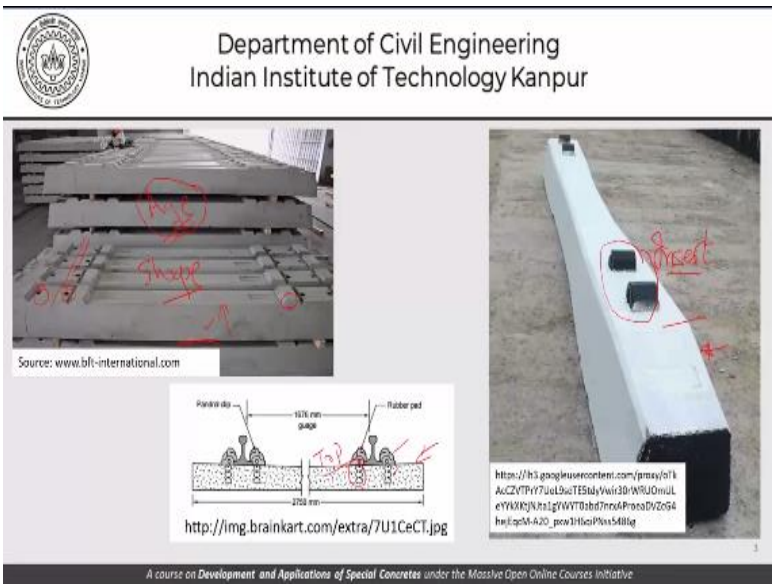
Development and Applications of Special Concretes
Prof. Sudhir Misra
Department of Civil Engineering
Indian Institute of Technology- Kanpur

Lecture - 31
Precast Concrete

Namaskar and welcome back to our series of lectures on Development and Applications of Special Concretes. And today, the focus is precast concrete. There are some special features about this very interesting method, which we will try to talk about today.

(Refer Slide Time: 00:30)



But the treatment of precast concreting today would be largely superficial and I do not think we will become experts. At best we can hope that you will be exposed to or you will try to learn about some features that you have to keep in mind when we are talking about pre-casting as a method of construction. For example, here is a picture of railway sleepers which are stacked in a plant before they are to be transported for placing in a railway track.

What are the kinds of things that you observe from here, which we need to understand? From a purely construction point of view, we are concerned about the shape. So, there is a very interesting shape. The sleepers have a certain requirement. You can see that this place is slightly higher, there are holes here. In fact, this is the

place through which we will run the rail on both sides. And there will be a fixture which we will just see.

Apart from that, what is the kind of material that we use, what is the kind of loads that we consider? The loads that we have to consider are not only the loads which the sleeper is under when it is in service, but also the loads while it is being handled in the plant. So, you can imagine that the sleepers were surely not cast the way it is shown. We will show you some pictures from that position to this position, what were the loads that acted upon during handling.

What was the age of the sleeper at that time, because at the end of it, this is a very important factor, when it comes to considering the strength and development in concrete. So, a concrete, which is mature, which is say 28 days old and so on is fairly strong, depending on what kind of mix proportions you have used, and all that. But at the younger age, say 2 days, 3 days, it is much weaker.

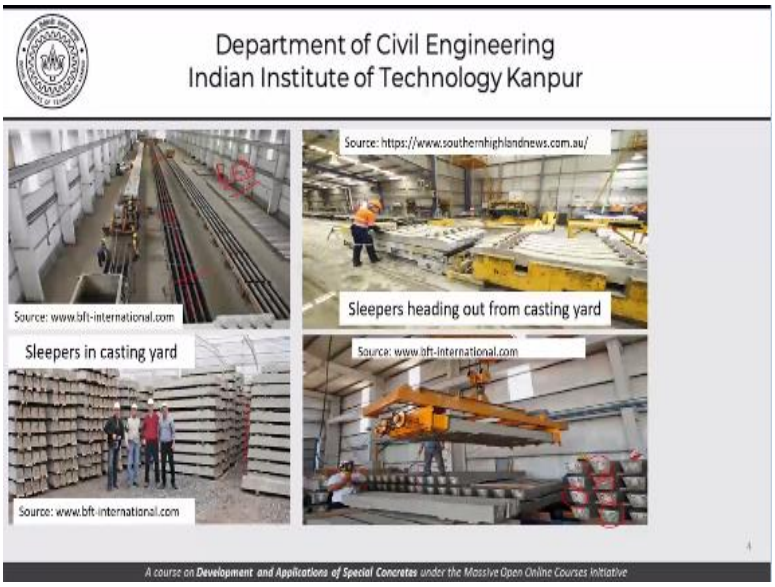
The strength development has not happened and if you subject it to any kind of major loads during handling, there is likely to be breakage. So, these are some of the things that you need obviously to keep at the back of your mind when you make a plan for using the construction process of pre-casting. Here is another picture of a sleeper with a different shape as you can imagine.

I chose this picture because these two inserts can be clearly seen in the picture. Now this is a schematic sketch of the sleeper and you can see that these are inserts. There is a rubber pad somewhere here. So, these are the kinds of inserts. So, this is a schematic sketch of a picture.

Let us not bother about the dimensions because these dimensions and drawings depend on what kind of sleeper we are talking about, what kind of railway we are dealing with and so on. But the principle as we can see from all these pictures is that these are inserts which have to be preplaced at the time of construction or at the time of fabricating the sleeper. What I want you to think about is the direction of casting as far as the sleeper is concerned.

Is this sleeper cast the way it is shown here? That is, is this the top surface or it is the bottom when we started to cast? For example, were these sleepers cast in this orientation with this being the top or this surface here was at the top? Think about it and possibly you will get the answer very quickly. The same question is important even as far as this sleeper is concerned.

