Concrete Engineering and Technology
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Lecture - 19
Concreting in hot weather

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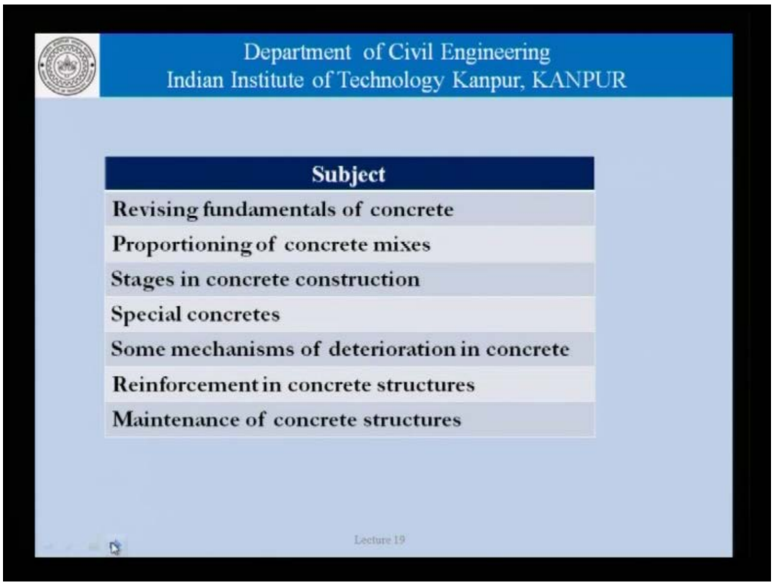

Welcome to this lecture on Concrete Engineering and Technology, where we are talking about all aspects relating to material selection, proportioning, construction and maintenance, as far as concrete structures are concerned. We have talked about special concretes. And in order to talk about special concretes, what we should know is what makes the concrete or the concrete operation special. For that, we have talked about variables which are now normal or out of that range. Any variable has a normal range, and then if it is out of that range, it means that the concrete should be considered special.

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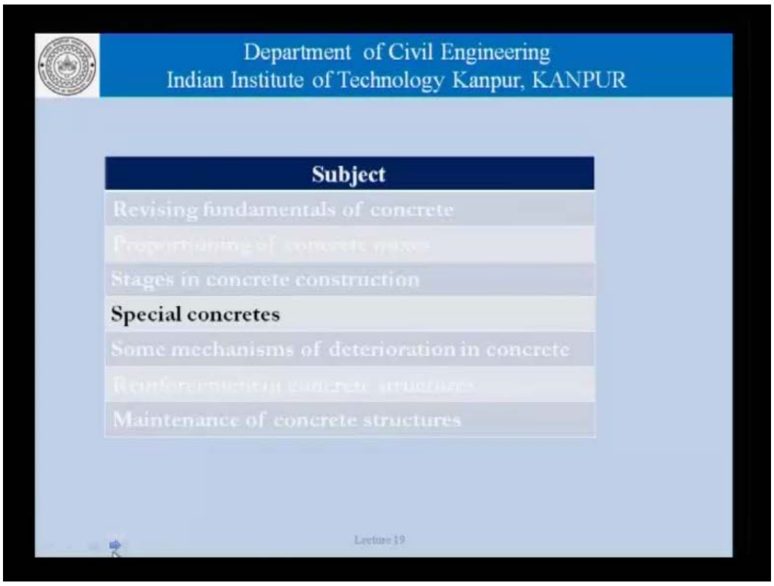

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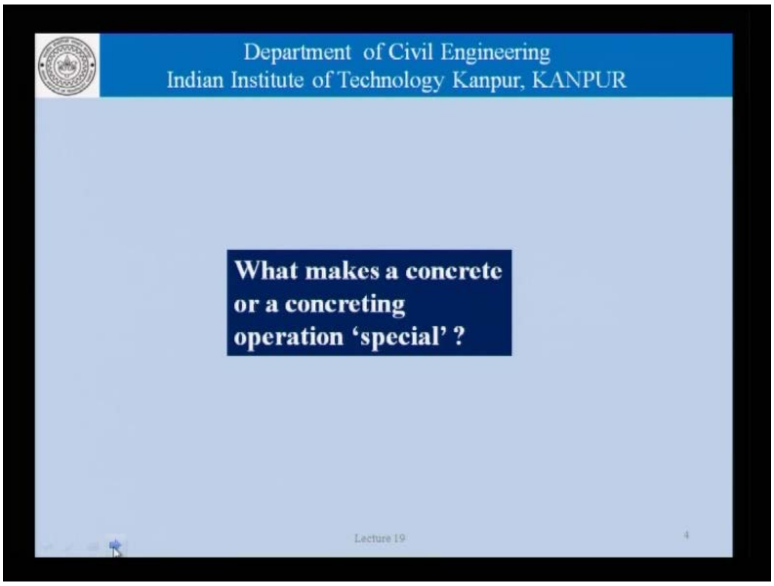

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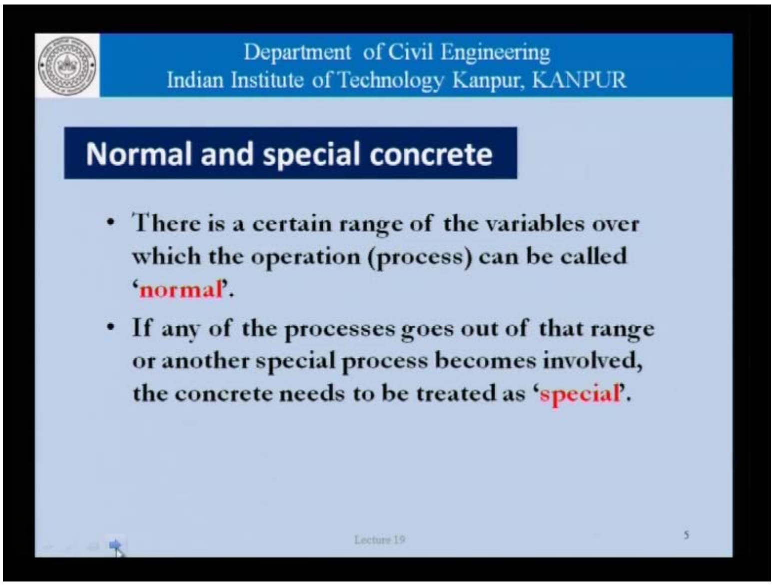

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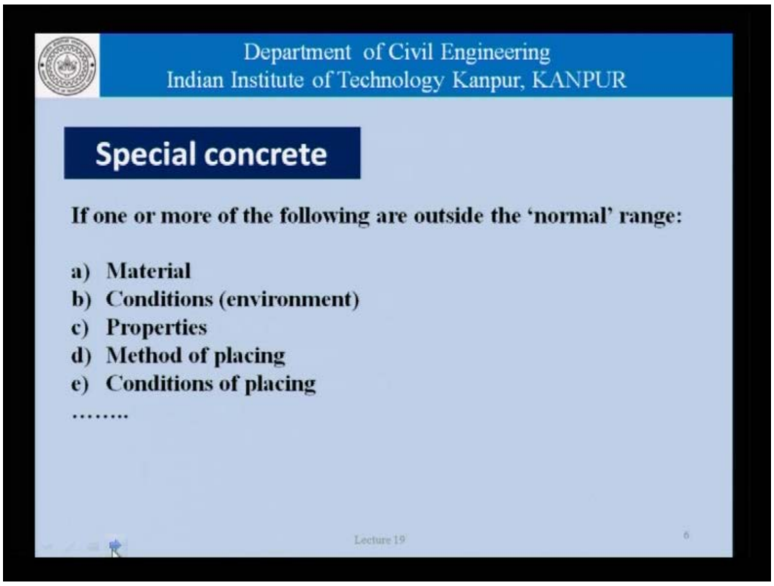

Now, what those variables could be are material, the conditions, properties, placing methods, conditions and so on. If you use fibres to the concrete it becomes special, if the temperature is too high or too low it becomes special, if the properties in terms of strength, workability, air content, density, so on. If they are out of the normal range, then the concrete becomes special. If the method of placing or conditions of placing are different then normal, the condition is special. And therefore, concrete needs to be treated as special, which means that all aspects relating to that concrete would need to be special.

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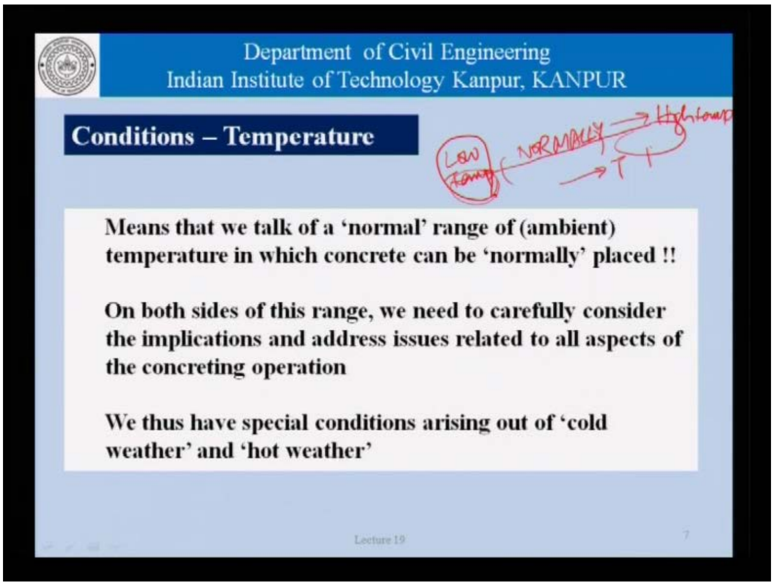

As far as temperature is concerned, then we talk of a normal range of temperature in which concrete can be placed normally. It means that as far as temperature is concerned, if this is that line which talks about temperature, there is a range here where concrete can be placed normally. As far as this temperature is concerned it is abnormal, it is special and similarly on this side also concrete deserves a special attention. So, here we are talking about low temperatures, and therefore we are talking about cold weather concreting. Whereas, on this side we are talking of high temperatures, and therefore we are talking about hot weather concrete.

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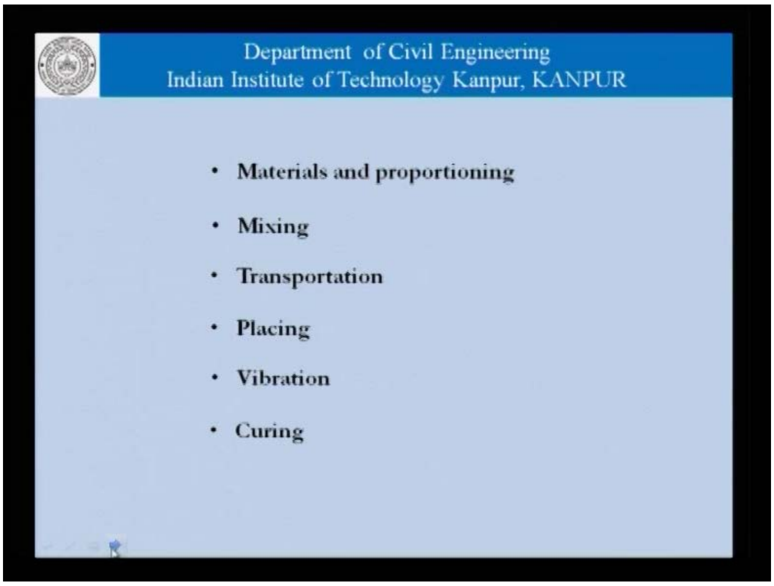

Once we talk about a special concrete, whether it is hot weather, low weather, fibre reinforced concrete, anti-washout concrete or whatever, we need to be concerned about all aspects relating to concrete operations. The materials in the proportioning, we need to be bothered about mixing methods, the transportation of concrete from the ready mix plant to the site of placement. We are bothered about or we are better we bothered about the placing methods that are used, the vibration or compaction methods that are used and also the curing methods.

