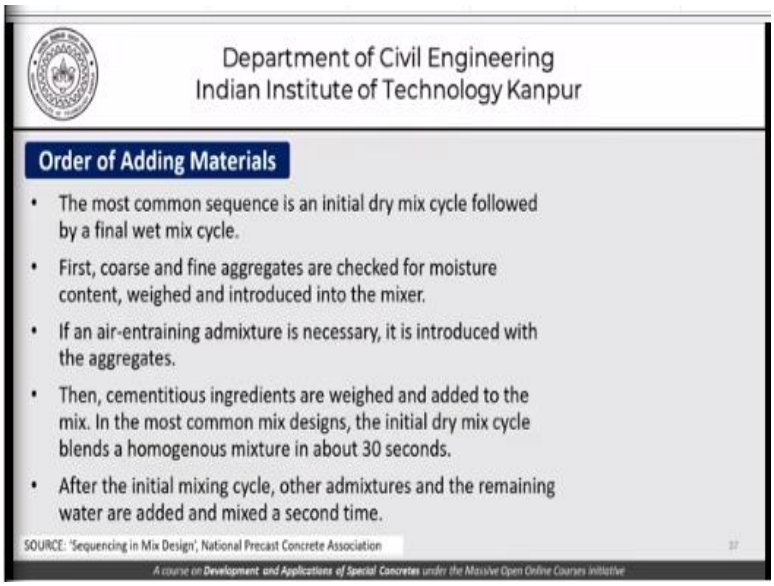

Coming back to our discussion on the order of adding materials the most common sequence is an initial dry mix cycle followed by a final wet mix cycle. First the coarse and fine aggregates are checked for moisture content, weighed and introduced into the mixer. If an air entraining admixture is necessary, it is introduced with the aggregates. Then cementitious ingredients are weighed and added to the mix in the most common mix designs.

The initial dry mix cycle blends the homogeneous mixture in about 30 seconds of course there is 30 seconds would depend on the power of the mixer and also the capacity and the volume of concrete involved. And after the initial mixing cycle other admixtures in the remaining water are added and mixed a second time, so that is the second mixing cycle that we are talking about.

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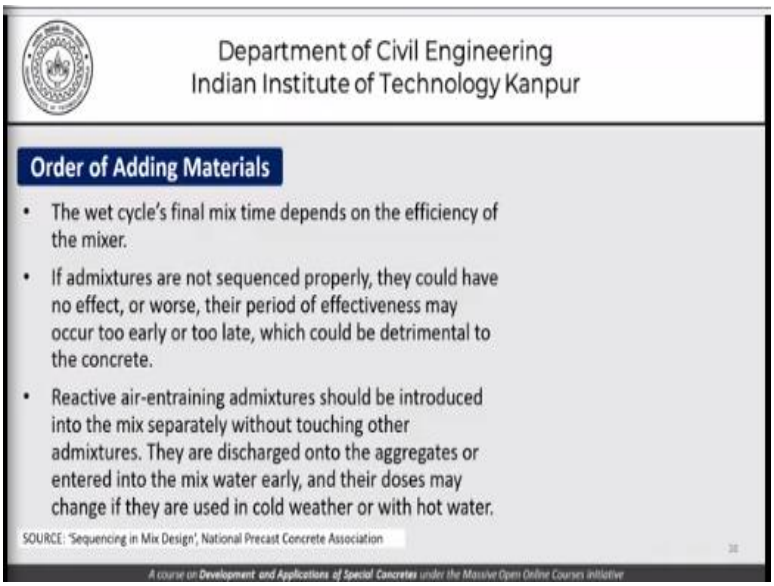

The wet cycle's final mixing time depends on the efficiency and the power of the mixer and also the kind of concrete being used and the volume. If admixtures are not sequenced properly, they could have no effect or worse their period of effectiveness may occur too early or too late which could obviously be detrimental as far as properties of concrete are concerned. Reactive air entraining admixture should be introduced into the mix separately without touching other admixtures.

They are discharged onto the aggregates or entered into the mixed water early and that doses may change if they are used in cold weather with hot water. If they are used in cold weather or with hot water, so even though we keep saying that the admixtures should be dosed in an aqueous state along with water and if the water is be significant. And if the water is significant or the amount of water is significant that should be properly accounted for in terms of it is adjustment with respect to the total water that is supposed to be added to the concrete.