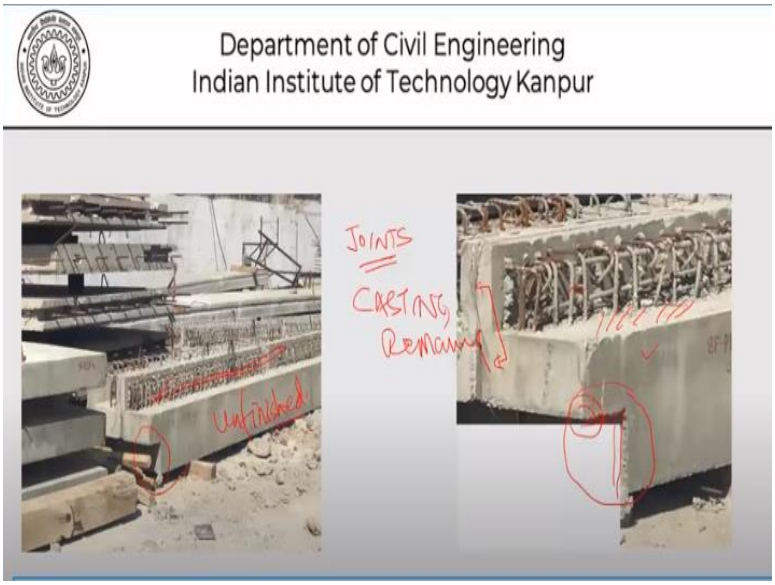
(Refer Slide Time: 04:08)



Moving forward, this is a sleeper plant, different sketches or different kind of photographs. And you can see that this is the sleeper bed. And we can see pre-stressing strands will be placed through these beds. These are long beds. And it is not one sleeper, there are several sleepers and the pre tensioning is carried out with the long strand and then the concrete is cast.

And the individual sleeper is created by cutting up this long member that we have created. Here are some pictures of the handling of the sleepers as they are being moved around. This is the sleepers heading out from the casting yard. These are being lifted and placed in position and you can see special marks on the surface. Now I am leaving it to you to think about what these special marks could be all about. And here are sleepers which are stacked in the yard.

(Refer Slide Time: 05:01)



Moving to a very different kind of precast product, this is something like an unfinished product. So, this is not a product which is going to be used as it is, but part of the structural member has been cast in the casting yard. And part of this reinforcement which has been shown here is left and will be cast in situ. I would like to draw your attention especially to this portion here.

That is, this is where we have to focus on or this is a place which needs to attract our attention from a construction point of view that what is the importance of this detail? This is possibly a beam which is going to be placed using this kind of a shape and this will be placed on a haunch or something like that. We have to be very careful that these edges are properly designed as far as the design stage is concerned.

And then there is a clear SOP on what is going to be done as far as this surface is concerned or these bars are concerned, whether they will be cleaned, not cleaned, left as it is. How much of concrete can be allowed to be remaining on these bars before fresh concrete is cast against the surface. So, these are some of the things which are very important to bear in mind, when we are talking of precast construction.

In precast construction, one of the most important and critical things is joints. Now, joints are true, even if the members are thoroughly finished. But here, it is not only the joints, but the casting of the remaining part of the concrete that we are talking about. So, this also has to be very clearly laid out and understood; the kind of concrete

to be used, its compatibility, how much time is allowed to elapse between the casting of this concrete and the fresh concrete that is going to be cast against it.

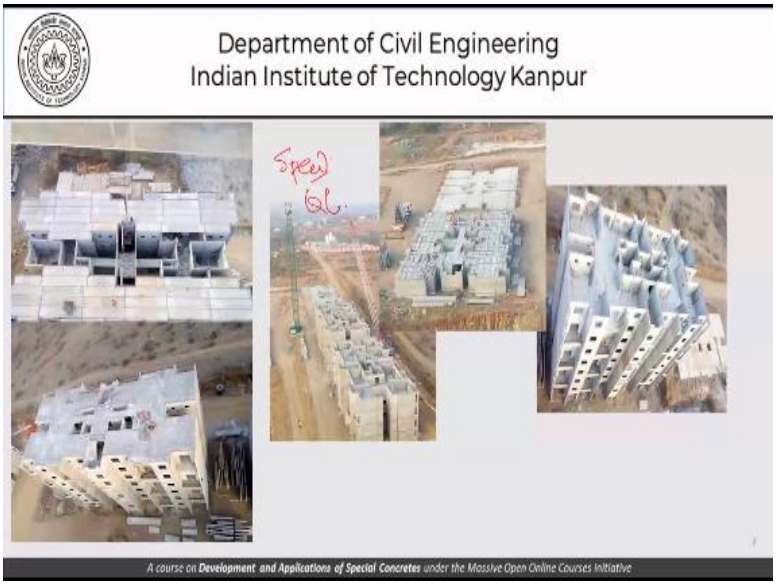
Because those are things which are important to determine the member behavior as such. Then here is another picture of some different kinds of precast products.

(Refer Slide Time: 07:01)

Here we have hollow slabs. And we can see that one of the considerations that will be involved, as far as our ability to use these members at site is concerned is our ability to transport them properly. Now as far as transportation is concerned, it is the weight and so on and so forth. But the length of these members. Suppose we need a lot of length here, there is a limit to what we can transport, there is a limit to the kind of width.

There is also the limit on the numbers that can be transported. In fact, one of the criteria which possibly would govern our width here would be how we will transport it to the site of placement. So, the transportation of precast members is also one of the things that has to be considered at the time of planning. Why do we do a lot of pre-casting? Because it adds speed.

(Refer Slide Time: 08:01)



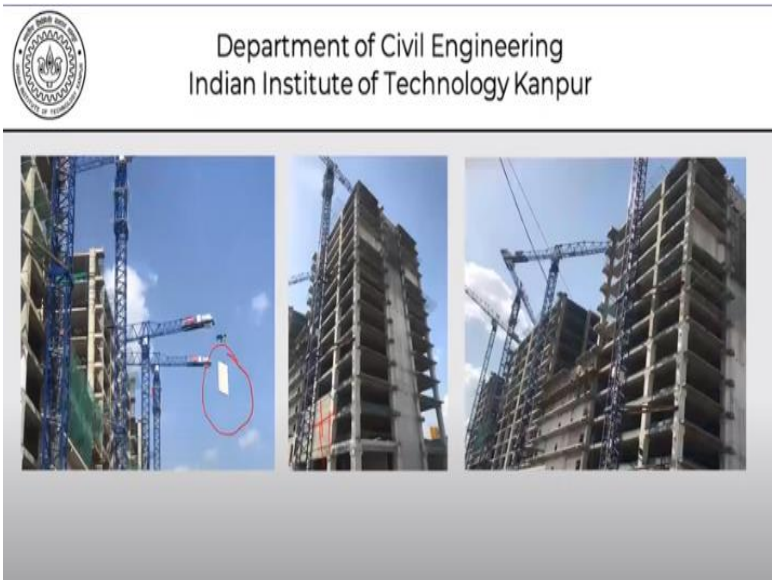
It not only adds the speed to the construction, but also it helps us in quality control. Because these members once they are created in a factory environment, it is easier to control the quality in the factory environment than at site. The at site, if we have less construction being carried out, there is less pollution, less need to store material there. So, we can possibly do precast construction in a smaller site, where there is no space to store and stack the construction material.