And after this, after the concrete is an operation that is the structure is in service, we need to bear in mind that the structure was constructed using a special concrete, even during the time that it is being maintained. And that means, operations such as inspection and nondestructive testing is taking place.

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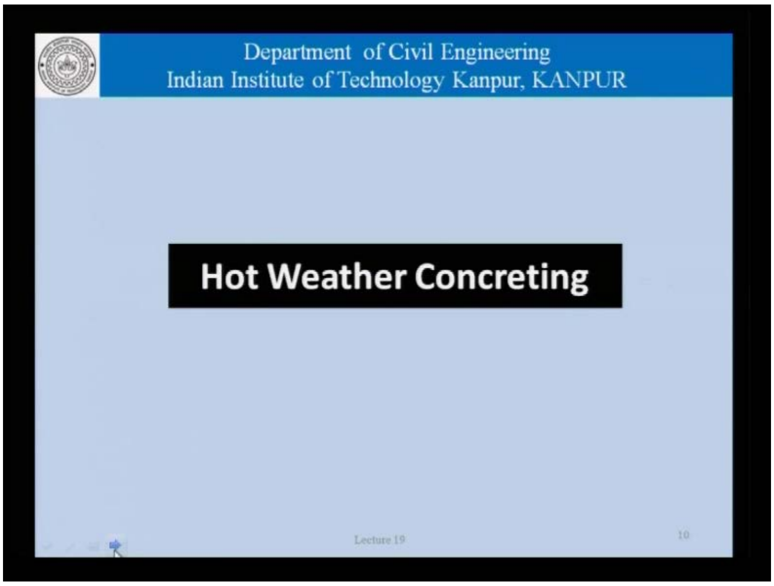

But, that is a different story we have already talked about cold weather concreting at a different occasion, and today the discussion is focused on hot weather concreting.

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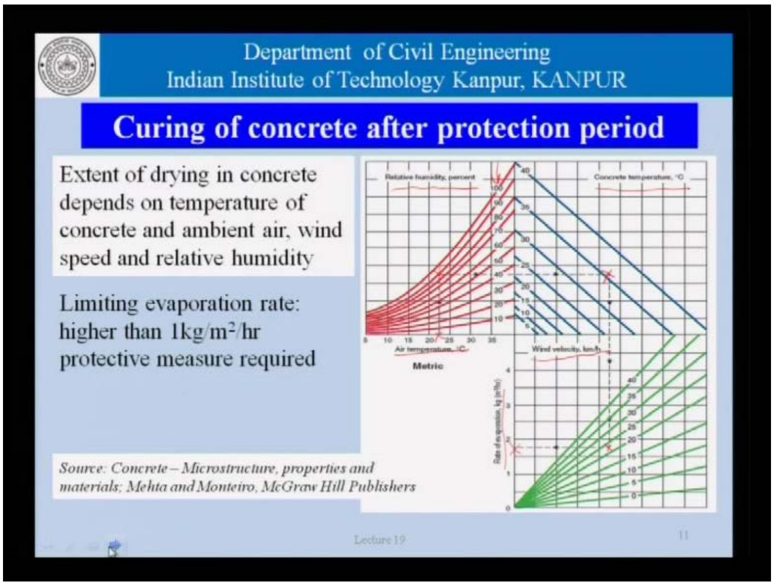

Now, hot weather concreting essentially implies a lot of grain on the concrete surface, immediately after it is placed, and this depends not only on the temperature of the concrete and ambient air, but also the wind speed and relative humidity of the atmosphere. And this picture relates some of these variables, we have the air temperature here, varying humidity is at this access, we have the wind velocities here varying concrete temperatures; and we have the rate of evaporations here for the different wind velocities.

So, basically the where to use this chart would be to start that an ambient air temperature, go to somewhere here look up the relative humidity. Turn right come to wherever the concrete temperature is dropped down to where the wind velocity is, and try to find out what is the applicable or estimated rate of evaporation. Now, if the rate of evaporation is higher than a critical number, let us say 1 Kg per square meter per hour. we need to put in place special measures; recall that we have been talking about, performance based design, performance based specifications.

And this here is there example where we are now inventing or we are putting forward a parameter are called the rate of evaporation, which should be at the bottom of our thought process, when we are trying to specify concrete under hot weather conditions. Or for that matter in the cold weather conditions, it is not enough to say that the temperature of the concrete should be so much, the wind velocity should be less than so much, and so on. What we are really interested to control is the fact that, the rate of evaporation from the surface of concrete should not be a certain should not be more than a certain number.

And that is something which we must understand as to what is an acceptable rate of evaporation, that we can live with, which we can counter using normal methods of curing. If that rate of evaporation exceeds that number, we need to put in special effort and special provisions as far as our specifications and quality control is concerned.

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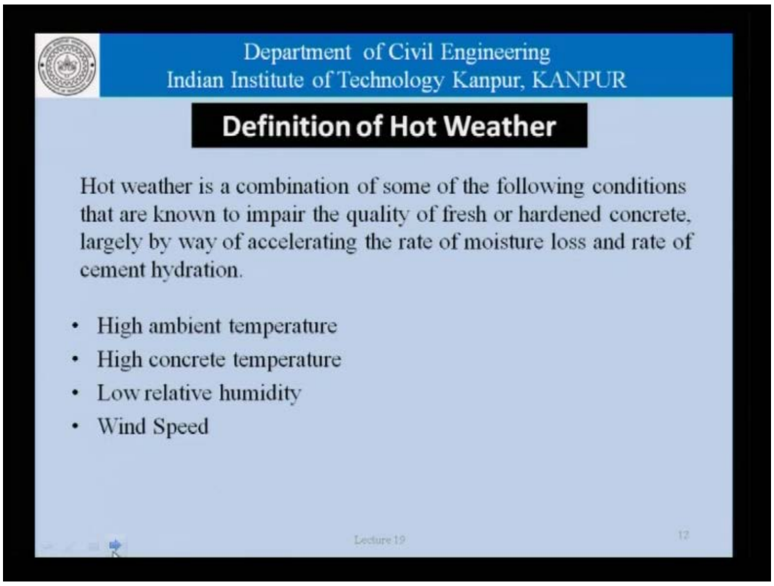

Now, hot weather as far as definition is concerned, is a combination of some of the following conditions that are known impair the quality of fresh or hardened concrete, largely by way of accelerating the rate of moisture loss, and the rate of cement hydration. Rate of hydration, the rate of moisture loss or rate of evaporation is what we were talking about in the previous picture, and some of these conditions are high ambient temperature. Naturally, if the temperature of the atmosphere is high, we can expect that the rate of evaporation is going to be high, and that is what will necessity that the concreting operation we called hot weather concreting.

Similar, is the case that the temperature of concrete, the temperature of fresh concrete is unacceptable. So, we have to have a range, where we say that well the temperature of fresh concrete should not exceed a certain number, less it attract the provisions of hot weather concreting. Low relative humidity also encourages, evaporation and loss of moisture from surface and we need to be careful about that.

Wind speeds also promote loss of moisture from the surface, and we have to look at a combination of all these factors before we decide, whether or not hot weather concreting provisions apply or not, as far as a construction project is concerned. We must remember that, these provisions need to be put in place, the values of these parameters needs to be put in place. Because, the moment we have the moment we have hot weather concreting provisions apply, there are economic or financial implications.

And it is important that those conditions which are tracked special provisions, which have financial implications are specifically laid out, less there be a dispute between the contractor and the client or the consultant and so on. So, it is very important in this day and age, where professions, where the construction profession is becoming more and more professional, that these provisions are as clearly laid out as possible.

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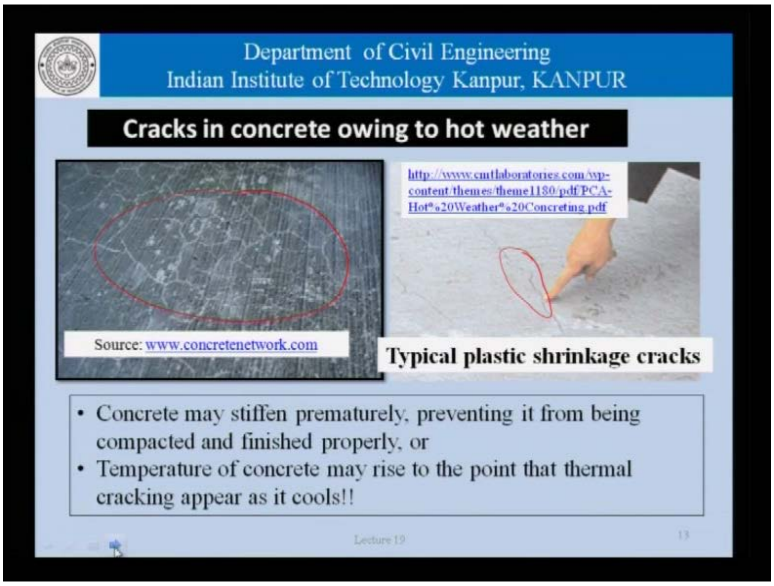

Continuing our discussion on the technical side of it, these pictures here shows some cracks that may arise in concrete owing to hot whether, so we can see some typical shrinkage cracks here. And similarly, shrinkage cracking on this surface of concrete, these cracks are largely surface cracks not very deep, but aseptically on the peeling and the less. We must remember that as far as hot weather concrete is concerned, it may stiffen prematurely preventing it from being compacted and finished properly. So, if concrete loses it is workability quickly, naturally it is compatibility and finishability suffer carrying on from that point, the temperature of concrete may rise to the point that thermal cracking may appear as it cools. And this is something which we will talk about, when we discuss issues related to mass concrete, and some discussion further down this module.

