So, do not go for water retention methods of curing. So, that will not be much effective for this high strength concrete mixes.

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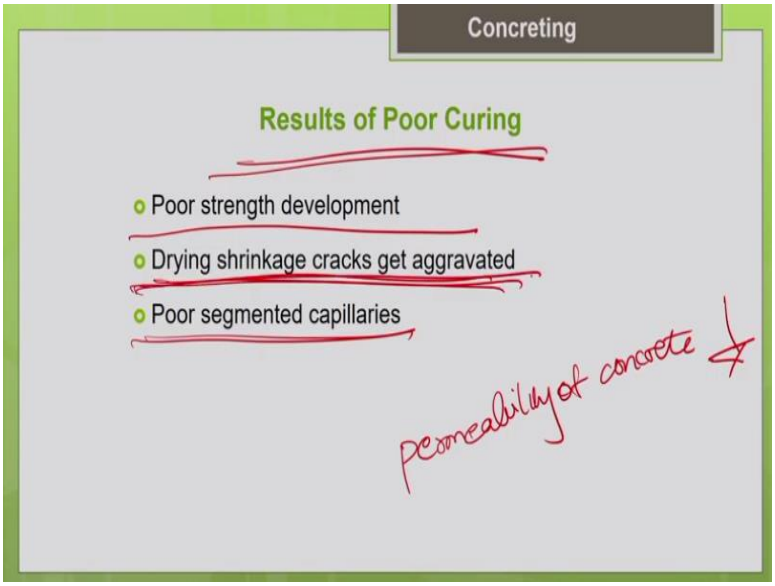

So, basically, if you do not do proper curing for the concrete actually the curing is the cheapest way to improve the quality of the concrete. So, like you can improve the microstructure. You can improve the strength and durability by facilitating the continued hydration of the cement. It is a cheapest method to improve the concrete property. But it is always overlooked at the project site.

So, many of the structure failures happens because of improper curing only. So, if you do not do proper curing obviously, since the hydration process is not completed, you will not get the desired strength. It results in poor strength development. And another important thing is shrinkage cracks may occur, if the rate of evaporation of the water from the concrete is very high. So, you know that the concrete is weak in tension.

So, this will result in the shrinkage cracks in the it results in buildup of tensile stresses in the concrete due to the drying which results in shrinkage crack development. So, to avoid the shrinkage cracks also, we have to start the curing as early as possible. And poor segmented capillaries, basically, when you do curing, what is happening? As it facilitates the hydration process, all your pores are getting filled with the hydration products.

So, the capillary pores are filled with the hydration products. As it fills the pores, the pores are getting segmented. As the pores are getting segmented, the permeability is getting reduced. The permeability of concrete is getting reduced. The concrete becomes more impermeable because the pores are getting filled with the hydration products and it results in segmentation of the pores. But if you do not do proper hydration, so, what happens?

Your capillary pores most of the pores are not filled with the hydration products. So, it results in poor segmented capillaries which increases even the permeability of your concrete and which affects the durability of the concrete in turn. So, your results of poor curing are your poor strength, poor durability and even the dimensional stability of the concrete is affected. It results in the shrinkage cracks also.

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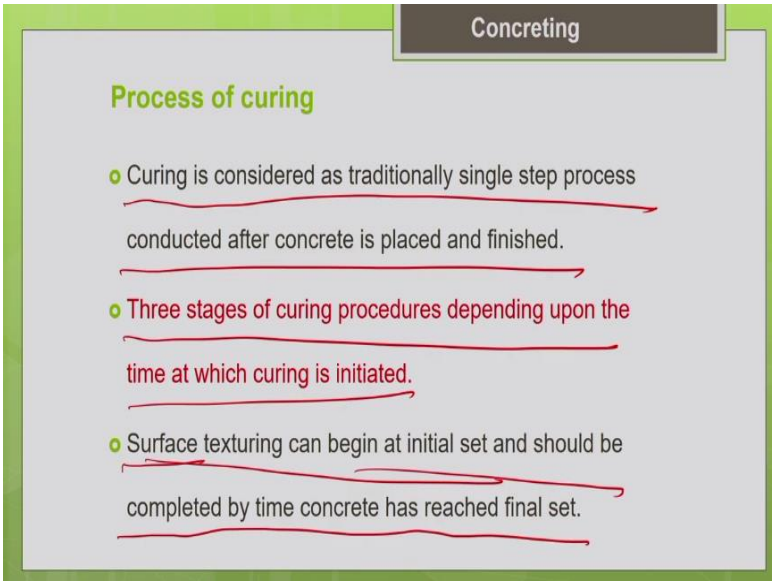

So, basically the process of curing earlier it was considered as traditionally as a single step only. So, very commonly we do this curing operation after the finishing of the concrete. So, mostly after the concrete attains its final set, we start applying water to the concrete for the curing purpose. This is a traditional method. But nowadays, we do the curing also in stages. So, I will tell you why we do it in stages later.

