**Maintenance and Repair of Concrete Structures**
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**Module No # 03**
**Lecture No # 13**
**Strategies and Materials for Surface Repair**

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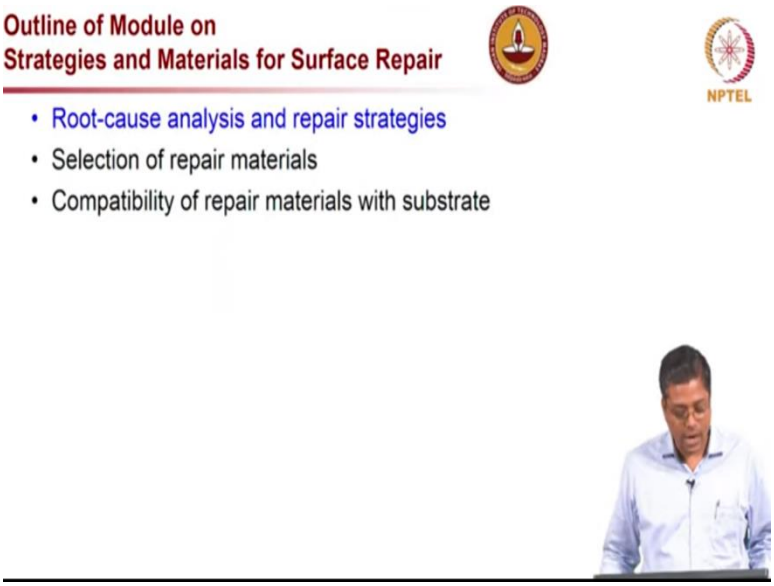


Hi. We will have 3 lectures in this module on strategies and materials for surface repairs and the first one is on root cause analysis and various repair strategie, then the second lecture will be on selection of repair materials and then the third will be on compatibility of repair materials with the substrate.

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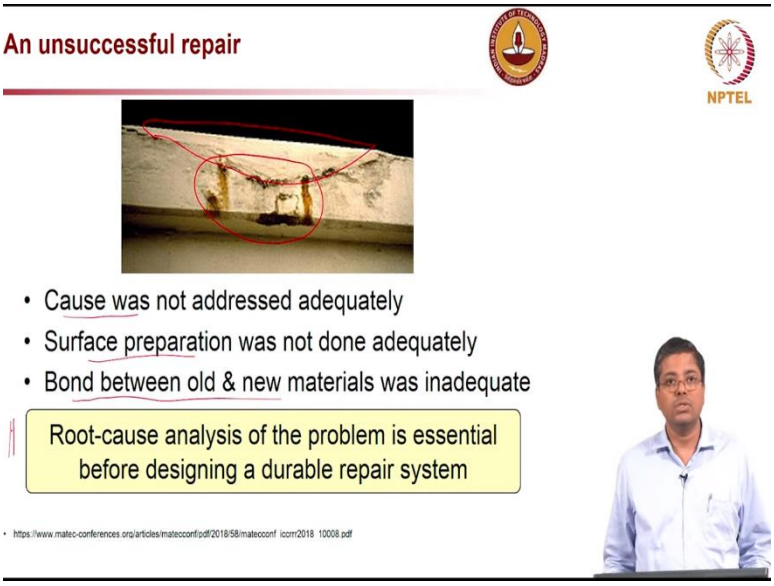


So first let me show you how unsuccessful a repair can be if the root cause is not well addressed. This is the picture showing leakage, the rust stains coming through the repair motor. Unfortunately within very short period of time you have significant rust stains that means the repair is not really functioning or it is not durable.

So why? probably the cause was not very well addressed and probably the surface preparation was not done adequately and also the bond between old and new materials was not adequate because of which further entry of deleterious elements could have happened through the interface between the old and new repair and the substrate. And also for some reason the corrosion continue to happen and then the end result is that the repair was really not successful.

So main thing in this whole lecture I will be focusing on is looking at the root cause. We have to really find what lead to the failure in the first place and then try to avoid that source of the problem. And then based on this root cause we have to design the durable repair system. So root cause analysis is very important.

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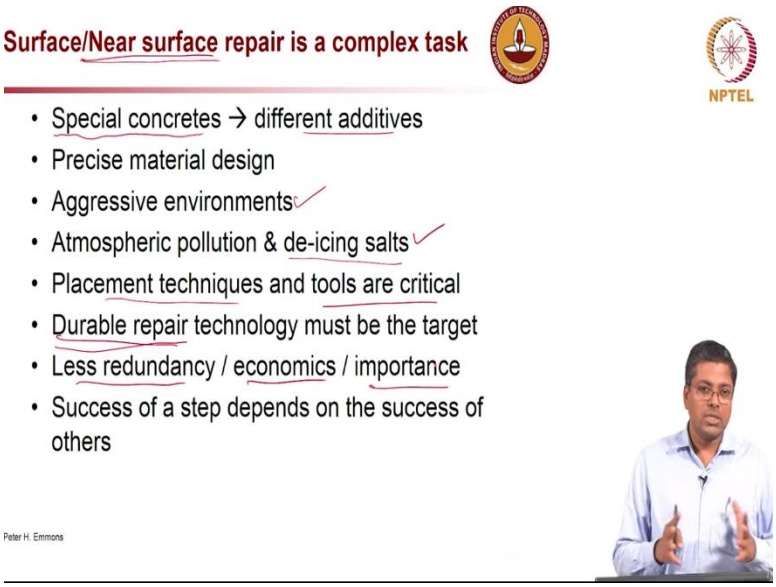


Now one more term I am going to introduce here near surface. This is to emphasize that in the entire lecture the surface means not the very surface of the concrete surface but the cover region. So I am going to call it near surface repair. It is a very complex task because most often you will be using some special concrete materials which will have different chemicals and the robustness of the mix is an important thing. So, precise material design is most often required. Because repair means the exposure was somewhat aggressive and that is why in the first place the structure started showing degradation. So those elements might still be existing. So you have to consider that also, aggressive environments. And atmospheric pollution and deicing salts or anti icing salt, deicing salts and anti-icing salts are very relevant for the places where it is very cold climate, also you can think of other sources of salts like marine exposure or coastal conditions or even chloride contaminated soil or ground.

Now placement techniques and tools are critical. You are not mostly talking about the large quantities of the materials but very small quantities but the way in which it is placed is very important. Adequate and specially designed tools are sometime very critical to complete the work on time with less effort and to ensure that the work is done in a quality manner. Now durable material repair technologies, this durability of the repair is also very important because you do not want to keep on going back again and again to the structure and keep on doing the repair at the same location. So durability of the repair itself is something which is very important to be considered.

And less redundancy, again that depends on how much money is available and how important the structure is and how important that particular repair is to the structure. Let us say if you have a very important structure it will be very difficult to get permission or access to do a repair. So when you get a chance you do a good job and make multiple systems to function together that means redundancy. So if there it's a not a very important structure then maybe you can reduce the number of redundancy but if it is very important structure then you have to really go for multiple systems so that the one system fails at least the other system take care of the structure and ensure that the repair is durable enough. Now success of a step depends on the success of the others. When you are talk about redundant systems there may be also cases for example let us say you are talking about providing a repair material and if the surface cleaning, which is the first step to do, is not well done then the next step which is the placement of the material and ensuring a good bond will not happen. So every step in the process of repair should be given adequate importance and because each steps has its own role.