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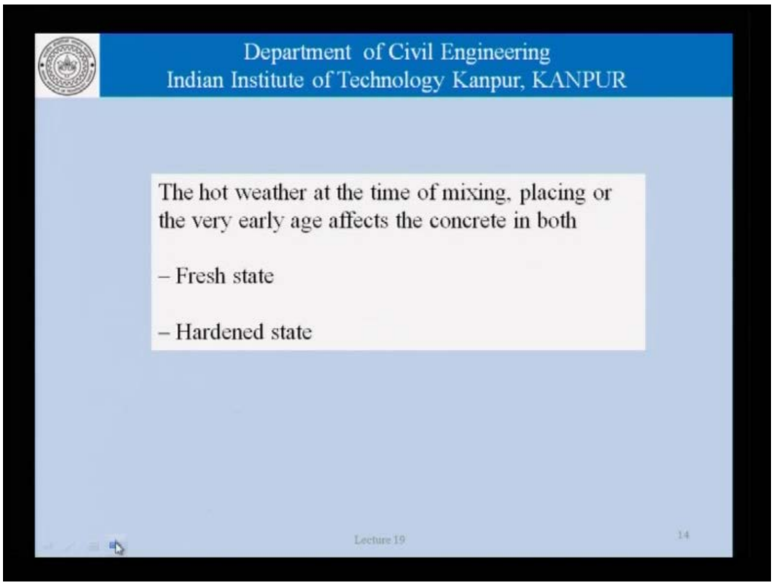

Now, hot weather at the time of mixing of concrete or placing, or at the very early age, affects the concrete in both, the fresh state as well as the hardened state.

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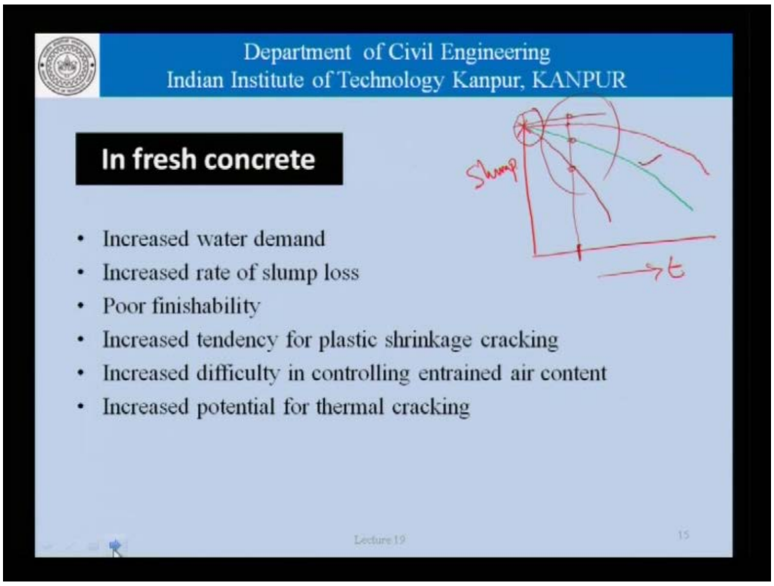

And to classify this discussion, let us talk about the fresh state first, it leads to an increased water demand, what it means is that, the required amount of water, the unit water content to achieve a certain workability increases, if the temperature is higher. It leads to an increased rate of slump loss, as far as slump loss is concerned, we have talked about this that as time goes on. And if read part slump on the y axis, if the concrete biggest with this slump that is the concrete slump, at the time of let say the discharge from the mixer in the batching plant.

The moment hydration starts, and that is starts as soon as water comes and contact with cement and therefore, hydration is already going on, even while the concrete is being mixed. Now, as more and more hydration products are getting formed, the workability is actually going down, if this was the initial slump over a period of time, we can expect that the concrete will stiffen. And this loss of slump may be gradual as shown here, or it could be rapid as it is shown here, so as far as hot weather concreting is concerned, we are looking at this scenario or more possibly something like this, which is more rapid.

And this slump loss really means that from the time that the concrete is released from the batching plant, till the time that it reaches the site of placing that is the construction site. We may already have had a certain amount of slump loss depending on the temperature, and this part needs to be factored in, when we are proportioning the concrete mixes, when we are transporting the concrete and so on, and so forth. Some of these points we will see subsequently in this discussion today. poor finishability.

Now, finishability as far as concrete is concerned requires that the concrete has a certain amount of moisture at the surface, as the surface becomes dryer the concrete becomes less finishable. And that is exactly what is happens when the concrete is being placed in hot weather, so as far as concrete in hot weather is concerned it has poor finishability. There is an increased tendency for plastic shrinkage cracking, there is an increased difficulty in controlling entrained air content, and there is an increased potential for thermal cracking.

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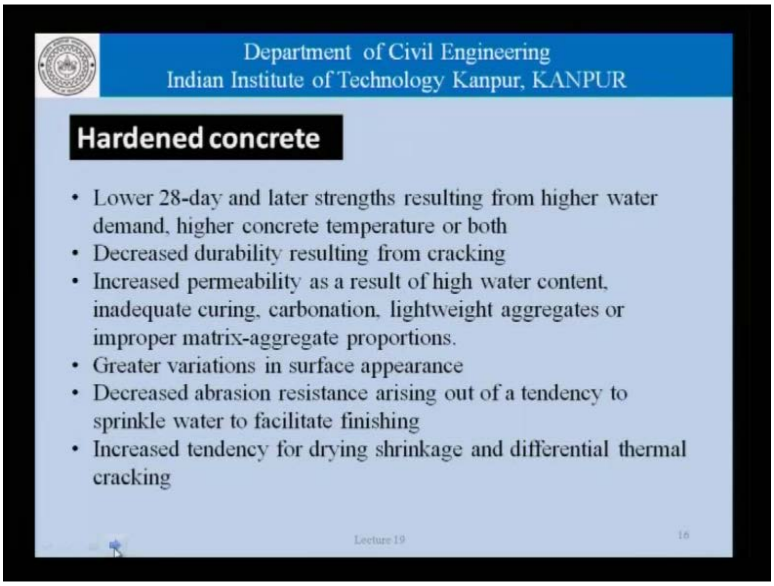

Now, coming to hardened concrete there is lower 28 day, and later day strength resulting from the higher water demand, because you would have probably added more water, higher concrete temperature of both. We could be encountering decrease durability resulting from cracking, it could be shrinkage cracks, it could be thermal cracks or any other cracks. We should remember that no matter what the width or the depth of cracks, any amount of cracking at the surface makes a certain amount of the cover concrete, vulnerable and dysfunctional, as far as it is role in protecting the reinforcement is concerned.

So, whether it is surface cracks or whether it is deeper cracks, we should try to present cracking in concrete, because the existence of such cracks is not taken into account at all, when we are designing the cover thickness. In adequate or increased permeability as a result of the high water content, in adequate curing, carbonation, lightweight aggregates and improper matrix-aggregate proportions. As I said was finishability needs to greater variations in the surface appearance of the concrete.

Decreased abrasion resistance arising out of a tendency to sprinkle water to facilitate finishing. Now, this here is the purely engineering or a purely field phenomenon, a work man whose trying to finish the concrete at the surface, at site would tend to spray or sprinkle some water on the surface, so that the concrete concerned be finished. Now of course, concrete can be finished and that water will or at least part of that water will also evaporate. But, that needs to an increased or that needs to a decreased abrasion resistance, because at the end of it the surface concrete now as a higher amount of a water; there is an increased tendency for drying shrinkage and differential thermal cracking.

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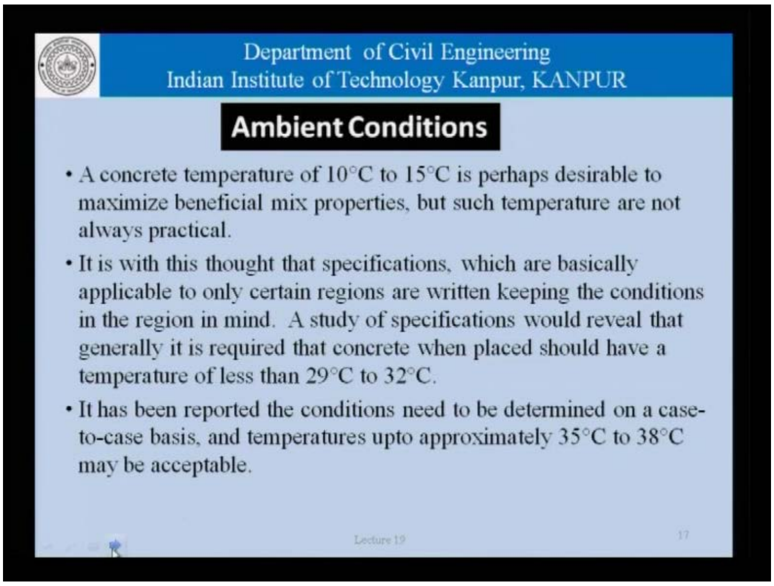

Now, as far as the ambient conditions are concerned, it is known that a concrete temperature in the range of 10 to 15 degree, is perhaps desirable to maximize the effects of concrete mixing and properties. But such temperatures are not always practical, it is simply not possible to be able to mix, and place concrete in this temperature range or any temperature range for that matter. And it is with this thought that specifications are provisions in course, which are basically applicable to only a certain region.

And therefore, written keeping the conditions in that region in mind are a very important document which must address conditions such as this, that is ambient conditions being non ideal. So, engineering is all about working in a non-ideal atmosphere, especially civil engineering where we are really working at sites, where natural conditions or weather conditions or simply beyond our control. All that we can do is to control local environments, at the site of placement, but not the environment around it.

A study of specifications would reveal that generally it is required, that the concrete when placed should have a temperature of less than 29 to say 31, 32 degree centigrade. Most specifications in the world would say, that anything beyond 32, 33 degree centigrade would qualify for a very special treatment as far as concrete is concerned. And similarly, different specifications may lay down different numbers, as far as the level at which that phosphoric temperature would necessitate the concreting operations to be called hot weather.

In other words, the conditions need to be determined on case to case basis, as far as hot weather is concerned and temperatures of approximately even 35 to 38 degrees may be acceptable. In fact the importance of specifications and variations there in, can be seen even is something very different that is the temperature at which concrete is cured, standard curing conditions for water and temperature when concrete cures for normal quality control is concerned are to be kept. In certain specifications the concrete should be stored in 20 degree centigrade, in certain specifications it could be 27 degree centigrade and so on.

This variation comes from the fact or at least, the one of the important considerations that leads to this difference is the fact that, concrete is actually been exposed to different temperatures, in different countries. And those specifications therefore, must reflect that temperature number 1, and number 2 it is uneconomical to spend resources in cooling or heating are curing bond to maintain standard conditions. So, it is a combination of economics and real conditions or the actual conditions at site, that primp is specifications in different countries or different regions to have different curing temperatures. Carrying that thing forward, we could also imagine that these specifications would be different as far as definition of a hot weather, or for that matter even a cold weather concrete is concerned.

