Maintenance and Repair of Concrete Structures
Radhakrishna G. Pillai
Department of Civil Engineering
Indian Institute of Technology-Madras

Lecture No. 19
Surface Preparation and Protective Treatments
(Placement of repair materials and curing)

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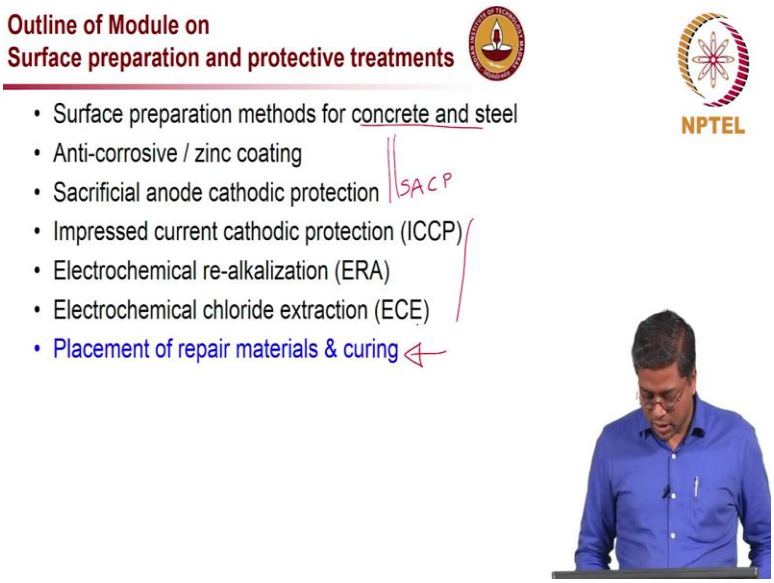

Hi, this is the fourth lecture in the module on surface preparation and protective treatments and in this lecture we will focus on placement of repair materials and curing. In the previous 3 lectures we looked at how to prepare the surface and of both concrete and steel and then we also looked at anti corrosive or zinc coatings and then looked at sacrificial anode cathodic protection, we call it as SACP. And then in the last lecture, we talked about ICCP, then electrochemical re-alkalization, and electrochemical chloride extraction. And in today's lecture we will be looking at placement of repair materials and curing. In other words, how to place the repair material after cleaning the concrete surface and after cleaning the reinforcement, then you have to place them and if you are doing some treatment like cathodic protection after installation of those anodes etc. How to place the repair material to cover the substrate and also looking at why curing is very important when we talk about the durability of the repairs. So, curing is very important.

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Now, this is how to place these repair materials. So, we are going to talk about these 7 different techniques in this lecture. So, basic thing is, use of trowels to place repair materials, then also dry packing, then form and cast in place, then form and pump concrete, then pre placed aggregate concrete, dry mix shotcrete and wet mix shotcrete, these are the techniques we are going to talk about today. Again, very briefly we will show you some examples of this and how these things are done.

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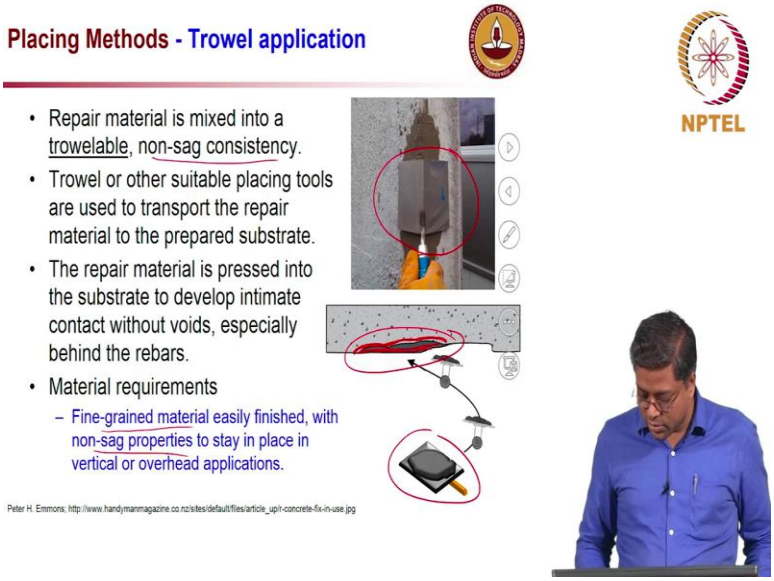

Now for Trowel applications, repair material should be trowelable or it should be wet enough, flowable enough, but not too flowable also and it should have good consistency, in other words it should not sag. See the picture on the top right, they are using a perfect tool like you can see, if

you want a 90 degree edge, the trowel itself is made of a metallic plate which is bent 90 degrees, you can get a fine finish. Why I put this picture is it is very important to show the importance of the tools which we use, you have to use right tools. That way the final product or the finishing will be very good. I will show one more slide on this with different types of tools later.

And other thing is, the picture on the bottom right, it shows, you take the material on a trowel and then you are placing it here, it should not fall off to the ground. If you are talking about a roof, which used to be a practice earlier, actually a couple of decades ago, if any concrete roof, first thing is after removal of the formwork they used to plaster the roof of the bottom surface of the roof. So it's not very easy to do and the mason should be highly skilled to do that also. So they place this or literally throw the mortar onto the roof surface or the bottom side surface and then the mortar should stick there, it should not fall off that is why the property of the mortar is also very important. So, it should be trowelable, it should be cohesive enough and it should also stick to the substrate concrete that means it should be having good adhesive properties also. So, fine grained materials, non-sag properties means when we apply this to the roof surface if it just falls off, then it is not really going to be a good repair that means, if it falls off, there will be some debonding or the adhesion is not good that is why it is falling off. And in some times it could be just because of cohesionlessness also, in such case it will fail in this right inside the new material which is provided. So, both cohesion and adhesion are important properties when you talk about placing of these kind of materials onto a surface where, which is horizontal and then where gravity comes into action.

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Now, these are other examples where on the column on the left side, you can see, again, a smooth finish is required. And on the right side, you can see it is on ground. So, all you need to do is place it and then trowel it well. So, for example, a new floor if you are trying to trowel it immediately after placing the concrete, it will not work very well because then it will actually pull the moisture also along with your trowel. So sometimes masons they wait for some time for it to get dried enough so that it becomes trowelable mortar, or concrete. So these things are important to note when you go for it.

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This is a set of photographs showing different types of trowels. If you want to talk about different shapes for specific applications, see, most of the time we don't invest much time on selecting a good tool. But if you select a good tool, it will really save a lot of time in the finishing process. And at the same time, at the end of the work, you get a very good finish. So I request like, it is very important for us to look for good tools. Also may be you can say that it is not available in the market, but, you also have to create a demand for different things in the market. So you have to ask, if you want a 90 degree trowel, which has that 90 degree as it is shown on the picture here., you have to ask the suppliers and then they will eventually procure those type of tools and then eventually our goal is all these things should be easily available in the market, so that we tend to use good tools. And it is very important, using good tools and specific tools for specific applications.

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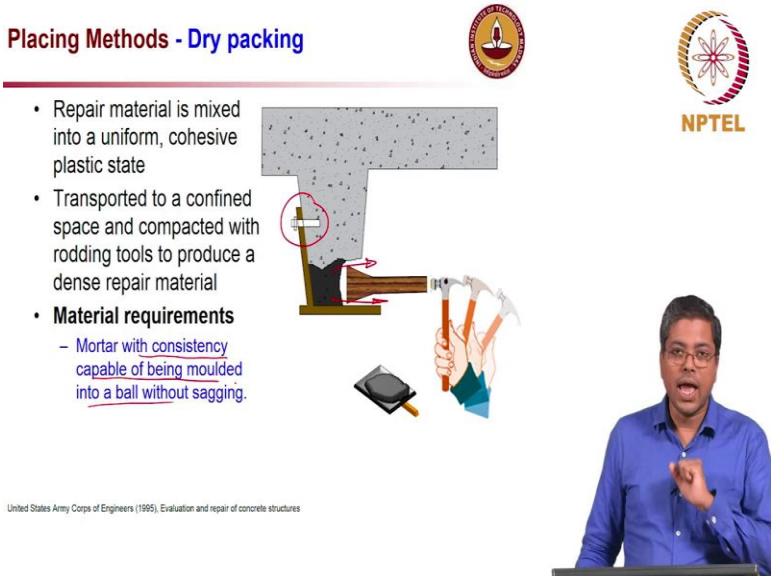

Now, dry packing method, as is shown in the picture on the right side, you can see this dark color region is the repair material which are putting at the bottom of this girder section. In dry packing basically, you have a very strong formwork which is attached to the substrate concrete. And then you basically hammer the relatively dry mix. It is not really a flowable material, because imagine if you hammer this on to a flowable material, the material will just skews out. So, it has to be dry enough so that the material does not skew out like this. Otherwise, if you have a flowable material, it just skews out and your hammer will go in, that does not mean that we will pack so you need relatively dry material to pack it that is very important. And the mortar with proper consistency capable of being molded, you check whether it is packable or not, you take it to mortar and then make a ball out of that in hand, if you are able to make a ball, then it is probably good enough to be able to pack it like as shown in the picture, either you push it into by hand or by a hammer or another tools available.