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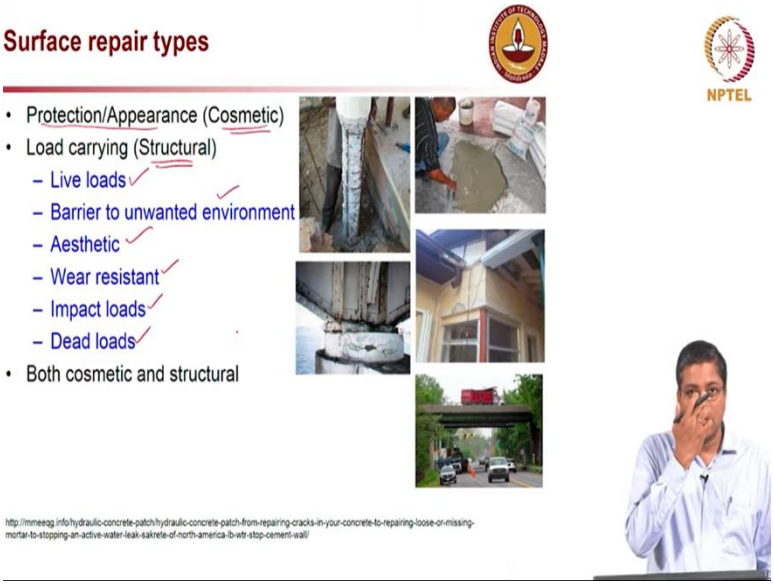


Now what are the different types of repair? Mostly it is either for cosmetic purpose or for structural purpose. So when you are talking about the protection or just appearance like a surface coating or something it might have a durability related issues also. But people look at some time just appearance, so we can call it as cosmetic purpose. Painting for example, it is the first word which comes to my mind when they say maintenance but there is lot more than that when you talk about maintenance. So appearance is very important and then the load carrying features or

the structural repair if you are talking, you have to consider live loads then barrier to unwanted environments then aesthetics, wear resistant, impact loads, dead loads all these different things which need to be consider while thinking about structural repair. And you will see both cosmetic and structural repairs in many places and sometimes both have to be also consider, it not only cosmetic features or not only structural features because even if the structure is very good you want the structure to look good. So cosmetic is also very important to consider. And at the same time in the reverse way you should not worry only about cosmetic because the functionality is the main thing and that should also be considered and given equal importance so both are important.

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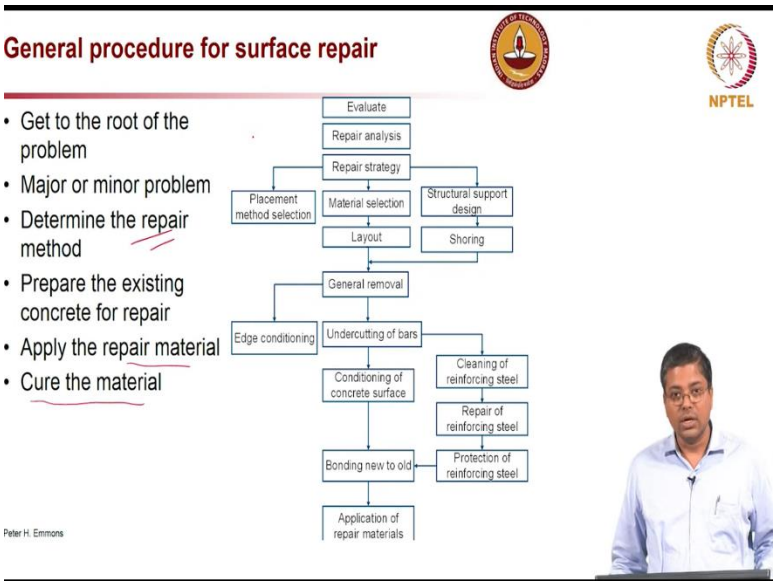


Now general procedure for surface repair, how do we split the whole action into various steps? The first thing is understand the root cause or get to the root of the problem and then see whether that problem is a major problem or a minor problem and then determine the repair method of what is the suitable method for that particular exposure condition, for that particular structural loading and for that particular problems.

So you will have lots of options when you talk about repairs and you have to really see which method is the best in terms of functionality, durability, feasibility, and economics. All those have to be looked at and then decide on a suitable repair method. The once you decide what to do then the next step is to prepare the surface of the concrete or to prepare the existing concrete for the repair work.

And then apply the repair work and then make sure that whatever the repair material is used is also very well cured. Like we discussed in the case of concrete construction, curing is very important. It is not only use of good quality materials like fly ash, slag or silica fume or anything for that matter, but at the same time you have to provide enough moisture or you have to provide enough water for the hydration reaction to occur. So, you will really be able to use the full potential of the repair material which is used. So what I just discussed is given here as in the form of a flow chart. You can just go through it in more detail later.

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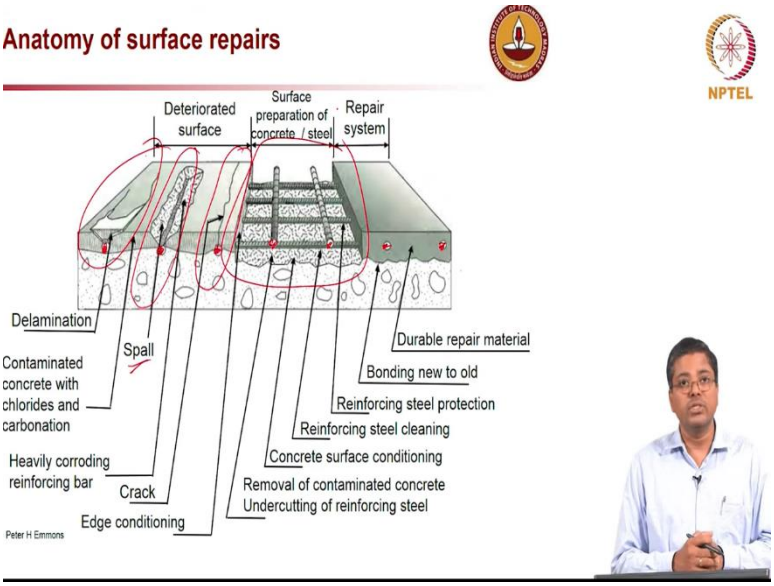


Now anatomy of surface repair, how this is happening. This is a nice sketch which shows what happens. So in case of a concrete reinforce concrete structure, first you will observe some cracks happening. You can see here these are the rebars 1, 2, 3 and initially there is if there is a slight corrosion happening then there will be some cracks and then this crack will further grow or the further corrosion will happen which will lead to delamination of the concrete which eventually spalls the concrete. And then once it is spalled then you have to really do a major repair and basically remove the loose concrete and then cut the concrete as you see in the section here, then clean the reinforcement surface and then apply the new repair material.

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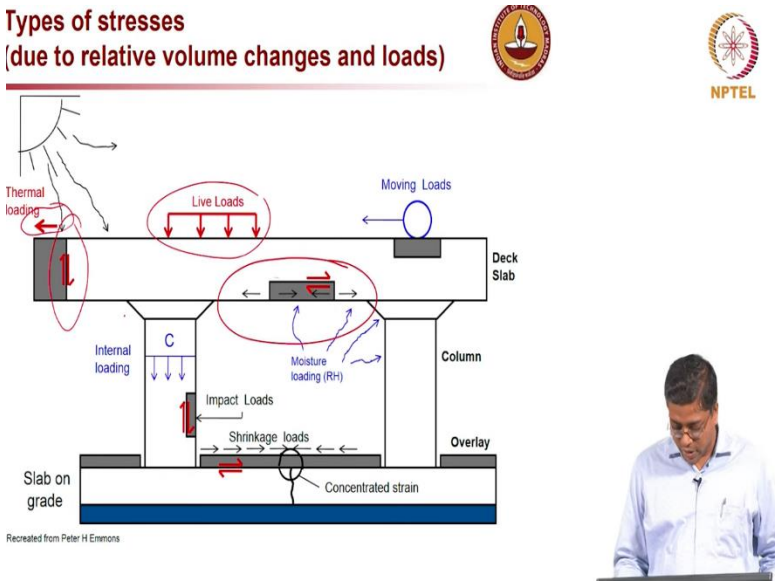


Now let us look at the types of the stresses which act on a structural element. Here I am showing an example of a bridge element with beam, column and a slab on grade setup where if you can see here shear will happen between the slabs and thermal loading will lead to expansion and shrinkage and then live loads from the vehicles and then moving loads we can lead to abrasion and removal of concrete surface. So and here if there is a difference in the moisture conditions or the temperature condition then you can see a lot of shrinkage happening. The grey portions here are different material or repair material as compared to the white region. So you can see that something happens and different type of repair might be required, for example here in this case here if I am actually replacing some concrete at the bottom of the bridge that what are the things which I should worry about? I must ensure that these red arrows indicated for the bond between or the shear stress between the existing and the substrate. So you have to really think about how compatible that material is whether that new repair material is going to shrink as compared to the existing material or the substrate. So you have to really look at many factors before just placing the new repair material.