We reduce the kind of noise that goes on or the disturbance that goes on in the neighborhood on account of the arrival of ready-mix concrete trucks, placing the concrete the kind of people working with concrete construction, and so on. So, there is definite element as far as speed and quality control and environmental concerns, space concerns, which push us towards precast concrete constructions in buildings in so many other components.

(Refer Slide Time: 09:07)

Here is another picture of building constructed, a high-rise building being constructed using precast elements. The same thing here.

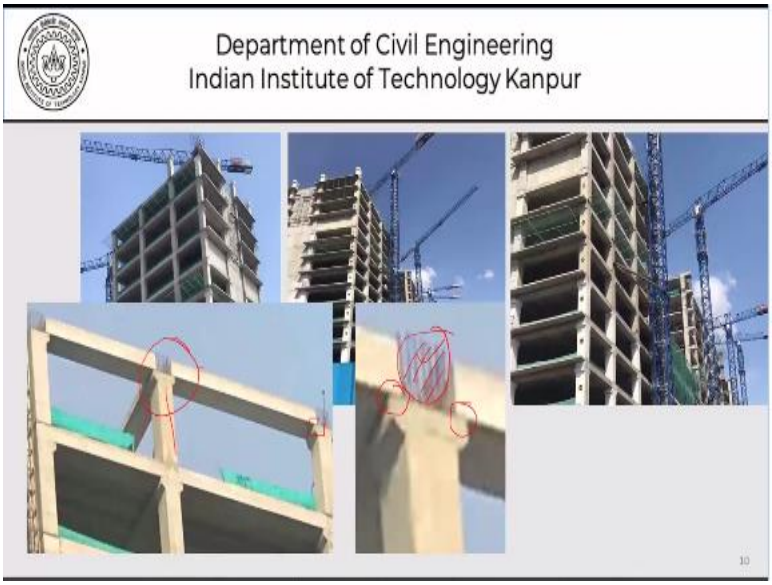
(Refer Slide Time: 09:17)



And you can see from this picture that basically precast construction involves a lot of equipment, especially cranes used to lift and place in position different elements; whether it is beams, columns, walls, parts of walls, and so on and so forth. Now these elements obviously have a lot of jointing issues. So here we do not have too much of construction to be done at site as we can see from here.

But there will be a lot of joints between panels. So, these joints have also to be appropriately accounted for when we are trying to plan our construction sequence.

(Refer Slide Time: 09:59)



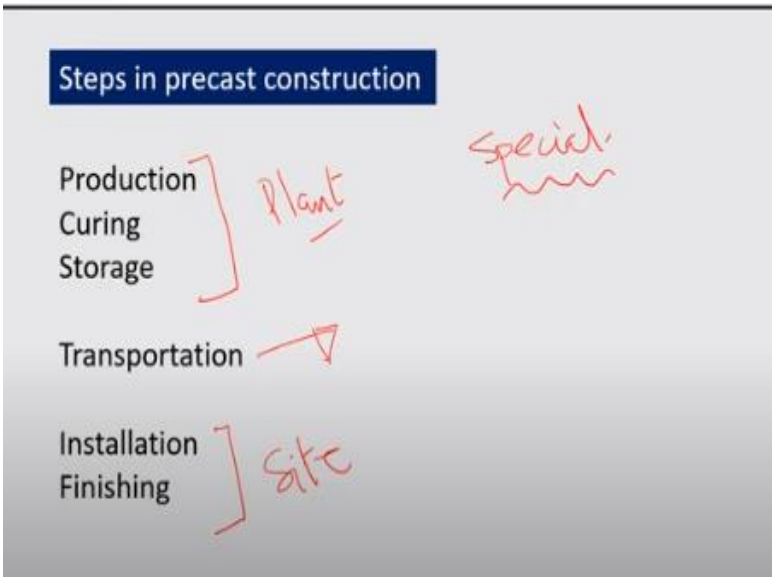
Now these pictures also are more or less similar to the ones that we saw last time where we are seeing a building been assembled, so to speak at site using precast elements. And this is the kind of a joint that we have here. So, you can see that there are beams. You can see that there are columns and there are beams. Now this point here, the beam column joint if you want to call it, this has been left for casting at site.

So, we have this part of the column here, this part of the beam here this part of the beam here, and this beam going out from here. This has been considered as part of the design and there is a jointing part here. Also please note, the kind of margins or the kind of dimensions which are involved, the accuracy which is involved in constructing these elements.

So, we have to be very careful when we are trying to cast these elements and place these elements, especially during the time that they have not been finally firmed up, the kind of construction which is involved here has not happened. These members are still reasonably vulnerable for displacements. And that sometimes becomes the cause for accidents when these precast members are placed in position but not securely fastened.

So there have to be arrangements made for temporary fastening of these members while the permanent solution or the permanent steps to be taken as part of the overall construction are done later on.

(Refer Slide Time: 11:38)

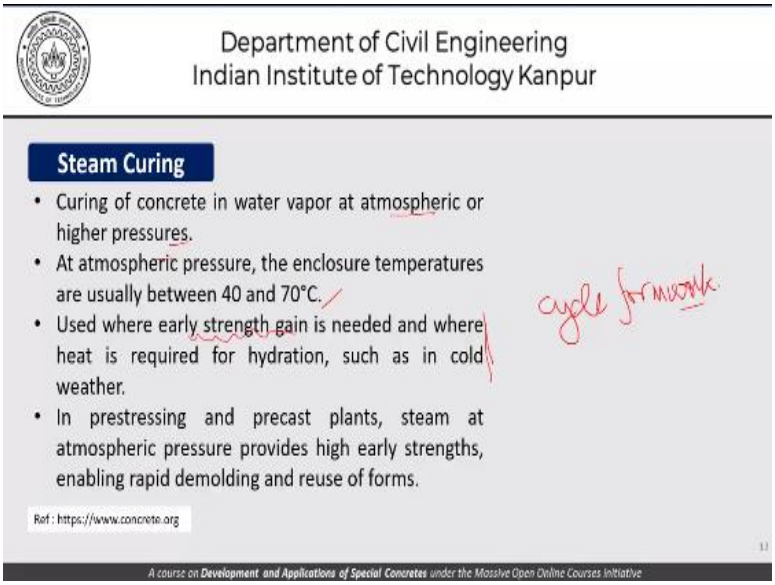


In summary, if we want to consider the steps in precast construction, obviously, there are production, curing, storage, installation and finishing. You would imagine that I have separated these two because this stage happens in the plant. We produce these members in the plant, cure them, store them and the installation and finishing this happens at site. In between these there is the stage of transportation.

