Maintenance and Repair of Concrete Structures
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Lecture -16
Surface preparation and protective treatments
(Surface preparation methods for concrete and steel)

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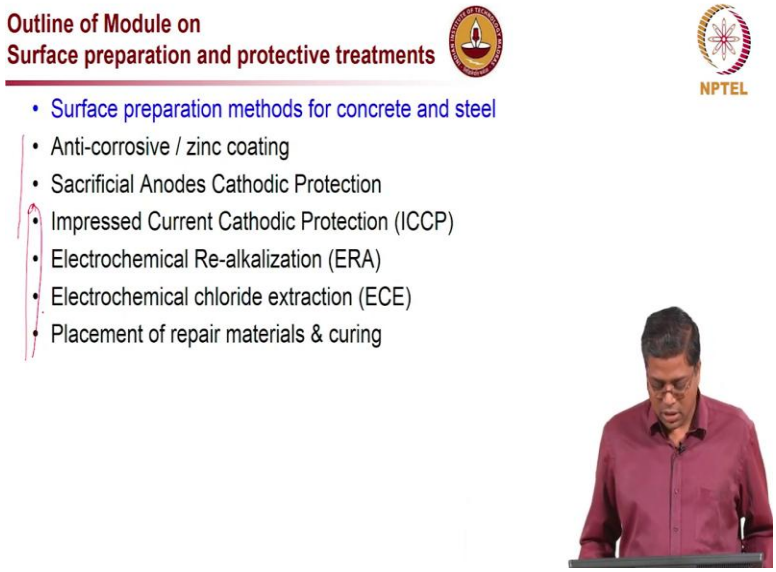

Hi, this is a module on surface preparation and protective treatments. In this, we will look at surface preparation methods for both concrete and steel. In the second lecture we will look at Anti-corrosive and or zinc coating and Sacrificial anode for cathodic protection. And then in the third lecture we will focus on impressed current cathodic protection and then electrochemical Re-alkalization, electrochemical chloride extraction.

And also the placement of repair materials, curing and their importance. So, this is how the module is split. So, today we will look at surface preparation methods for concrete and steel.

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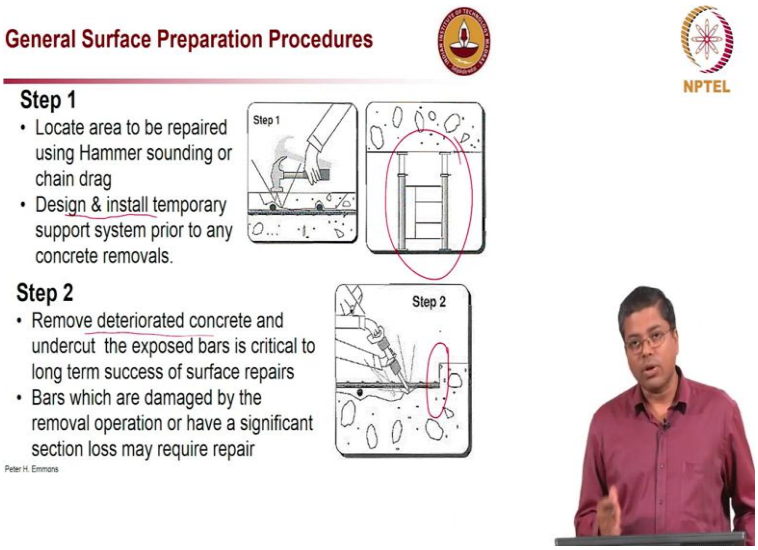

We will look at what are the general surface preparation procedures and then later we will talk about different type of tools available for various cleaning and cutting and all that steps. Now, locate area to be repaired using hammer sounding or chain drag that is the step 1 and then you can see here whether you do some non-destructive testing or whatever way we talked about that in our previous lectures on delamination and how to detect delaminated area in concrete.

Then, the next step in the process is design and installing temporary shoring system. That also we talked earlier then comes the removal of the deteriorated concrete. So, as you see in this picture, you need to use a jackhammer or some kind of tool to remove and the bars which are damaged by the removal operation or have a significant section loss. So, in this process, let us say in the process of removal of the concrete, the rebar should not get damaged.

And in case if something like that happens whether you cut the rebar or something whatever it is. If it happens, then you have to replace those rebar. For example, if I am cutting this region here, this part here. If I use a saw cut and then to cut the edge, in that process, if the rebars are cut, then definitely that rebar need to be replaced. Even if it is a partial cut, there will be stress concentration so you have to replace that rebar or better is to avoid such things.

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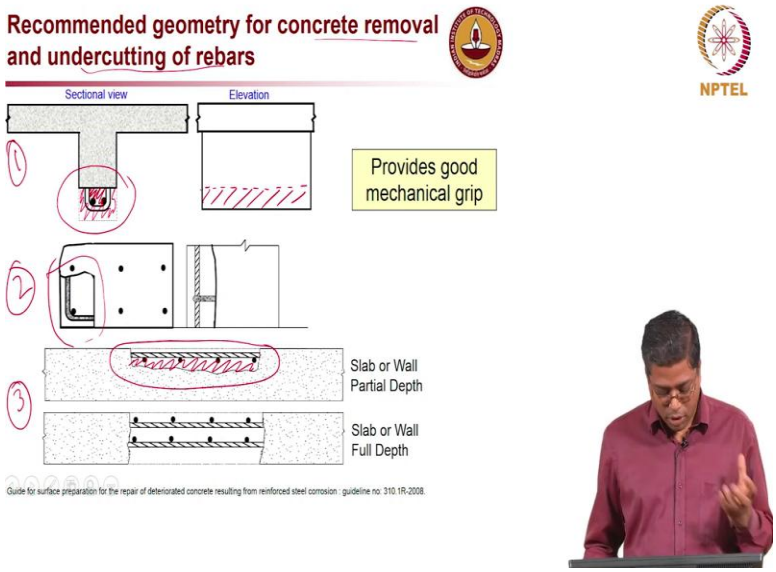

Now, recommended geometry for defining the removal region or for defining from which location concrete should be removed and also for undercutting. So, if you are talking about a beam as you see in the top left, this is a sectional view and the right side is the elevation of the same beam, this portion has to be removed. In other words, this much region has to be removed, the hatched region has to be removed. And that ensures that the new concrete or the repair material will also go and fill in this space inside the stirrups that ensures better mechanical grip and the concrete or the new repair material will not fall downward.

So, this is the repair material. Now, if you are talking about an element something like this, this is the number 2, this is number 1, this is number 3. If you are talking about something like this a corner or something, then again you have to make sure that there is an under cutting process or in other words, the concrete from behind the stirrups or the rebars need to be removed. In case of a slab again here we can see that the concrete below the reinforcement like this concrete here is removed so that the proper grip is provided.

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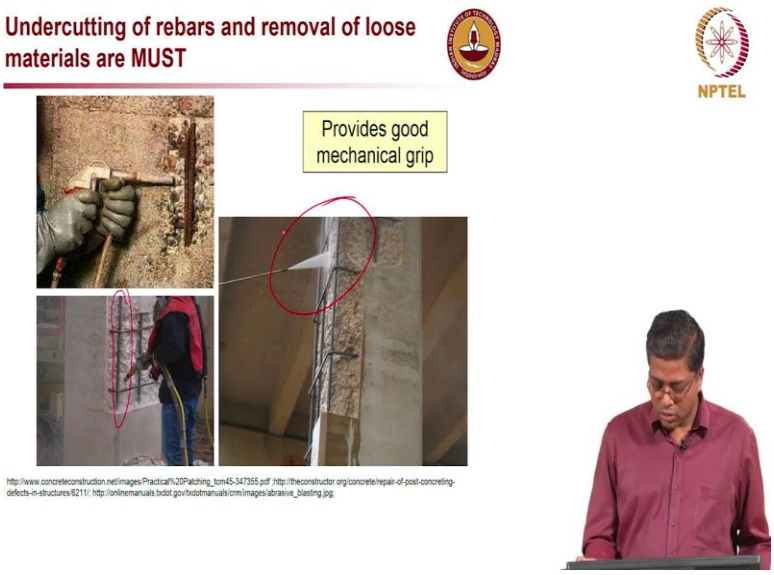

So, undercutting is very much important. This is an example showing, how undercutting can be done. You can see various applications where these are the rebars which were actually embedded and now completely the rebars are exposed and the concrete behind the rebar is also removed. And different tools are available for this to remove concrete like water jet. So, you can see this is a water jet here which is used to remove the concrete until the concrete behind the rebars are also removed.

