Basic Construction Materials
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Module No # 08
Lecture No # 37
Metals 3 – Part I

Welcome to this lecture; as part of this course on basic construction materials in this module, we will be looking at metals. It is the third lecture in the metals module, and we will be talking about coated reinforcement and prestressing steels and some test methods as part of this lecture.

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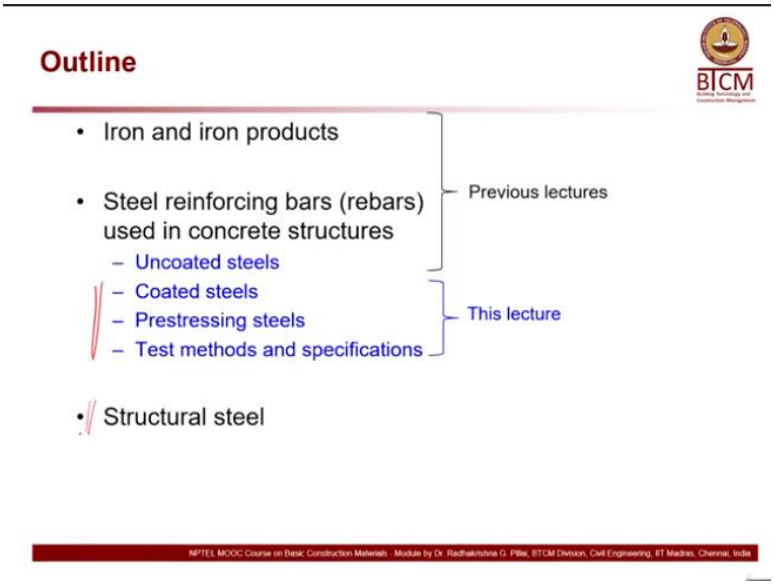

So this was the outline in the previous lecture; we talked about iron and iron products and looked at uncoated steel reinforcement. Today we are going to talk about coated reinforcement prestressing steels and test methods and specifications. So also, we will have another lecture on structure steel by Professor Arul Jayachandran.

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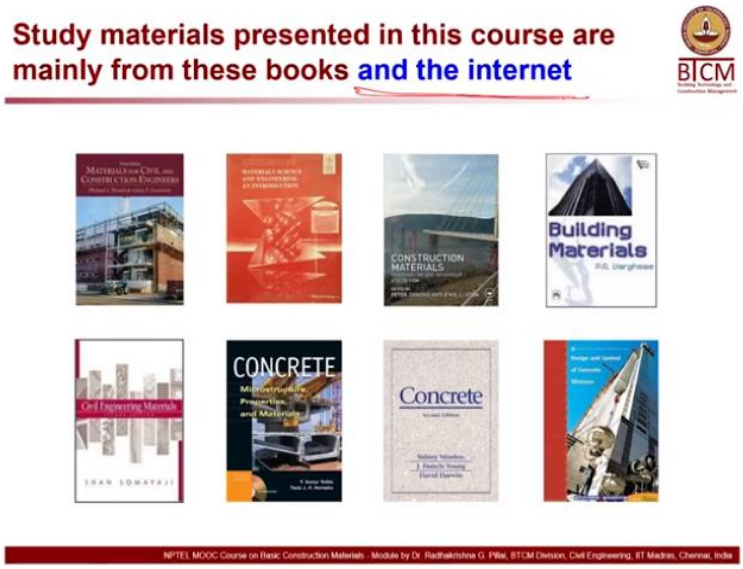

These are some books which we use for this course materials development. Also, we use a lot of information from the internet to make the course more informative, easy for you to understand for demonstration purposes, etc.