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And where these kinds of things are are applicable. You can see on the left side, if you have some small holes or took a core and then you want to pack that core back in. And as it is shown here, it is an end of a tendon system, again you can see these circular regions where actually use the dry packing is a very good idea. Also when you talk about dry packing, typically the water binder ratio of that material will be relatively less and that will also ensure that it is a non-shrinking material. Because you want that once it is packed it should not shrink. So, typically with non-shrink grout or a relatively dry mortar, we can actually go for this packing. Again when I say non-shrink grout, but still you can hammer it depending on the depth to which you have to fill. So, these are some examples on where we can apply this dry packing. Whichever structure, if it is a vertical element, if you take a flowable mortar or a very flowable concrete, you cannot pour it into that vertical element, I mean for example, in that picture on the left side, if you have a hole which is horizontal, if you pour the material will just flow out. So, in such cases you have to use relatively dry material and even if it is non-shrink grout material you can fill it and provided a port or something on that so that it does not flow out. But anyway the point is wherever there is a possibility of flow of the material because of gravity action, you can use this dry pack technique to fill the cavity or void.

And another example here underside of a girder, if you make very flowable material, it may not fill very well. It will just flow out it will be very difficult to even finish the repair work. So,

people generally go with dry material here, which will have good adhesion and cohesion. So, by hand also you can pack it, pack the spaces.

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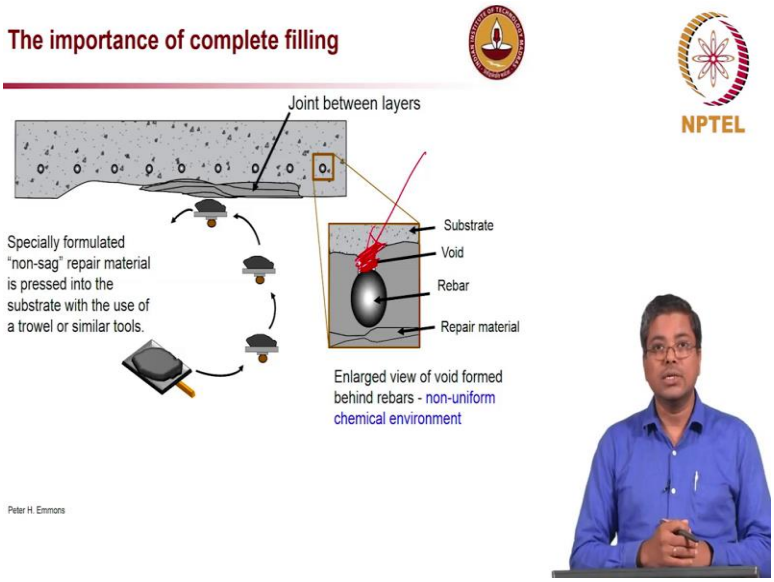

Now, when you do this dry packing, one very important thing to note down is that it should be completely packing the space around the steel reinforcement. If it does not happen, let us say you are just superficially placing the material over there instead of really packing it, what will happen is as you see here on the picture, on the right side, you can see there is an air void or a space which is left behind the rebar or the undercut region. So, that space also should be filled by the mortar so that the steel gets a uniform chemical environment around the surface. So, in this particular case some portion of the steel is exposed to air whereas the remaining portion is exposed to the repair material, but ideally what we should do is this region also should be filled with mortar. So, there should be no air void as it is shown or marked right now.

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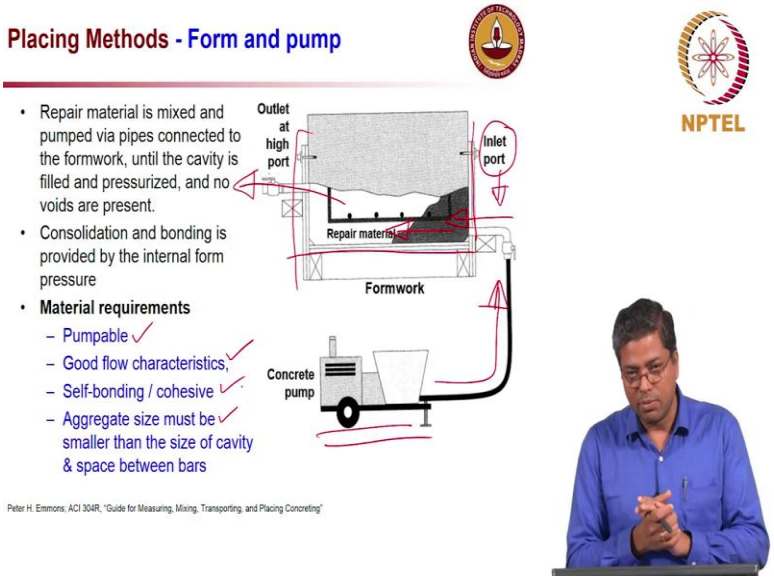

Now, there is another technique is form and pump concrete. Form which helps in defining the space or how much area should be filled up in what shape and then a pump is a technique by which you place the concrete. So, as you see in this picture here you have a concrete pump which fills or pumps the concrete into the formwork region, you can see the formwork region here. Also you notice an outlet is very much required, an outlet is kept on the bottom portion of the space which needs to be filled and also you see an inlet of the concrete which comes out is at the bottom right. So whenever you talk about pumping, it is always good to go for an inlet which is placed at the bottom portion and let the air pressure or the pump pressure push the concrete from bottom up, that is how the idea. In this case you can see the concrete is flowing this way from right corner to the left and it is displacing the air which is present and then air comes out through like this. So, finally, the entire the cavity or predefined spaces filled with repair material.

Again, the concrete or the repair material should be pumpable. What do you mean by pumpable is mainly it should be segregation resistant and it should flow well without much of pressure requirement. So, this is very important, because the material should not segregate if it is segregated, it will get choked or clogged inside the pump itself. Good flow characteristics, self-bonding, it should be cohesive and aggregate size must be smaller.

So, when you talk about repair there will be undercutting and the space behind the rebar also will be very limited, in such cases you should ensure that the size of the aggregate is relatively or is

smaller than the clear spacing between the reinforcements and concrete so that you get an integral concrete.

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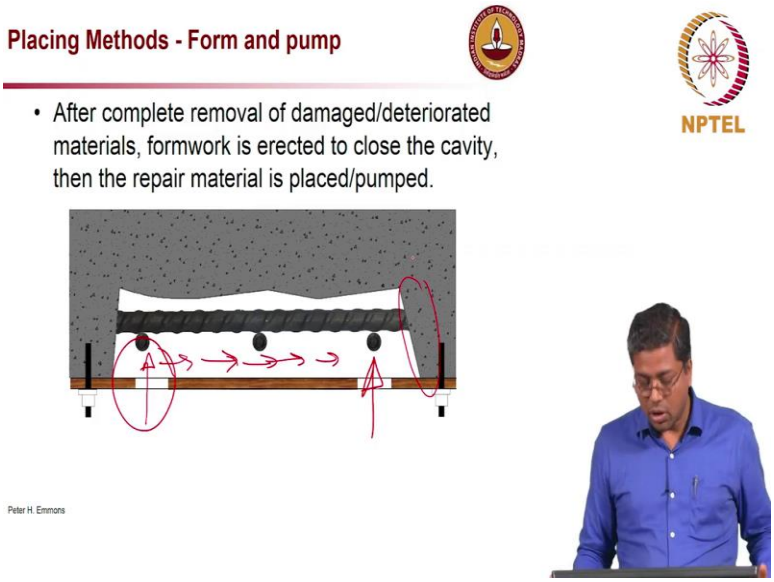

This is an example or an image showing similar thing where if you are talking about a long beam or something, it is the side view of the similar beam, if you can think you can also say here, because all the time you may not be able to provide a outlet at the top, depending on the direction in which it flows. So, in this case, if I am saying a long beam or a girder where I start pumping in and let the concrete flow this way and until the concrete reaches here, then I will close this portion and then start pumping here. So, when you have a long sections available, you can fill from one end to the other by moving the outlets because otherwise it creates layers which eventually does not help in filling the portion above the rebar.