So, basically earlier curing was done in only one step, mostly after the finishing of the concrete curing is done. But now, we do the curing in stages. Curing is considered as traditionally as a single step process conducted after the concrete is placed and finished. But nowadays we do in stages, as I told you. There are 3 stages of curing depending upon the time at which the curing is initiated.

So, as we discussed earlier for finishing, finishing we do between the initial setting and the final setting. Surface texturing or finishing can begin at the initial set and should be completed by the time the concrete has reached the final set. Now, we will see what time we should start the curing?

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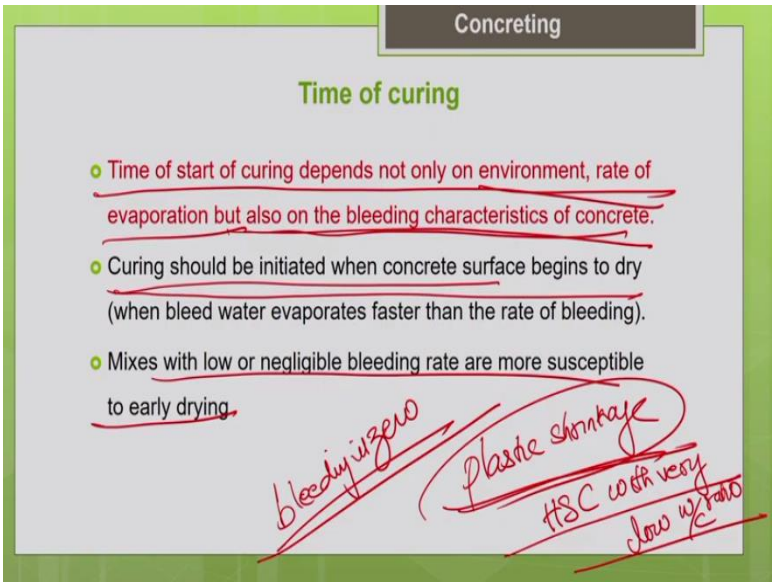

So, generally we cannot generalize when the curing has to be started for a concrete. What should be the right time of curing? Because, it varies from concrete to concrete, it varies from environment to environment, where the concrete is being done. So, basically in aggressive environment conditions where the rate of evaporation is very high due to high wind velocity or due to high temperature, there we have to start the curing as early as possible.

And on a similar note, if your concrete it also depends upon the concrete composition, if your concrete is having I mean it is designed with a very low water to cement ratio, say for example, high strength concrete mixes with very low water to cement ratio, so, where you have used even silica fume, so, the mix is very cohesive there will not be any bleeding at all. So, the bleeding is negligible or almost zero bleeding.

In that case, you have to start the curing as early as possible otherwise, what happens is your drying will result in shrinkage cracks. They call it as plastic shrinkage cracks plastic shrinkage, the shrinkage which occurs in the fresh state of the concrete. So, particularly it happens for the high strength concrete mixes with very low water to cement ratio. So, there will not be bleeding at all, bleeding is zero or negligible bleeding.

In some form bleeding also helps the concrete to certain extent. When there is bleeding on the top surface of the concrete, you can see that it will try to reduce your shrinkage and shrinkage cracks. So, to certain extent I can say. But in high strength concrete mixes since there is no bleeding at all, so, there are more chances that the cracks can occur in the plastic state of the concrete and those cracks are called as plastic shrinkage cracks.

So, that is where we have to start the curing as early as possible. And, when to start the curing? It depends upon the actual composition of the concrete and also it depends upon the environment where the concreting is going to be done. So, time of start of curing depends not only on the environment. So, it depends upon the rate of evaporation, but also on the bleeding characteristics of the concrete.