So it is not only strength some times because most often we see people talking about just strength and then we know put micro concrete and say that this repaired. But you have to really think about the many factors. Ensure that the bond between the existing substrate and the repair material is also very good. So that you do not have many problems later on and you will end of doing into repair of repair later.

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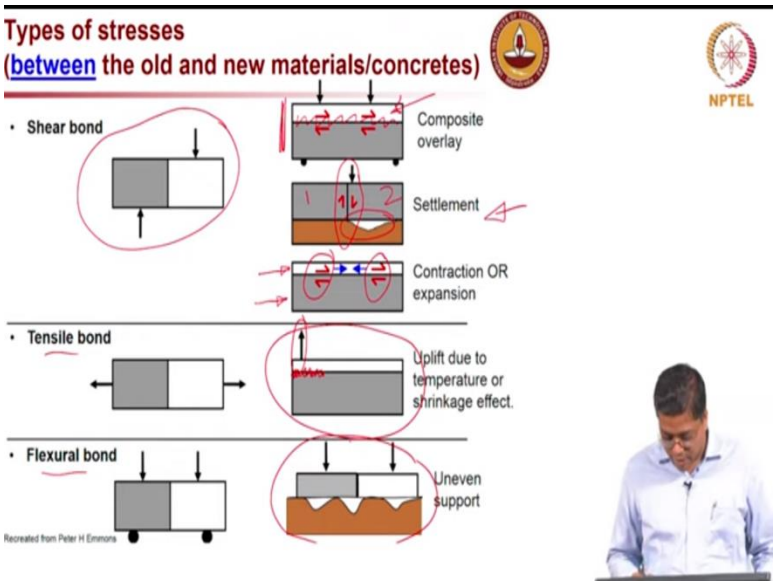


Let us look at the type of stresses between the old and new material or concrete. So as you can see the sketch here we are looking at basically the shear bond, tensile bond and flexural bond. Let us first talk about the shear bond and in case of a composite overlay let's say on a bridge deck you will have an additional layer then when you select this additional layer which indicated by white region, the bond between the overlay and the substrate is very important otherwise you will see probably delamination not because of corrosion, in some cases even water can get in and then it will create significant debonding of the overlay. And also by the flexural action or the bending, both the overlay and this substrate concrete, both this system should bend together, it should not bend like a laminated system. Both should act together so for that to happen the bond between these two are very important.

So in another case if you have settlement, let us say the brown color in this picture indicates the soil below and if you have a cavity or something below one of the slab then again you will have a shear force acting at this intersection or the joint between the two elements, between element number one and element number two, you do not want such things also. And if you are talking about the temperature variation and if the coefficient of thermal expansion for this material is different than for other material then also you will have some expansion or contraction happening, differential expansion or contraction happening which again lead to shear stresses between the top and bottom will layer in this particular system. So we have to really think about the shear bond and how well these elements which are in contact are bonded.

So similarly, tensile bond is also very important. As you see in this case here you can see there is an overlay and let us say there is some traction or some kind of lifting force is acting, tensile bond plays. Traction is horizontal. Let's say if there is a lifting force acting on the overlay then the bond here that is the tensile bond is very important to consider, not the shear bond in that case but the tensile bond.

Now flexural action again if you have an uneven support, the system will try to bend and then how well the joint will function during that bending action. So right now here the joint should be intact to take care of even when the flexural forces are acting.

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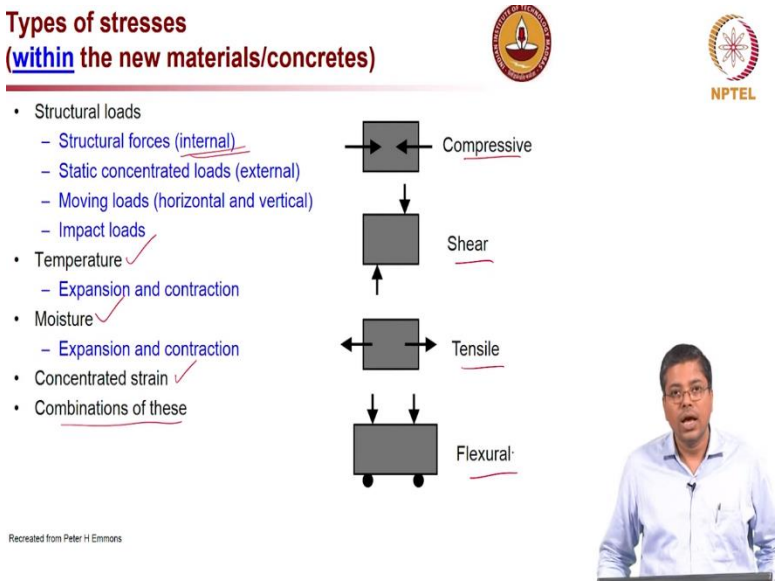


So now let us look at the type of stresses within the new material that means here you can see the sketches are having only the dark shaded or the grey shaded elements. Like in the previous case we had both dark and white or grey and white that was mainly to indicate old and new materials. Here what we are talking is what type of stresses could exist within the repair material itself.

So here also we will have internal stresses develop maybe because of some chemical action happening inside or maybe because of shrinkage like due to the temperature variation or due to the moisture conditions and also you might have concentrated strain or in other words near the crack locations that is. And maybe you may have all this combination also happening in the

repair material. So compressive, shear, tensile and flexural all these have to be consider and these kind of stresses might be exist within the repair material.

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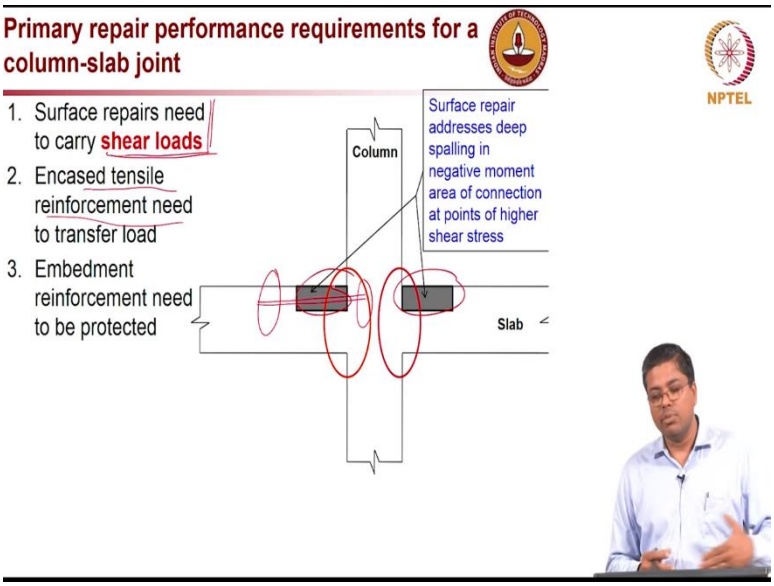


So let us look at primary repair performance requirements or crucial performance requirement for a column slab joint. So the main things is the surface repair, if it is deep enough, imagine this grey shaded region in this have actually got damaged and then you have to repair that region because it is near the support you have to ensure that the new material which is provided will also be helpful in handling the shear loads at that location.

When you talk about the repair material, what the existing system was actually on supposed to take care of, what type of loads and the new material should also be able to take that type of load. Or you can think about what lead to the failure and what is the failure and If I put the new material what is the type of load which will be acting on that new material. So in this case there will be significant shear load so the material the new material should have good shear strength also.