So these are some of the intricacies associated so, multiple inlets might need to be designed. Depending on the size of the repair, dimensions of the repair work you are talking, you have to decide what type of formwork is required and how it can be pumped efficiently. How the material can be pumped into the cavity efficiently. When I say efficiently it also means that effectively because you have to really fill the space behind the rebar also. So, both efficiency of the entire work and effectiveness of the work must be considered.

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Now, these are again some more examples showing where this kind of pumping is adopted, especially when you talk about column jacketing or enlarging the size of the column there it is widely used. And this is again a micro concrete which is being pumped as an overlay or a screed concrete or any such applications wherever micro concrete is used, you have a funnel type setup here or a tank for the material which is then pumped into the space where it need to be filled.

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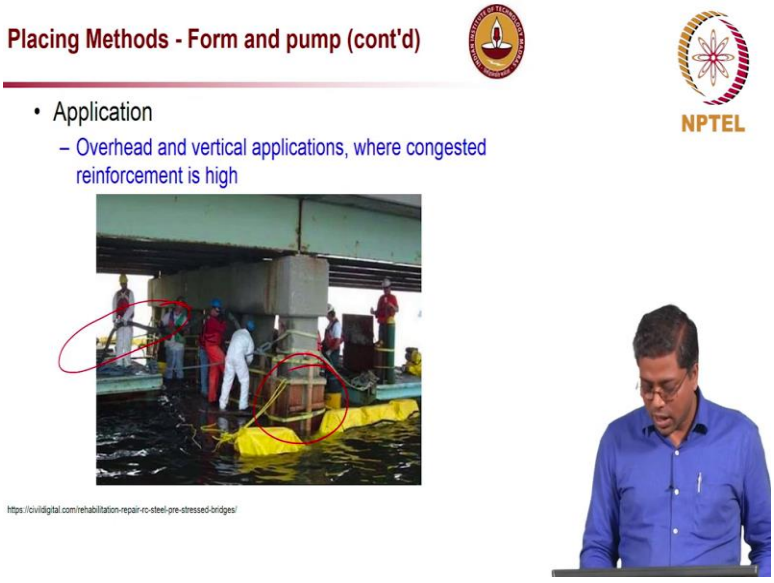

This is another example showing column jacketing work where again it can see here the people are actually standing on floating platforms and it is not that easy to work environment, so, you create a encasement and then you pump the concrete into the space in between the existing column and the formwork. And you can see here, this is the formwork made out of wood, and

you have a concrete column and then the space in between is filled with the pump, you can see this person here holding the hose, concrete hose. Why I am showing all these pictures to you is to tell you that these kinds of things are widely used in construction and there are a lot of challenges in construction. It is not just getting any concrete, getting any pump and you pump, it will not work. You have to really look at pump pressure, how the quality of the material, the flow characteristics of the material, and what is the dimension of the area which needs to be filled all these have to be looked at so, you really need to engineer the materials, adopt good construction practices, and select good tools.

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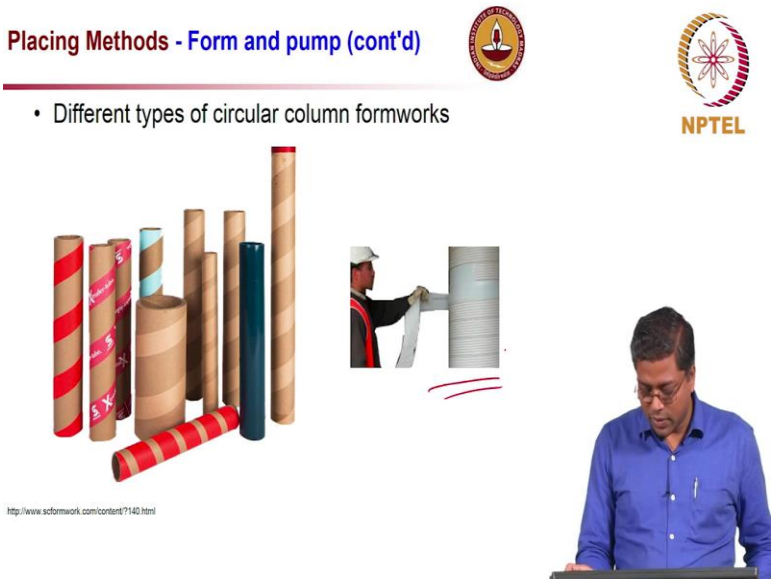

In the previous slide I showed about square columns actually, but we also see a lot of rectangular columns in our structures. I just wanted to show because this is not something which is widely used in our country, when you talk about circular columns. Nowadays, these type of column formwork which are made out of cardboard are available, and it they even come in with more than a feet in diameter. So, once you put this then you can place the concrete. One typical example where you can use this is a electric lamp post or wherever you need a pedestal, you need a circular concrete element there, and also for columns. So wherever you think of a cylindrical shape, you can use this type of formwork. You place it and place the concrete inside and remove the paper cardboard just after the concrete get sufficient curing. So, as you see on the picture on the right side, you can easily remove this thing and it is a very environment friendly product also because it is just cardboard.

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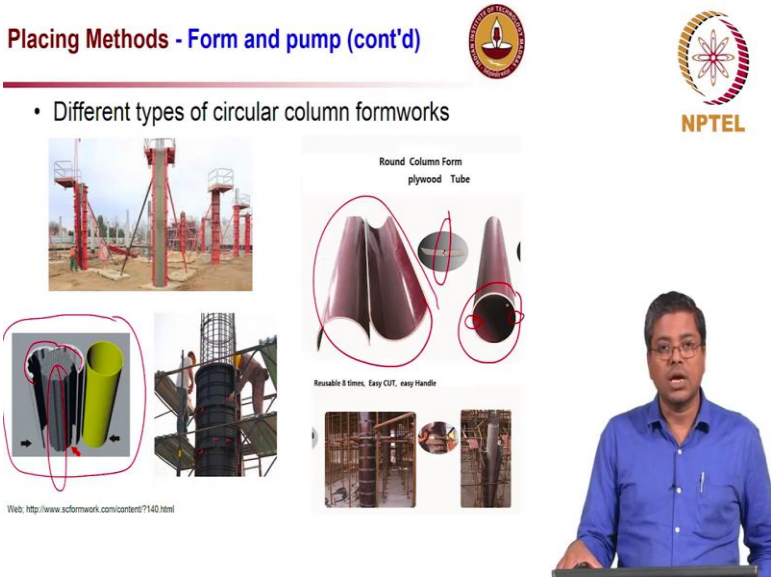

Now, these are some examples to show when you talk about repair or even construction of new con columns. What are the types of form works which can be used, on bottom left picture you can see one type of setup where there is a slit and at which you can open the formwork, you can see and it is two pieces. So, after the construction you can remove that, also if you want a specific shape of your column like some kind of architectural design, like you see here the grooves and etc. then you can make your form or mold your formwork accordingly and then make it. It is because otherwise what you will be doing in this particular case is you will make a cylindrical column and then ask another person to come and make those grooves which are going to be more time consuming, but if you have a, mold which makes that shape inside then it is much easier. So, in the long run if you have large number of columns like this to be made, these kind of tools or this specially designed formworks will be of very good use in completing a good job in short period of time and get away good finish at the end, that is also very important getting a good finish. And also other pictures, you can see here that again a two piece column formwork and you can see how you connect these pieces like a lock and which will form something like this. So, you can see here there are a lock here and another lock here. So, these kind of things are in a form work can be utilized to speed up the work and at the same time get good finish of the concrete surface because in circular columns, you cannot really rely on a mason to get a perfect circle and also is it is very difficult and time consuming process. But if you adopt these kinds of tools, or this kind of specially designed formwork, you can save a lot of time.

If you are talking about a jacketing then also you can adopt this kind of formworks for repair. Make this kind of formwork and then fill the repair material into the space between the form and the existing columns, as I showed on the bottom left.

I am showing you all these, so that you can think about these different ideas and then try to implement such things in the construction projects.