So, for aggressive environment where the ambient conditions are very severe, high temperature, high wind velocity where the rate of evaporation is very high start the curing as early as possible. And also on the bleeding characteristics of the concrete that depends upon the mix composition. Curing should be initiated when the concrete surface begins to dry. So, when the rate of evaporation is faster than the rate of bleeding, obviously, it indicates that the curing should be initiated.

Then mixes with low or negligible bleeding rate are more susceptible to early drying. That is what I told you. So, if your mix composition is such that it has very low water to cement ratio in those mixes bleeding will be negligible. Very cohesive mixes with low water to cement ratio, you can see that bleeding will be negligible. So, the concrete will dry faster. So, that is why to protect those mixes you have to start the curing as early as possible.

We cannot wait till finishing. So, you need to start your curing even before finishing of the concrete for such mixes. Obviously, before finishing of the concrete, I cannot apply water as my curing method. I cannot supply water for curing because supplying of water as curing that itself will damage your concrete. So, before the concrete attains its final set if you try to supply water to concrete for curing that will damage your concrete. That is why we need some other form of curing. That is called as initial curing.

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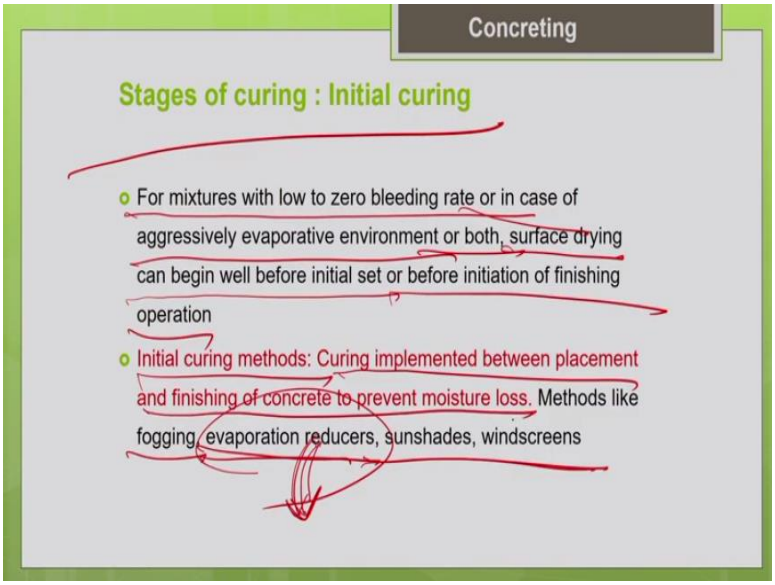

So, here what we do is we just do some fogging or we just cover the concrete with a sunshade or windscreen so that you can control the rate of evaporation. We cannot apply water. That is final curing. So, in initial curing, what you do is just to prevent the rate of drying to prevent the loss of water due to evaporation, so, what you do is even before finishing this can be done.

Before finishing of concrete, curing can be done. So, what you do is you can do some amount of fogging. Commonly what they do is they put some sunshades or windscreen, so, to prevent the loss of water due to evaporation. If that is not possible they can go for fogging also. Or, in some cases, they even use evaporation reducers. So, what are these evaporation reducers? These are basically some chemicals, water based chemicals which are sprayed on the surface of the concrete.

So, when these chemicals are sprayed on the surface of the concrete, they form a film on the oil kind of film on the surface of the concrete and prevent the evaporation and reduce the rate of evaporation of water from the concrete surface. They are effective only for some period of time. So, this you should not confuse with the curing compounds which we use it for final curing.

So, this last only for a shorter time, evaporation reducers these chemicals will be effective only for a shorter time. So, you should keep reapplying depending upon the aggressiveness of your environment. And one demerit of the evaporation reducer is it may sometimes leave staining it may leave some stains on the concrete surface. That is one disadvantage. And it is preferable to apply this evaporation reducer when the concrete bleed water is already there on the surface.

So, before the concrete dries, when the bleed water is there, at that state itself we have to spray the evaporation reducers. That is the best way to apply it. So, when do we do the initial curing? For mixtures with low to zero bleeding rate, that is mixtures with very low water to cement ratio or very cohesive mixes high strength concrete mixes so, or in case of aggressively evaporative environment where the temperature is high, wind velocity is high or both the cases are prevailing together or both, in these cases, initial curing is needed.