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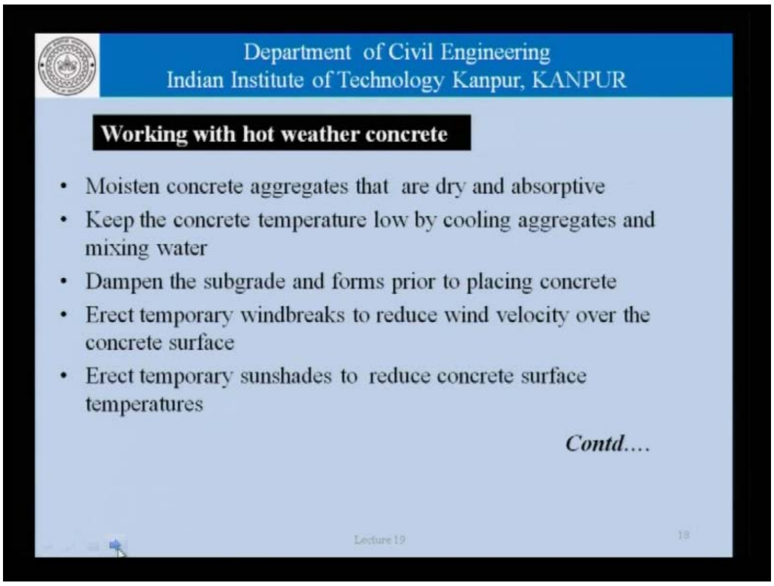

When we working with hot weather concrete, we may like to take special steps such as, moistening the concrete aggregates that are dry and absorptive. If we moisten the aggregates, they would absorb less water, they would tend to absorb less water and whatever water is available shall we used for maintaining the workability of the concrete. You may keep the concrete temperature low, either cooling the aggregates or by cooling the mixing water, we need to dampen the sub grade and forms prior to placing concrete.

Concrete should not be cast against very hot surface, whether it is a ground surface or it is a form work. And if the form work is couching hot especially for example, if we are using steel plates, the plates could be really very hot in a hot summer day; so those plates need to be cooled down by sprinkling water. At the same time we must ensure that the water is not sticking to those plates, and the sub grade does not have a pool of water gathered some where.

We may erect temporary windbreaks to reduce the wind speeds, over the concrete surface, so like I said it is not possible to control the wind speeds in an open site. But we can, but what we can do is to erect temporary structures to put at the actual site of placing, at least till such time as concrete has gathered sufficient strength; or the fresh concrete is protected before it is exposed to the elements of nature. We could erect temporary sunshades to reduce the concrete surface temperatures.

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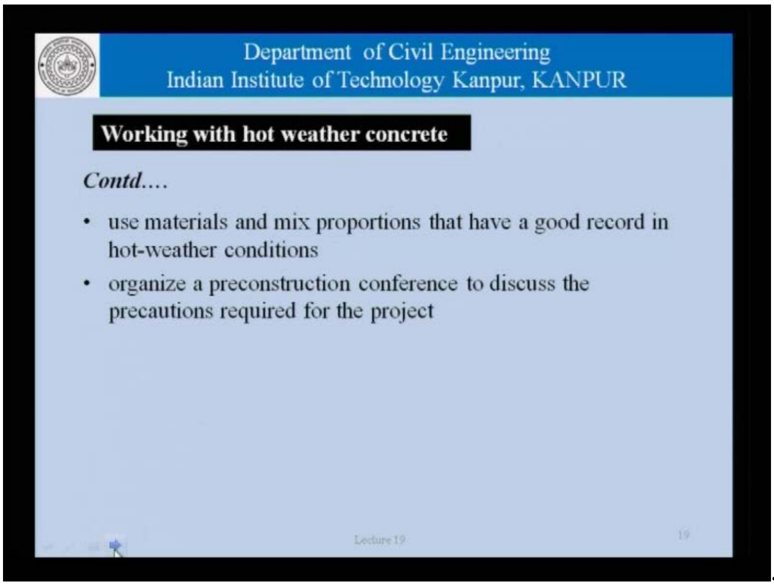

And continuing our discussion, we may use materials and mix proportions that have a good track record in hot weather conditions. We need to organize a preconstruction, conference to discuss the precautions required for the project, and the actual scheme of operations, and figure out whose responsibility will be the different operations.

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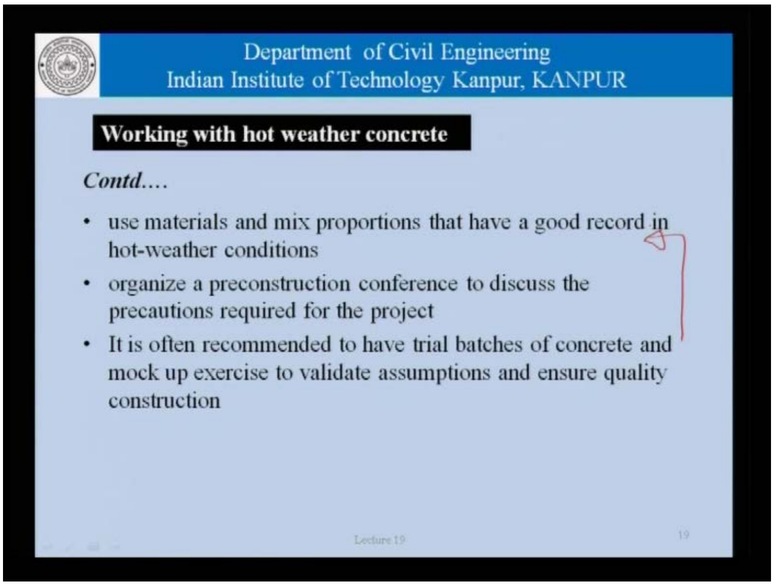

It is often recommended to have trail batches of concrete, and mock up exercises to validate assumptions, and ensure quality construction, as far as this part is concerned this is related to the discussion here. At the end of it there are assumptions, there are estimates, whether it is the a strength development is concerned, whether it is the rate of evaporation is concerned; whether it is the special curing method that is going to be used is concerned, whether is the actual material which is going to be used as a curing compound is concerned and so on. Therefore, it is always better to have a trail run use the actual materials, use the actual proportions of concrete, cast a mock up structure in the actual conditions. And measure the parameter that we want to use as a yard stick or a benchmark of the form, of concrete in that weather.

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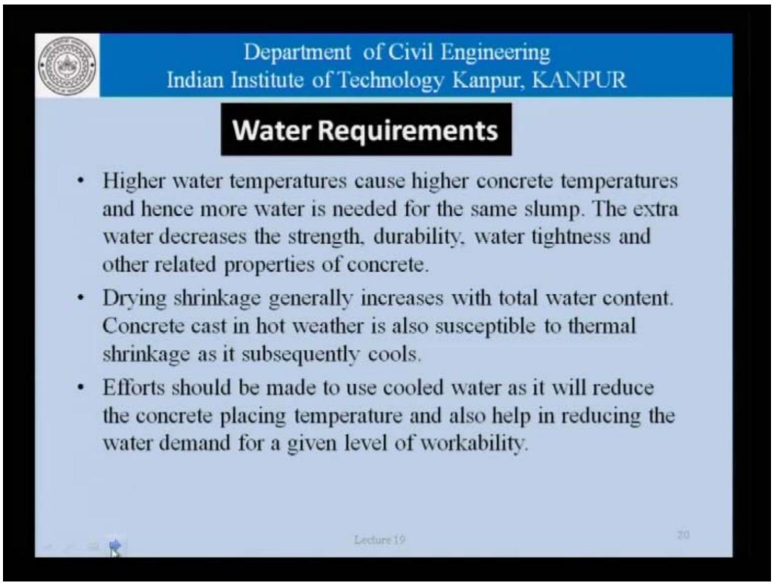

As far as water requirement is concerned, we already said that higher water temperature cause higher concrete temperatures. And hence more water is needed for the same slump, and extra water tends to decrease the strength durability, water tightness and other properties of concrete. Drying shrinkage increases with the total water content, and concrete cast in hot weather is also susceptible, to thermal shrinkage as it subsequently cools. And effort should be made to use cooled water, as it will reduce the concrete placing temperature and also help in reducing the water demand, for a given level of workability.

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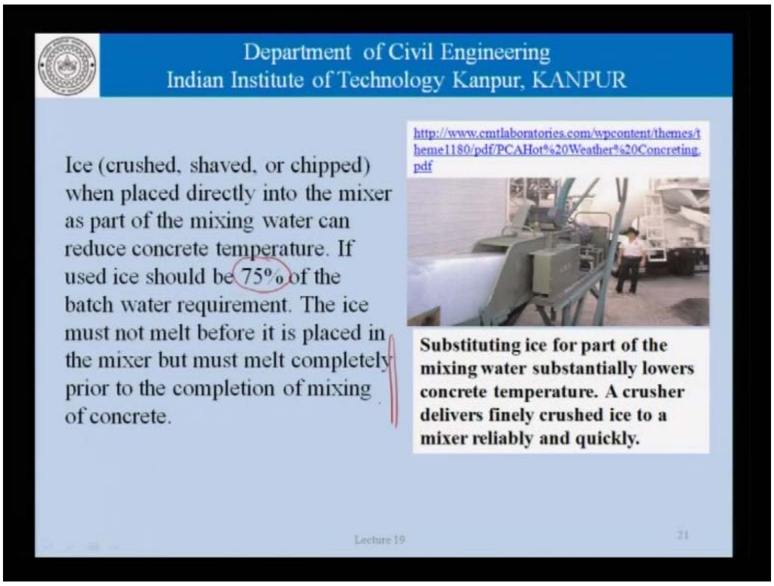

This picture here shows how ice is being crushed, and will be used in the batching plant as a partial substitute for mixing water, substituting ice for a part of mixing water, substantially lower the concrete temperature. And ice whether it is crushed shaved or chipped, when a placed directly into the mixer as part of the mixing water, can reduce concrete temperatures. But it should be remembered that not more than a certain number of course, the number that I have given here 75 percent, but it should be remembered that not more than a certain percentage of the mixing water should be used as ice, we cannot put all ice in it.

Certain amount of water with a certain amount of ice, the ice must not melt before it is placed in the mixer, but must melt completely prior to the completion of the mixing of concrete. So, these are some of the specifications or these are some of the precautions that one must take, this part here would basically define what kind of ice pieces or particles can be used in the process. Because, the mixing time is fixed, and during that time it is not possible perhaps for large chunks of ice to melt, at the same time if the ice is shaven or chipped to very, very fine size, it will be less effective.

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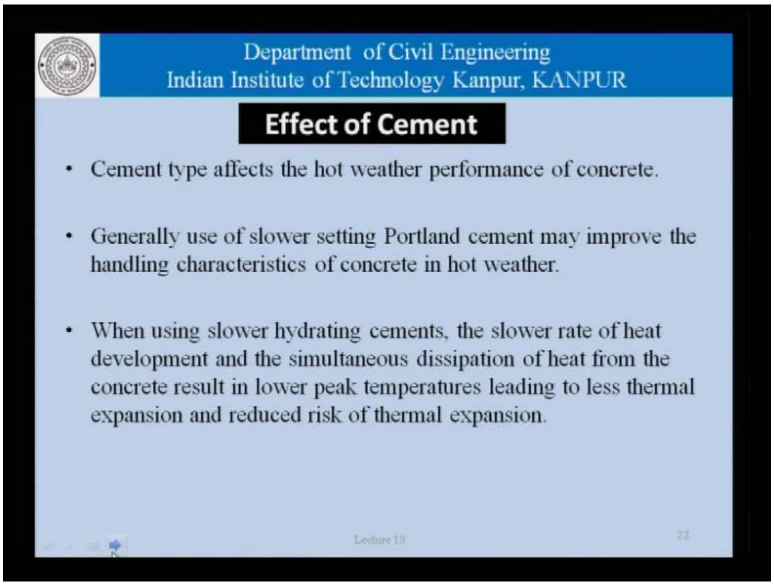

Carrying on as far as ingredients is concerned, let us talk a little bit about cement, the cement type affects the hot weather performance of concrete. Now, cement type means the chemical composition or constitution of cements, in terms of the (( )) tricalcium silicate, dicalcium silicate, tricalcium aluminate and the C4F. Generally use of slower setting port land cement may improve, handling characteristics of concrete in hot weather. Because, if the cement tends to set slower than normal, it gives so much more time to the engineer, to be able to place the concrete and finish it, and that increases the quality as far as the final product is concerned in hot weather. When using slower hydrating cement, the slower rate of heat development and the simultaneous dissipation from the concrete, results in lower peak temperatures leading to less thermal expansion, and reduced risk of thermal cracking.