Now you have in this case the reinforcement which is inside. So if you have reinforcement here that also should be able to transfer the load from this portion to this portion. So the repair material has to protect the steel reinforcement and at that same time is able to transfer the load from one point to other point through the repaired region. Now protection also is very important,

in other word we should not have a very poor quality material which will not give sufficient protection from corrosion especially for the rebar.

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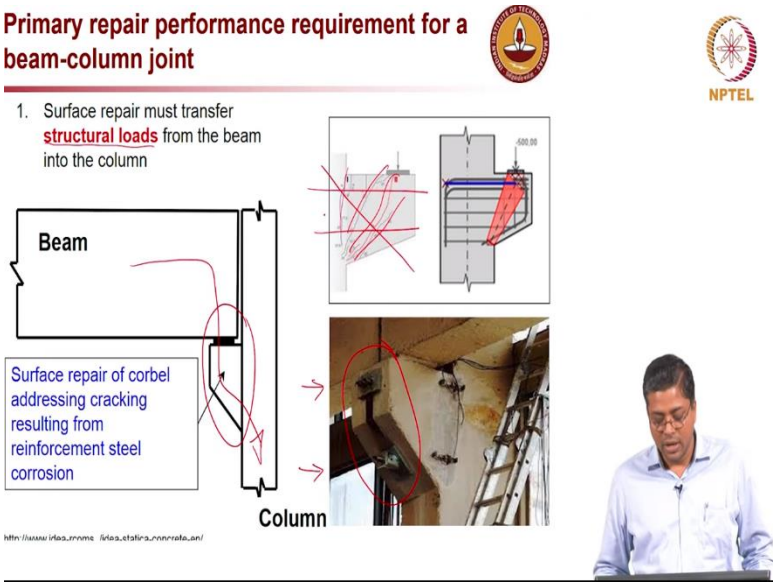


Now let us look at the beam column joint again, typical corbel support as you see here. Now here also it must transfer the structural loads which are coming from the beam to the column. So the load transfer is from here has to be transferred to the column. So we have to see what type of stress is acting and at which point in the corbel system. And if you are in repair project you have to see how you repair with minimal effort that is also very important. Because you may have many solution but the solution is feasible or not is also something important to look at. So as you see here in the picture of the bottom right you can see how the cracks are. So ideally speaking I can say I have to put something like this reinforcement or a tie to take care or to close the crack and then to take care of those loads in the direction perpendicular to the crack.

But, when you talk about constructability that may not be a good way to do so, it might be easy for anybody to actually provide something which is horizontal as you see in the picture at the bottom. In this particular case there are two post-tension ties are provided. You can see one here and then one at this level and both are horizontal because that is easy to work with and install. So we have to really see what the feasibility of the repair is. It is not just providing a solution and that is where it is become very important for the person who designs. They should also think about how the design can be implemented or in practice.

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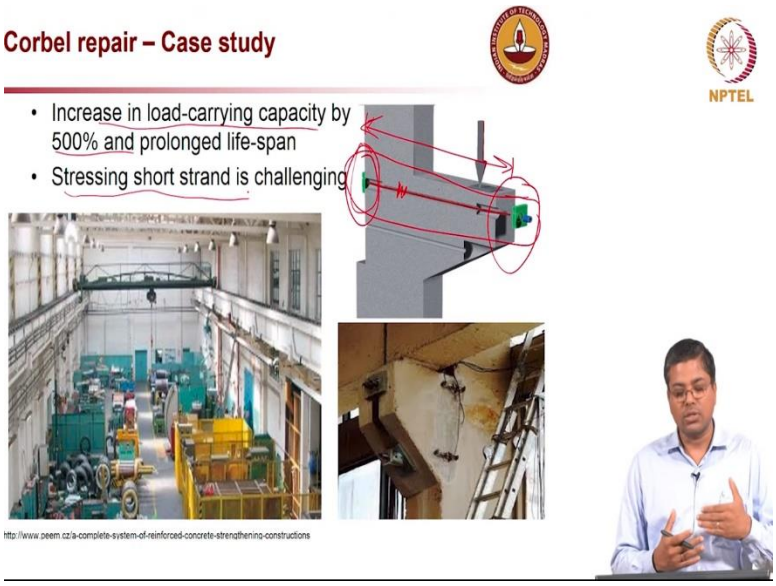


Now this is a case study on this kind of repair where whatever I just discussed you can see here, this is the support coming and this is the tie provided. So again in this particular case if the corbel is very large, if the width and depth of this is very large then maybe this tie going from one side to one end to the of the corbel or from this end to this end might be very difficult to do. If it is very deep then you can even think of how to provide an anchor without really drilling a hole through the corbel, a full depth hole. Maybe you can provide something up to here and then you have some kind of anchoring system depending on until where you can reach and particular loading conditions and the crack locations etcetera. And also in some cases you may not have access to the back side of the corbel. So in such cases also you may have to see whether some kind of anchoring inside or embedded anchor system can be used.

So anyway point is that you have to look at these site conditions, what are the constraints at the site and then come up with a design methodology for repair. Now in this particular case there was demand for increase in the load carrying capacity by 5 times or 500%. One important thing to note here, stressing short strand is very challenging. Because when you talk about a very short strand if you have slit of let's say just a millimeter or 2 or something then that might significantly reduce the residual stress on the strand. So you have to really think about, if it is long strand then it is easy for anyone to stress even if there is a some seating laws something like that it might not significantly affect. But in case of a short tie there you have to really think about whatever the

initial slippage or seating laws etcetera are not significantly high so that still sufficient stress is or pre-stress is remaining in the system.

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Here I just wanted to show you an example where a damage has happened because at the time of erection an impact load can happen and then also improper edge designs. So you can see the damage at the edge is very significant, exposing the reinforcement which will also not look good but at the same time it will also lead to other problems. So erection is also something very important to look at. During the erection we should not allow any impact load to happen.

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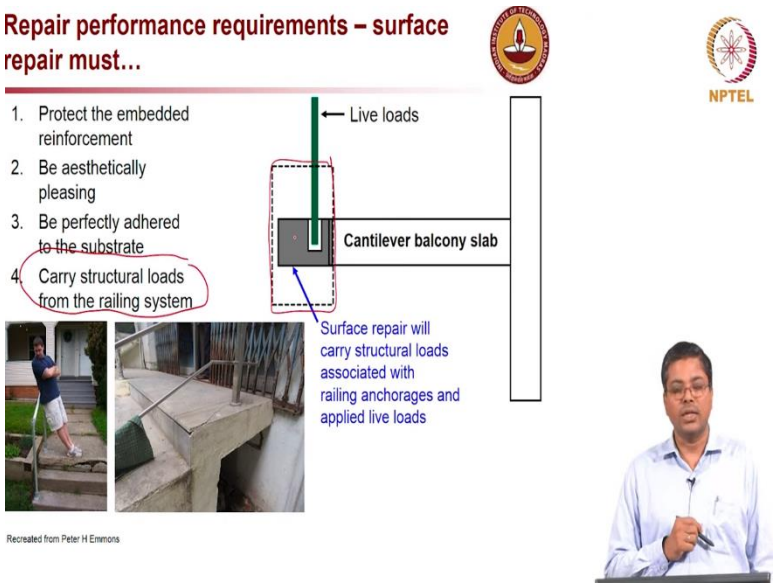

Now another thing is repair performance and what are the requirements when you talk about surface repair. They must protect the embedded reinforcement that is one thing and then it should look good or aesthetically pleasing. And the repair material should be adhered well to the substrate. Now this one on the right, side the sketch is a very typical damage which we often see in wherever we go staircases you are in a railing you can see that to provide maximum space available on this surface there is a tendency to move the railing to the edge as much as possible, to the left end in this case and which provide very limited space for the material outside of the rail. So in some cases this becomes so thin that it is very difficult to prevent the cracking. As you see on the picture on the bottom you can see that if a person is leaning like this there is a significant stress acting at the concrete right next to the bottom of the rail and there is a cracking, you can see here there is this origin is cracked. So to prevent this type of cracks what we have to have is significant material on the outside of the railing. As you see here you can see all the entire railing or the particular repair region should be well addressed. And it should be able to take the structural loads coming from the railing system. So if you know that this much load is coming maybe you can actually use a higher strength material and without really increasing the size of the element you can still get the strength which is required.