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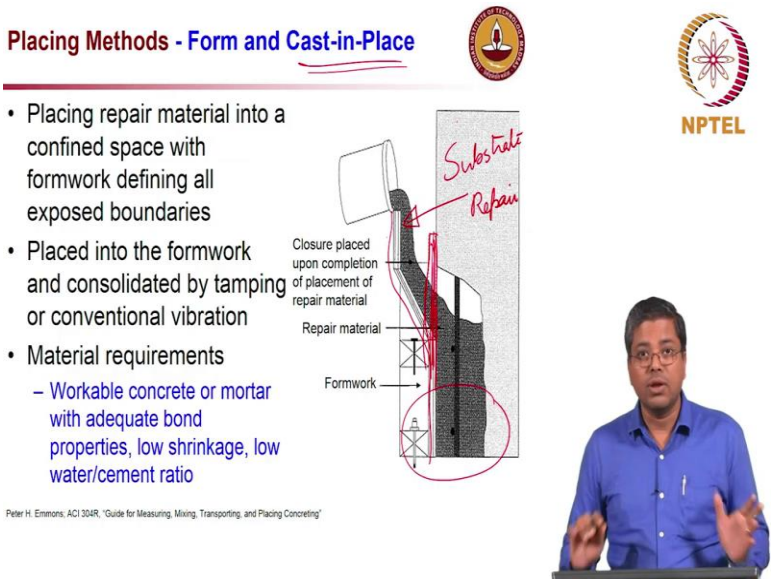

Now, form and cast in place, in previous slide we were talking about pumped concrete and here we are talking about cast in place, in other words, you are basically pouring or placing the concrete in the formwork. As you see here, the gray color is substrate and the dark color is the repair material and then here is the cavity and then you can see the formwork made like this so that you provide sufficient space to flow, there is also a dotted line here that indicates that some other portions of the same column because the shape has to be well defined. So, wherever the you are placing the concrete only that portion need to be deviated like towards the left, as you see on the for sketch. So, the remaining portion can still form the same shape as it is required.

Wherever you need basically some openings at an interval of let us say 1 meter or 2 meter depending on the case, you can make an opening through which you can place the concrete and remaining portions can have this continuous formwork like this. So, again material should be

workable, once you pour or place the concrete it should flow and reach and fill all the cavities that is very important.If it is not having good flow again you will see that a lot of pockets here and there will be formed which is again not a good repair.

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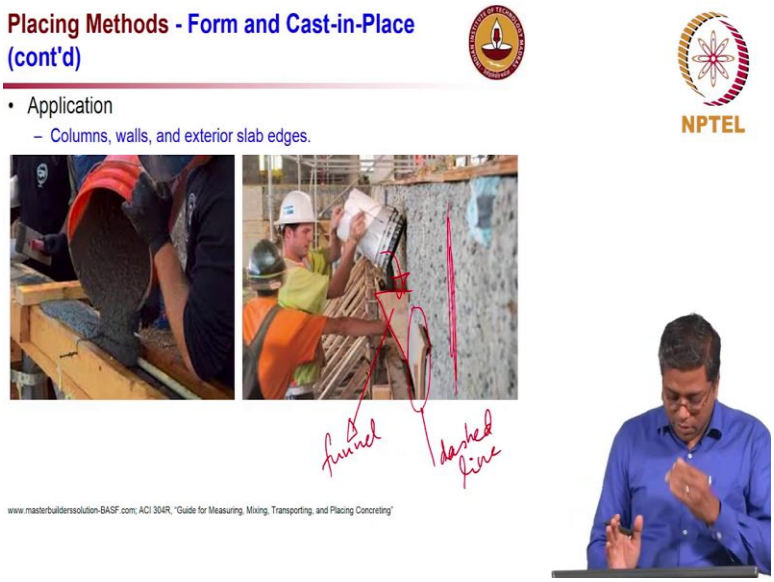
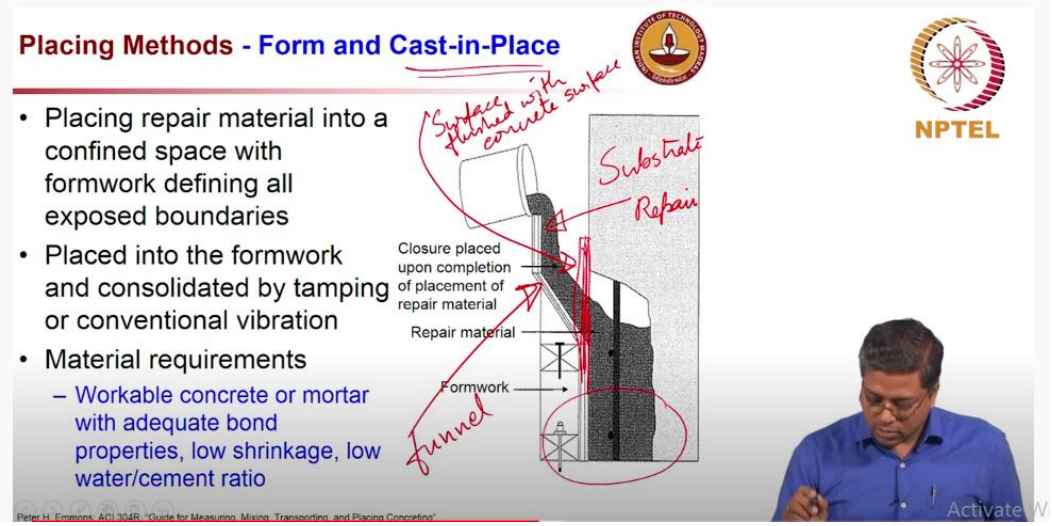


This is again examples to show, you can see here, this is being floor, poured into this, but again you can see here this portion is actually having a flat surface which is flushed with this surface. And you can see a conical thing which is like a funnel type setup where through which the concrete is poured into and this region.



So I am going to show you the previous slide this is this is the funnel part and this is the other surface, surface flushed with concrete surface.

So, you can see very clearly this image shows how these projections need to be made not everywhere but some regions so, you get nice product at the end.

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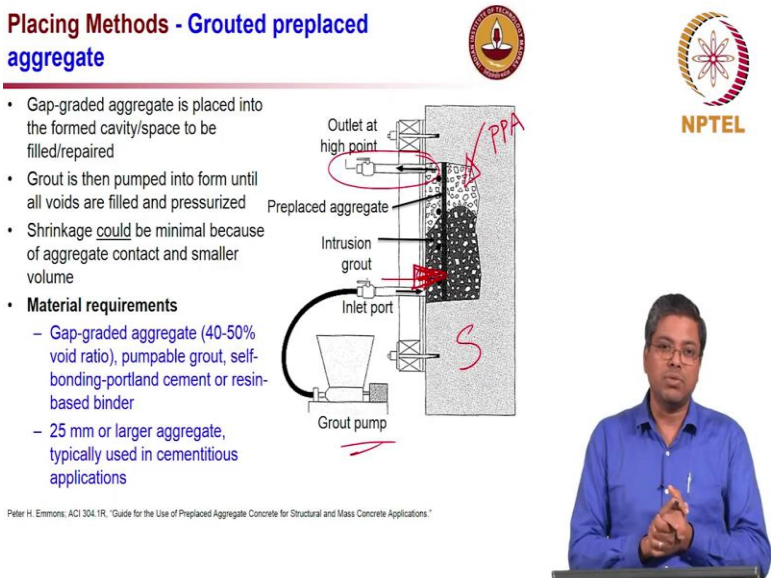

Now, another technique is grouted preplaced aggregate. So, you can see here again a grout pump and in this light gray region is the substrate and you can see here preplaced aggregate. So, idea here is, first you make the formwork and then fill the space with aggregates and saw that there is sufficient air voids or space available for the grout material to flow. And then you pump the grout material through this opening inlet, again notice that that the grout inlet is at the bottom portion and we push the aggregate the grout upward. So, you pump and then push the grout upward and there is an outlet also here, it displaces the air inside the preplaced aggregate and replace that with the grout and then eventually you get a nice concrete itself because eventually this cement paste goes or grout goes in between all the space between the aggregates and fills up and then you get a nice concrete at the end. And this is done especially where you cannot really pump the concrete by itself, if you have let us say a repair work where when you talk about pumping concrete there, infrastructure required is much larger, size of the hose also should be probably sometime large, the pump pressure should be large. But in case of grout pumping, it is just cement paste or a cement slurry, that can be pumped with lower powered machine machinery. So, the investment required is also going to be less in case of grout pumping than when you talk about concrete pumping.