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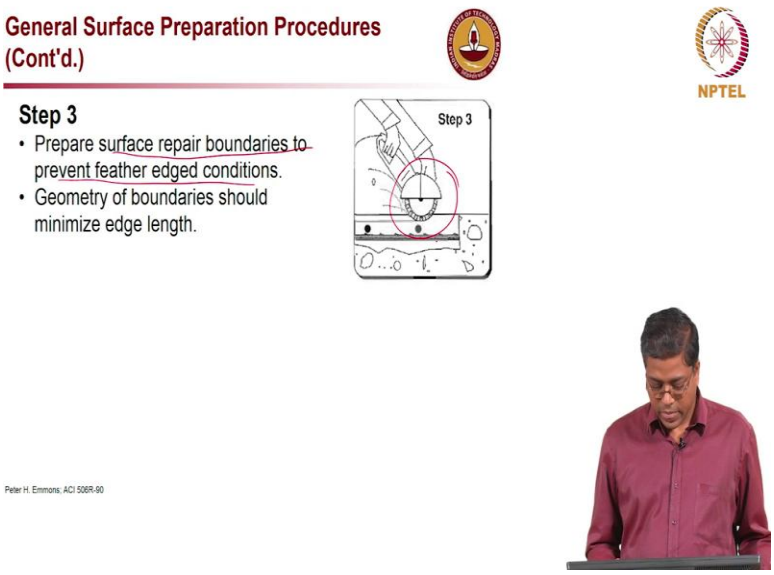

Now, step 3 is preparing the surface boundaries to prevent further edged condition. Geometry of boundary should minimize edge length. So, you can see here saw cuts are used to cut the region.

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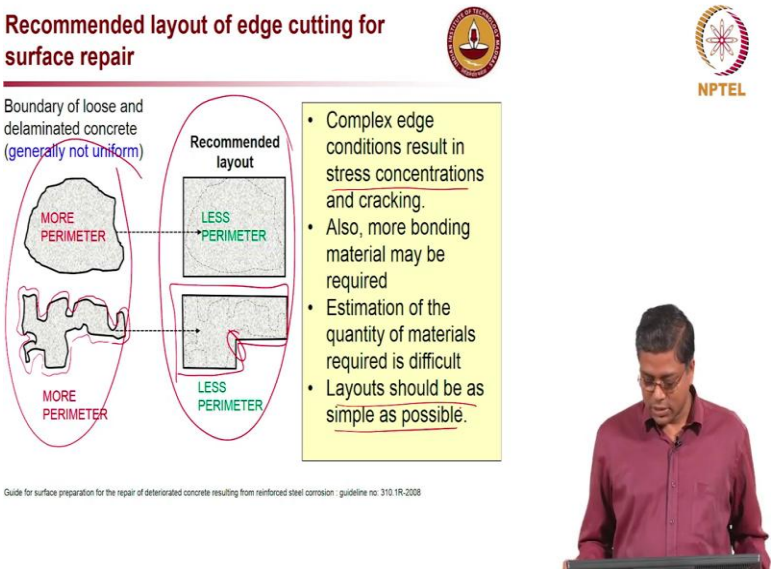

Now, if I say how do we cut that, how to define this boundary? Let us say you have a patch repair but as you see in the left side it is an irregular shape. Let us say the concrete damaged area is irregular in shape. But when you talk about repair, if the shape is irregular that means, let us look at the bottom left, there are lot of regions where the shape is so irregular and there are lot of regions where stress concentration can happen.

And also the perimeter of this surface here in this case is much larger than if I actually make an assumption and cut something like this as you see in the bottom right. If the perimeter is very large, the amount of bonding material required also will be much higher, but if you make a cut like this L shape it looks neat. So, aesthetically also it will be pleasing to see and also we will need less bonding material and at the same time, there will be no or limited region where stress concentration can happen.

In this case, probably this region you may have stress concentration but again it is much limited as compared to the case on the left side. So, I am showing here 2 cases where more perimeters and this is the recommended layout with less perimeter and a well defined shape like a rectangle and an L shape. And also in this case if you follow the well defined space, the estimation of the amount of materials required to repair is also easy to calculate.

Because surface area I can define very well and amount of material required also can be defined very well which is good for both contractor and the client. And at the end, we get a nice or a very simple shape and also aesthetically pleasing.

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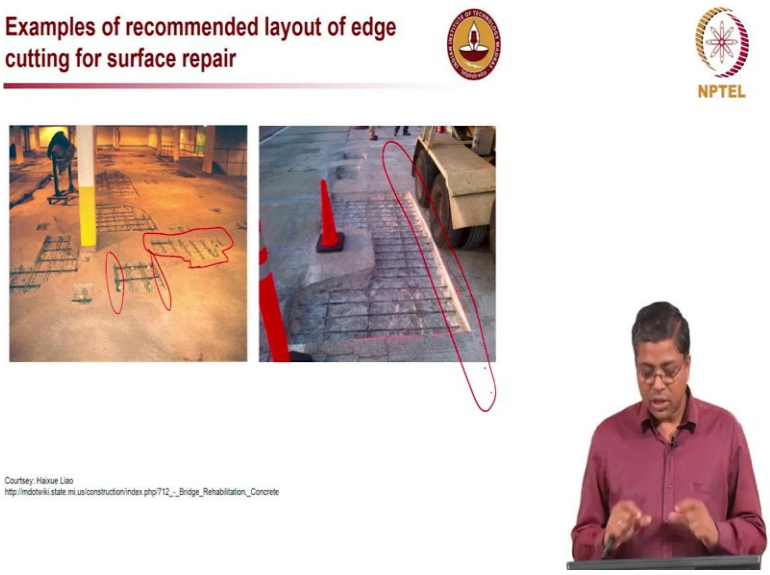

Now, these are some of the examples where you can see in all these, there is a straight cut which you will see here also you can see it is cut in a very straight well defined manner. And here on the right side image also you can see a cut something like this is made in a well defined manner. So, this is how repair work should be done. Now when you make these cuts, make sure that you don't cut the rebar as you see on the right side image.

If you cut here, if the cut is deep, then you may cut the rebar also that must be avoided. So that is something very important. So, the depth of the saw which you use is very important when you talk about this.

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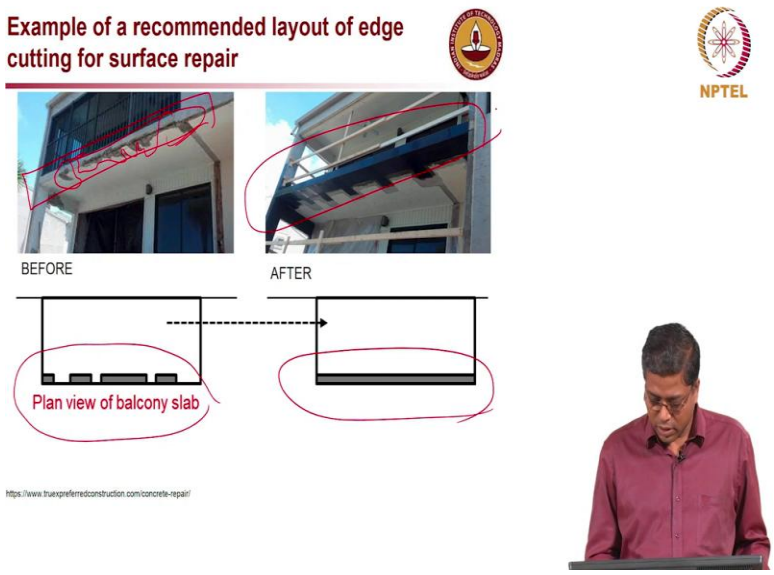

This is another example of a recommended layout of edge cutting for surface repair. As you see on the photograph on the left side, you can see some region, it is not that very well defined only some region it is spalled. But may be the corrosion is happening in the other region also and to avoid a future problem it is better in these cases to cut something like this. So, instead of something like this or defining the repair work something like this, we better go for something like this.

As you see on the right side where the repair region is much better defined, very simple one straight cut and you see the picture on the top right where such a repair has been done. In this case some fiber wrapping and lamination also installed. But the point here in this slide is just to tell you that the definition of the repair region make it as simple as possible.

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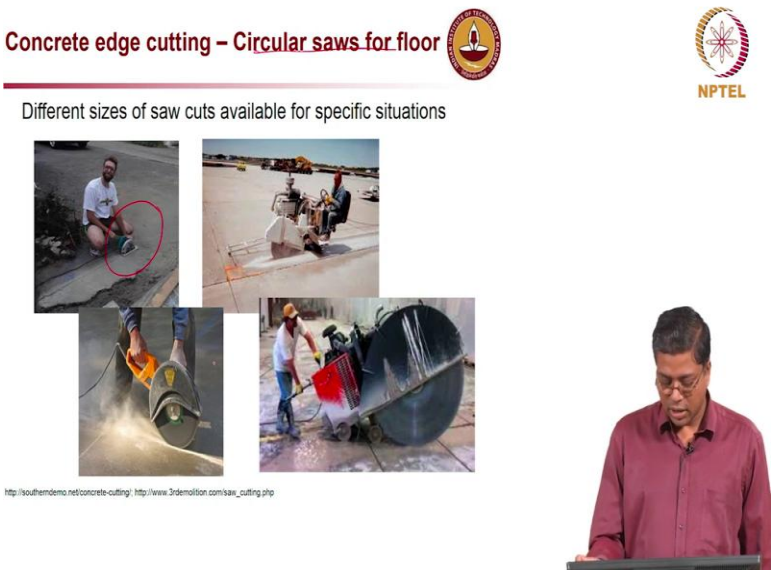

I will show you some special tools which are available. I mean towards the end also I will tell selection of tool is also very important because you can actually save a lot of time and get higher quality repair work if you use right tools. Now, for example, whenever you talk about surface repair, first we need to define the repair region or region for repair.