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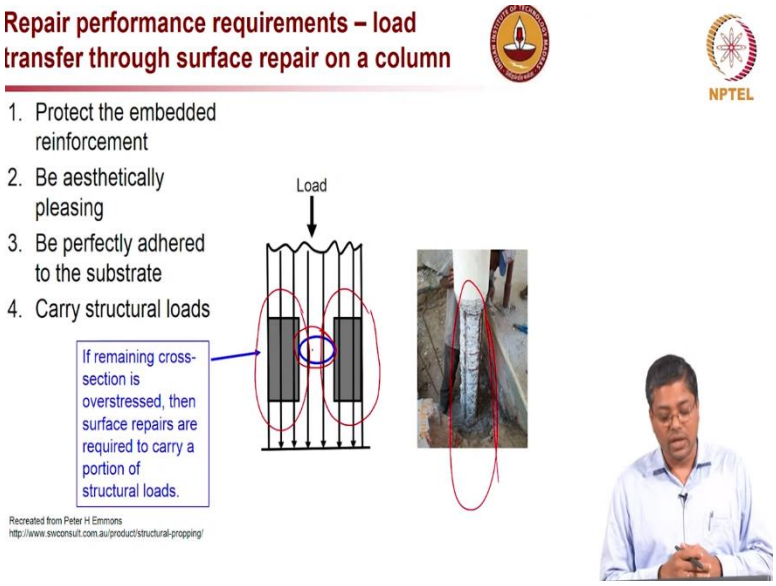


Ok now when you talk about the load transfer through surface repair on a column, you can see an example here at the bottom right where a column was experiencing significant corrosion. And the entire cover concrete is removed at this particular stage and gone for replacing with a new

material. The stress level in the concrete should be noted. That means if the amount of removal of the concrete is very less or concrete is removed only near the surface then the surface repair may not require carrying the structural loads because these vertical lines which you see here are actually the stress path (next slide). And then what you see is even if the repair material which is the grey shaded region, is not taking any load still there may not be significant increase in the stress level in the remaining portion or in the substrate concrete.

But if the amount of repair material is more like in this case you can see here (above slide) or in other words the there is a significant damage and more cover concrete is removed and then you are replacing that with repair material. This is probably the case as you see in this picture that significant amount the entire concrete cover is removed in this particular column and then you are providing a whole new cover concrete. In such case if the cover concrete is not taking the load then the stress taken by this concrete which is marked by the blue ellipse at the center that might be significantly high. So it becomes very important for the repair material to be a able to take the load. So the load should go through the repair material. In other word load transfer should happen through the repair material.

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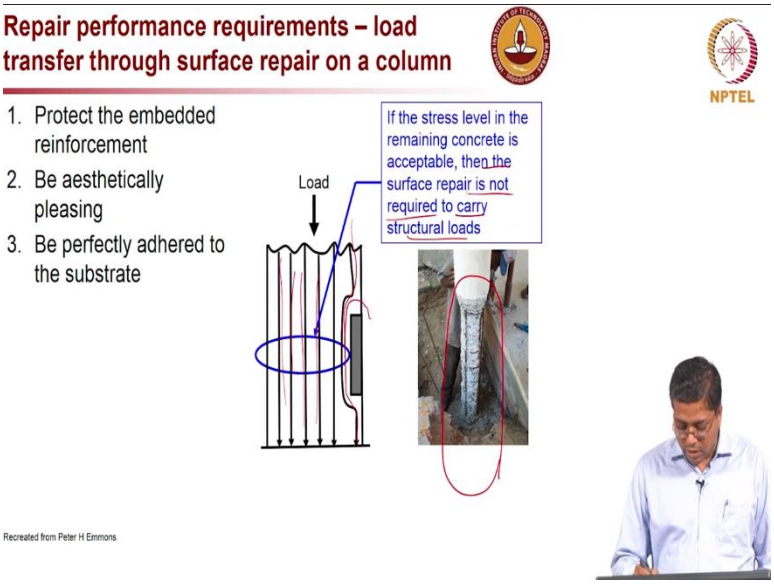


If the thickness of removal of material is less then it is not always. But when you go for a deeper repair then definitely the repair material should take the load and should be able to transfer the load. And when I say transfer the load this point number 4 is very important, they must be able to carry the structural load.

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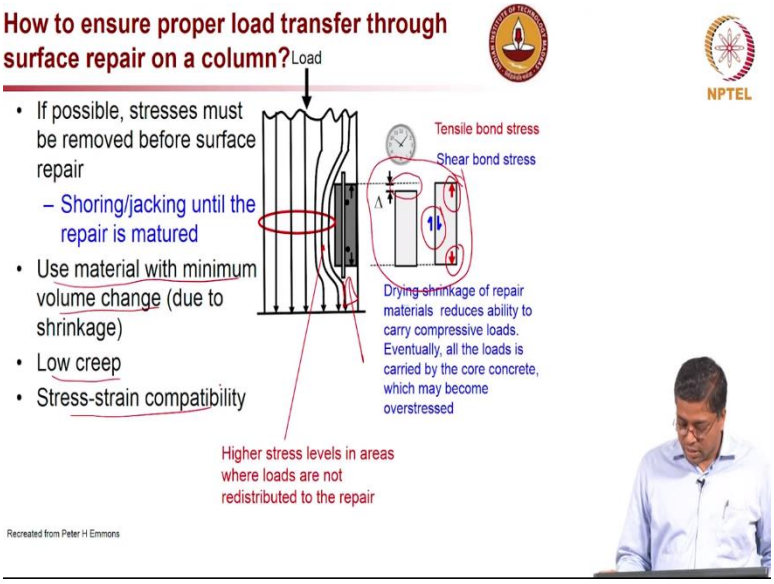


Now how to ensure that this proper load transfer is happening because repair material is a new material and the column which is already there is of old material which might have under gone all the shrinkage, all sort of such mechanism and further deformation might be less in that material, but in that case of repair material it is still new material so it might have might experience shrinkage unless you ensure that the repair material is having very limited shrinkage.

So anyway let's say as a theory if it is going to experience some shrinkage, this shrinkage will develop some shear stress between the substrate and the repair material and that will lead to reduction in the height of the repair material and it might also happen, let's say coefficient of the thermal expansion of the repair material is different from that of the substrate concrete and maybe there is some expansion happening let's say there is a lot of moisture getting into this column and then the repair material expands then you will have shear stresses because of the expansion. So both expansion and contraction you have to consider. So basically the dimensional variations can happen. Now how do we ensure that even if there is a dimensional variation there is still a stress transfer or load transfer? We can provide a rebar as it is shown here, provide a rebar which goes through the repair material and transfer the load to the substrate. So this is also something very important especially when you are talking about structure which has significant loading etc.,

So the selection of material becomes very crucial here. You have to use a material with minimal volume change that means either due to shrinkage or due to creep and then essentially you have to have good strain compatibility also.

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Now this is an example showing more details of this particular repair work. Probably there were lot of capillary pores in most of the concrete columns and that absorbed moisture from the ground during the raining season. You can see that columns are all damaged about 1 or 1.5 meters mainly because of the capillary suction of the moisture from ground and maintaining it wet and then that leads to significant corrosion. Because why I am saying that this portion of the concrete is intact it does not have any problem that. So definitely moisture is the problem here. So if you want to repair this structure you provide a new concrete and make sure that that new concrete is actually having good resistance against capillary suction also or water sorptivity of the concrete can be checked before using it.