You know that in concrete 75% or more of the volume is occupied by the aggregates. So, you first place the aggregate and then compact them or, make sure that it is reasonably filled well. And then after that, just fill the space in between the aggregate using cement grout that is the idea here.

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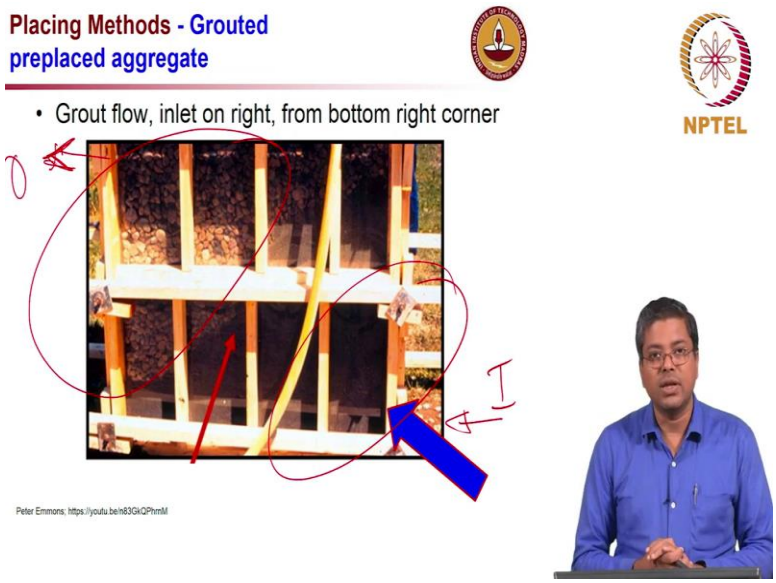

I am going to show you some picture, on the top left of this photograph, you can see that preplaced aggregates and on the bottom right you can see that the space is being filled by the grout. So, again here also the inlet should be at the bottom and outlet should be at the top here, so that the air gets displaced first, and then the ground replaces all the air inside the space between the aggregates and so, at the end you got a very fine concrete similar to our normal concrete.

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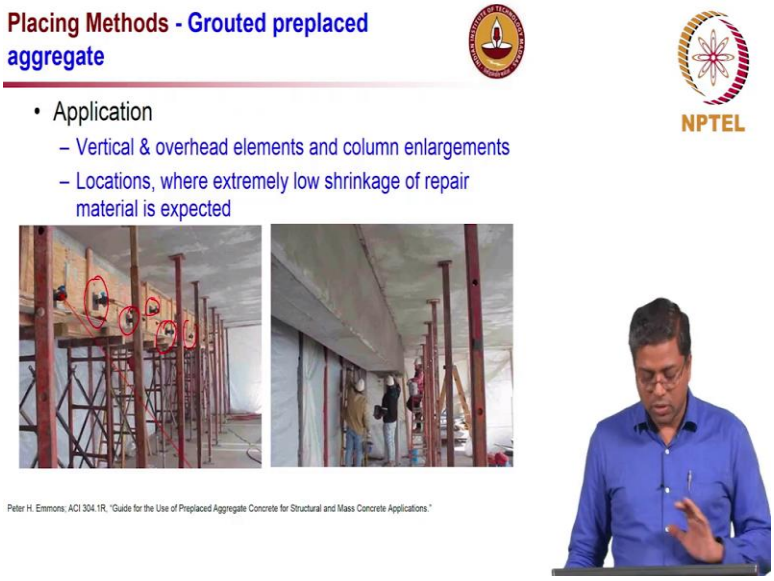

And these are the examples where these type of applications have been practice. You can see here a lot of pumps here for filling the grouts and also air outlets at the top, depending on the cover region which need to be replaced. So, first a formwork is made with both inlets and outlets, inlets being at the bottom portion and outlet being at the top portion and then space inside the formwork is filled with aggregate. Mainly large size aggregates, 25 mm or larger aggregate typically used, then fill the space with cementitious grout and then after that once that hardens you can remove the formwork and you get a nicely finished concrete.

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Now, another thing is shotcrete, this is also widely used especially when you talk about tunnel or any anywhere where large area needs to be covered and where if you are employing one human

being to do or a mason to do a troweling, it will take long time, so in such case shotcrete is widely used. Two types of shotcreting exists, one uses a wet mix and the other one uses a dry mix, wet mix process and dry mix process. The both these are going to discuss in detail. In the wet mix process, you have a concrete which is already wet concrete and you just pump it, in the dry mix the materials are relatively dry, I mean not like flowable but relatively dry, and then you can see pre-dampness or it relatively dry and then the remaining water required is provided at the end or right at the nozzle. This is the water supply as you see this is going right into the nozzle point.

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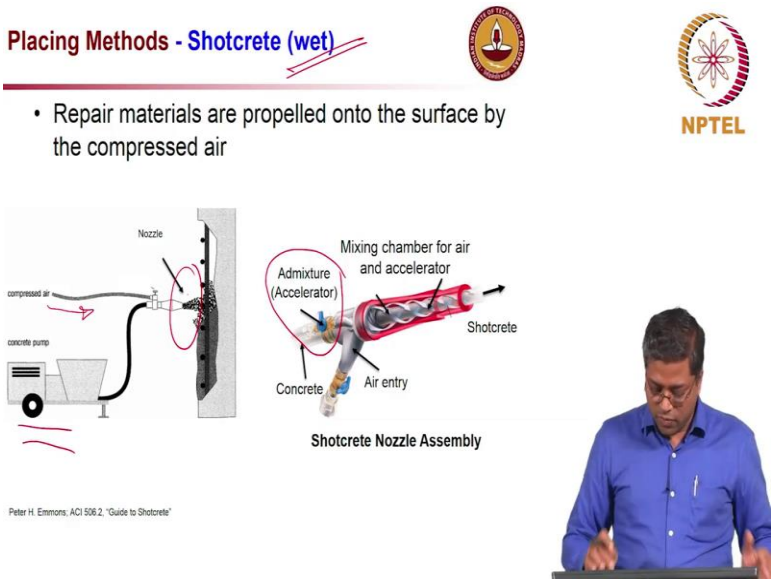

Now, how is this applied so, we are talking about wet mix, you have a concrete pump and then compressed air is used to push the repair material and you can see here a nozzle and it is directly sprayed on to the region which need to be repaired. You might see this in many places where large surface typically horizontal surfaces or where you expect like a retaining wall or something like that or tunnels where you might expect some rebound also.

So, let us see how this rebound can be handled. So, here in this example, you see a nozzle and then the concrete is or repair material is sprayed on to the repair the surface which need to be repaired, and how do we make sure that the moment the shotcrete or the material leaves it should be flowable and it should actually flow through the nozzle and at the same time the moment it reaches the wall it should be setting so fast. So, fraction of a second is given to set it. How do we

achieve this is by providing an admixture which is an accelerator and where is this admixture provided is right at the point where the material is released from the nozzle. So from the tip of the nozzle to the wall, you have fraction of seconds, so as soon as it reaches there, it gets set and set accelerated. So you have a good setting of this concrete and it does not fall off from this surface. So we call it rebound, that volume should be very limited. In other words, when whichever concrete fall onto the surface, it should stick there it should not fall off.

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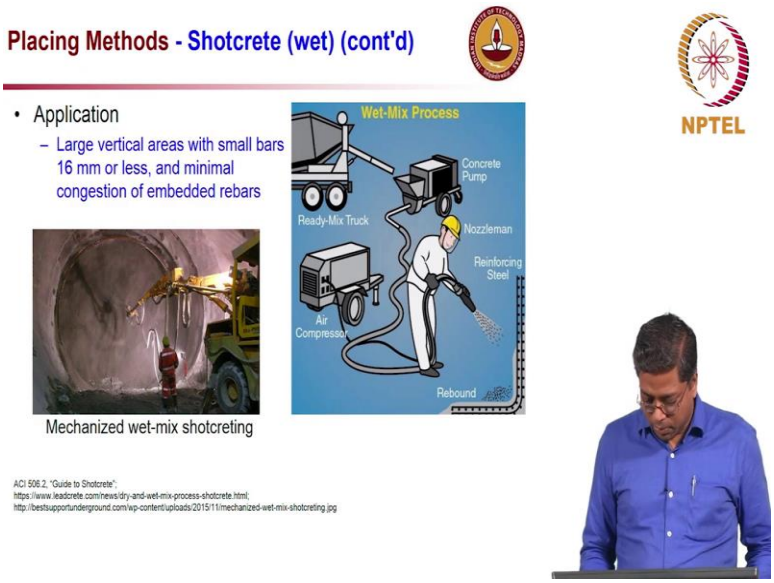

And so it is an example you can see it is a tunnel construction. Again, this you can say it is a new tunnel but even for repair work this is widely used because repair work is sometimes you cannot really reach that region,, it is far away up, you can do this without really making scaffolding, etc. That is a key advantage of this. In this case, you can see in the tunnel, you don't need any scaffolding, this robotic arm just goes and then sprays this concrete wherever it need to be sprayed. That is the advantage of this technique; large area can be covered in short period of time.