So, here surface drying will can begin well before the initial setting or before the initiation of the finishing operation. So, in these cases, drying of the concrete can happen even before the initial setting of the concrete or even before the starting of the finishing process. So, before finishing process itself, this necessitates initial curing to be done to prevent the surface drying of the concrete. So, what are these methods?

Initial curing methods are implemented between placement and the finishing of the concrete to prevent the moisture loss. So, basically, we do this curing between the placement of the concrete and the finishing of the concrete to prevent the moisture loss. So, as I told you even before the start of the finishing process also you can do the initial curing. I cannot apply water but I can go for some wind shades or sunscreens.

Or, I can do fogging. Or, I can spray the evaporation reducers chemicals on the surface of the concrete. So, these are just done to prevent the rate of evaporation from the surface of the concrete. This is called as initial curing because we can do it even before the start of finishing operation.

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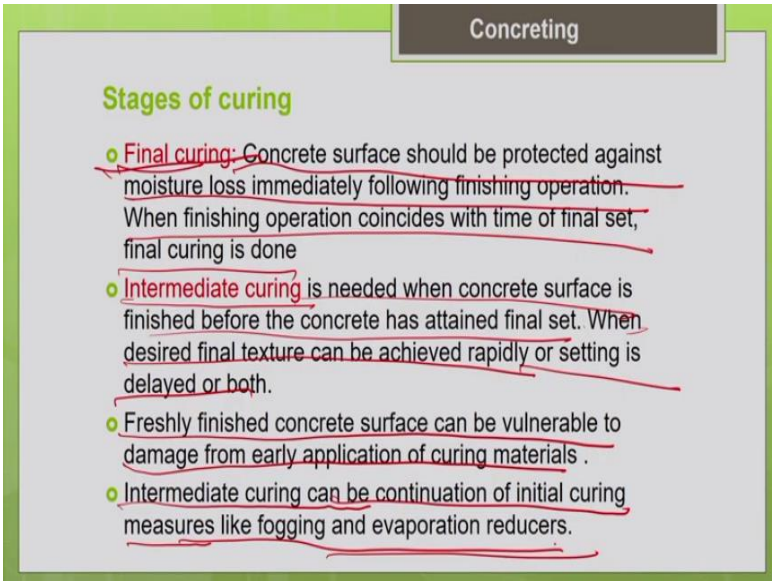

So, the next is about the final curing. So, basically as I told you the traditional way is after the final finishing of the concrete immediately following the final finishing after start the curing that we call it as a final curing. That is the traditional way of during the curing of the concrete. So, the ideal case is your final finishing will be coinciding with the final setting time.

Once the concrete has attained the final set you can easily apply the water for the final curing. So, there the concrete will not get damaged because of application of the water. So, that is the right time to apply. After the final finishing, after the final setting of your concrete you can apply the water to do the final curing of the concrete. But, in some cases, what happens is your final finishing will be completed even before the final setting of the concrete.

So, before the concrete attains its final set itself your final finishing will be completed. So, but before the concrete attains a final set it is not advisable to supply water for the final curing because it may damage the concrete. So, but still we have to prevent the drying of the concrete. How to prevent it? For that we need to do some intermediate curing. So, the curing which we do before the final curing, that is called as intermediate curing.

The same initial curing what you did, you can just continue. The same fogging method or you can spray the water evaporation reducers. So, those things you can continue till the concrete attains its final set because only after the final set it is advisable to go for the final curing methods like application of water. So, till that time, you can continue with the initial curing and you call it as intermediate curing.

So, that is why I told you we do curing in stages depending upon the environment requirement and depending upon the concrete composition. It is not just one step. So, what is this final curing? So, concrete surface should be protected against a moisture loss immediately following the finishing operation. After the finishing operation is done, that is a traditional way, once the finishing is done immediately we have to do the final curing to prevent the moisture loss.

So, mostly the finishing operations coincides with the time of the final set so that it will be convenient to do the final curing. There you can apply your water and do the final curing. But in some cases intermediate curing is needed. When? When the concrete surface is finished before the concrete has attained the final set. In some cases, before the final set itself we complete the finishing process.

So, because in those cases doing the finishing is when desired final texture can be achieved rapidly. You can easily achieve the final texture. Or, if the setting is delayed that could be the reason for completion of final finishing even before the final set. So, in those cases where the finishing operation is completed before the final set but the concrete has not attained the final set, I cannot go for final curing.