So, you can see different size of circular saws are available if you are talking about a very thin concrete cutting, some typical circular saw can be used and depending on the thickness of the concrete floor. I am really showing tools for cutting floors. You can actually go for different type or different size of blades and that will really ease your work and then at the end you have a very nice edge cutting or edge is well defined for the repair region. And at the same time, the amount of work is done in a very short period of time. So, that is also important. Imagine this if you are actually using some small chiseling tool are something that will take days and days to get the same amount of work, but if you use a saw and then you can actually get it done very fast and at the end the work will be of good quality.

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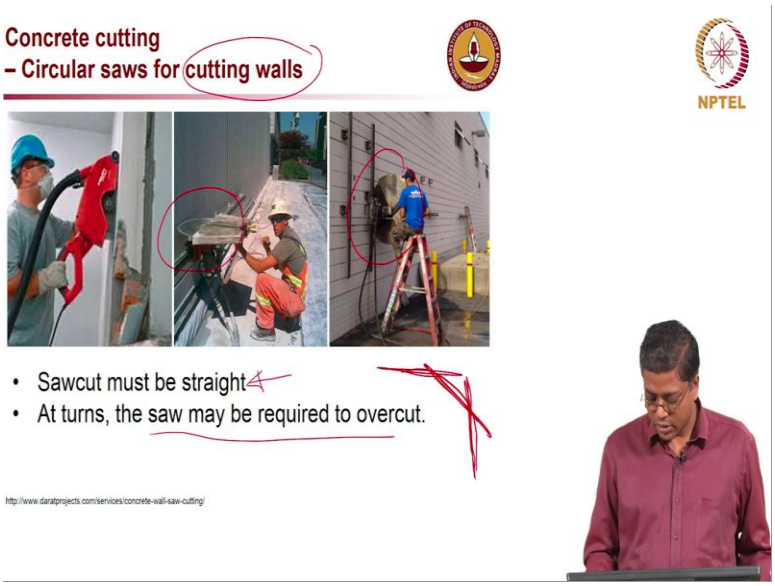

So, previous slide we looked at floors. Now, there are also some special cutting tools available for cutting walls. You can see here again, the saws of different sizes, this is a large saw blade; here you can see the blade is very large in diameter. So it depends on how deep you want to go and then how well defined you want your surface to be. Now, whatever cut we make, it should be straight.

And if there are curvatures required for the cut which we need to do, then may be required to overcut. That means, if I have a curvature to be cut like this, first I may have to go a little bit like straight line and then again like this and then again like this. So, that is how we really make the curvatures, you cannot really make, curved cut depending on the radius of curvature.

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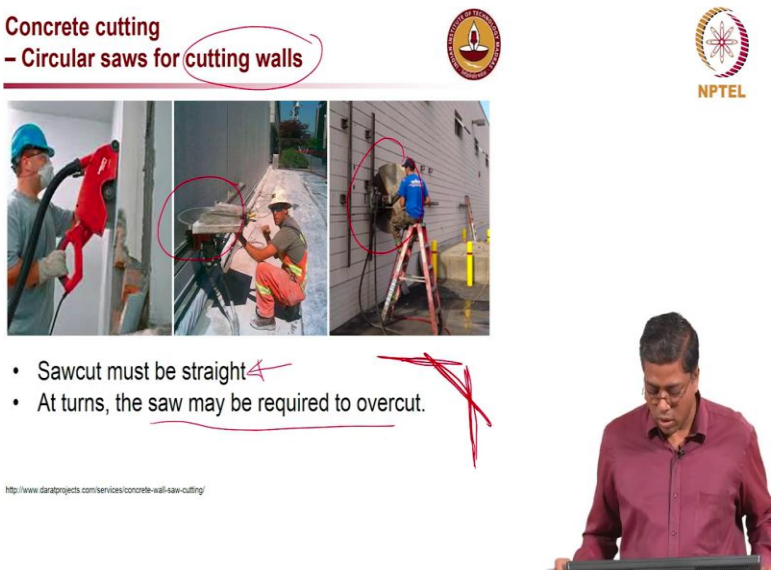

Now, concrete cutting and this is again for cutting walls, you can see for cutting walls, steel is well known pioneer in making these kinds of tools. And you can see here it is not a circular saw. It is kind of a rectangular saw as you see here, the blade is going something like this and you can make deep cuts without. So as you saw in the previous one, for cutting something like this, you need a very large saw or blade which makes it a little difficult for holding the tool.

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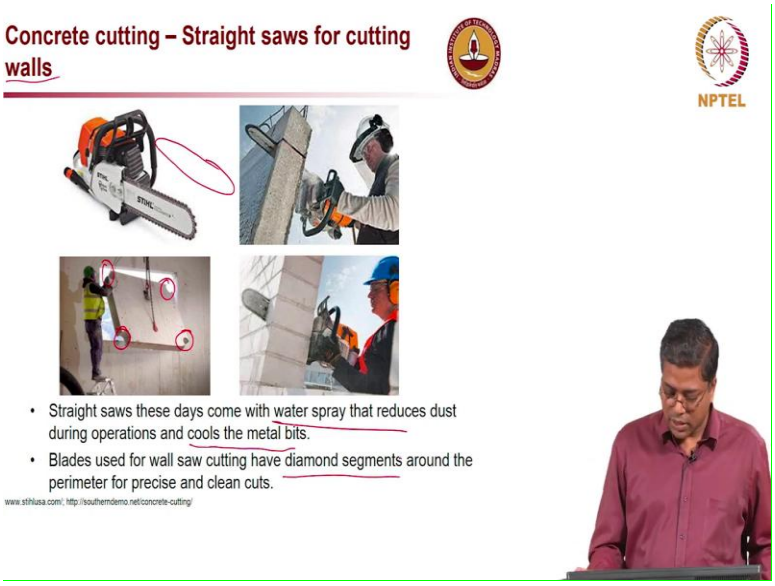

So, in this one, it is very handy tool and you can see on the picture on the bottom left, very large piece is easily cut out, cores were removed here, so we will define the corner of the

cut of the rectangular section and then you can make four edges and it is very easy. Now, when you talk about cutting always there is a possibility of dust coming.

So, these days there is also water spray that reduces the amount of dust which is flying during the cutting operation and at the same time it also keeps the metal bits very cold so it does not wear off very fast. And also diamond Coated or diamond tips are provided on these cutting tools so they can really cut through very strong concrete elements also.

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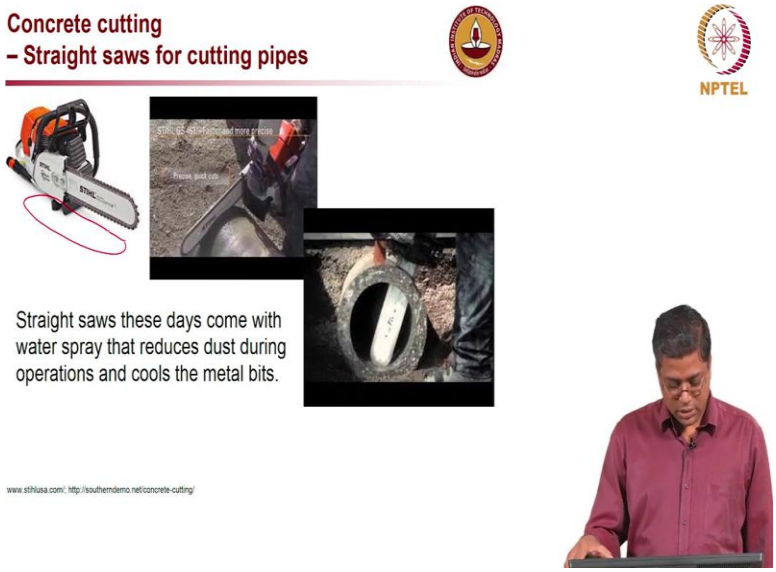

Now also, if you are talking about a work associated with concrete pipes, there also this kind of saw blade can be used and these are straight saws not the circular saw which we used to use in earlier time. So, straight saw they can go very deep. Deep cuts are possible, that is a main advantage. This actually comes from the timber industry. That is where it was originally introduced to cut trees.