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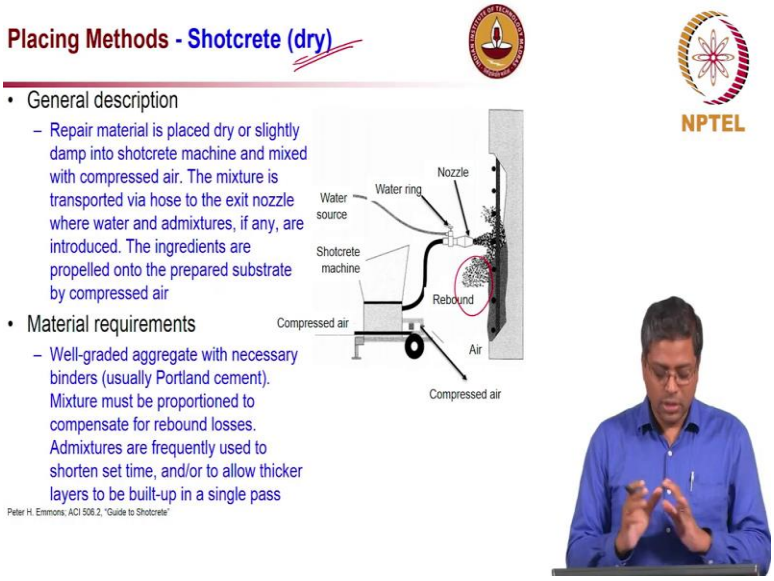

Now this is for dry mix. Here you can see again a lot of rebound material as I mentioned earlier. How do we prevent that is by again if you make the concrete with some accelerator you can actually prevent or minimize the rebound. But that is one major concern when you talk about shotcrete, a lot of material which is lost due to rebound. So, if you can design a material, which will have minimal rebound that is a very good choice to go for and materials like that is widely available in today's market.

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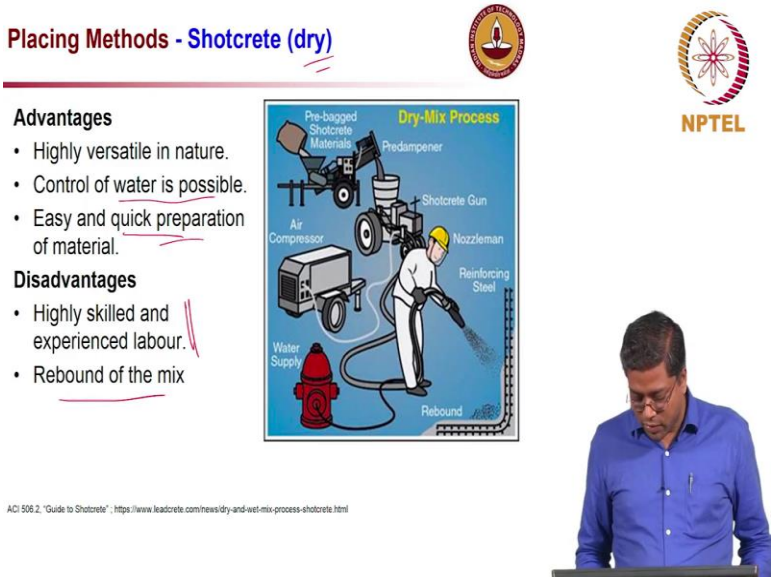

Now, what are the advantages and disadvantages? Again, highly versatile, you can apply anywhere you want and then control of water is possible and easy and quick preparation because you are talking about dry material, it is just getting packets together and then mix them and you

need highly skilled and experienced labor because when you talk about these nozzle, it is not that easy to handle, there is a vibratory effect is there and then there will be a back pressure. So, an experienced or a skilled laborer is required to control this nozzle and make sure that you get uniformly thick material on the entire surface which you are applying. And also density of the material, you have to make sure that it is uniformly applied or uniform thickness because you don't trowel the shotcrete at surface, it is not a practice, you just leave it like that. So need to get a good finish and reasonably uniform thicknesses. So the laborers should know how to achieve that. Rebound of the mix is a disadvantage we already discussed, but there are techniques now available to make sure that the rebound is minimal.

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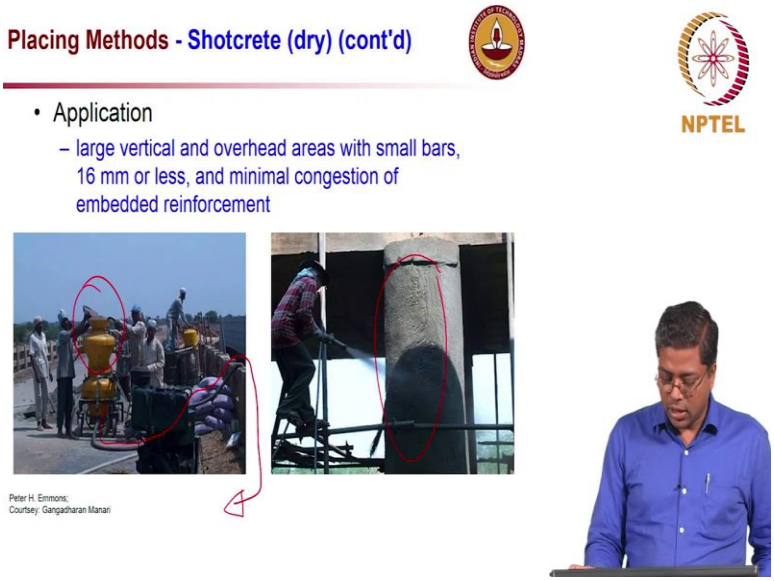

This is one application, you can see on a column where shotcrete is being applied. On the left side, it is dry mix which is being mixed. And then you can see the pump going like this and then it goes to the bottom of the bridge, where you see on the picture on the right side. So, again, you can do these things far away, imagine if this was actually done by a mason and you are taking small containers, small amount of material and then placing by hand, it is going to much longer time. When you look at the entire work required it could be relatively easy and you can finish the job at much earlier than if we were doing it with the hand application.

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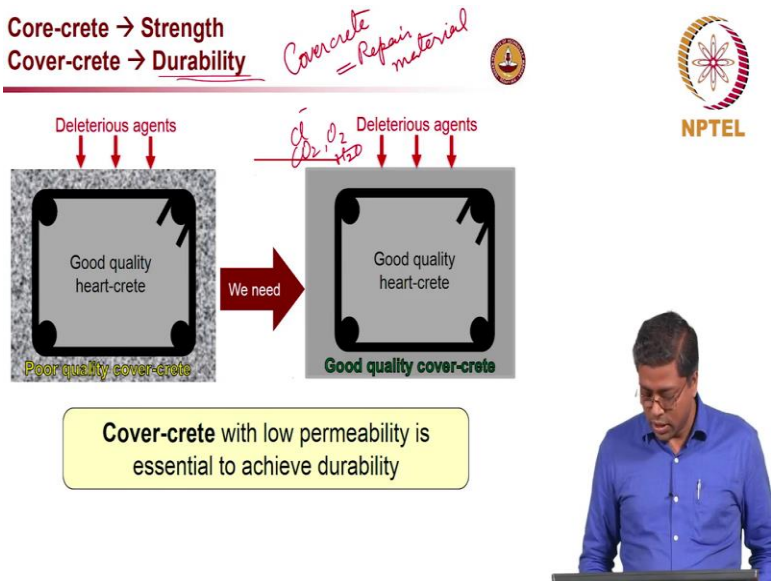

Now, let us look at how important curing is when you talk about durability of repair materials. Now here on the top I have written core-crete enhances the strength or ensures that the concrete structure has good strength and good quality cover-crete is very important for ensuring durability. Now, when you talk about repair, most of the time repair material functions as the cover concrete. So we can say cover-crete is equal to repair material or repair material essentially becomes the cover-crete. Now if you do not cure the cover-crete or do not cure the repair material, what you will essentially get is, as you see on the picture, the peripheral region of the concrete or the repair material once hardened, it will have a lot of pores inside as compared to the heart-crete which is inside the stirrups. Because if you don't cure well, the water which is available at the peripheral region evaporates and if you are not replenishing that water, then that repair material cannot hydrate and become more and more compact or dense, then eventually less permeable cover-create will be the result. So, what we need is for durable concrete is we need both cover-crete and heart-crete to be of good quality that means to be highly impermeable in nature.