I cannot apply water for curing. So, what we do is to do some intermediate curing either you can continue your initial curing itself that we call it as intermediate curing. You can do some fogging or spray some evaporation reducers. Those things you can try as intermediate curing before the final set of the concrete. So, why we need this intermediate curing? Because till the concrete attained its final set it will not be able to receive the final curing methods because of whatever methods we follow for final curing like application of water.

All those things may itself damage the concrete before the concrete has attained the final set. Freshly finished concrete surface can be vulnerable to damage from early application of the curing materials. So, that is why we should not do the final curing till the concrete attains the final set. So, that is why you can go for intermediate curing before concrete attains its final set.

It can be just a continuation of initial curing measures like fogging and the spraying of evaporation reducers.

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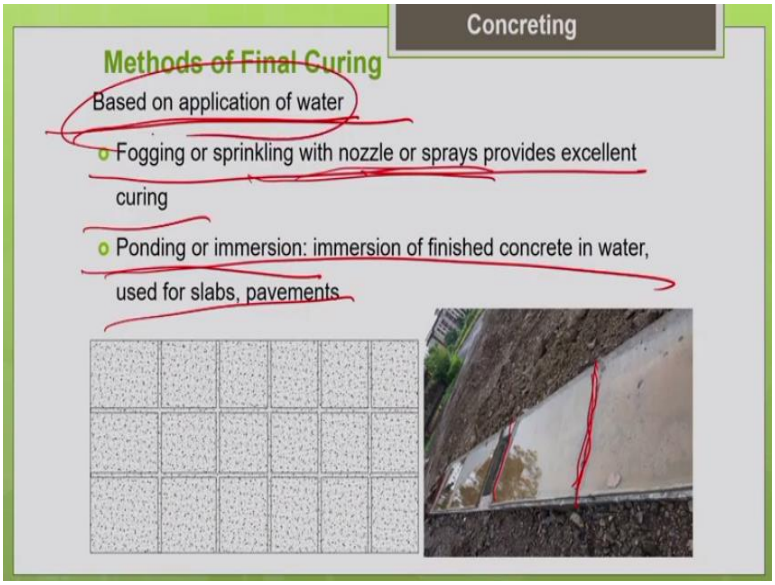

So, what are all the different methods of final curing? So, let us see. So, mostly the traditional way is we apply water for the final curing that is the commonly adopted method and that is the best method for the concrete. So, particularly for the structural elements which have larger surface area like your slabs and pavements, what we do is we go for method called as ponding or immersion.

So, what we do is we construct small barriers like this with the mortar or the concrete. We construct small barriers and allow the water to stagnate on the surface of the concrete. So, when we allow the water to stagnate on the surface of the concrete, it prevents the loss of water from within the concrete to the outside environment. And also it will supplement whatever water it has lost.

So, that is ponding is the best method for these slabs and pavements. It will prevent the shrinkage cracks. So, it is an effective method to prevent the plastic shrinkage cracks in the slabs and the pavements. So, what are the other methods of application of water? You can go for fogging or sprinkling with nozzle or sprays. So, all these provides excellent curing. These are the methods based on application of water.

So, as I told you, the methods of curing we can classify into 2 methods. In one method, we directly apply water. So, in another method, you just prevent the loss of water from within the concrete to outside the environment. So, now we are discussing the method which is based on application of water. You apply the water which is the best method. Particularly for mixtures with low water to cement ratio, we should go for methods based on application of water.

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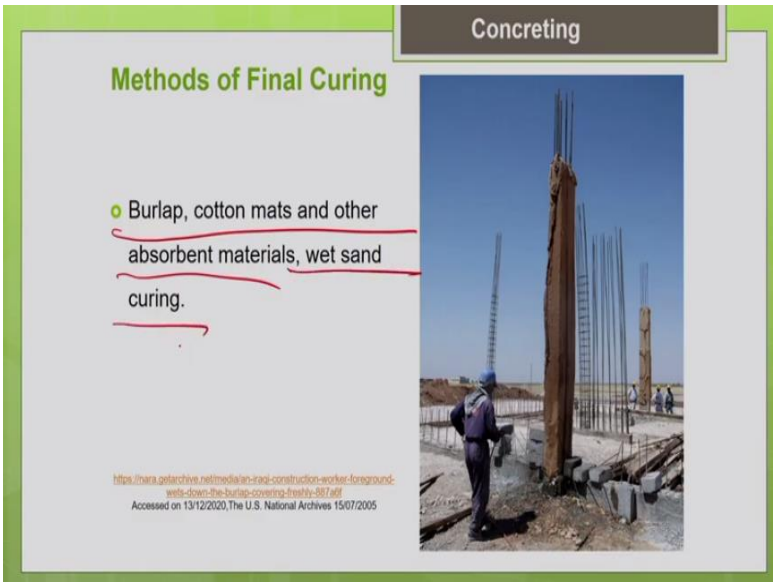