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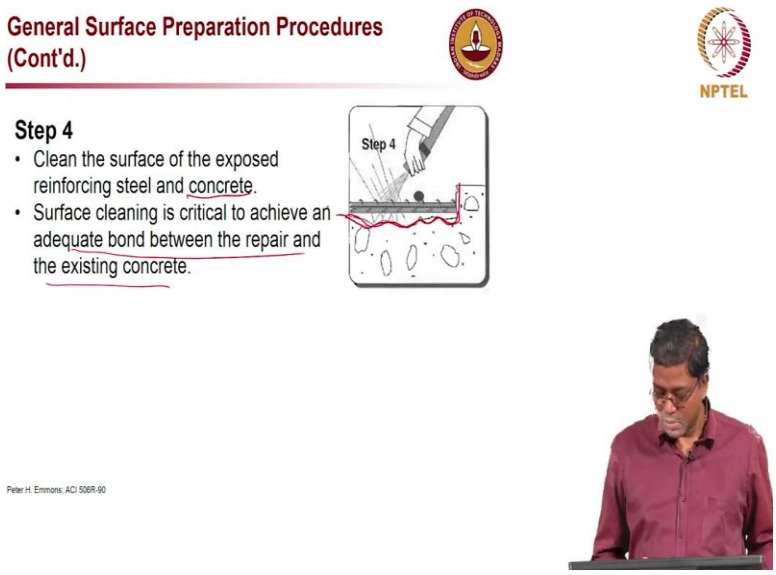

Now, the next step is once you cut the concrete or once you define the region then clean the surface of the exposed reinforcing steel and concrete. Concrete surface cleaning is very important when you talk about bond between the repair and the existing or the concrete substrate. So, the bond in this region here is very important and to achieve a very good bond, that surface should not have any loose material it should be very well cleaned.

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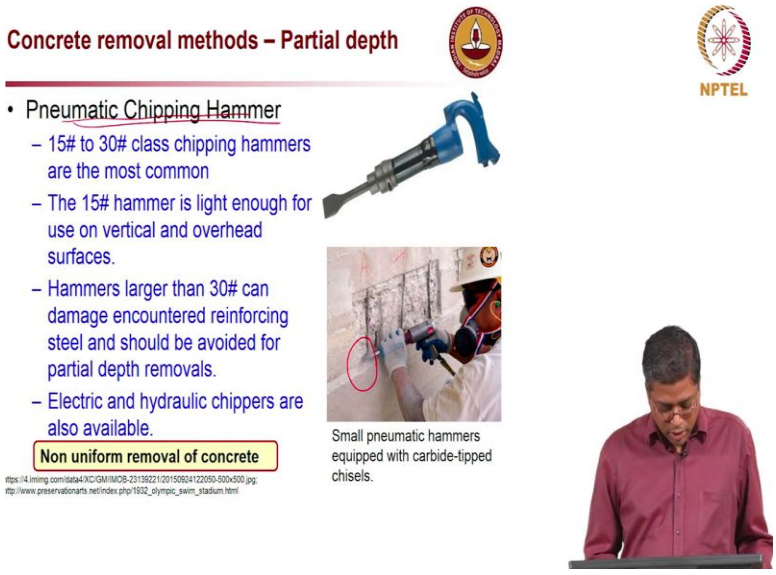

Now, when you talk about removal of concrete if you are talking about partial depth or if you were talking about full depth, there are different type of tools available for these different applications. And it is very important that we select the right tools, because if you don't select right tool and then use not an adequate tool, it will end up in taking long long time to prepare the

surface and construction time is going to be more and that those kind of delays may not be suitable in most cases because, when you talk about repair, you are talking about a structure which is already in use, it is not like a new structure.

So, when it is already in use, you want to minimize the disturbance to the functionality. So as fast as possible finish the repair and then return the structure. So that means, open the structure for use. What it means is the turnaround time should be very limited. When we say a low turnaround time that means you have to go for right tool and essentially it saves time.

Sometimes we think if I have to have some special tool then it is going to take more money, maybe people generally don't go for it, but actually, if you really think about it then the entire project cost, you will have an asset first of all, you will have a tool with you and at the same time which can be used for next project also. So, if you think in long terms having good tools always help.

So, this is one such tool which is pneumatic chipping hammer, basically air pressure and then you have a hammer. So, it is like a replacement of the chisel which we used to use in olden time I mean we still use. So, but here, the amount of manpower required and the time required is much less because everything is done in a mechanical way and Automatic tools are available. Now, these chippers working both on electronic and hydraulic principles are also available.

One thing is, there is a possibility of non uniform removal depending on the level of the skill of the worker. At the end you may have a non uniform but in most cases it may not be a big problem as long as there is a proper cleaning of the surface after removal of the concrete is done.

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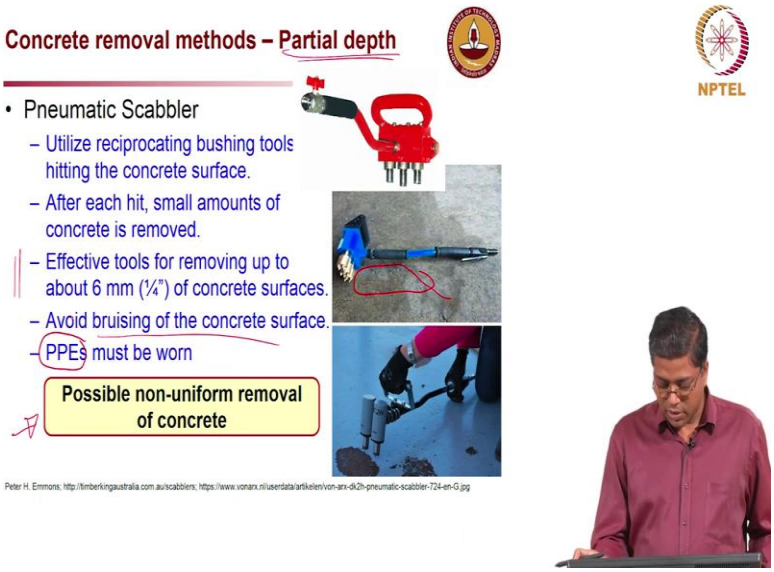

Scabbler again working on air pressure and then again it is for partial removal and it is very effective when we talk about removal of about 5 to 6 mm of concrete, very thin layer of concrete. So, as you see on the picture on the bottom and the middle one you can see that, for very small region or light removal this could be very useful. Again, there is a possibility of non uniform removal and unwanted concrete also need not be removed. You should not cause bruising of the concrete surface.

So, that depends on the amount of the time you apply at the same location. And again all these power tools when we talk about we must wear proper personal protective equipment, so PPEs must be worn.

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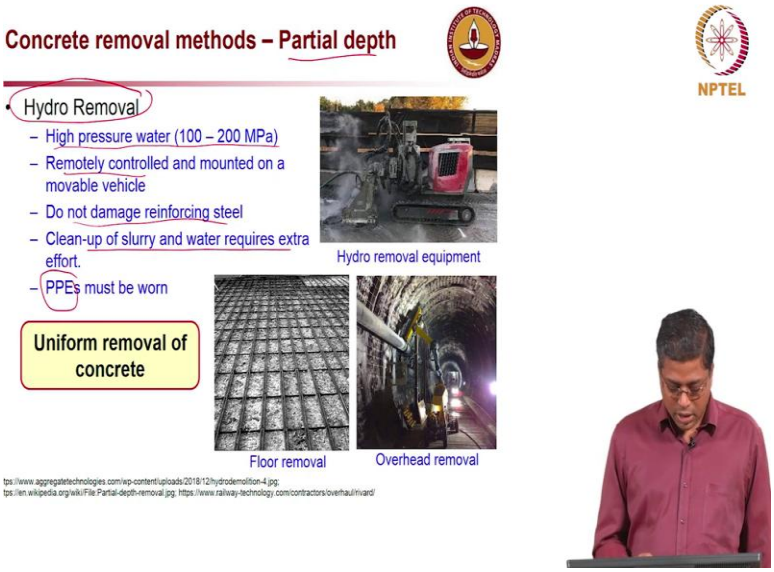

Now, another thing is again for partial depth removal of concrete, hydro removal or use of water jets to remove concrete, sometimes high pressure water let us say from about 100 to 200 MPa water pressure is used and then it is remotely controlled as you see on the photograph on the top right, it is an equipment where water jet is applied and it is an unmanned equipment and it does not damage steel that is a good thing about it. So, the concrete is removed layer by layer.

And one negative thing is we have to actually clean up all the slurry which sometimes requires extra effort to clean all that from the site. Again, because you are talking about very high water pressure PPEs must be worn. Imagine you are talking about cutting concrete. So, if that water jet is hitting on your skin, it is going to cut the skin too. So that is very important. So, special protective gear must be worn.

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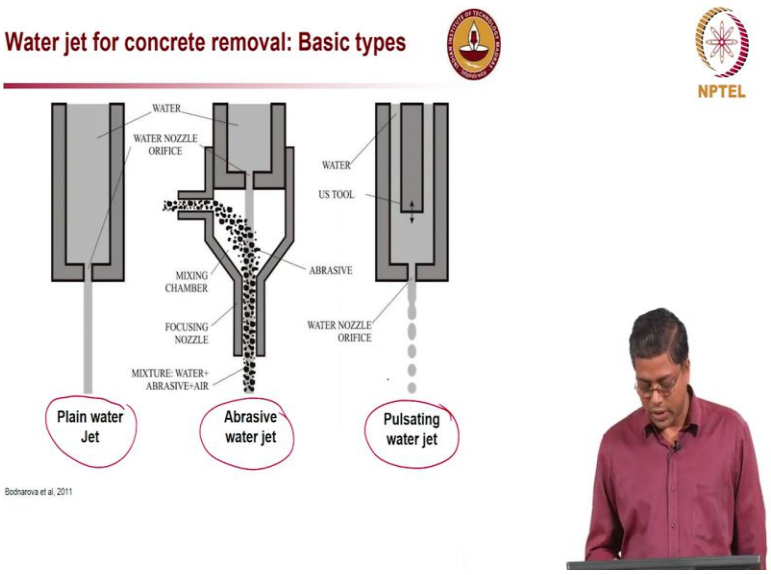

I am going to show you some detail about this water jet, where plain water jet and abrasive water jet that means the water jet with some abrasive material inside and pulsating water jet. In a particular research study these 3 were studied and how effective each one of these is.