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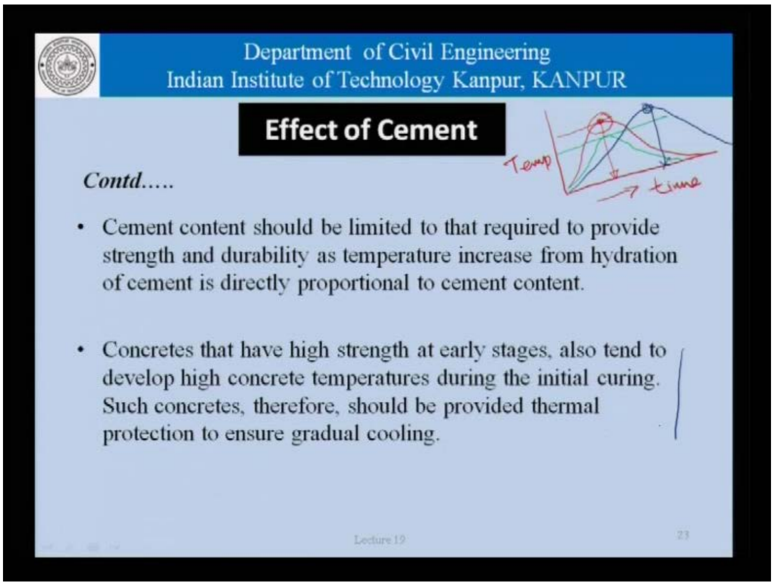

We may also try to limit the cement content or the unit cement content in the concrete, but keeping in mind that the amount of cement that means to be there is obviously there, for example, from the point of view of strength and durability. On the other side of it, concretes that have high strength at early ages, that are required to have high strength at early stages. Also tend to develop high concrete temperatures during initial curing such concretes therefore, need to be provided thermal protection to ensure gradual cooling, at the end of it, the basic discussion is the following.

The temperature increases and then decreases this is time basically if we look at how the temperature of concrete changes, this is a picture which shows that as the hydration continues the temperature increases and then reduces. This increase in temperature is coming from the fact, that the heat dissipation is lower than the heat generation on account of hydration. So, the two parameters that define this discussion is the peak temperature, and the time it takes for this temperature to rich.

If we have somehow able to reduce this peak temperature to something like this, or we are able to delay the peak as shown here, our life as far as the problems on account of common stresses will be much easier. So, as far as hot weather concreting is concerned, the discussion is more or less similar; hydration is also related to strength development. So, as we have talking about here, in concretes which are required to have high early strength, they also tend to have a high generation of heat in the begging. And if that happens we need to have special precautions taken to ensure cooling, or appropriate cooling, in order to make sure that cracking does not happen in the end of the day.

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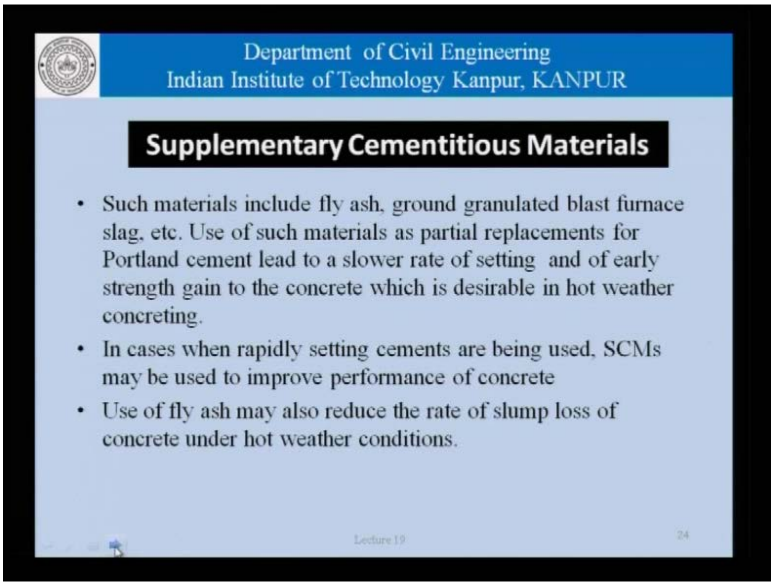

Coming to mineral admixtures or supplementary cementitious material, such materials including fly ash ground granulated blast furnace slag etcetera, can be used. And there use as partial replacement for port land cement, lead to a slower rate of setting and also a early strength gain to the concrete, which is desirable as far as hot weather concreting is concerned. So, we reduce the amount of heat generated, and also we delay the hydration process, slow it down, in cases when rapidly setting cements are being used, mineral admixtures may be used to improve the performance of concretes. Further, the use of fly ash may also reduce the rate of slump loss for concrete, under hot weather.

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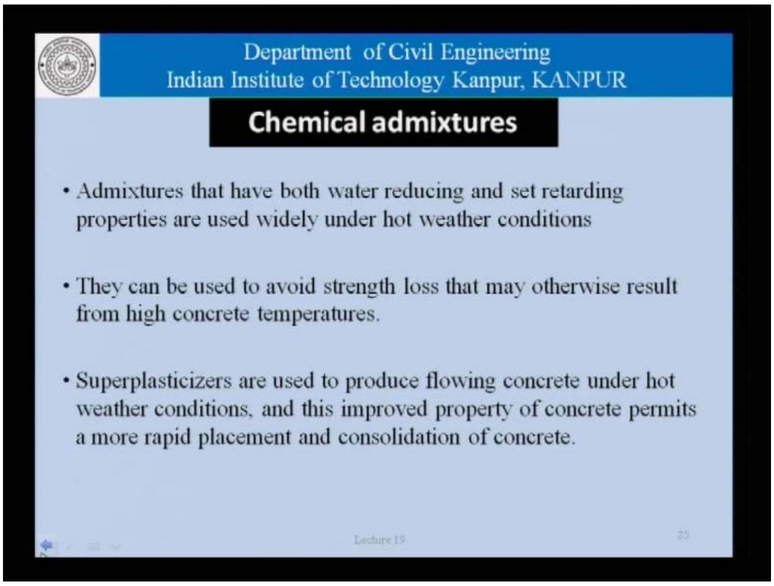

Continuing our discussion with chemical admixtures, admixture that have both water reducing and set retarding properties are used widely, when we are trying to work with hot weather concretes. And they can be used to avoid strength loss that may otherwise result from high temperatures and concrete, and super plasticizers are used to produce flowing concretes on the hot conditions. And this improve property of concrete permits more rapid placement, and consolidation of the concrete. So, it is really just using the properties of plasticizers or super plasticizers, (( )) advantage, as far as hot weather concreting is concerned. We should remember, however to make it a point to check the compatibility of the chemical admixtures used with the cement, and at high temperatures, or at the normal temperature at which it is being used.

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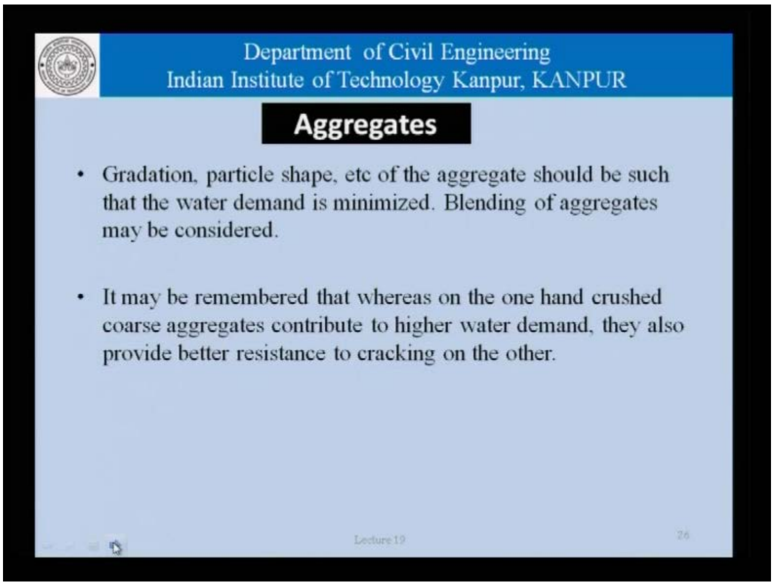

As far as aggregates are concerned steps can be taken to ensure, that the degradation and the particle shape of the aggregate is such that, the water demand is minimized. We could consider bending of aggregate as an option, and remember that whereas, in one hand crust coarse aggregates contribute to a higher water demand, they also provide better resistance to cracking on the other hand.

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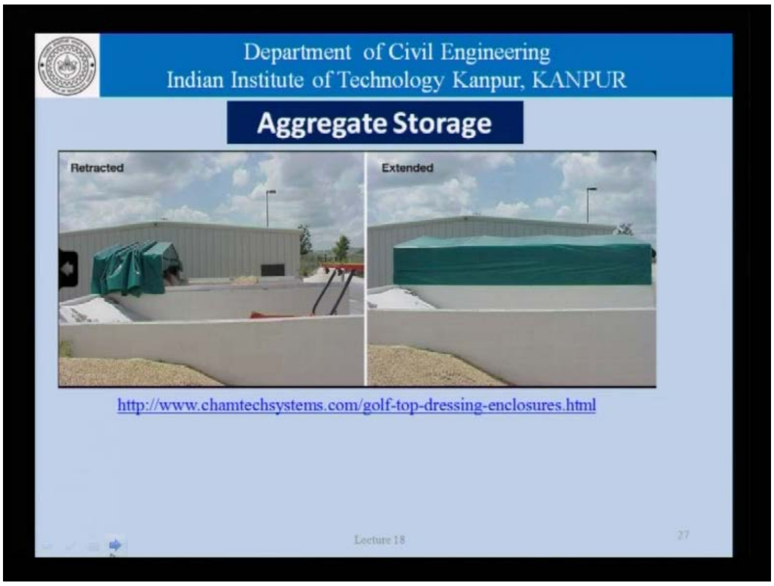

This picture here shows storage of aggregates or facilities that need to be erected, or put in place at site in order to protect the aggregates from the high temperatures that we are likely to experience.