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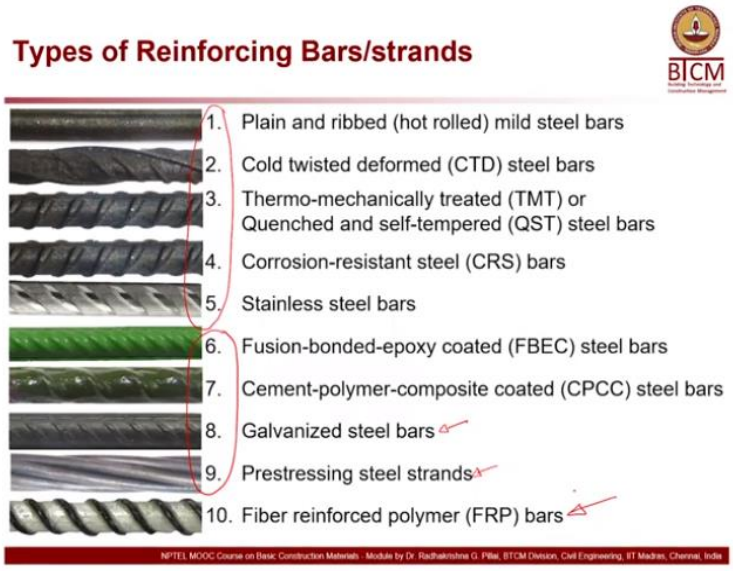

So the type of reinforcement which, is uncoated reinforcement, and these are the five major types of uncoated reinforcement that we already talked about in the previous lecture. Today we will talk about 6, 7, 8, and 9, that is, 6, 7, and 8 are coated reinforcement that is fusion bonded epoxy coated rebars typically which comes in like green color coating rebars.

And then cement polymer composite coated rebars (CPC), coated steel re-bars and then galvanized steel rebars, and then the prestressing strand. This is of much higher strength compared to typical rebars, and then applications are also very different. We also have today in our industrial lot of these fiber-reinforced polymers or FRP rebars which are essentially plastic rebars.

We will not cover that in this particular module, but I just thought of telling you that material like that or a product like that is available to replace steel reinforcement. So it is essentially plastic, so it is lightweight it is very easy to construct with essentially a composite material.

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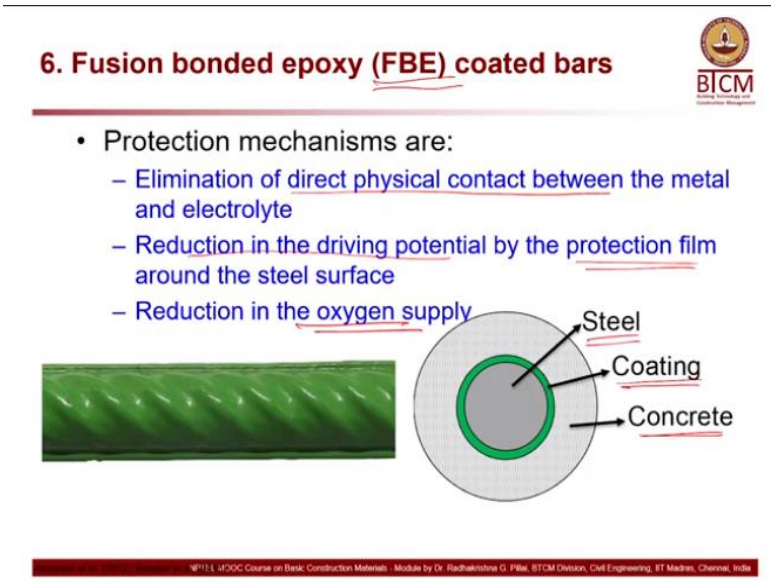

Now fusion bonded epoxy coated re-bar FBE fusion bonded epoxy coated. So let us look at What are the protection mechanism? So why we use this or this kind of rebar. So as you can see in the picture, there is a green color coating made of epoxy. So you have this green color coating on the reinforcement you can see the cross-section at the right side.

This is the concrete, so you have the steel reinforcement and then a green color epoxy coating covered by the concrete. So this is a system we are talking about when you put these types of rebar in the concrete. It is not painted; it is an epoxy coating. There is a slight difference between painting and coating. So this coating eliminates direct physical contact between the metal, the steel, and the electrolyte, which is the concrete.

So there is no direct connection between the steel and the concrete, if it is a very good quality epoxy coating and it also reduces the ability the potential difference, you know what the driving force for the corrosion reaction to happen? So there is protection, so a mechanical barrier is actually provided, and because of this, you also have a reduction in the oxygen supply at the steel surface.