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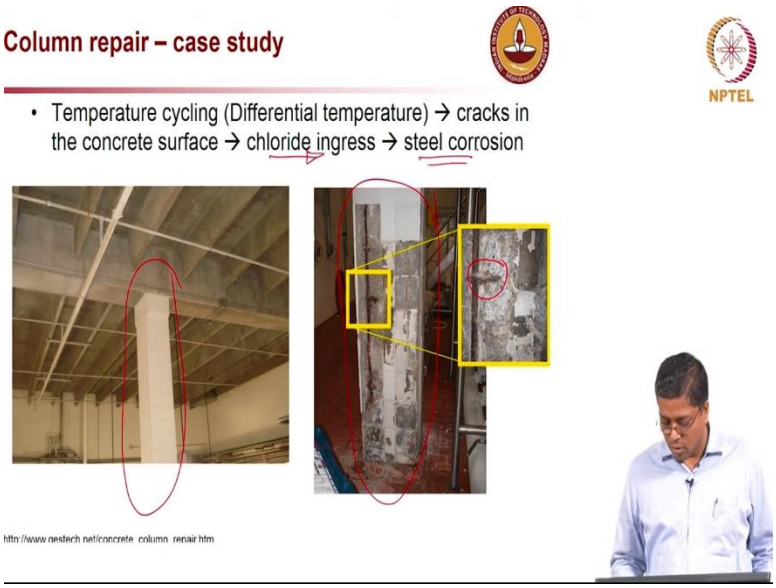


Now it is another example on column repair, a case study got this from the internet, but I found it is very interesting and good case study to discuss. You can see the picture here which is before repair how it looks at the top. You can see that top of the column is good but at the bottom of the column this is how the situation was. You can see significant corrosion and which led to delamination. This was a factory, a chemical plant where there was significant variation in the temperature and at the same time the ambient environment had significant amount of chlorides. So chloride ingress was high especially where the temperature was more and which was at the bottom there was some equipment which are pumping high heat. So you had high temperature and at the same time chloride environment which led to ingress of chlorides especially at the bottom of the column and then eventually led to steel corrosion and how do we repair?

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The first thing is to put shoring, basically the column is destressed or there is no stress or load acting on the column. Let me just go back to previous slide here also you can see that the load acting on the column is completely released, you can see shoring on this over here and these are the supports provided the steel props. Releasing the loads from the columns is very important when you talk about repair. So here also you can see there is this shoring to release the load from the column and then column is prepared for high strength concrete pour.

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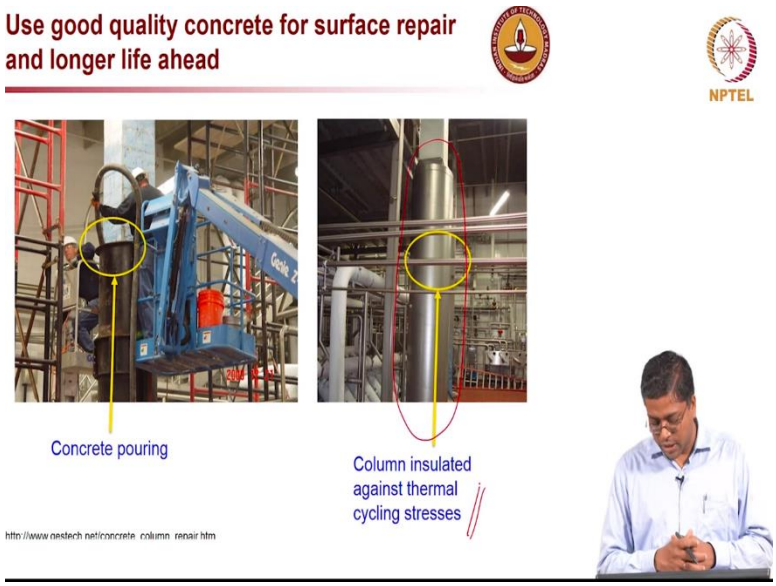


What I mean bY prepared for is surface preparation. You have to remove all the loose materials and clean the reinforcement, remove the spoiled concrete and then provide nice form work. And also in this particular case they changed the shape from rectangular to circular shape and the

concrete in this case is SCC was poured because it is a chemical plant so always you will still have the aggressive environment which existing from earlier. So we have to consider that the environment is not going to change. So the only this is we can change is quality of the concrete cover. Thermal cyclic stresses to be considered, the particular concrete which used was selected with very low coefficient of thermal expansion and at the same time covered with a metallic casing. In this case you can see stainless steel pipe is provided so it looks very good right now

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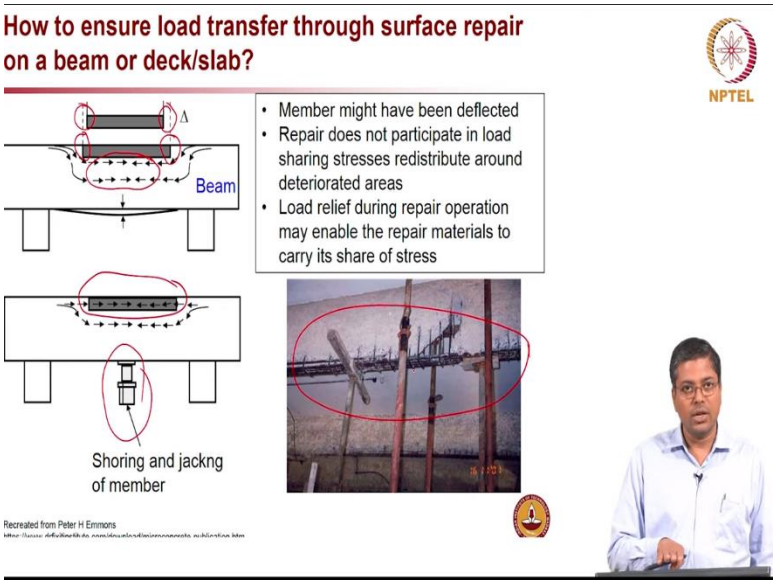


So another example for a beam repair, you can see how the stress flow can happen first. If the repair material which is the grey thing here, either shrinks or expands, in this example I am showing the shrinking, what will happen is it will get disconnected from the substrate, you can see here this is a shrinkage happening, and there will not be direct load transfer through the repair material when it is trying to flex or bend.

So what will happen is that stress will be more on the substrate or the remaining concrete will have more compressive stress or in other words this region will experience more compression because the repair material is not taking any load. So how do we prevent this from happening? First thing is you have to provide a shoring, lift the beam or girder upward and get the horizontal shape or all the deflection have to be removed, made it to zero and then you place the repair material so that when it tries to bend again that repair material will also come into action. You can see very clearly on the bottom picture, these arrows are provided inside the repair material that means the load is transferred through the repair material also. So again the picture on the

right side shows an example where something similar to shoring is done. Again in this picture we are talking about the repair at the bottom surface not on the top surface.

Shoring is important then you have to see what type of material and where it is applied. Release all the load acting on the member, apply the new material and then ensure that the new material is in contact with the substrates. So that when the load is applied it is taken by both the new material and the substrate concrete.

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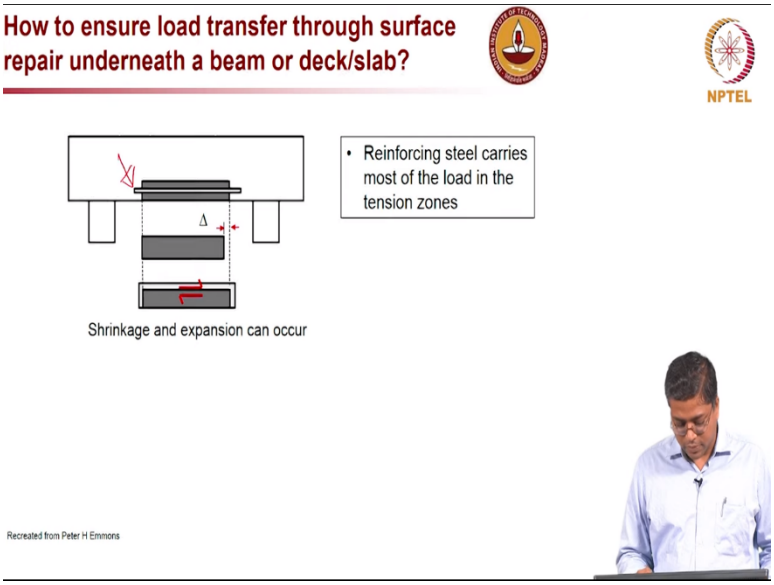


Now how to ensure the load transfer through surface repair underneath a beam? Now here you can see a rebar also provided because here when we talk at the bottom because the type of the load is tensile load which is coming there. When there is deflection in this beam tensile load which is coming so that repair material should be able to take provide adequate protection for the rebar because most often the rebar has to take care of the tension. So you provide a rebar and ensure that the rebar is actually well protected so that it can last long and then provide that the adequate or the additional tensile strength required.