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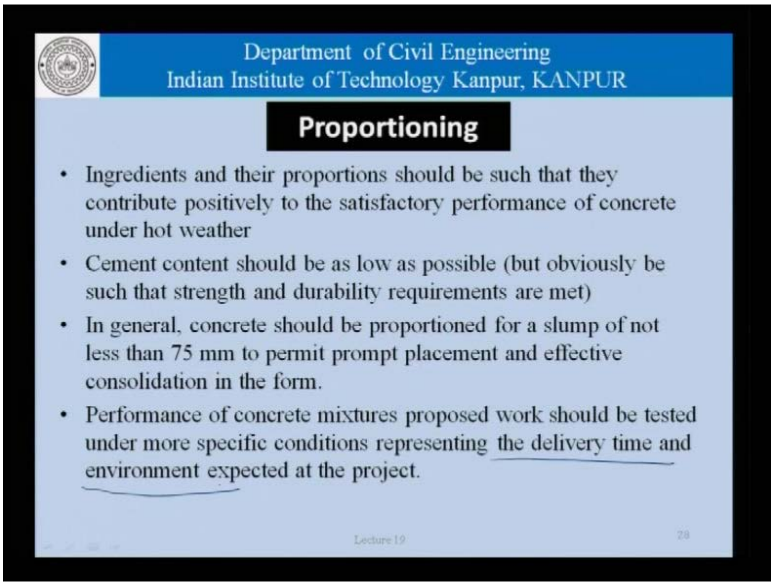

Coming to a proportioning of mixes, ingredients in that proportions should be such that, they contribute positively, to the satisfactory performance of concrete in hot weather, Cement content should be as low as possible. And in general we should proportion a concrete for not less than slump of 75 to 80 mm, to permit prompt placement and effective consolidation in the form work. If we choose to have slumps which are stiff, they make the handling of concrete difficult, and if the handling is difficult in hot weather especially, the situation becomes even more complicated.

If we work with a reasonable slump, the concrete can be handled effectively or more easily in terms of transportation, placing, vibration and finishing. As we have said before, the performance of concrete mixers proposed to be used in a particular work, should be tested under this specific conditions in which even the concepts. Or in which even variable such as, the delivery time and the environment expected at the project or accounted for. This basically means that the slump loss at a particular temperature is properly accounted for when we are trying to do the design of mixes.

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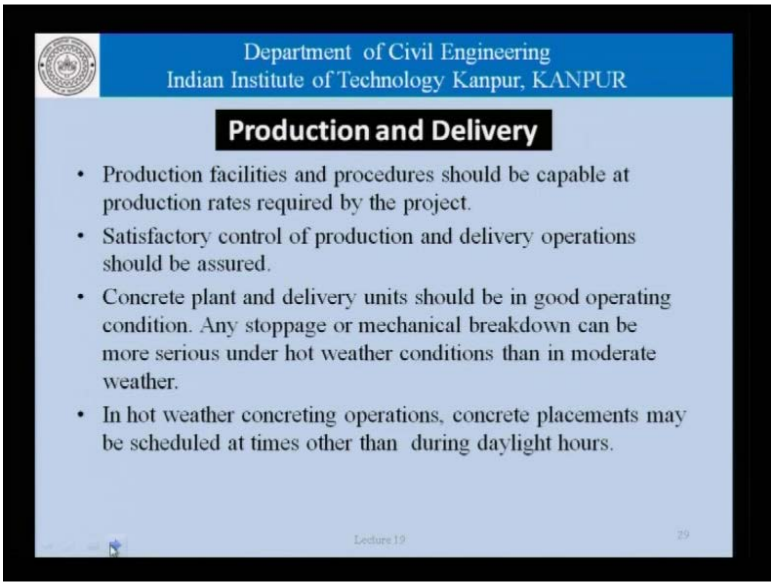

Now, coming to production and delivery, the production facilities should be capable of production range, required by the project, we must remember that. Concrete is being produced at the batching plant, it is been transported through trucks or whatever other means, and is being placed at a particular site. Now, unless the placing rate or the rate of consumption the placing site, the rate at which its being transported and the rate at which it is reproduced in the batching plant, these three parameters are properly synchronized; here will be problems as far as getting the concrete of the right property, at the right place is concerned.

The problems will be there even in normal weather of course, it is only compounded when we are talking in terms of hot weather, and that is why we need to have special provisions or special attention being paid, in order to control the production and delivery operations. It is obvious to say that, that concrete plant and delivery units should be in good operating conditions, and like I have said that any stoppage or mechanical breakdown can be more serious, under hot weather conditions.

Then in moderate weather, or normal weather we must be open to the idea that hot weather concreting operations, may be scheduled at times other than, the normal daylight hours, the days are typically much hotter than the evenings or nights. And in analysis should be carried out to ensure or to determine, how much is the benefit of carrying out the casting operations at night. And if those benefits in terms of the performance of concrete, and in terms of the quality of concrete construction that we get out way, the inconvenience of carrying out the operation in the night we must adopt that.

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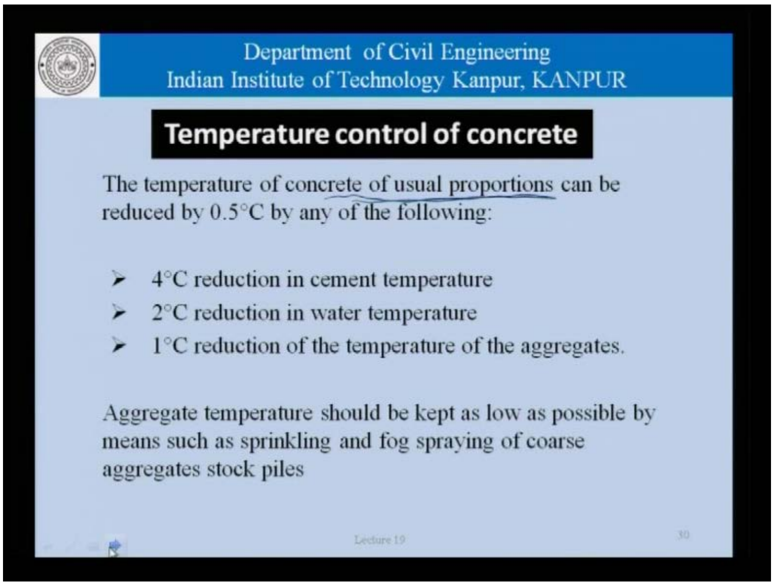

As far as the temperature control of concrete is concerned, the temperature of concrete of usual proportions can be reduced, by about 0.5 degrees by any of the following methods, a 4 degrees reduction in cement temperature, 2 degree reduction in water temperature, and 1 degree reduction in the temperature of aggregates. We must remember that the at the end of it concrete is a mixture of cement, sand, coarse aggregate and water, or may be mineral admixture. Each of these have their own temperatures, and when they are mixed in a certain proportions, there is reason to believe that the temperature of that mixture will be related to the temperatures, and the relative proportions of these ingredients.

We leave it out as an exercise to carry out a calculation by which we try to find out, that if the concrete has usual proportions that is normal proportions. If you are talking in terms of a concrete which is a water cement ratio about 50 to 55 percent, as a water content of 160 to 180 Kg's of water per cubic meter and so on. We want to change or if you want to change the temperature of concrete by half a degree centigrade, we have the option of playing around with the temperature of cement, water or the coarse aggregate, cement water or the aggregate.

And because of their different proportions in the mix, their temperatures need to be adjusted to different degrees to get the final result, or to get the same final result. Aggregate temperature should be kept as low as possible, by means such as sprinkling and fog spraying of coarse aggregates.

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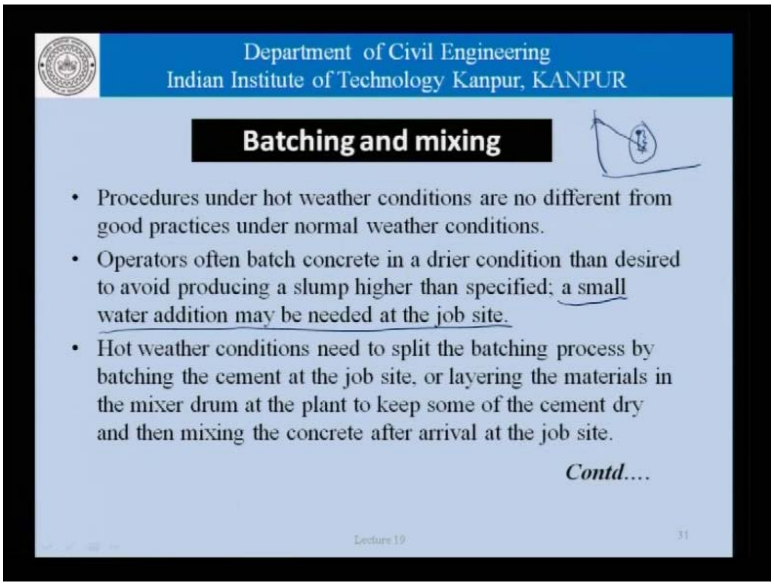

And stock piles as far as batching and mixing is concerned, the procedures in the hot weather conditions are no different from good practice, under normal weather. Operators often batch concrete in drier conditions than desired, to avoid producing a slump which is higher than they specified, addition of a small amount of water may be required at the job site. Now, this part here that is addition of a small amount of water in job site, is something that we have not talked about anywhere in this course, except when we were talking about proportions perhaps.

Where we say that out of 180 Kg's of water that is required we mix a 180 Kg's at the plant, and the remaining 20 Kg's at site. Now, this normally should not be done, concrete must be produced as a single entity, as an entity which is ready for use. Except under special conditions such as hot weather concreting where concrete needs to be, where some water may need to be added at the site of placement, to enhance the workability of the concrete.

So, what happens in that case is that, if the slump of the concrete has gone down to a certain point, we add the water and remix the concrete, we somewhat increase the slump and therefore, the placeability of the concrete. Usually that should not be done, and the implication of doing that should be thoroughly examined before it is permitted for use.

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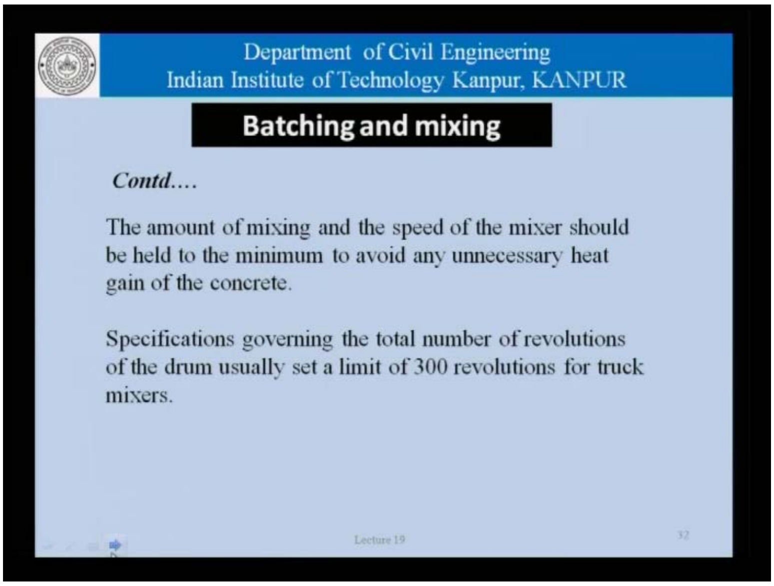

Continuing with the discussion the amount of mixing, and the speed of the mixer should be held to the minimum to avoid any unnecessary heat gain, as far as concrete is concerned. Specifications governing the total number of revolutions of the drum usually set a limit of say 300 revolutions for the truck mixer.