So, we have to consider this entire cycle, when we are talking in terms of precast concrete construction and that is what makes it special, because this is not something which we bargain for when we try to think of normal concrete construction. In normal concrete construction, the members are not transported, it is the concrete itself which is transported. So here when the members are being produced, the handling of concrete is slightly different than handling of concrete in normal construction.

No discussion of precast concrete and precast concreting methods can be complete unless we would spend some time on steam curing.

(Refer Slide Time: 12:50)



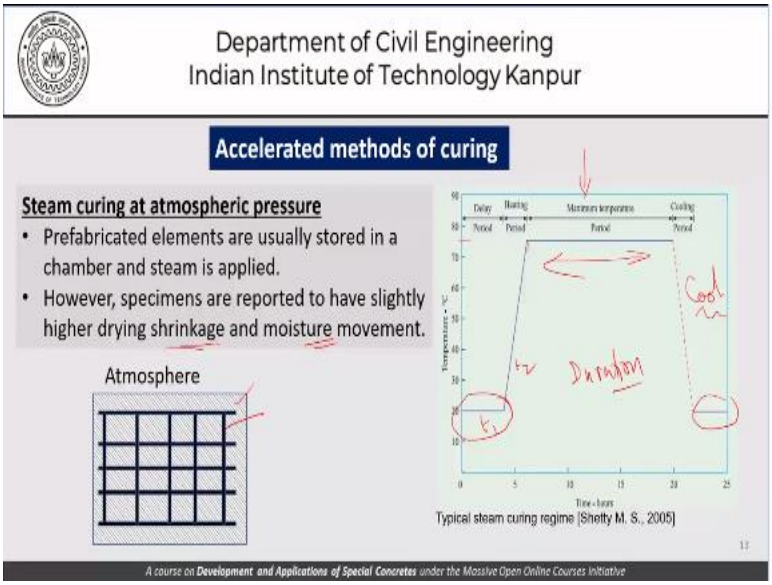
Now you would recall that we have done a little bit of discussion on steam curing in our earlier modules when we are talking about the curing methods, but to revise that and also draw some attention to the specific things that are important when it comes to precast concreting, steam curing is the process of curing of concrete in water vapor at atmospheric or higher pressures.

We can do steam curing at atmospheric pressures or at higher pressures. At atmospheric pressure, the enclosure temperatures usually range between 40 and 70 degrees centigrade. This method is used where early gain of strength is needed, where heat is required for hydration such as in cold weather. As far as precast constructions are concerned, we are often interested in early strength gain, because we want to cycle the form work.

We want to release the form work as quickly as possible so that the production can move on with the smaller number of formworks and for a smaller area. So, if you are not able to remove the formwork from a member then it has implications in terms of the production capacity of the plant and therefore, early strength gain is one of the key parameters as far as precast concrete construction is concerned.

In pre-stressing and precast concrete plants steam at atmospheric temperature provides high early strengths enabling rapid demolding and reuse of forms as we have just discussed.

(Refer Slide Time: 14:23)

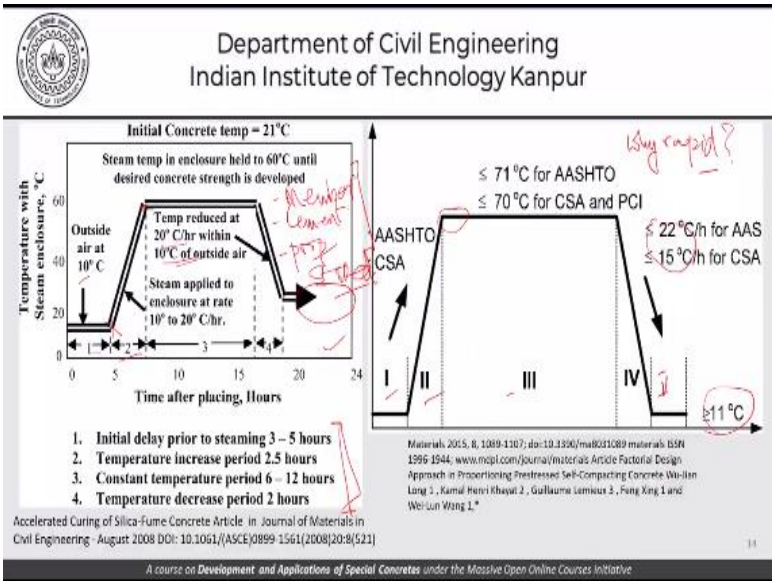


Accelerated curing methods. This is a slide which we have seen from the previous discussion, in the previous module. This shows you a typical steam curing cycle. This is the kind of temperatures to begin with in terms of hours. Then we gradually raise the temperature to this level which would be about 75, 77 degrees centigrade, keep it for that range here and then cool the concrete, not rapidly but gradually and then maintain it at this temperature.

So, we have to have specific durations which define what kind of a curing cycle will be involved in terms of the length of this t_1, t_2, t_3, t_4 and t_5 and also the temperatures at which we will move. So, the prefabricated elements are usually stored in a chamber and steam is applied. The specimens are reported to have slightly higher drying shrinkage and moisture movement when it comes to using precast concrete with steam curing.

So, this picture here is of course a diagrammatic or a schematic sketch of the RC members that are being stored and subjected to steam curing.