So the cover-create or repair material should be of very low permeability or highly impermeable so that the deleterious agents like chloride, CO_2, oxygen, moisture, all these cannot penetrate into the concrete cover. So, that is something is very important, curing is very important to ensure that the repair is actually durable.

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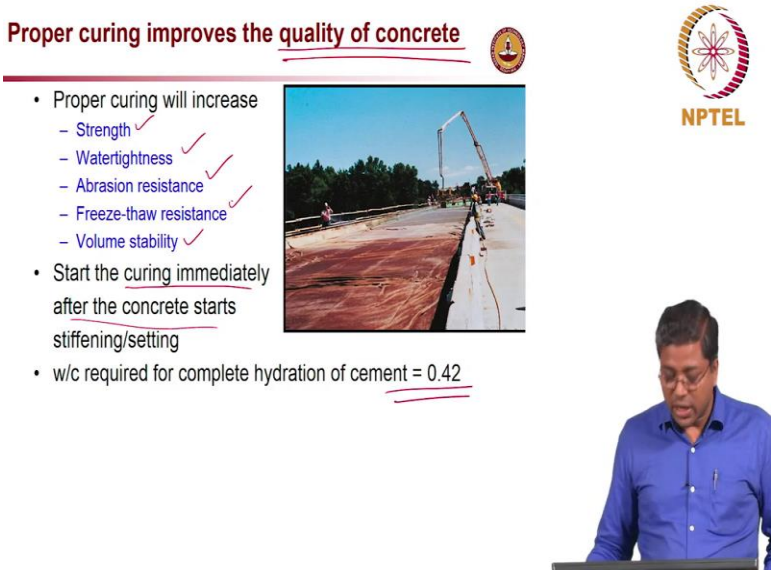

Now, before going into how curing is done I am briefly telling what are the advantages of curing. It will enhance the quality of concrete significantly. So, strength can be enhanced, water tightness, abrasion resistant, freeze-thaw, volume stability, and shrinkage, all these properties are influenced by the amount of curing or by the amount of hydration which the repair material goes through. So, more the curing, the more will be the hydration at the early stage and you will not have other problems. So, durability is very much enhanced if the concrete is cured or if the repair material is cured well. So, when do we start, start the curing immediately after the concrete or the repair material starts setting or stiffening. If it is really plastic you don't pour more water on top, it will deform the whole concrete but wait for until about final setting and then you can start curing but you don't allow the concrete to dry at any point. So, the moment there is a little bit dryness, you immediately have to replenish that with more curing water. Now, water cement ratio required for complete hydration of cement is about 0.42 theoretically.

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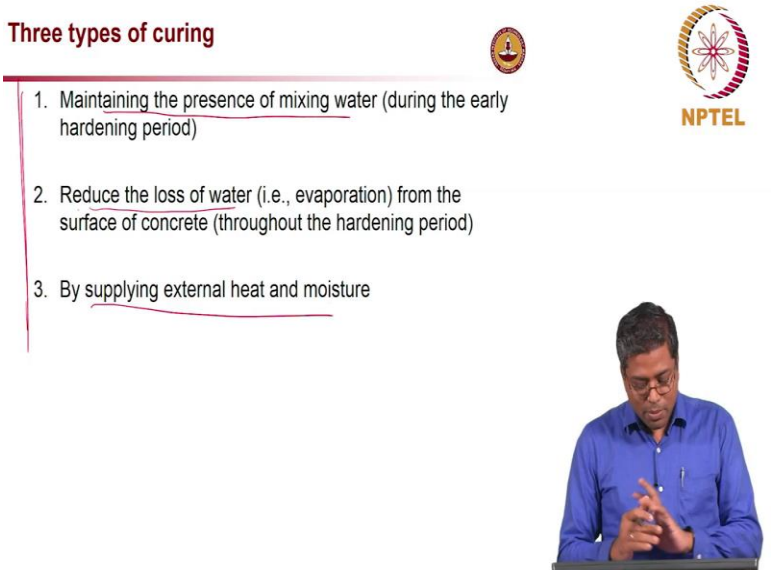

Now, if we can make sure that all that water is available within the concrete, then you will have good curing can happen or good hydration can happen. Now how do we ensure that there are three ways by which you can cure, maintain this presence of mixing water, whatever the water is designed as per the mix design maintain it and then reduce the loss of water in other words prevent evaporation and the third one is supply external heat and moisture, this is mainly steam curing, but in this lecture I am not going to cover the third point, I am going to show you the first two.

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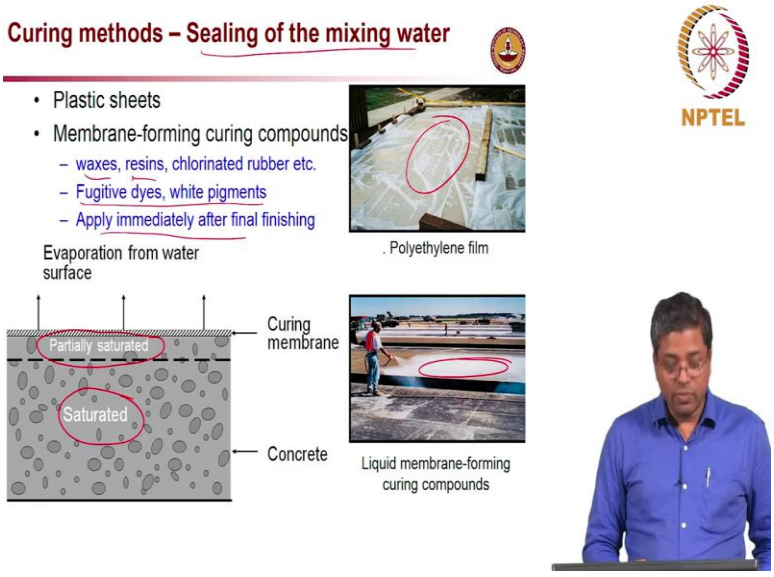

Now, here you can see sealing of the mixing water. In other words, whatever water you added to the concrete, make sure that that is available for complete hydration, how do we seal? You can

see in the sketch on the bottom left, there is this saturated concrete and then there is this partially saturated concrete that means near the surface you lose water because of evaporation. So, we ensure that this does not happen is by applying a curing membrane. We can see here, this is the curing membrane, very thin film of a polymeric material which is applied on the top and that helps in preventing the further loss of moisture from the concrete cover. And you can say how do we know that the curing compound is actually applied, there are now curing compound which comes with color and pigments typically white color. And immediately after the final finishing, you spray this material on the concrete cover which prevents further evaporation and as time passes, this color fades away. It comes in waxes, resin based, water based compounds are also available and also you can put polythene sheet that is also a good way to prevent the further loss of moisture.

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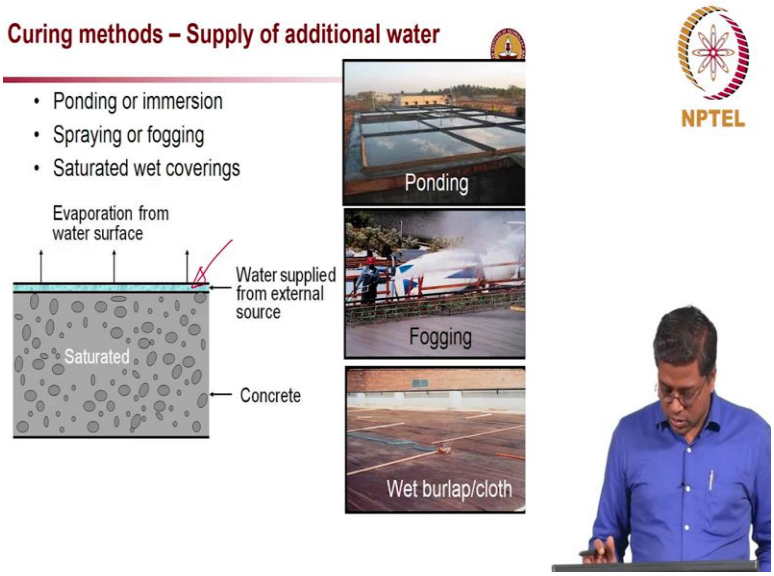

Now, other ways ponding this is also very good, probably the best way is ponding, it making sure that there is sufficient water is available for the concrete. So, you can see here there is a pond of water or a water reservoir on the concrete surface. Fogging and wet burlap or cloth, these are different types, I am going to show you some pictures on this of this wet burlap.