At the same time, it is not as simple as just adding that admixture to the water, we must be sure that the temperature of water is such that the addition of the admixture will still be as effective as the designer had meant it to be.

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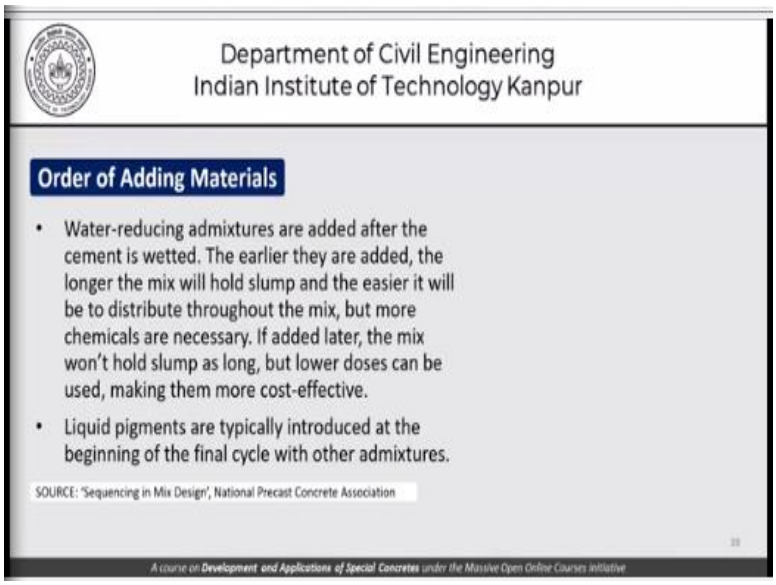

Water reducing admixtures on the other hand are added after the cement is wetted. The earlier they are added the longer the mix will hold the slump and the easier it will be to distribute throughout the mix but more chemicals will be necessary. If added later the mix will not hold slump as long but lower doses can be used making them more cost effective. Liquid pigments are typically introduced at the beginning of the final cycle along with other admixtures.

So, these are some of the guidelines basically highlighting the importance of having a proper order of adding materials to the concrete especially the admixtures.

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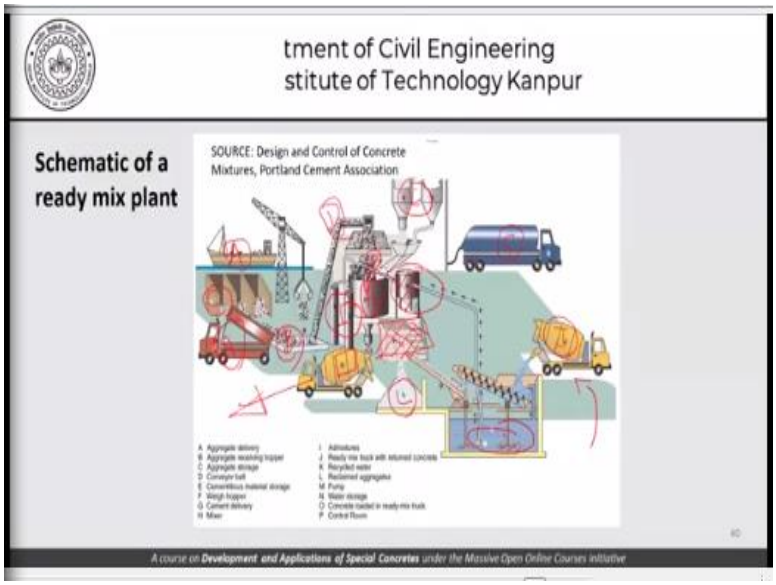

Now coming to an end of our presentation today which dealt with the mixing of concrete. Here is a schematic of a ready mixed plant, this picture here shows A as aggregate delivery either from here or from here. Then we have B which is the aggregate receiving hopper, C is the aggregate storage that we have here then we have this aggregate being delivered to this area here using a conveyor belt that is called D, F is my weighing hopper where the aggregate is weight and fed into this mixer H which is the actual concrete mixer.