(Refer Slide Time: 15:36)



This picture here is another of those specific details coming out of an article, 2008 where we say that okay, outside temperature at 10 degrees centigrade for one hour, and then for two hours, it takes for the temperatures to be built up from this level to say about 60 degrees. The temperature is reduced at the rate of about 20 degrees per hour to within 10 degrees of outside temperature and then the concrete is simply stored.

It is not the concrete which is really stored, but the member which is finally taken to the storage yard. So, there is an initial delay prior to steaming. There is a temperature increase period, there is a constant temperature period and a temperature decrease period. So, this is what defines the steam curing cycle. And this cycle needs to be developed for each member depending on obviously the kind of cement that you are using.

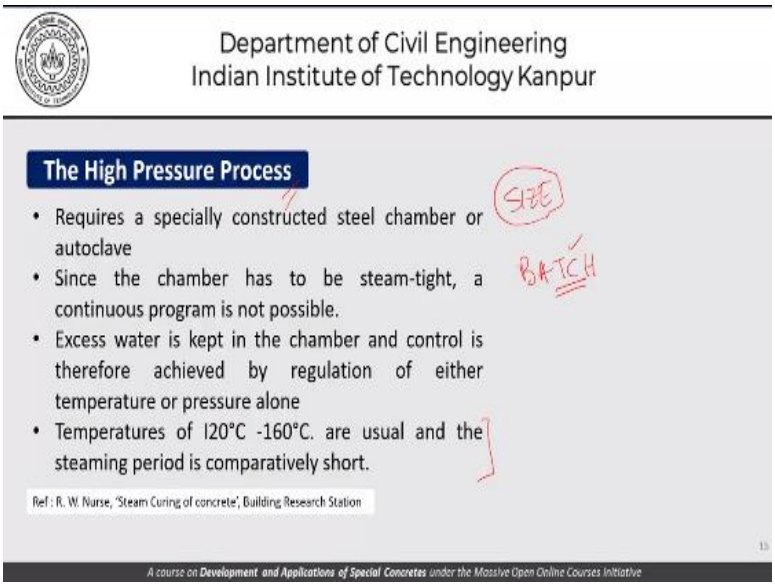
It will also depend on the proportions of concrete, the kind of strength that you are talking about, and obviously the kind of member that you are dealing with. So, it is very difficult for any code or any document to give you a specific guideline on how the cycle can be designed, can probably be laid out, but the actual numbers have to be worked out by engineers using the specific information and the requirements that we have.

This picture again is another example of a similar steam cycle with zones 1, 2, 3, 4 and 5, which is 5 here. Now these 5 zones representing something similar to this as

prescribed by different codes; AASHTO, the CSA and the PSI and so on is specifying the maximum temperature at which the concrete is to be cured or the concrete members are to be cured.

And the maximum rates of cooling that can be accepted or that is acceptable when it comes to cooling the members. I am leaving it to you to think about why we cannot have a very rapid rate of cooling. Why we do not have a rapid rate of cooling is something which I am not answering for you today. I will leave it to you to think and come up with an answer for yourself. And the storage temperature is more than 11 degrees centigrade, which is perfectly fine as far as we are concerned.

(Refer Slide Time: 18:00)



Let us spend a minute on the high-pressure process for steam curing in the precast concretes. This process requires a specially constructed steel chamber or an autoclave because we are going to elevate the pressures. So, we needed steel chamber and an autoclave. Since the chamber has to be steam-tight, a continuous program is not possible. That is, we cannot have concrete members being placed all the time.

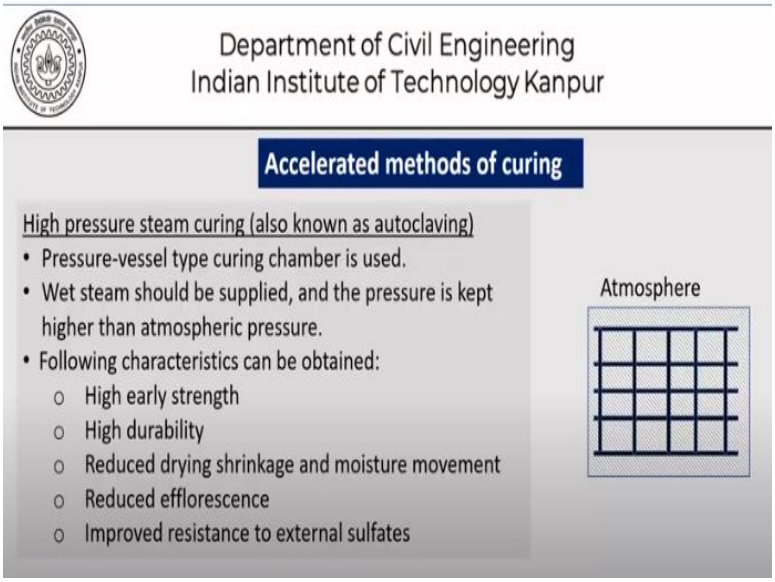
So, it is very close to a batch process. So, we have the steam chamber, we fill it up with a certain number of members that it can accommodate, close it, steam cure those members, open the chamber, remove them and then use the chamber once again. So that is close to a batch process and has its own limitations as far as productivity is concerned.

Excess water is kept in the chamber and control is therefore achieved by regulation of either the temperature or pressure alone. The temperatures of 120 to 160 degrees centigrade are usual in the steaming period is relatively short. The temperatures are much higher than the other process that is the low-pressure process and could be about 120 to 160 degrees.

Recall the kind of temperatures that we saw in the steam curing cycles, they were about 60 to 70 degree, 75 degrees. Here we are talking of 120 to 160 degrees, but the steaming period is comparatively short. So, one has to make a decision as to what kind of temperatures and what kind of time we are going to use when it comes to steam curing of members.

Of course, another thing that has to be kept in mind as far as the high-pressure process is concerned is the size of the members and the size of the chamber involved. So, if the members are very large, then the chamber also has to be equally large and that sometimes governs the choice of whether we can go for high pressure process or not.