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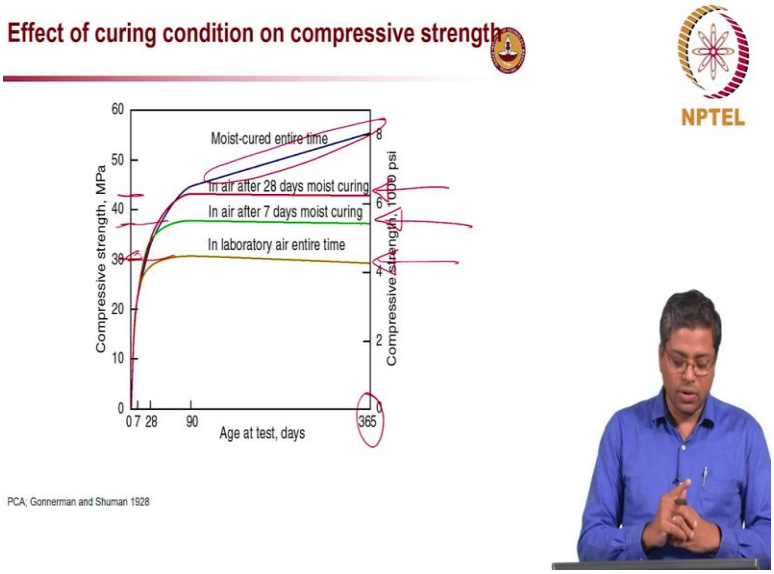

Now let us look at what is the effect of this curing on compressive strength. So, as you see here, the blue curve here is a moist cured condition, moist curing for the entire time, the time goes up to 1 year on this graph. So, you can see that even after 90 days up to one year, there is a slow increase in the compressive strength if you continue to cure, which I am not saying it is practical all the time, but just for our understanding of the importance of curing. And then if we cure for 28 days, 28 days of moist curing followed by exposure to dry air, then you get this red curve which we can say a compressive strength of 43 MPa. If it is 7 days of moist curing followed by air curing, then you get about 38 MPa. And if you don't cure at all, if you did not have moist curing, in other words if you leave it for direct exposure to air immediately after the construction, you get only 30 MPa. So, you can see that there is about 15 MPa difference from no curing to 28 day curing. So, definitely curing influences the strength, final strength of the concrete and more than this it influences durability significantly, if you did not cure the concrete very well the near surface of the concrete will be very porous which will influence the durability of concrete.

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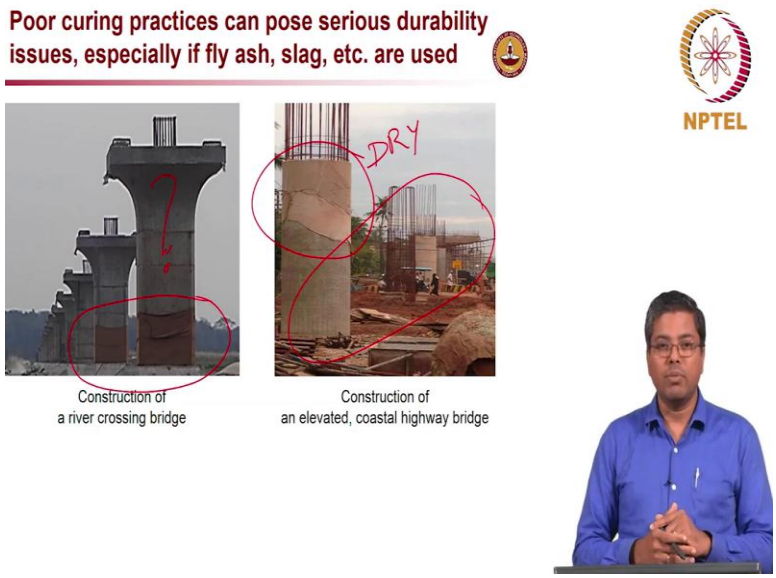

So, I am going to show you some examples of poor curing practice. See in the two slides ago I showed this is wet burlap or ways by which you cover the concrete so that the concrete surface, the near surface gets sufficient water for continued hydration. So, here you can see as probably prescribed in the contract, there might be wet burlap like this. Yes, that is wet agree. But what about this concrete here, it does not get any sufficient moisture for continued hydration. And if we think very carefully, this particular bridge, the bottom portion was constructed earlier than the top portion. So, at any point of time if the practice is very good, the latest portion of the concrete should be having a proper curing in other words the sack should be at the top also. Now you go to the right picture you can see that the sack is at the top but it is unfortunately a dry sack. So, again when I say in the two slides earlier I said wet burlap that means this sack should be wet. It is not just to provide a shade from sunlight, but it is to provide sufficient moisture for the cover concrete and you can see here construction is still going on. It is not that these columns were cast way early and then its curing period is already over, no. I myself took this image. So I know what is happening at that site. So many places, you will see that the process of curing neglected, if it is neglected, the full potential of the repair material will not come.

Now, these two pictures are about new construction, but the same technique or the same principles are equally valid for any repair which you do, because when you talk about repair, you are essentially talking about something which is the outside concrete or peripheral concrete. So, anything which is exposed to the atmosphere need to be very well cured and it need to have

sufficient moisture and make sure that it is not just to provide a wet sack but provide them for sufficient duration and wet, not just dry.

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There is another example where, again wet sacks are provided but not on the entire surface. As you see on the left side, this is a new highway being constructed and there are a lot of places on this concrete which is not getting sufficient moisture, like this point here, there are a lot of spaces in between the wet sacks. We should cover the entire concrete, so that the structure as a whole is fully durable otherwise what will happen is the portion which is in between these sacks, they will not have a very good durability and those little portions will degrade faster than the other portions which are very well cured. So, let us cure the concrete completely, entire surface should be cured not just here and there. On the right side is actually a railway platform where they put a new overlay, I took this picture also, and you can see that only some portions is repaired what about the remaining region on this concrete surface? So, the lesson here is cover the entire surface of the repair material. So, this is very important to note otherwise you will not really have long last repair, the repair will not be durable enough.

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Now, to summarize we talked about different methods of placing repair materials. We talked about trowels, different types of trowels, dry packing, form and cast in place concreting and then form and pump concrete and then preplaced aggregate concrete and also talked about shortcreating with both dry and wet mixes. And towards the end, we talked about the importance of curing, how important it is to cure the repair material properly so that we get the full potential of that repair material and eventually that will help in ensuring that the repair is durable.

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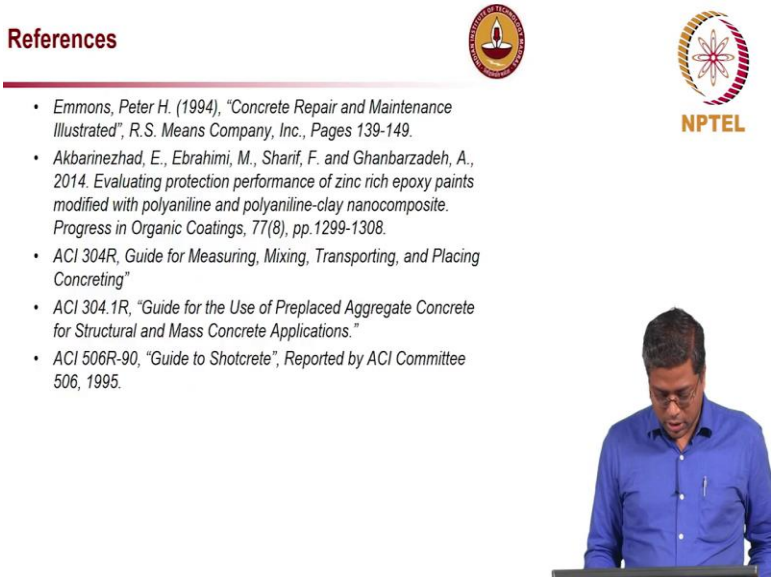

I think this is the references used for making this lecture. And thank you very much.

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