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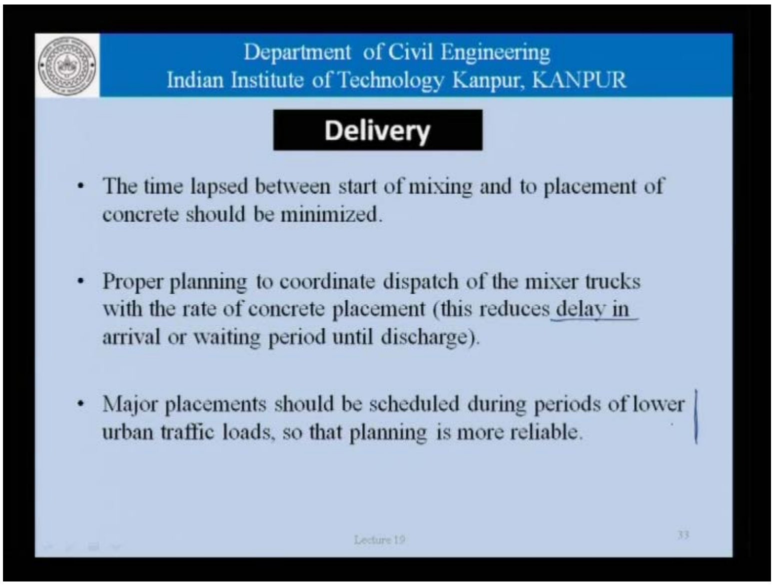

Now, coming to the delivery of concrete from the batching plant to be site of placement, the time lapsed between the start of mixing to the placement site, should be minimized. And we need to have a proper planning to coordinate the dispatch of mixers, and the rate of concrete placement, and that is what we talked about when we said that, the delivery plan has to be drawn up. And this will reduce a delay in the arrival or waiting periods of agitator trucks or whatever means we are using to transport the concrete.

We could also consider the possibility of scheduling major placements of concrete, during periods of lower urban traffic loads, so that the planning is more reliable. And this is another aspect of trying to work in the half day periods, that is late evenings, early nights or may be mater times.

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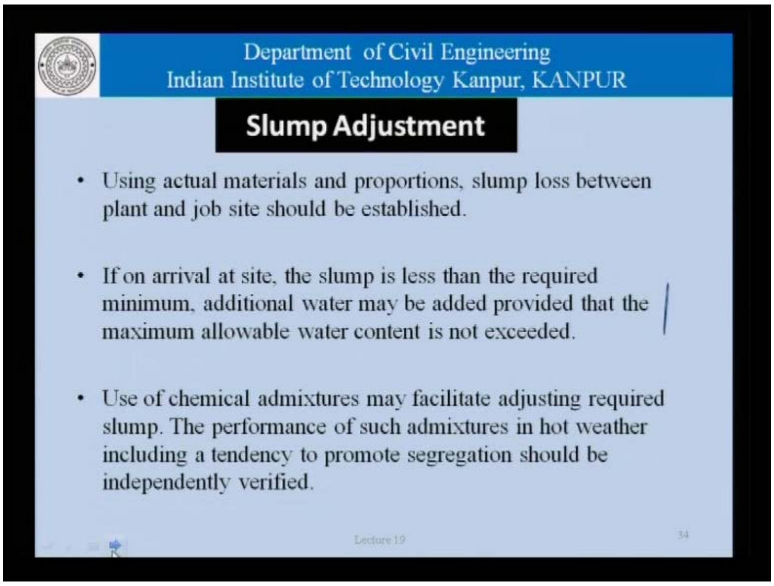

Coming to slump adjustment, the actual materials and proportions, the slump loss between the plant and the job site should be established. The slump loss relationship, as to how much slump loss actually occurs in a particular concrete, in a given condition that needs to be established very clearly, when we are working in hot weather. Now, if on arrival at site the slump is less than that required minimum, there may be provision to add additional water, provided that this addition does not mean that the maximum allowable water is exceeded.

And that is what I said when I am, and that is what I meant, when I said that the addition of water at the site should be very, very carefully and tediously permitted, (( )) after examine all the implications. And use of chemical admixtures may facilitate the adjustment, as far as slump is concerned, but the performance of these admixtures in hot weather, including a tendency to promote segregation should be independently verified.

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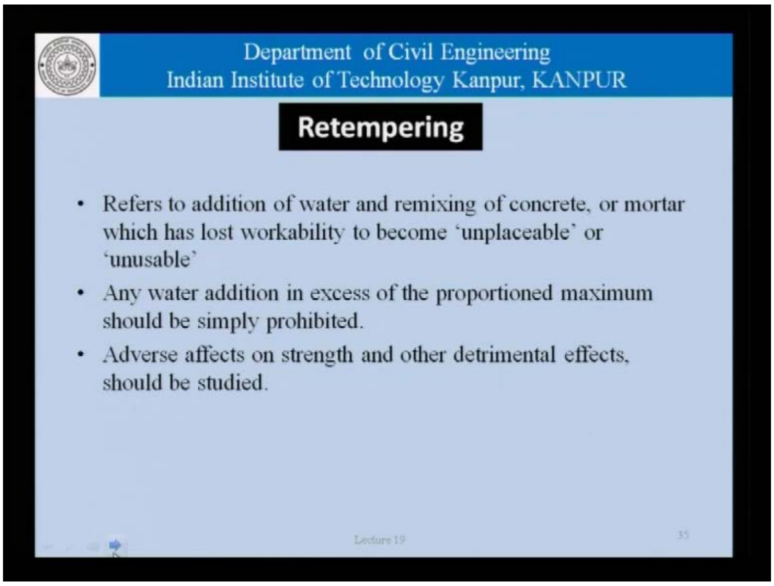

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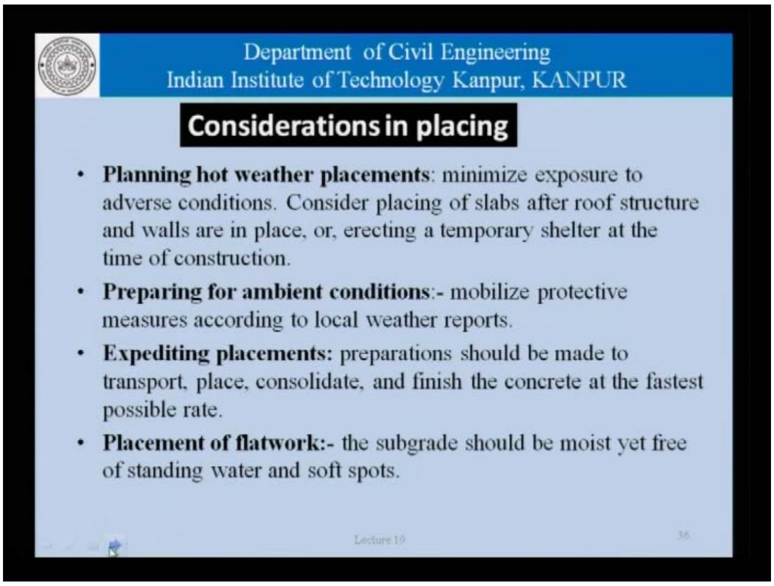

This process of the addition of water, in the second stage or a third stage is called retempering, so this retempering refers to addition of water and remixing of concrete or mortar, which has lost workability to become unplaceable or unusable. Any water addition in excess of the proportioned maximum should simply be privated. Adverse affects on strength, strength development and any other detrimental effects should be absolutely established, and only then permission for retempering should be given.

When it comes to placing, we need to minimize exposure to adverse conditions consider placing of slabs, after roof structures and walls are in place or erecting temporary shelter at the time of construction. Mobilize protective measures, according to the local weather reports, and preparation should be made to transport, place, consolidate and finish the concrete in the least time, at the fastest possible rate. And the sub grade should be moist yet free from standing water or soft spots, if we are trying to place concrete against the ground.

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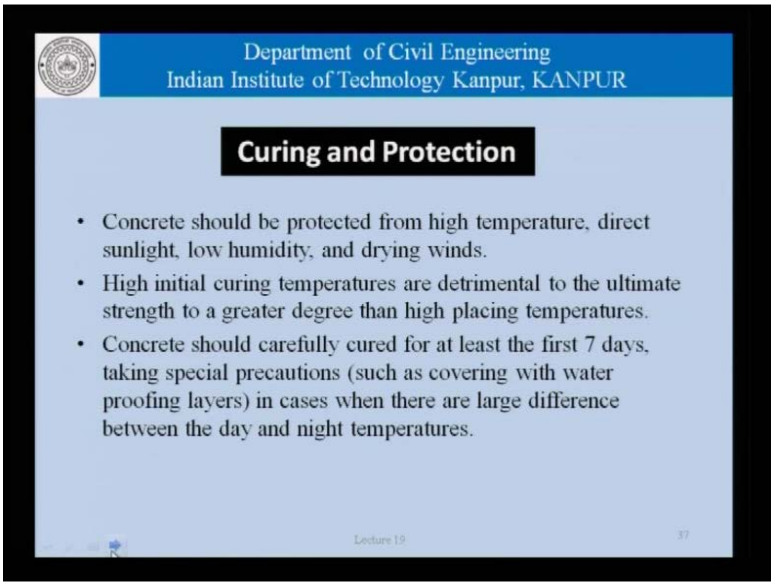

Now, coming to the curing and protection which is important part of a special operation in this context, concrete should be protected from high temperature, direct sunlight, low humidity and drying winds. High initial caring temperatures are detrimental to the ultimate strength, to a greater degree than high placing temperatures, and that must be born in mind. And concrete should be carefully cured for at least the first 7 days, taking special precautions such as covering with water proofing layers, in cases when there are large differences between the day and night temperatures.

Certain environments do not have a large difference, as far as the day temperatures and the night temperatures are concerned, but in certain cases there are very big differences between the night temperatures and the day temperatures. This has to be explicitly understood by the concrete engineers, or construction engineers, when they are trying place concrete under these conditions.