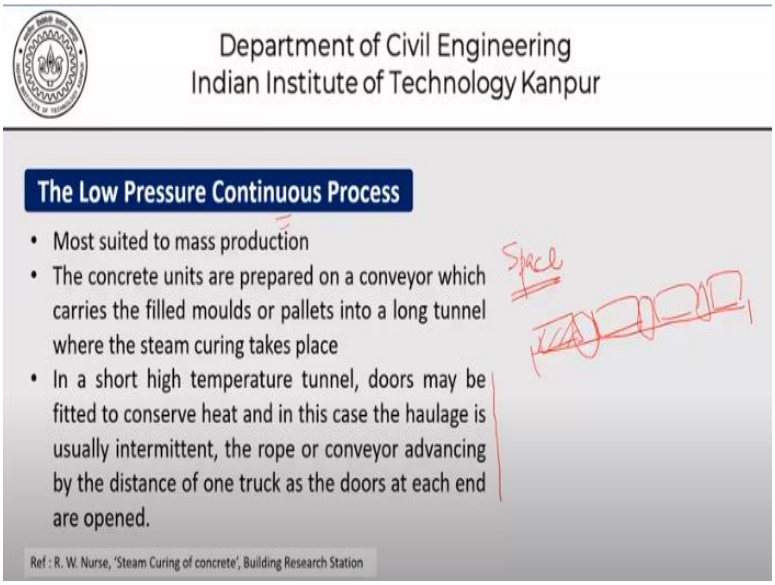
(Refer Slide Time: 20:00)



This slide, we have already seen in our previous discussion, when we talked of high-pressure steam curing known as autoclaving. That is what we just described. The pressure vessel type curing chamber is used. Wet steam should be supplied and the pressure kept higher than atmospheric.

And we can obtain the kind of characteristics which are mentioned here, high early strength, high durability, reduced shrinkage and moisture movement, reduced fluorescence and improved resistance to external sulfates. This slide, we have taken from the previous discussion that we had, in possibly module three.

(Refer Slide Time: 20:38)



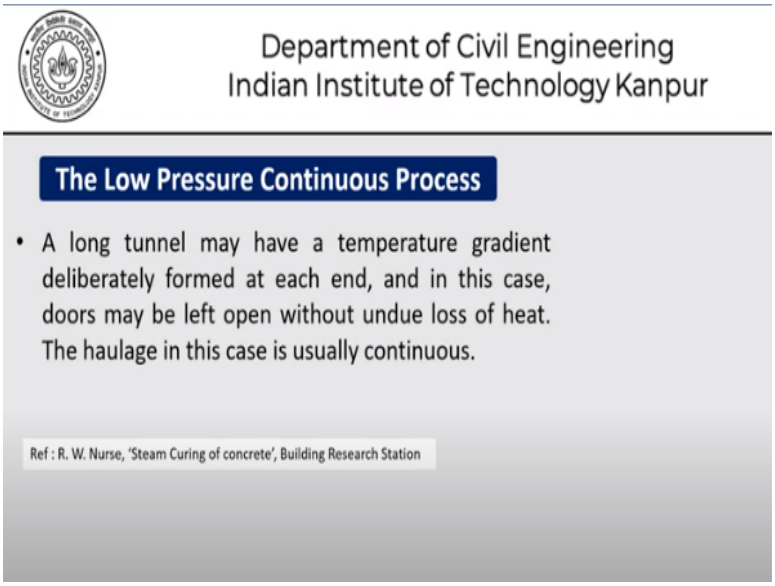
And now coming to the low-pressure continuous process. The continuous because it is not a batch process, like we talked in the case of an autoclave. It is most suited for mass production. And the concrete units are prepared on a conveyor, which carries the filled molds or pallets into a long tunnel, where the steam curing takes place. And in a short, high temperature tunnel, doors may be fitted to conserve heat.

And in this case, the haulage is usually intermittent. The rope or conveyor advancing by the distance of one truck as the doors at each end are opened. So, these are some of the logistic issues. These are operational things which we have to keep in mind when we are talking in terms of the space requirement or the space planning in a precast factory.

That what is the kind of length that we will require, what is the kind of area that will be required to accommodate a certain number of stacks. So, if this is our member size, we have to have some operating space in between. Recall the picture that we saw for the sleepers and then we decide that okay, this is the kind of space that we will need as far as storage of these facilities is concerned during steam curing.

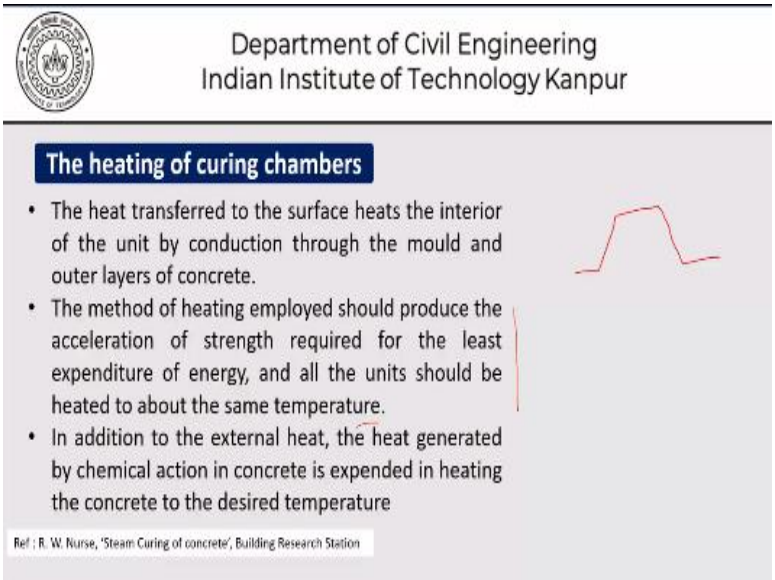
Of course, once they are steam cured, then there is another cycle or another step where this steam cured members are taken off for storage before, they are being transported to the site or being cured in another regime, maybe water, maybe air before they are actually transported for placement. A long tunnel may have a temperature gradient deliberately formed at each end.

(Refer Slide Time: 22:19)



And in this case, the doors may be left open without undue loss of heat. And the haulage in this case is also continuous. The haulage in this case is usually continuous.