So, this picture again shows the curing based on application of water you can see they are covering with wet gunny bags, wet burlap or cotton mats, any absorbent material you can put particularly for the vertical elements. We can like columns we can go for this kind of method. So, for the slabs, we can follow ponding or immersion method. We can allow the water to stagnate easily.

But for vertical elements like column, we can go for these kind of methods. You can go for water spraying. You can go for the wet gunny bags, wet burlap or cotton mats, any absorbent material. You can soak it in water and put it on the surface of the structural element. You can also go for wet sand curing or wet earth curing.

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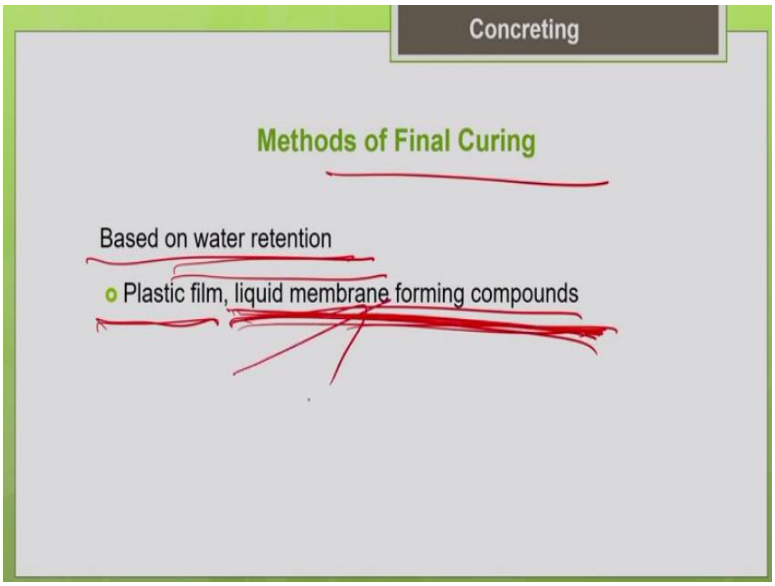

So, the other method which I told you is based on water retention. So, here what we do is we do not apply water for curing but we prevent the loss of water. So, how to prevent the loss of water? You cover the concrete surface with a plastic film or any polyethylene film and prevent the loss of water from within to outside environment. This is very commonly followed in places where sufficient water is not available for curing where there is water scarcity.

And in some structural elements, which is not easily accessible which is where it is not possible to continuously apply water curing. In that case you can go from water retention methods. It depends upon the accessibility of the structural elements for the water application. Some cases, we have to go for water retention only because certain cases it is not possible to continuously supply water for the curing.

In that case, you can go for water retention method. So, cover it with a plastic film or you can also spray some curing compounds. So, these are entirely different from the evaporation reducers what we have discussed earlier. That we applied before the finishing of the concrete. That is why initial curing. This membrane forming compounds or the curing compounds which we use it for the final curing.

So, this also we just spray it on the surface of the concrete. It will remain on the surface of the concrete. It will be effective for even 28 days. So, depending upon the chemical which we are going to use and it will facilitate the self curing of the concrete. So, that means it will prevent the loss of water from within the concrete to outside environment. So, another thing is this will not result in any staining.

As we discussed for the evaporation reducers, there will not be any stain formation. And it lasts for a longer time. As I told you even up to 28 days it can remain. But one thing you have to be careful is this we should do this membrane curing we should spray this membrane curing compounds only when the concrete is completely dried. There should not be any bleed water on the surface. If there is any bleed water on the surface that will affect the efficiency of these compounds.