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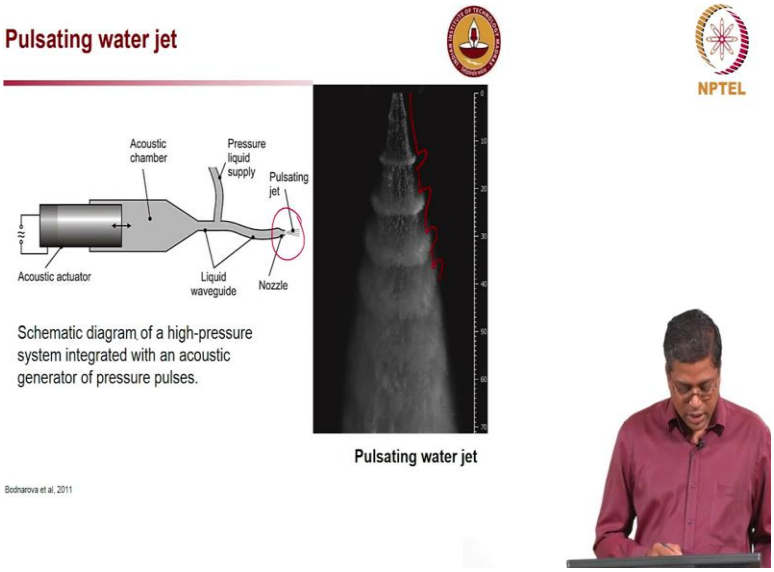

So, this is schematic diagram for a pulsating water jet. So, you can see here the pulsating jet that means, it is sprayed, not continuously as you see on the picture on the right side, you can see that, there is like this, you can see here there is a gap between each jet which is coming, so it is like a pulse. So, pressure is very high again in this.

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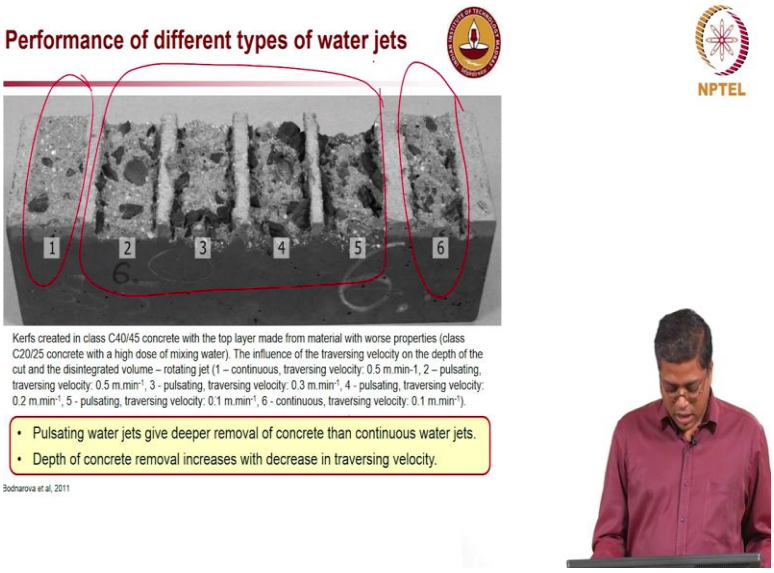

This is a photograph here shows how the different type of water jets can influence the rate of removal of concrete as you see on this picture, the number 1 and number 6 are examples of the effect due to continuous water jet in other words the water is continuously flowing or jet is continuous. And in this case between 2 to 5, these 4 were done with pulsating water jet you can very clearly see 1 and 6 the amount of material loss is less and 2, 3, 4, 5 the amount of material loss is very high.

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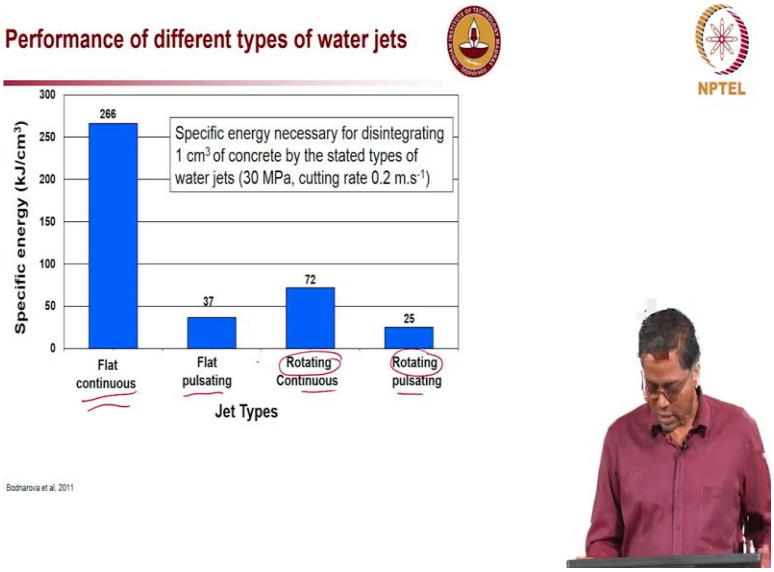

And this is again, just a graph showing very clearly the difference, when you have a flat and continuous that means the energy required to remove the same amount of concrete is very

high whereas, you have pulsating or even if it is continuous, but not the flat water spray, it require less amount of energy to remove the same amount of concrete.

So, definitely the type of tool which you use really influences the outcome that is the message from this. So, you have to use right tool. So that you don't have to spend much energy and money at the site, invest that money on a particular tool and then spend minimum amount of time at site which is good for everybody else also and then you get the work done at fast rate that is the best thing.

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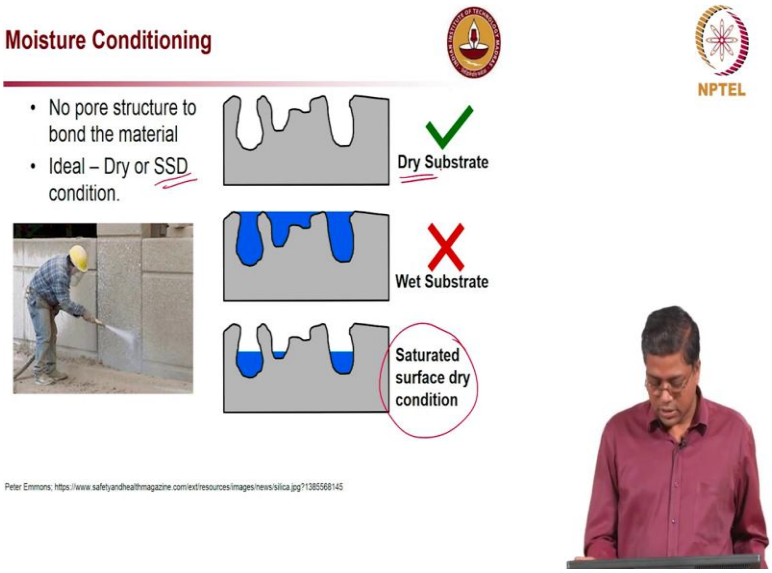

Now, after removal of concrete you might expect that there will be these micro-level uneven surfaces on the concrete surface. Now, what will happen? Imagine in the case of a wall this may not be always a case but, if you are talking about a floor, water can get filled in this fine pores. So, it is very important that the water from the fine pores must be removed or mainly you must ensure it is at least a saturated surface dry condition.

So, if you have too much of water in this fine pores which are created because of the concrete removal processes, then when you add new repair material, either locally you will have very high water-cement ratio and at the same time that will lead to a very poor quality bond. So that is why very important to keep the surface either dry or saturated surface condition. Dry is

best, but saturated surface dry condition is also sometimes ok, because always you cannot; I mean but at least it should not be completely wet.

Some water maybe some time ok or you allow that water to get absorbed by the surrounding concrete, allow some time. So, it will dry but best is to keep it completely dry and then follow the manufacturer recommendations, if they say moisture in the surface then go for it, the cleaning water should not be left inside this.