Because you know that oxygen and moisture are essential elements for the corrosion reactions to happen, you have both oxygen and moisture in the cathodic reaction. So if you can stop either one of them, you cannot have corrosion. So this epoxy coating provides a physical barrier, and it is provided to reduces the driving potential, and also it provides the barrier against the oxygen.

So at the steel surface, you do not have any oxygen or moisture if you have the excellent quality epoxy coating

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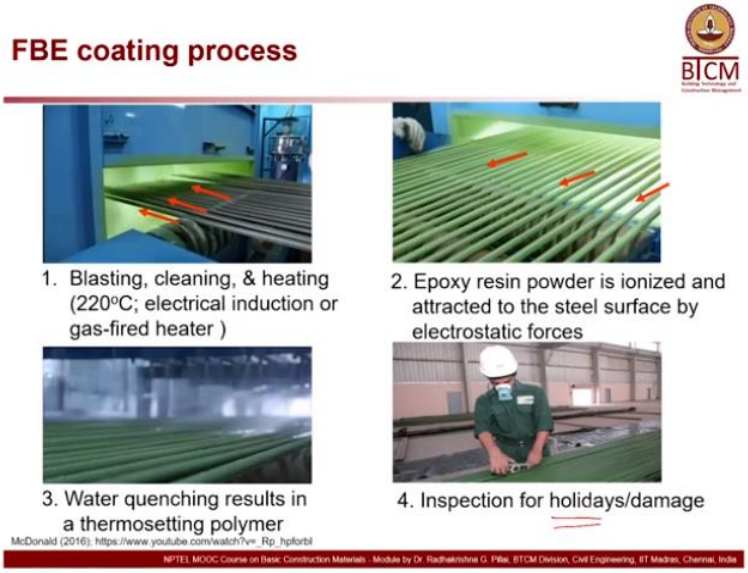

Now let us see how this epoxy coated rebar, or rather fusion bonded epoxy coated rebars, are manufactured. I would request you not to use the word just epoxy coated rebar. We have to emphasize that wherever we write about this type of reinforcement, we should write fusion bonded epoxy coated rebar because the coating will not stick unless you go for fusion bonding.

Just applying coating on the steel surface does not help to get a very good contact, it will be just like painting rather than a coating. So let us see how it is manufactured. So as you see on the top

left image, you can see a clean re-bar is passing or is pushed into the chamber where there is a mist of epoxy. And this re-bar is not just clean, but it is also at a higher temperature.

So that you can see about at 220 degrees Celsius bars going into this chamber. So what will happen? If you have a mist of epoxy, they will try to fuse and stick to the steel surface. So that is why we call it fusion bonded epoxy coating. So on the top right, you can see that the bars are coming out, now that they have a coating on the surface. So epoxy resin powder is ionized and attracted or fused to the steel surface by electrostatic forces, and on the bottom left picture, you can see once the epoxy is coated, this coating happens is still the bar is really hot.

So if you do not quench or cool it down, what will happen is the epoxy will start flowing downward, around the surface of the re-bar. So we quench that steel; it gets solidified very fast and prevents the epoxy flow around, and then you also have to inspect the bars for holidays and damage. So what are the holidays? Holidays are small micro pinholes that could be there on the epoxy coating.

So if you have these tiny holes which you may not be able to see with your naked eyes, you will need other technology or tools to test these holidays, like brushes are available to which we can use to check whether there is a holiday or not. So you check all these; if it is all fine, you can use this bar for construction.