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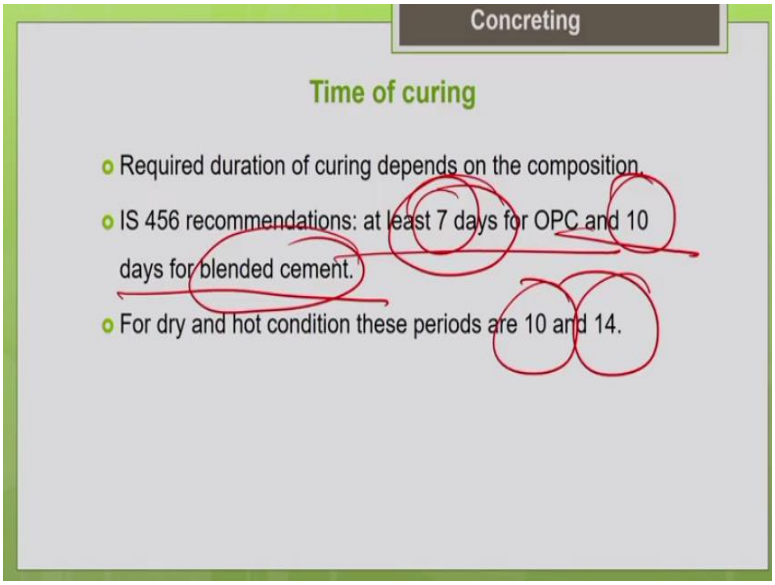

So, how much time you are supposed to do the curing operation? So, obviously, there is always some time constraint in the project sites. We cannot doing a curing for a very extended duration is very difficult or challenging with the construction project sites. So, as per the IS code, at least 7 days of curing is needed for a concrete with ordinary Portland cement.

So, the number of days or the duration of the curing also depends upon the composition of the cement type. If you are going for OPC that is ordinary Portland cement, at least 7 days of curing is needed as per the IS code guidelines. But if you go for blended cements where we use fly ash or slag as a replacement for the cement. So, there you know that these pozzolanic materials like fly ash or slag, the hydration process will be very slow.

So, since our hydration process occurs in a delayed manner or in a slow manner, to facilitate the hydration process or the pozzolanic reaction, we should continue the curing for even 10 days, if you are going for blended cements. So, these are the guidelines available in IS 456. Also, it depends upon the environment. For very dry and hot conditions, you can extend this duration further from 7 to 10 days and from 10 to 14 days for very dry and hot condition places.

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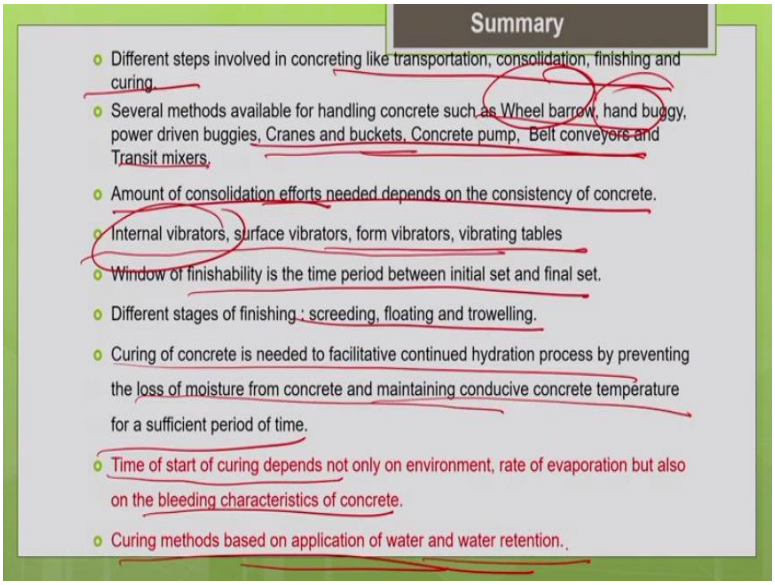

So, we have come to the end of this lecture. So, let me summarize what we have discussed so far. So, we have discussed about different steps involved in the concreting process like your transportation of concrete, consolidation, finishing and curing of the concrete. So, basically there are so many methods available for handling the concrete. We have discussed about the simple methods like wheel barrows and buggies and advanced methods like pumping, belt conveyors, cranes and buckets and transit mixers.