(Refer Slide Time: 22:36)



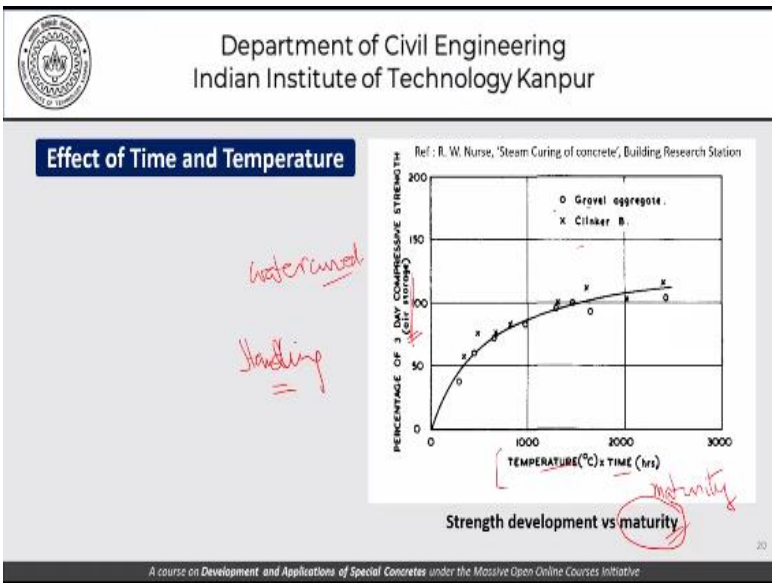
Now as far as the heating of the curing chambers is concerned the heat transferred to the surface heats the interior of the unit by conduction through the mold and the outer layers of concrete. The method of heating employed should produce the acceleration

of strength required for the least expenditure of energy and all the units should be heated to about the same temperature.

So, these are quality related issues that all the units should be heated to the same temperature. That means we should have in our steam chambers or the tunnels or whatever we call them a proper control of the temperature reached. So, the cycle that we talked about, that should be appropriately maintained and monitored and the records kept appropriately that for each cycle, what was the kind of heating rates or cooling rates.

Or the durations, the temperatures at which the members were cured, so that there is minimum variation of quality of members produced in one batch to another batch and so on. In addition to external heat, the heat generated by the chemical reaction in concrete is expended in heating the concrete to the desired temperature.

(Refer Slide Time: 23:47)



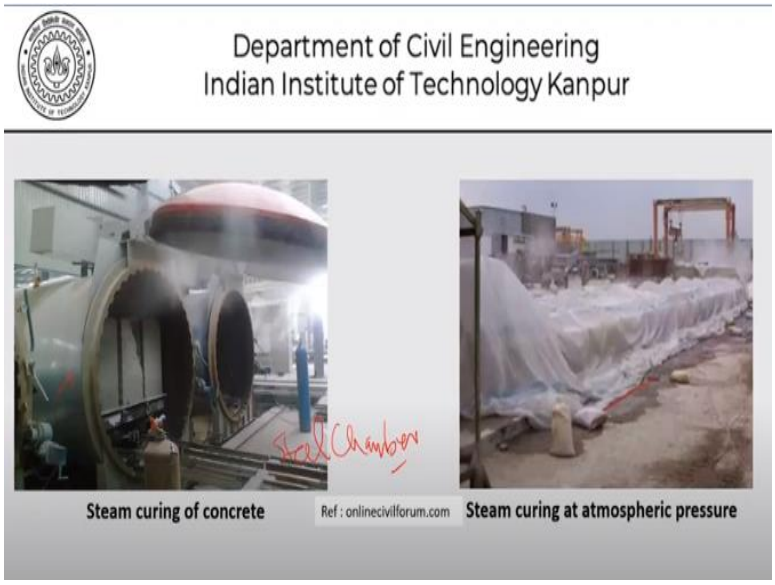
This picture has been included only to draw your attention to the temperature time combination, which we have already known is maturity and how this maturity can be used to assess or compare the strength at different temperatures and times. If you see this graph, you will notice that we are comparing it with respect to the percentage of 3-way compressive strength in air storage.

So, if this was not air storage, if it was water cured, and then we are trying to compare our results, the results could be slightly different. The bottom line being that in these

kinds of discussions, it is very important to properly understand the concept of maturity and make sure that we have the right kind of estimates being made as far as the concrete strength is concerned.

Because that will essentially determine our handling protocol that okay what is the kind of strength that we expect in the member at a particular date or in a particular time so that we can subject it to certain kinds of handling.

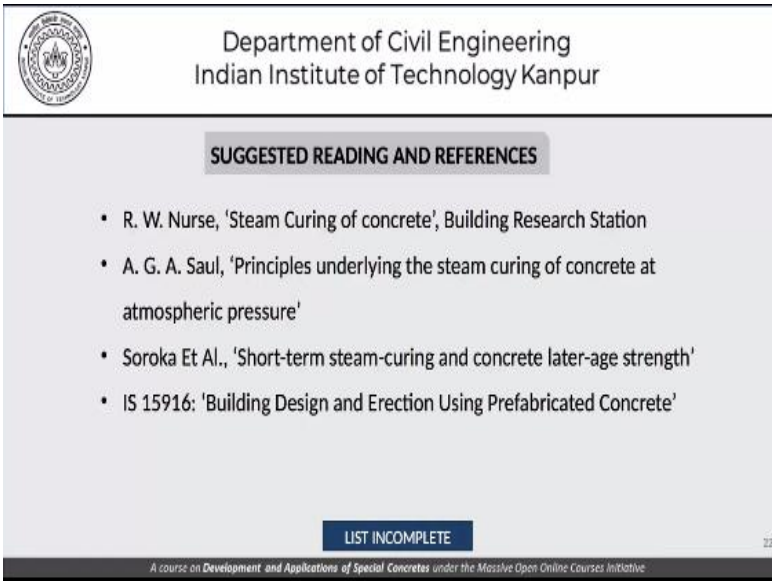
(Refer Slide Time: 24:58)



This is a pictorial representation of the steam curing of concrete in steel chambers as we call them, or autoclaves. So, you can see that this is concrete members. We are placing them inside. We seal this steel chamber and cure them under high pressure at high temperature. Whereas, this is a steam curing in the atmospheric pressure.