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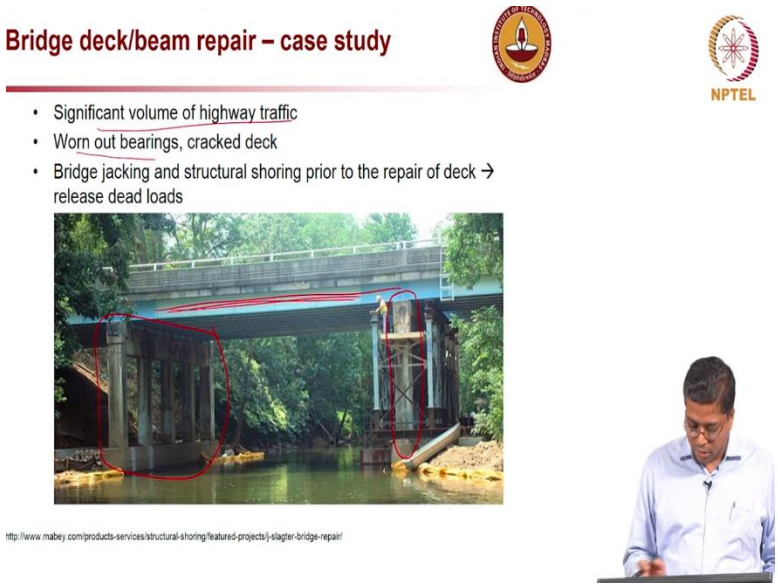


Now this is another example you can see a very highway with a significant volume of traffic. But the bearings were worn out. This is something which happens in many bridges the neoprene pads or shoes in a those joints element get really degrade very fast because sometimes they do not get sufficient importance at the time of construction and also it gets overloaded or especially for the fatigue type of loading or repeated loading if they are not well rated then those materials will fail where the girders or steel probably are performing well.

So point I am trying to make here is every element in a structure is very important. It is not that only the big the large girders or columns are important even the connections are also equally important for good performance of the structure. Because if the connections do not perform well then that will induce the additional loads on to the structural elements and the joints might fail. And then you will see this significant deflections and girder comfort will not be good and you will also see the impact loads acting. So these are all something more serious attention need to be given even for these small elements.

Here also you can see shoring is done, the load from this deck this girders is directly transferred to the ground so that there is no load acting on the on the column and bend cap here. So repair is actually happening on this and the bend cap on either side.

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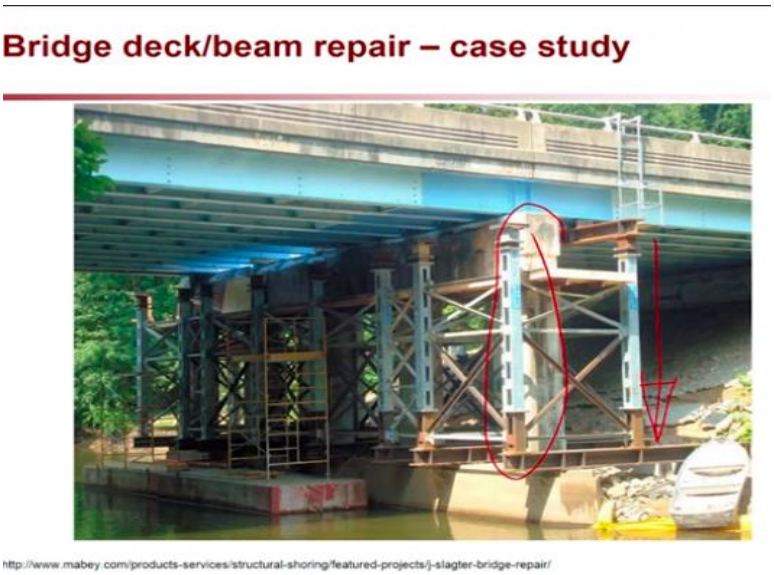


Now you can see little bit closer image here this is the portion where repair is happening. And this is a good support, the load is directly transferred from the steel girder on the top to the ground and you have a concrete bend and the concrete column.

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I can see here this is again the concrete girder beam which is repaired and you have concrete columns also. And here the load from the steel girders is directly transferred through this, through these steel columns and into the ground.

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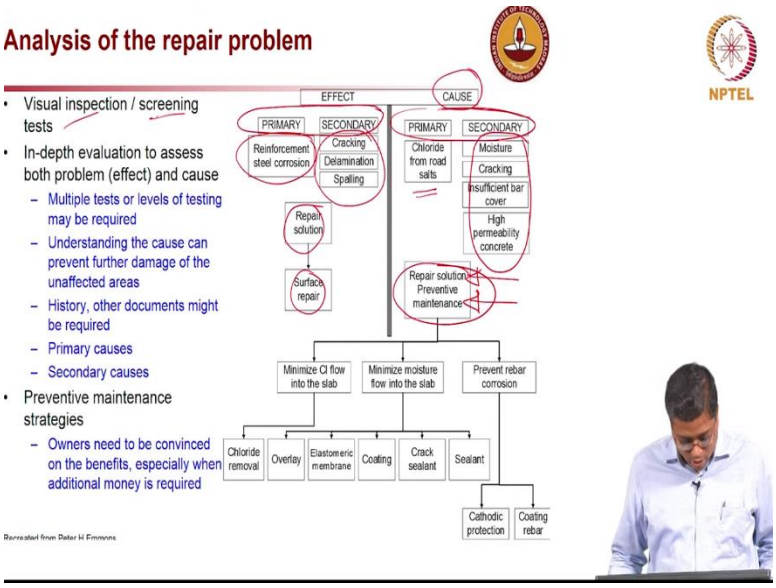


Now analysis of the problem, first thing when you go for inspection, What all thing we need to look for? And then try to access the primary and the secondary effects which is probably visible when you are at the site, you can see what things are visible no deep thinking at that time but first you see what is visible to you. One thing which should be visible is the steel reinforcement is corroding and the other things, because of the reinforcement corrosion you may also have cracking delamination falling etcetera.

Now what to do you may have to go for a solution which could be a surface repair. And if you say these are the primary and secondary effects which are manifestation of the problem and you can actually see them. Now why they happen that is the cause when you look at again you can split the cause in to primary and secondary. If you are talking about chloride from this salt or whatever the external environment marine's environment or chloride rich ground water whatever it is there is presence of chlorides and what that will do in case of more presence of moister is it will lead to corrosion and cracking. If the rebar cover depth is very limited or the quality of the concrete is very bad then this chloride will ingress. If you do not have moisture, if you do not have cracks, if you have sufficient cover and if the concrete permeability is very low then even though there are chlorides outside the concrete they may not be able to enter it so easily.

So it is a combination of both primary and secondary causes, must be looked at and identify then accordingly figure out what is the repair strategy and then the preventive maintenance, because it is not just repairing and after repair you had to ensure that the repair is not going to experience

the same problem. So that is why here there are two things, one is repair solution and then also preventive maintenance for the repair. And all these have to address in the future times. So again this corrosion or the structure got damaged because of something which was not done earlier. So learning from the lesson, we should repair and make sure that such repairs are not needed later on. So that is why preventive maintenance strategy is very important to know.