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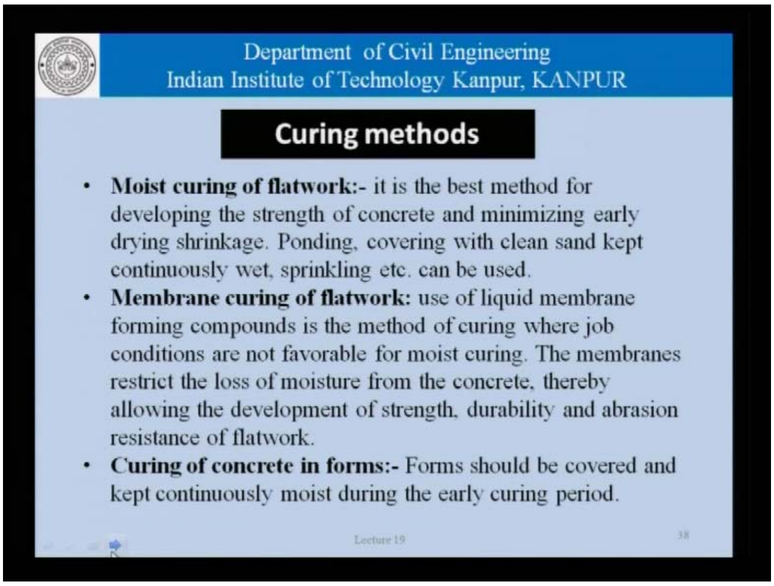

Now, coming to curing methods as far as moist curing of flatwork is concerned, the best thing is to moist cure the concrete, as far as the strength of concrete and drying shrinkage considerations is concerned. We may consider ponding covering with clean slay, ponding with water or covering with clean sand which is kept continuously wet, sprinkling etcetera. We get consider the option of membrane curing of flatworks, use of liquid membrane forming compounds is the method of curing where the job conditions are not favorable for moist curing. And these membranes restrict the loss of moisture form the concrete, there by allowing development of strength, durability and abrasion resistance of the concrete. Of course, as far as concrete in forms is concerned a form should be covered and kept continuously moist, during the early curing period.

So, if we see here, there is nothing really new as far as hot weather concrete is concerned, and these are common or common sense methods, or to do things as far as normal operation is concerned, except that in hot weather, it becomes even more critical that these operations are carried out the due (( )).

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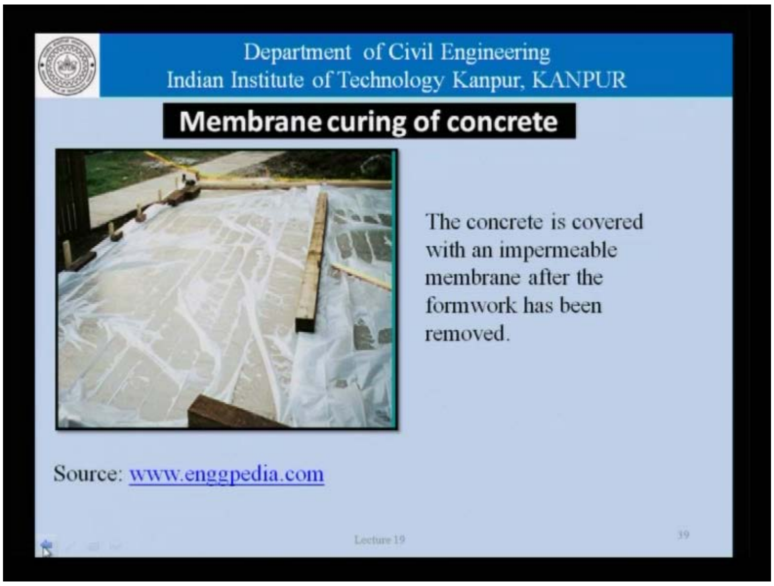

This picture here shows, a membrane or a waterproof membrane covering a concrete structure after the forward has been removed.

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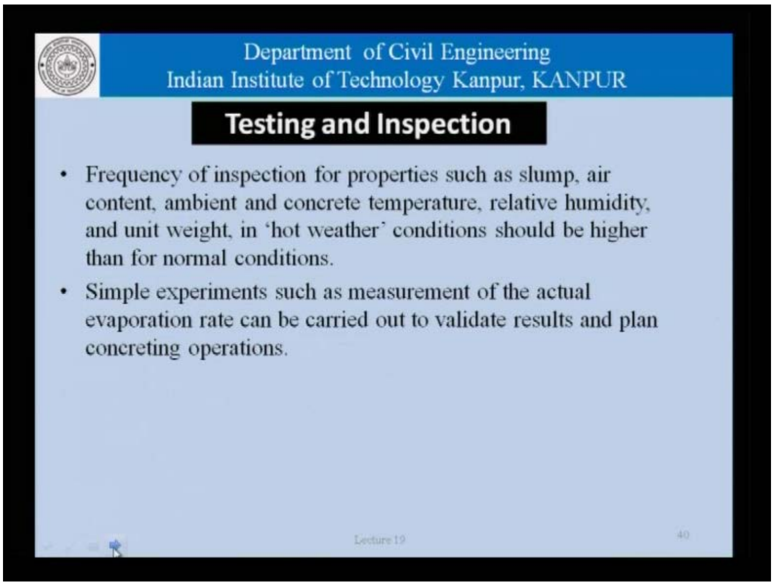

Now, coming to the testing of concrete, the frequency of inspection for properties such as slump, air content, ambient and concrete temperature, the relative humidity and unit weight, in hot weather conditions may require to be higher than for normal conditions. Now, this is another aspect of quality control, the frequency of testing needs to be related to the likelihood of damage, and since the likelihood of damage in hot weather is higher, the frequency should be higher.

Simple experiments such as the measurement of the actual evaporation rate, can be carried out to validate the results, and plan the concreting operations. We recall the graph that we saw to estimate the rate of evaporation, depending on the temperature of the air, the temperature of concrete, the wind speeds and so on; that rate can be validated using simple experiments of water evaporation.

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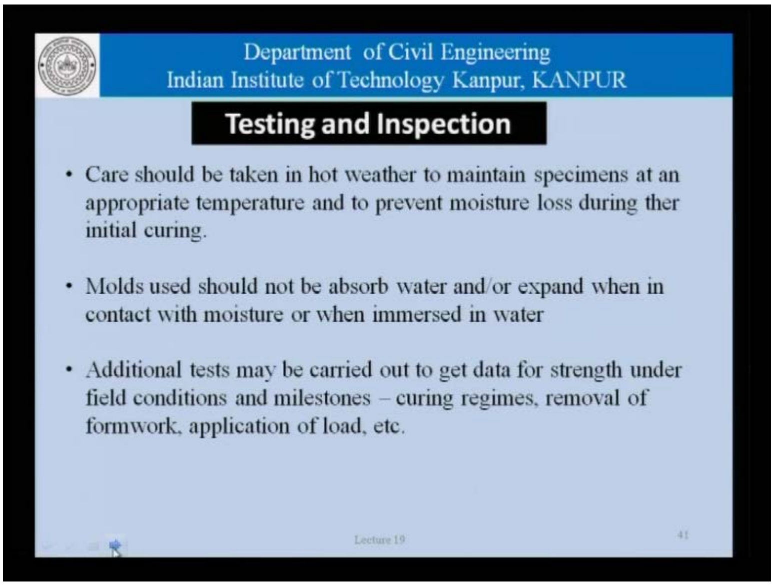

Continuing with our discussion on testing, we need to take care the specimen that are taken are properly stored, at an appropriate temperature, and moisture loss from them is prevented. We should use molds which do not absorb water, and or expand when in contact with moisture or when immersed in water, there are different kinds of molds which are available as far as concrete specimens are concerned.

Additional test may be carried out to get data for strength under field conditions, and milestone such as went to stop a certain curing regime, what should be the time for formwork removal, application of load and so on. Given the fact that we concrete is not being cured under normal conditions, or standard conditions, the data found standard conditions is of limited value and therefore, we may need to carryout additional test, under specific conditions

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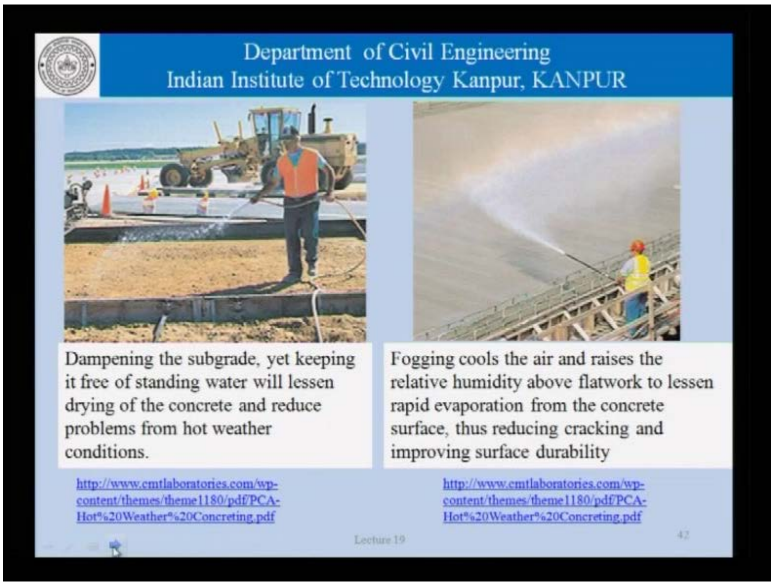

These pictures here show the dampening of sub grade, to cool the surface before the concrete is placed. And fogging of air to raise the develop relative humidity, above the concrete which is been placed as measures for ensuring proper construction, or quality construction in hot weather.

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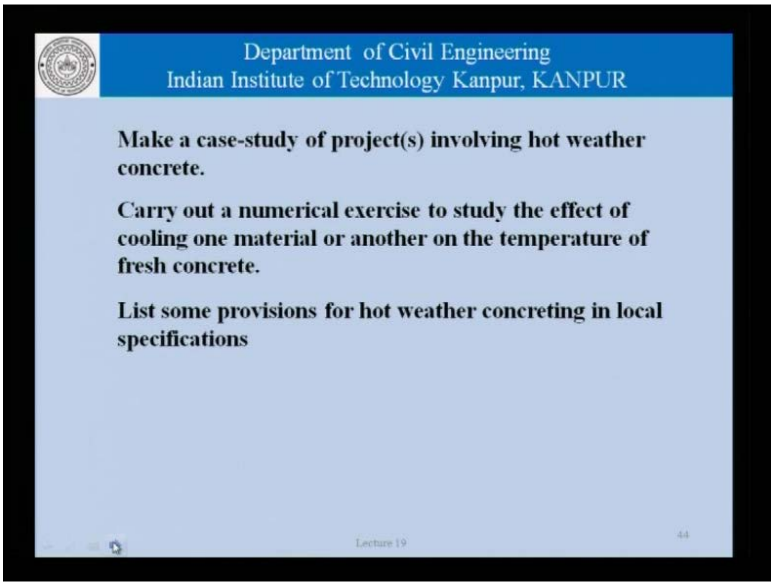

Before we close, a couple of quick questions, try to make a case study of projects involving hot weather concrete, including the conditions of that project, which could be in terms of temperature, the relative humidity, the temperatures in day, the temperatures at night, different seasons and so on. The actual mix of concrete used, the types of methods which were used, for quality control, carry out the numerical exercise to study the effect of cooling, one material or another on the temperature of fresh concrete.

We saw that cement, water or the coarse aggregate needed to be cooled, to different degrees in order to get a certain reduction, in the temperature of fresh concrete. And now that is something which needs to be numerically carried out, and I am leaving out that exercise as a homework, we could also list some provisions for hot weather concrete in local specifications, try to make a list of some of this specifications. This presentation here is largely based on the provisions, and the discussion that is given in American concrete institute, kind of specifications or documents.

There are other documents which address these issues there are text books which deal with it, some of them are given in the references to this module you may like to draw comparative statement. Outline in the different, outlining how different specifications of books define hot weather concreting.

Thank you.