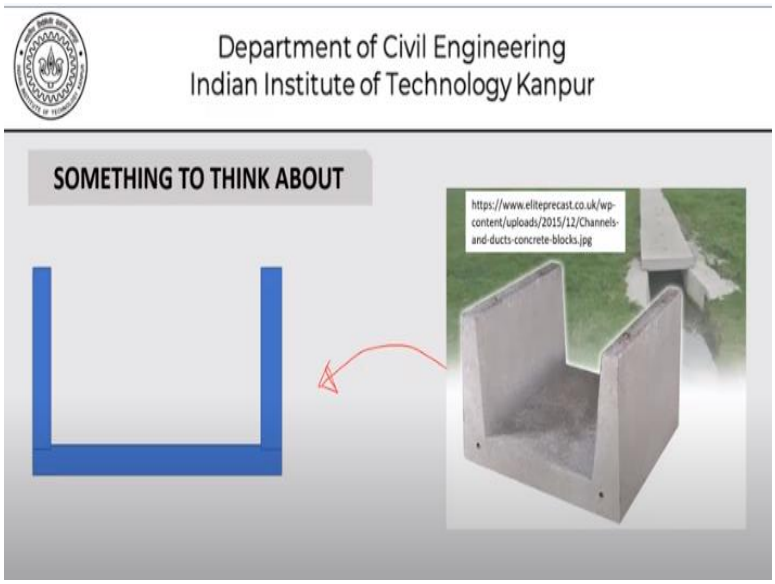
So here we have stacks or lengths of members being stored, appropriately covered so that the steam loss is minimized. And then the concrete members are moved on for further curing or storage as the protocol may decide. So, with this we come to an end of our bird's eye view of pre-casting and the kind of considerations which are involved.

(Refer Slide Time: 25:48)



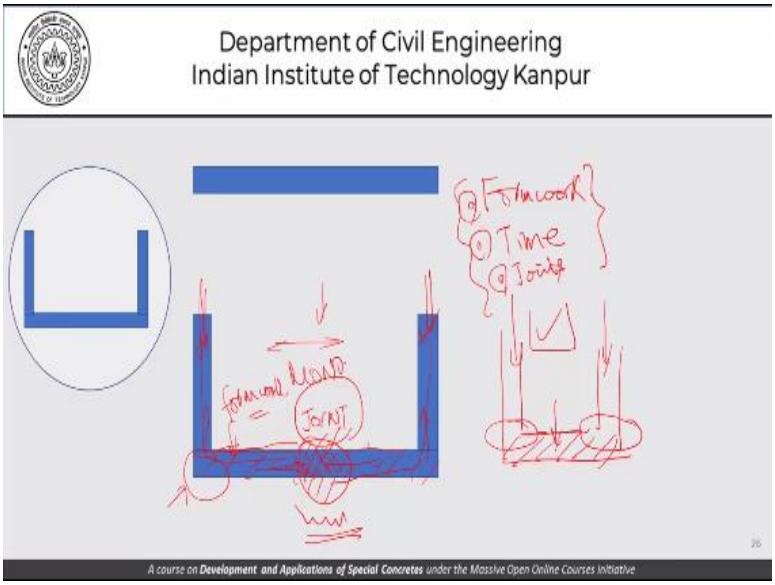
And here we have some simple references, which you would probably look up to enhance your knowledge and try to understand this process better.

(Refer Slide Time: 25:57)



Before we close our discussion, let me try to give you an assignment to think about. Let us take a look at this very simple looking U-shaped channel which has to be precast. I am not giving you the dimensions, but we will try to discuss how the process is to be planned. So, if I convert this into a simple U-shaped structure, what are the steps that will be involved in constructing this in a precast factory?

(Refer Slide Time: 26:30)



If you want to construct this for example, one way is to do the slab part first, and then cast the walls. So basically, the kind of considerations that I want you to think about is formwork. What kind of formwork will need to be used in creating this shape, which is the final product. In this case, we do not need formwork at the top, we can just simply cast the concrete.

And after it has been cast, then we place the formwork here and here and cast these walls possibly together. So, we place the formwork and we cast the concrete in a normal manner. This place will have a joint. So, there will be a cold joint involved as far as this construction is concerned. So, two considerations we have identified. One is formwork, the other is cold joint.

So apart from the formwork and the joints, there is this issue of timing, that how much time will be involved in creating this shape. So, in this case, if we allow the slab to be cast, then wait for some time to fix the formwork and do the concreting for the walls, surely, they will become a cold joint. And this process is not very conducive or does not give us too much of advantage as far as pre-casting is concerned.

Somebody says that we want to use self-compacting concrete to make a shape like this. So, in that case, we do not need to go through the slab and then the wall kind of a discussion. We can try to introduce the concrete from the top here and have the concrete flow through the vertical part and the horizontal part and meet somewhere here except for the fact that we have to make sure that this does not become a joint.

This does not have any problems as far as the jointing is concerned. It should be a monolithic construction. That is this concrete and this concrete should properly engage with each other in this portion. Apart from that, we also need to ensure that we have formwork on the top. Because after this concrete has been placed, this part has been filled up, we will expect the concrete to rise as far as these walls is concerned.

So, this will happen only when we have the top surface here having the formwork. So, this is the other consideration that while we are trying to introduce the concrete from the top, we have this issue that the concrete has to flow through a long distance through this bend here and we need a formwork on the top.

If we want to avoid this and that will happen depending on what is the kind of actual width involved, what is the kind of distance that the concrete is expected to flow and so on. We can have a situation that instead of having the concrete being fed only from the walls here, we can have the concrete being fed from a center.

We need to do the concrete thing from the center here, fill this up properly and then try to introduce concrete from the top of the wall. In this case also we will need to have formwork on the top if we want to avoid a cold joint here. If we do not cast the entire U as a single unit, it does not give us the advantage of pre-casting.

So basically, the decision making as far as the construction sequence is concerned has to be taken in view of the formwork, in view of the time that is involved, and also the joints that are involved in the construction process. So, this is very important when we are trying to plan construction activities. It is very easy to say that we will precast this U-shaped channel, but we need to draw up this procedure, depending on the kind of geometry that we are dealing with.

I am leaving it to you to think about how we go about casting an I girder considering these things that we have. And what are the places that are vulnerable from the point of view of quality control. For example, in this case, we saw that this portion here is surely vulnerable from the point of view of quality control, because we do not expect or it is likely that the concrete does not mix here properly.

And we have some kind of issues relating to the jointing of the concrete coming from the two ends. So, with this, we come to an end of our discussion on the pre-casting of concrete. And I look forward to seeing you in the next class, which will be the final class as far as this module is concerned. Thank you once again.