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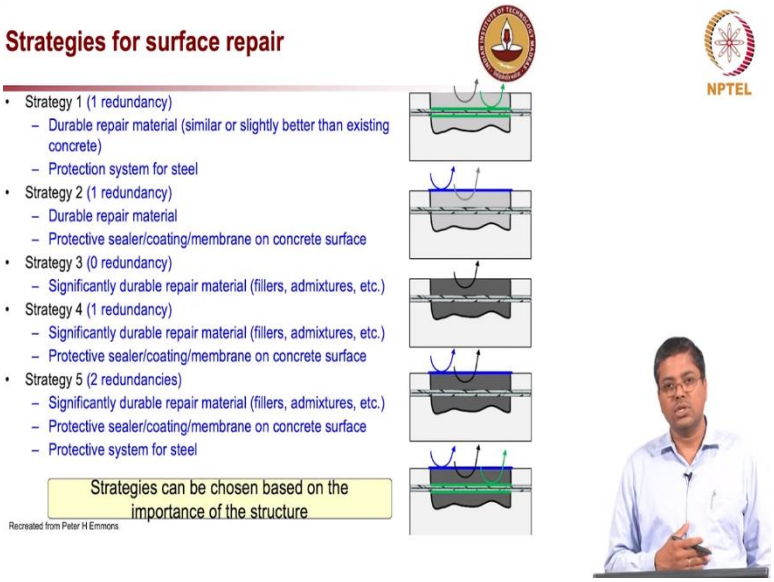


Now after all these if you are talking about what are the strategies which we should adopt because in the next lecture we will talk about different type of the repair strategies. Here I am showing 5 sketches on the right side where you will notice that the black or the grey portion is the repair material, you have reinforcement going through and on the first one here you will see that there is green coating also which is coating which we provided to the reinforcement and so in the system one or strategy one you are seeing one redundancy that means two repair system are there. One is the repair material itself which is the grey shaded region and the second which is the redundant system, the coating. So both this will help in preventing corrosion of the reinforcement.

So why we are calling redundant is let's say the repair material itself, even though we recommended a good material, for some reason did not function very well and the chloride penetrated through and reach the rebar. Now for giving the protection for the steel, there is an

additional coating available, if it is in good shape, if it is in intact or crack free or damage free coating then that will protect. Which is the idea of good quality fusion bonded epoxy coated rebar but some times that they do not work because of cracks and etc. on the rebars or the damage on the rebar or even UV exposure of the rebar so these kinds of things you have to ensure.Point is there are two systems working there to protect the steel from corrosion.

In this strategy two where you have one redundancy, now the two systems here are the repair material which is the grey shaded region which is this and also you have a surface coating provided or coating provided on the surface on the concrete not the surface of the steel reinforcement. So first protection here comes from the surface coating and if that fails then you have a good quality repair material which will provide additional protection to prevent the entry of deleterious elements from the external environment and which will eventually lead to corrosion.

So multiple strategies can be adopted and of course we cannot provide all this strategies for all the repairs available, but we have to think about the money available. And at the same time we also have to think about are is it really required, how important the structure is or how easy it is to do. Let's say you are suggesting all the 3 repair system like as you see here in the strategy 5, but it is not really an important structure and it is probably very easy to go back and repair after some 10 years or something. In such case you may not want to go for all the redundancies, but if you are talking about a very important structure, let's say the bridge which is in down town or in a very important intersection or a fly over where it is not easy all the time to go and repair to get permissions to repairs and also there is lot of heavy traffic so in deviating the traffic is not that easy. In such cases you want to have uninterrupted traffic system. In such cases you may want to go for multiple systems which will function, if one fails the other will take care of this structure and then it will help in enhancing the life of the repair itself. So these are multiple strategies or different types of solutions available, depending on the money available and depending on the importance of the structure and we have to decide which strategies to be adopted.

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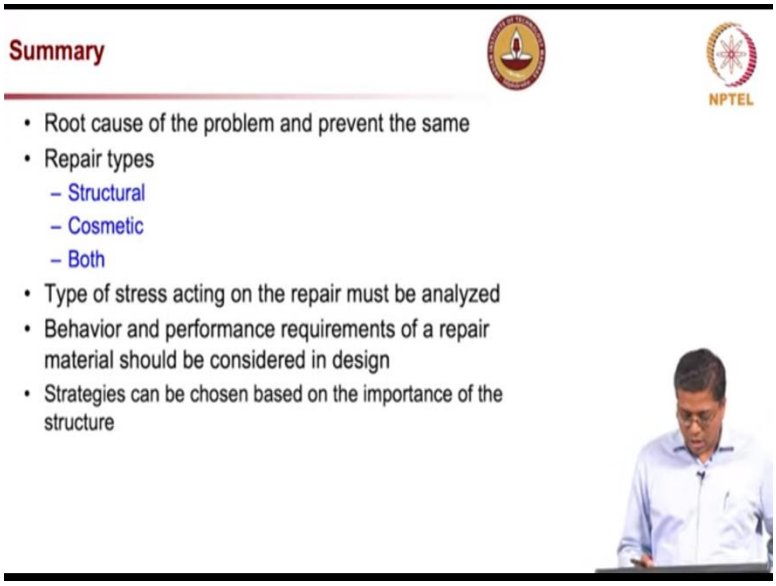


So to summarize, when you talk about strategies and repair materials, the first thing is you have to look at the root cause of the problem, what lead to the problem in the beginning and then prevent the same in future that is also very important. One example, let's say the corrosion happen because of a broken drainpipe, the first thing to do is before even repairing the structure that you have to go and install a new drainpipe so that the moisture attack is not there. So which we often see in many cases that you do not really address the root cause but keep on repairing the structure. So from now on I request you to look at root cause of any problem and address the root cause first. And we talked about different type of repair, sometimes it could be structural reason, sometimes just cosmetic and some time we have to consider both structural and cosmetic. And then we looked at type of stress acting on the repair materials, sometimes the stress is because of the reactions happening within the material and sometimes it might be because of two elements or between the two elements, in other words between the repair and substrate. So you have to see what are the type of stresses acting, you have to think about the shear bond, tensile bond, flexural bond etc., sometimes in a compressive stresses.

So these stresses will lead to some interaction between the two materials which might affect the bond. So bond strength between the material systems is also very important. And we looked at also the performance requirements of a repair material like this bonds strength etc. that is important. And also we talked about, when you repair a column or a beam first thing to do is release the existing load and then go for repair so that the repair material will also help in transferring the load from the substrates through the repair material to the other portions of the

concrete. So load transfer is very important. The repair materials are not there just for cosmetic purpose but they are also supposed to take part in carrying the structural loads.

Now lastly we will discussed about the different strategies, there are multiple strategies are available. But you have to look at the economics and also importance of the structure and importance of the repair and then decide whether to go for redundant protection system or not.

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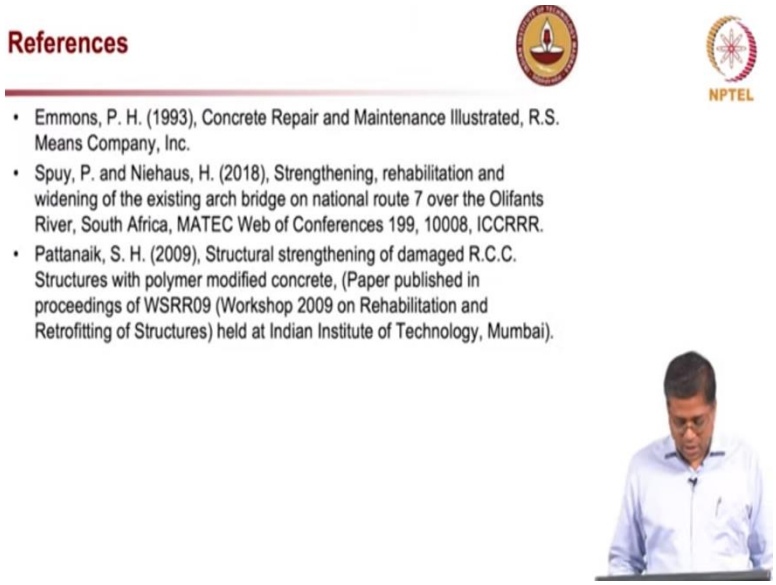


I think with that we will stop and these are the references used for making this presentation lecture. Thank you.