So, the selection of the method which method you are going to select for handling a concrete it purely depends upon your productivity requirement. So, every device has its every method has its own productivity, we have discussed about what is a possible productivity with every method. So, depending upon your job productivity requirement as mentioned in the contract documents, you have to make the selection of your method.

Obviously, it has to fit into your project budget also. But whatever method you choose, it should not result in segregation of the concrete so that you should be very careful that it should not result in the segregation of the concrete. So, then coming to the consolidation of the concrete as I told you, the amount of consolidation depends upon the consistency of the concrete. So, for stiff mixes, you need more amount of consolidation.

For high consistency mixes, you need less amount of consolidation. So, even the frequency and the amplitude of the vibration has to be matched with the consistency of the concrete. That is what we discussed. For stiff mixes, go for high amplitude and low frequency vibrators. For

highly consistent mixes, go for low amplitude and high consistency vibrators. So, that was the guideline.

So, different methods are available starting from internal vibrators, surface vibrators, form vibrators and vibrating tables are there. The best thing is your internal vibrators. But in some locations you can see that internal vibrators are not feasible either because of thin sections or because of congested reinforcement. In those cases, we have to go for either surface vibrators or external vibrators.

So, then coming to finishing of concrete, the finishing you should do only between the initial setting time and the final setting time. That is the time period. And we have discussed about different stages of finishing like screeding, floating and troweling. So, as I told you, between every stage of finishing you should give some time interval. As a concrete dries up only it is possible to do the smoothing smoothening and the polishing process.

So, the concrete should be dried enough to withstand the weight of the finishing machine or the finishing person. So, I told you the guidelines also how to find the time of the exact time of the finishing. So, then coming to the curing of concrete, curing is a very important step. It will help you to facilitate the continued hydration process. So, based on curing only, you can have a very good microstructure in the concrete.

So, basically, why do we do curing? We need to prevent the loss of water or the moisture from the concrete and we need to maintain the concrete temperature so that the hydration process will continue for a longer time. So, that is the reason we should go for curing of the concrete. So, if you overlook the curing, you will not get continued hydration. You will not get your desired strength. You will not get your desired durability of your concrete.

So, when to start a curing? That depends upon the environment. We cannot generalize. For an aggressive environment where the rate of evaporation is high, you have to start the curing as early as possible even before the finishing you can apply some initial curing in some aggressive environment. It also depends upon the composition of your concrete. If a concrete has negligible bleeding or zero bleeding in that case you have to start curing very early to prevent the plastic shrinkage cracks.

So, you have to go for some initial curing also in addition to final curing. So, there are different methods of curing we have discussed. Some based on application of water and some based on water retention methods. That the best thing is always application of water, but in some places it is not possible to apply water continuously. So, we go for water retention methods.

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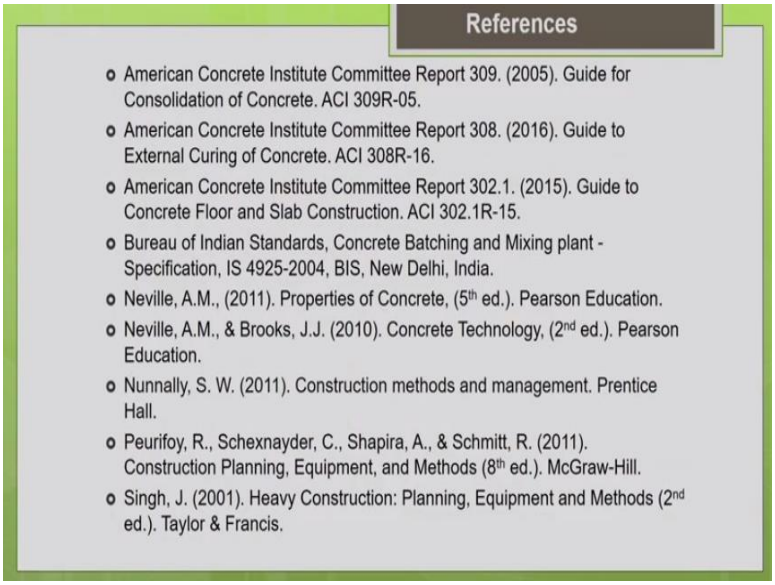

So, these are the references which I have referred for the preparation of this lecture, thank you.