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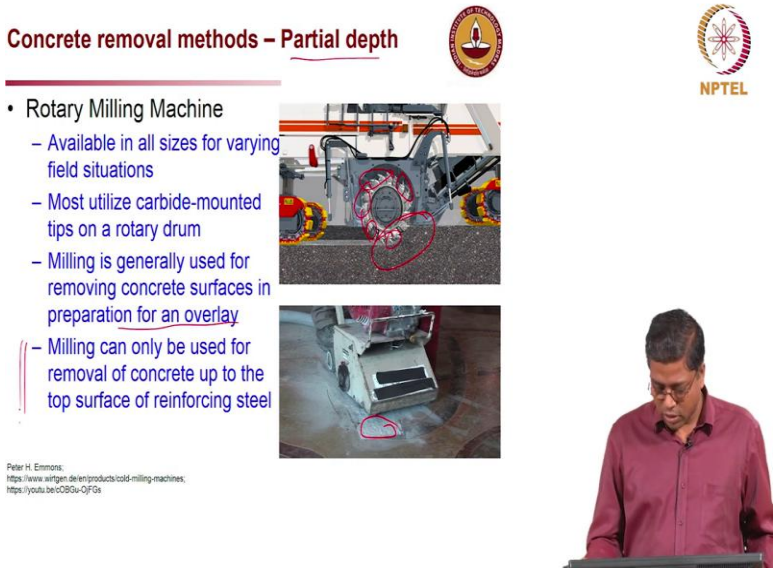

Now, another tool for partial depth removal is rotary milling machines. Again you can see here existing concrete can be removed and the surface can be removed with this, very nice diamond tipped tools here very hard the metal with the very high hardness and such tools can be used and you can see this is also removed. Now, especially this is used when you talk about very large surface like in case of a highway or road structure or a pavement where you want to provide an overlay.

And in such case you want to ensure that there is very good bond between the overlay and the substrate. So, milling machine will also ensure sufficient roughness is there on the concrete surface and one thing is you cannot mill it beyond the cover depth. So, if the cover depth is non uniform then it might be a problem in using this type of tools. But if cover depth is

uniform or the cover is at least some minimum number then up to that depth you can probably go for removing concrete up to that depth.

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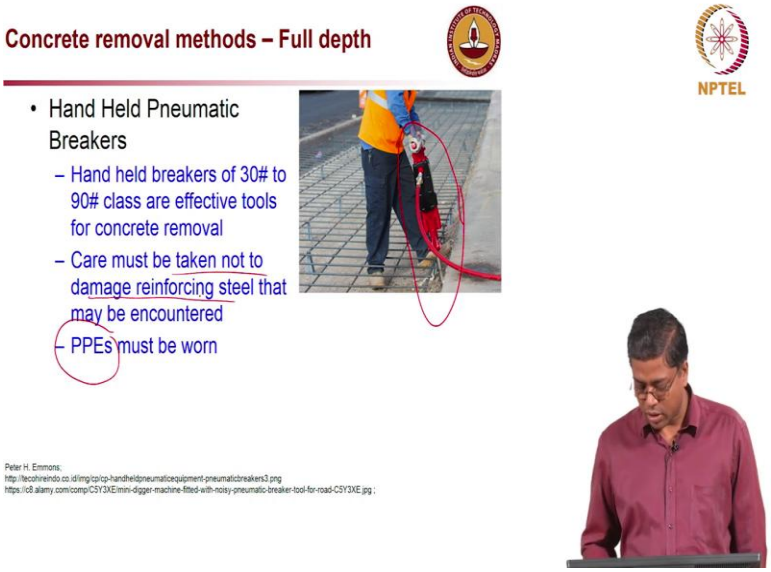

Now, this is also widely used tool in India we call it usually jack hammers. It is essentially a hammer which keep on hitting the concrete heart and different capacity hammers are available and but again PPEs must be worn when we use this. And other thing is that it should not damage the reinforcing steel that is inside the concrete.

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Now, when you talk about full depth removal of concrete, not just partial depth removal, then you might need a more powerful tools because you are talking about much deeper removal

of concrete, deeper that means high volume also. And then usually these are all fitted on to this large construction equipment. As you see on the picture on the right side, you can see here there is a bit which is fitted on to the end of this backhoe here, this is another example.

Both are for removal of road structures and it is typically remote control because the amount of pressure you are talking is very high. And again, you should avoid bruising of the concrete, PPEs must be worn that is something which we have to really work on.

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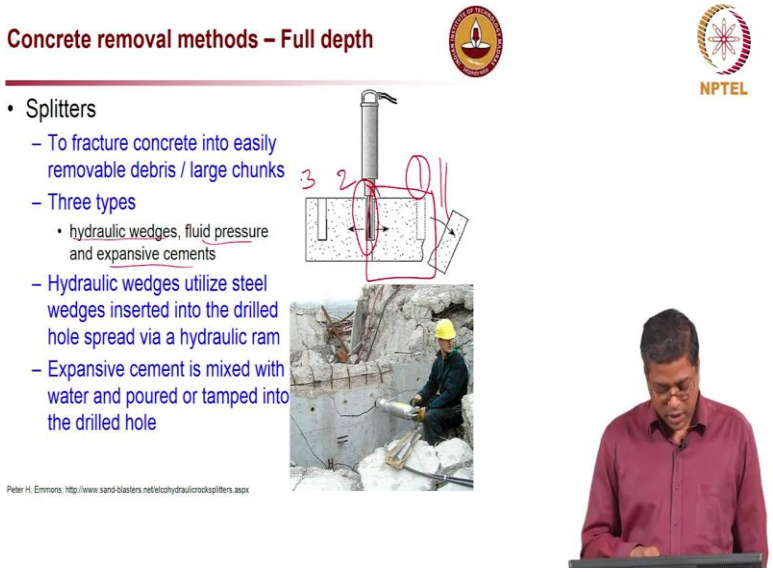

Now splitters here you can see usually the holes are drilled like this and then you insert something into the concrete and then you exert a lateral pressure which will split the concrete like you see here. It is splitting the concrete here also a crack is formed, something like that. So, you go deeper into and then provide lateral pressure either by a hydraulic wedge action or a fluid pressure or even some cement which you put inside.

And then let it expand which creates a lot of lateral pressure and then that is how we do this and in the sequence in which you apply is also very important. For example, in the case which I am showing here, if the slab is ending here then this could be the first hole which we need to do and then split it and then come here this is number 2 and then in that will remove this concrete.

And then come for. So, you have to see how do I progress you cannot start from the center of the slab or something, you have to start from an edge which will make the job very easy.

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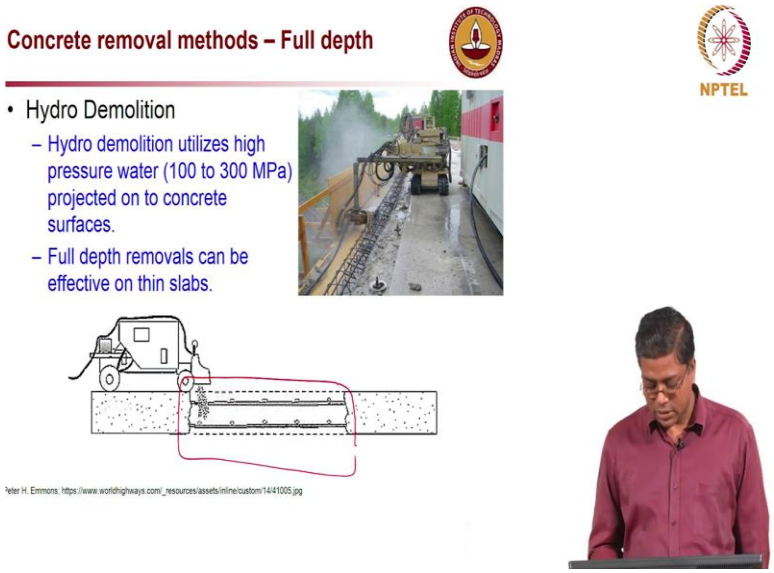

Now, Hydro demolition again for partial removal of concrete, here again, I think I already discussed this a little bit, but you can see here full depth is removed. Especially when you talk about the thin slabs, we can actually use this Hydro demolition or water jets to remove even the full depth concrete and the good thing is the steel rebar is still intact, it does not really do anything to the steel reinforcement. So that is the advantage of this. Steel is still maintained as it is whereas the entire concrete is removed.

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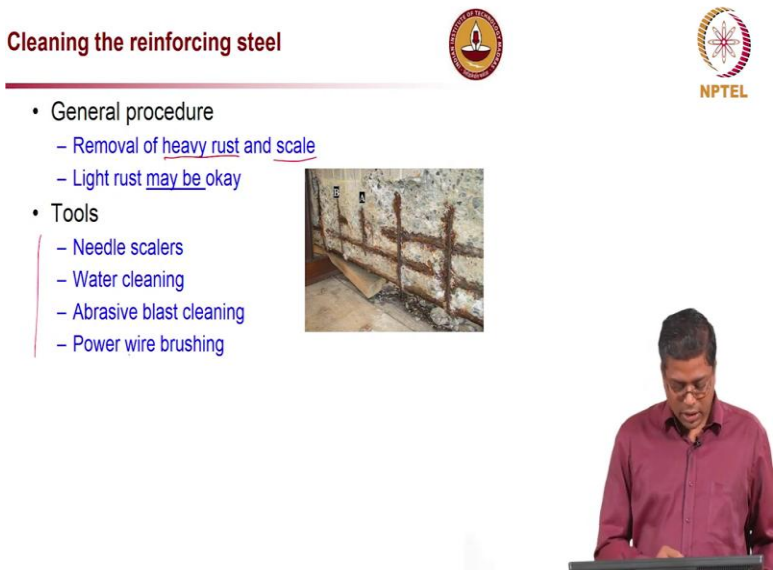

Let us now talk about how the steel reinforcement; not about the concrete but about the steel bars. How do we clean the steel bars? Because it is also very important after the concrete is removed. You can see on this picture here, the concrete is removed, but now you can see corroded steel rebars. So, what do you do before placing the repair material you must ensure that the rebars are also or the surface of the rebars are also prepared for the repair work.