Now obviously H is not alone the mixer you have to have other things going into this mixer, and E here is the cement, the cement is being fed into the mixer from here through after being properly weighed and I here, this is the admixtures being added to the mixer. Now once the concrete has been mixed here, we have O which is the ready-mix concrete agitator truck ready for dispatch to the site.

Now apart from this operation which is one side which is the manufacture of concrete and it is delivery to site. We have this part here which is designated as G which is the cement being brought into the plant and being stored in the silos. And apart from that we have this J, now what is this J? This J is the ready mixed concrete trucks coming back from the site to the plant and these trucks could have some amount of concrete in them.

Now this concrete has to be washed and what we will get here is recycled aggregates. So, these aggregates which are washed off, they are properly, it is ensured that these aggregates can be reused this becomes a pile here which is called reclaimed aggregates, and they could be used in concrete if it is permitted. And then of course the water here with proper quality control issue, and then the water here can be connected to this concrete tank to this water tank which also feeds the water to my mixer.

So, in fact I should have probably discussed this or pointed out the location of this water tank which feeds the water into the mixer. So, this water is connected to this water tank here and of course to control the whole operation of this batching plant we have a central control room here. So, this control room or through this control room all these operations which are going on that is aggregates, storage, their delivery to the hoppers.

And hoppers to the mixer, the cement delivery to site, storage in the silos and it is delivery finally to the hoppers, the water, the admixtures, the trucks being taken off to the site and the trucks returning from the site. All this is monitored and controlled through this control room. So, this concludes our discussion today on mixing of concrete, of course the idea was not to make you an expert but only to highlight some of the issues that are involved as far as the operation of mixing is concerned.

So, that you know that this operation even though it appears to be or it may look very simply but has it is own nuances and a lot of fine print. So, I will encourage you to visit a ready mixed concrete plant or read a little bit more about the different types of mixers that we have talked about and that will give you a better picture of what goes on when we are trying to mix concretes. And that is especially relevant as I have emphasized when we are dealing with special concretes.

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This is an incomplete list of some of the readings that you may like to do, to educate yourself and here are some problems to think about.

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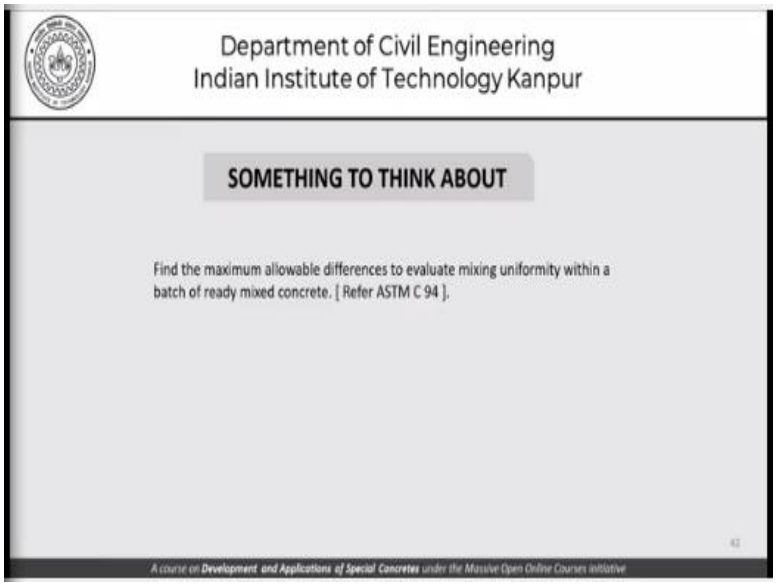

What is the maximum allowable difference to evaluate mixing uniformity within a batch of ready mixed concrete plant? Obviously, we understand from statistics that no matter how hard we try, we cannot get the same quality, exactly same quality from one batch to another. The only thing is there has to be a control on the extent of variation, and what is the level of variation that is allowed as far as different batches are concerned.

I would like to read documents such as ASTMC 94, and other relevant documents to get a better picture or to get an answer to this question. Thank you for your attention and I look forward to seeing you in the next classes this week, when we will talk about shotcreting and high strength concrete, thank you once again.