So, heavy rust if it is there must be removed and scales if it is there that also must be removed. But if there is only light rust which you can remove by your hand if it is the case then it may be ok to remove and the slight cleaning would be sufficient in such case even an emery paper or something you can use but again the light is based on the judgment of the person so if it is so hard to ensure that it is really light, otherwise it is better to remove the rust completely.

And make the bars really shiny as much as possible means grayish in color. So that there is no rust present and also there are no particles which cause the rust like chlorides and others are also removed from the steel surface. Now, some of the tools needle scalars, water cleaning in the jet also abrasive blast cleaning, sandblasting and then power wire brushing..

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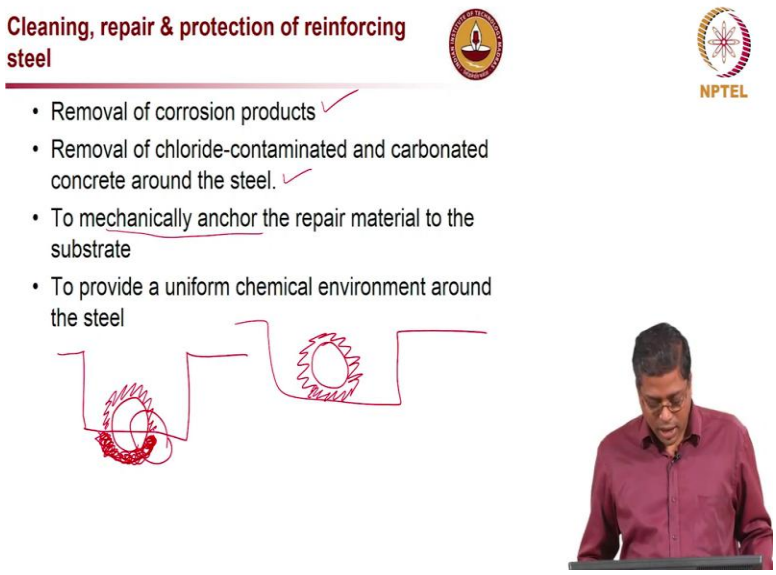

So, all these are the tools which are used for removing the rust from the steel reinforcement. Main idea is removal of corrosion products that is rust and then removal of chloride contaminated or even carbonated concrete around the steel. Because this chlorides and carbonation is the reason for the steel to corrode. So, if we leave that type of concrete there then the steel might corrode again even after providing new repair material.

So, that is why it is very important to remove the entire contaminated concrete or bad concrete from the steel surface. And we talked about under cutting that is important to mechanically anchor the repair material to the substrate. And when you talk about substrate undercutting let us say this is this is how the rebar was and when we are undercutting.

So that means when you undercut after the repair material, the entire surface of the rebar, all the full circle even behind the bar you get the same, the bar is exposed to the same cementitious system. If you don't do an undercut, so let us say here, if the bar is something like this that means it is not an undercut case. In such case the new repair material will be only up to here.

This portion at the bottom of the bar that is this portion, this darker shaded portion that will be the old concrete and the portion on top half will be new concrete and that will create a battery like here. So what it means is there is a possibility of corrosion to happen in the very near

future, this is the problem because most of the time we do not do all this cleaning and don't do repair work properly.

And then what happens is in another 3, 4 years again the same steel continues to corrode and then there is a significant problem and then the repair fails. So, this is where cathodic protection and the proper preparation of the concrete surface and the steel surface becomes very important. So, let us stop doing this patchwork, when there is a corrosion, do the patchwork in a proper way do proper undercutting.

Then place the proper repair materials and if necessary also adopt cathodic protection so that the repair will be durable. The durable repair is our key objective here.

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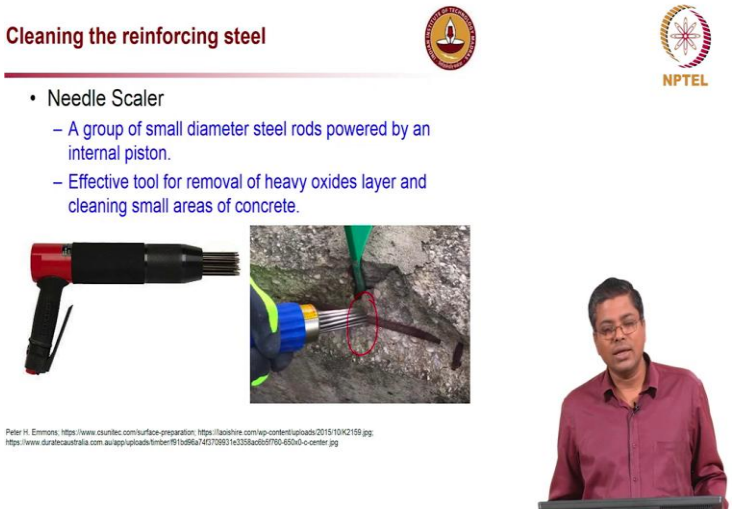

Now, this is another needle scalers you can see here they are used to clean the rust from the steel reinforcement and these are also available in a different power. Imagine using a tool like this and clean this rebar instead if you are actually telling a person to go take a wire brush or an emery paper and then go clean the rebar surface, you will not be able to remove the thick heavy oxide layers or the heavy rust which is on the steel surface. So sometimes we must go for these heavy duty tools. Otherwise the repair work will be not of good quality it will fail very soon and then you will end up in spending again and again. You need more and more money to do the same work.

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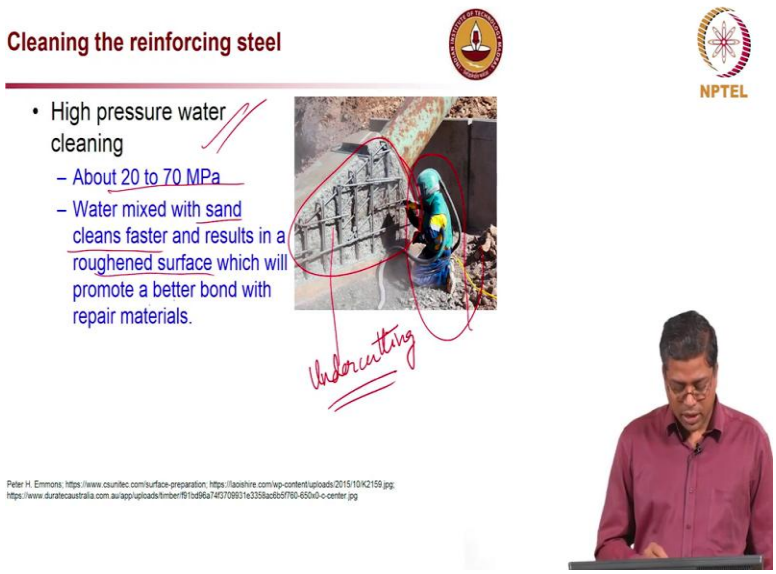

High pressure water cleaning. You can see here this entire rebar concrete is removed. A perfect undercutting is done. You can see here undercutting. Undercutting is very important when you talk about the repair work. And water mixed with sand cleans faster. Because when you talk about sandblasting, it generates a lot of dust which creates an uncomfortable environment.

You can see the person here actually in a full gear fully covered, because the pressure is very high you can see here 20 to 70 MPa pressure is used and then it creates a roughened surface which will promote better bond with repair material so that is very important to use this high quality specific tools for achieving the target.

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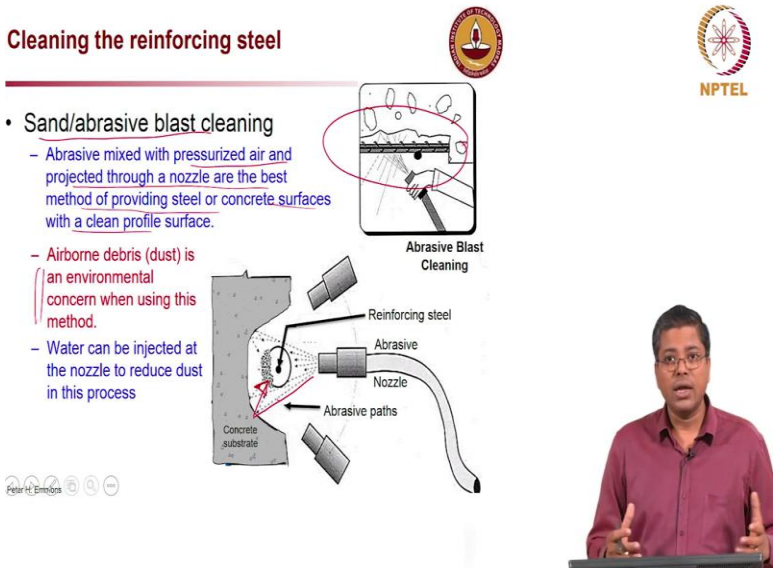

Now sand and abrasive blast cleaning in the previous slide it was mixed with water and here I am showing if it is not mixed with water how it is. Again, similar you can see here, pressurized air projected through a nozzle a best for cleaning both the steel and concrete surfaces environmental concerned when it is dry, but nowadays there are also tools available where there is a vacuum attached to the sandblaster so you don't really see dust around.

So, whatever dust is created, it is immediately collected, so that the dust pollution is not concerned. So, point is we have to use these kinds of tools and the contractors and the stakeholders must enforce this thing also. They should promote the use of these kind of tools by seeing the advantage and getting a better quality repair work done by the end.

Here you can see when you use this abrasives jet it will also clean the rust at the backside of the rebar. So, it will hit the concrete surface first and then reflect back on to the steel. Let me show you more clearly. It hits the concrete surface, reflect back onto the steel and then again behind the rebar also it is cleaned. That is the beauty of it.

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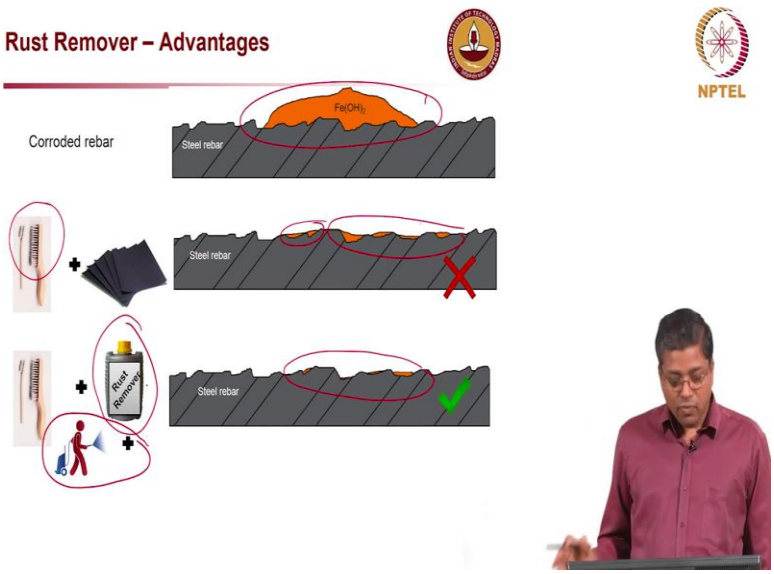

Now another material available is rust remover not by mechanical action, but by chemical action. What is the advantage of that if you say? In the top image you can see a corroded rebar; lot of corrosion and if you take an emery paper or a wire brush or something like that, still there will be some rust which is actually attached or adhered, well entrapped inside the flakes or the scales on the rebar surface. As you see here these rust were actually very difficult to remove.

Now, my proposal would be you do this first use the mechanical tools to clean maximum rust possible. Then you also provide rust remover which is chemical which can be basically acids, which can actually remove the rust and then you have a very well cleaned surface for the application of the repair material. You can also go for these water jets that will also help much better than just going by emery paper or something, but the choice of this water jet or rust remover will depend on the amount of the repair work.

If it is a small region to get a water jet, it might be very difficult, nobody would even come for doing the work because, it is much expensive. So in such case get a small bottle of rust remover and do it that might work better. So the engineers have to make the judgment on which type of tool is good for specific application.

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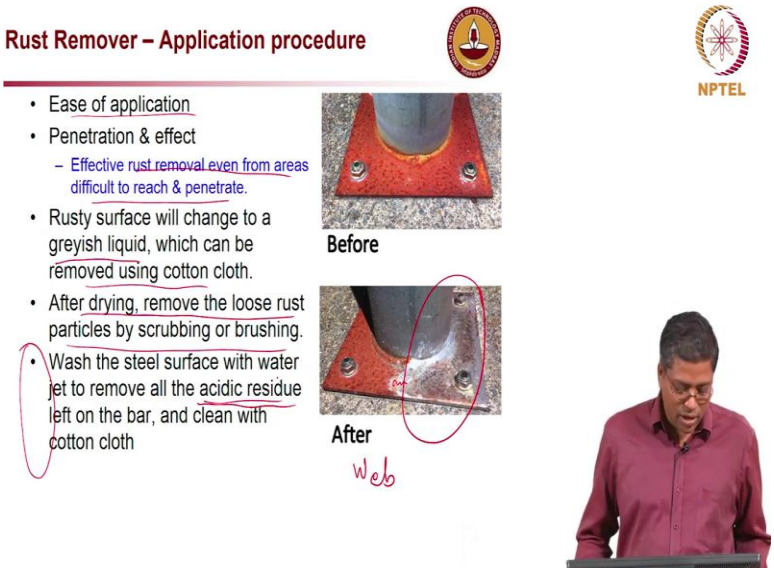

Also rust remover, it is very easy to apply. The picture here is not about steel rebar in concrete but this is something which I found from the internet from the web but it just explains very well how it works. So, it is very easy to apply and then effective rust removal even from areas which are difficult to reach and penetrate.

It means, if you are using a mechanical tool, you cannot reach it, but even on the micro scale, if you look at the very fine pores on the steel surface, it can. Where the mechanical tools may not be effective in such case the chemical will actually penetrate and clean the entire surface as you see on the bottom right.

You can see this region is very well cleaned, there is not much rust left which is difficult to achieve with a mechanical tool and grayish liquid, which can so the it converts into a rusty surface will change to a grayish liquid and then which can be removed and this is very important after drying remove the loose rust particle by scrubbing so everything has to be removed.

And this is the most important part here wash the steel surface with water jet. Why because these type of chemicals are essentially acidic in nature and you don't want to leave any acidic residue on the steel surface. So, cleaning is very important when you are talking about rust removers they are not supposed to stay there on the steel surface for long period or after

removing the rust they need not be there. So it has to be water washed very well. So that Future corrosion will not happen.

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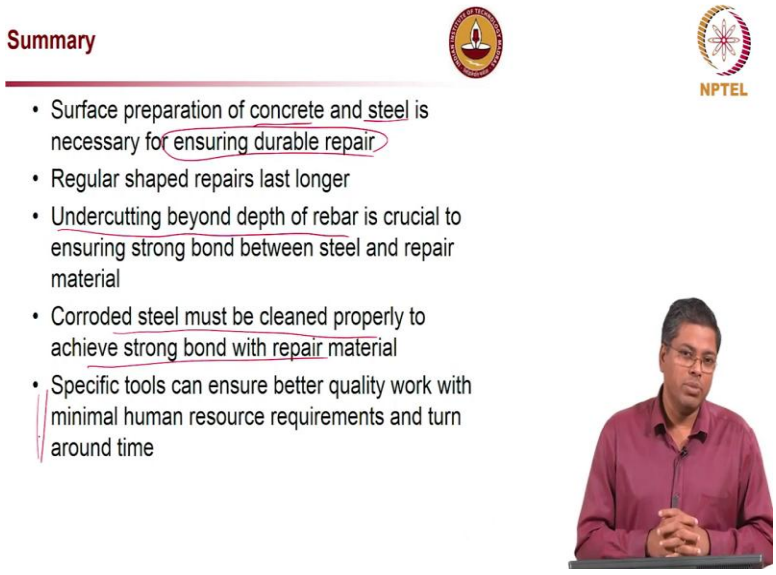

So, to summarize, we talked about surface preparation of both concrete and steel, it is very important to ensure durable repair and regular shape repairs last longer, because irregular shape there will be stress concentrations and it will be difficult the quality of the work will not be that good as compared to the simple shape and that also helps in estimating the amount of materials required.

And also aesthetically pleasing and undercutting beyond the depth that means the entire rebar surface should be exposed even the surface which you cannot see or behind the rebar that concrete also should be removed. So that, you get better mechanical grip and at the same time, the rebar will complete the full circle or the full surface of the rebar will be exposed to the same repair material.

So that, you don't have any potential for corrosion cell to develop. In other words, no steel should be exposed to both the old or the substrate concrete and the repair material. It the entire steel should be covered by the repair material and at the ends or the edges you can provide cathodic protection to prevent halo effect, which we will discuss in the next lecture.

And then, the corroded steel also must be cleaned properly to achieve very strong bond it is not only the concrete but the steel surface also should be very well cleaned. And as much as possible the rust must be removed. And then specific tools can ensure better quality work and selection of tool is very important. We must think that if you get a proper tool, you will actually spend less time at the site.

Just imagine a case where you are nailing onto the wall, if you take a rock piece and then try to hammer it and in a second case, you take a proper hammer and hammer it. In which case if the work will be of good quality and definitely if you have a proper hammer, it will be much easier to do and it will be safer to do rather than using a rock piece with irregular shape because in practice we do all this things.

That is why I am telling so. This is the time for us to change the way we think, there should be a significant change in the mindset of the decision makers. Also to tell people on site to go for better quality tools and when you go for better quality tools your work will be easy to do more comfortable and it will take less time and at the end, the end product will also be very good and durable.

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And these are the references I used for this lecture. And thank you next lecture we will talk about corrosion, the treatment for the steel. How we can protect the steel from corrosion. Thank you.