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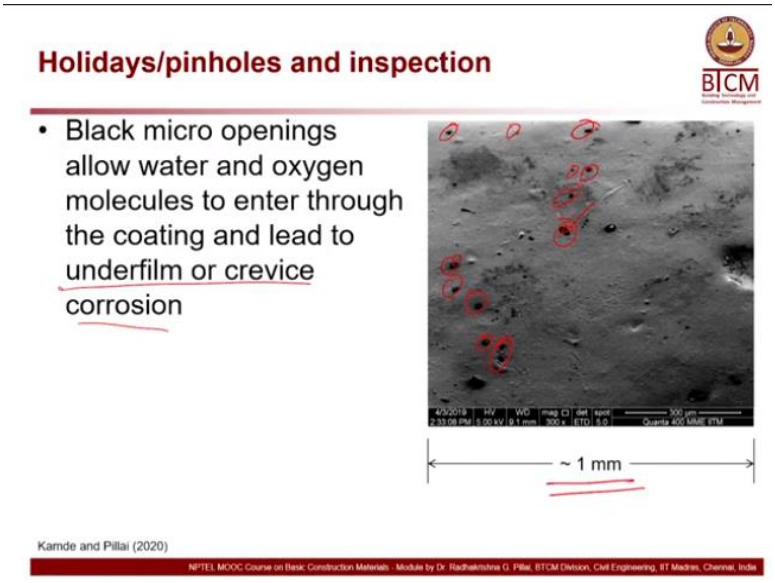

Now the problem is most often you know there could be holidays or pinholes, and this is a picture on the right; if you see it is a micrograph, you can imagine the size of this micrograph is only about 1 millimeter. So in 1 millimeter that small size, there are so many of these black spots which you can see these are all black spots through which water molecules, oxygen etc., can penetrate.

So when you see this is a green surface, but when you look through a microscope, that is why it is in greyscale. However, the point is that you can have a lot of these pinholes or the holidays on the rebar surface. So when you have something like this, it is very difficult to prevent corrosion and what type of corrosion, it is called under film or crevice corrosion. You, can Google on what crevice corrosion is to read further about it.

However, under film corrosion or crevice corrosion is the typical damage mechanism or corrosion mechanism which is happened in this kind of bars if they are not of good quality. One example where you can find this kind of corrosion is if you go to your house, see the gate where steel is used, and you have a painting on that. Even if you do a very good painting, you will see that after few years. What will happen you will start seeing blisters on the gate right on the steel surface or window grill, doors etc. You will start seeing blisters.
Why are these blisters coming? Because on the paint there are still these kinds of holidays or pinholes which are present. Through which oxygen and water molecules can go through. So are they can go through these pinholes and reach inside the steel.

Once they get inside, then they get trapped in there, and crevice corrosion can happen. Let us not go more into detail on that, but I am trying to show you an example that you can very easily see when you look around a metal gate at your home or a window grill where you have applied paint. But you can still see blisters because these micro very fine pores are available on the paint surface to which moisture and oxygen can penetrate.s

And they will get trapped in between their or paint and the steel surface, and then it will start corroding.
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Another way of these bars getting damaged is that the pinhole in the manufacturing facility itself, if the coating process is not done properly, on the site when we will bend these rebars. Ideally speaking, you are not supposed to bend it after applying the epoxy coating. In Abroad the bars are bend first, and then they are epoxy coated.

However, unfortunately, this is not the practice in our country, even though it is now recommended in the codes, you can see on the photograph. We bend the bars after they are brought to the construction sites, which is not a good idea; it should not be practiced. What will happen at this point here? Wherever we use that little tool to liver and liver to bend the re-bars, what will happen?

A pinch because epoxy is a very soft material, and you are using a metal tool like this is a metal tool right, you have rebar you can see that lever arm.

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So that metal tool is used to bend it. So what will happen as you can see on this picture, you can see exactly where that person who holds this lever to bend the bars will have pinching you can see here pinch. So this is something which needs to be avoided. So we should not use any hard metals as tools this.

So the best thing is to bend these bars first, coat them with epoxy coatings, and then bring them at the sites. But because of cost issues and all, people are not doing it, but actually, we are harming the rebars. Moreover, when you expose these rebars at the construction site for an extended period of time. What will happen is that the volatile materials on the epoxy is essentially a chemical. So when it is exposed to sunlight, it will become brittle. Suppose we at our home if we leave plastic outside for some few months you will see that they will start becoming brittle and deteriorate. A similar thing happened to this epoxy also; they will start becoming brittle. Moreover, if you bend a bar which is having brittle epoxy, it will crack.

So this is shown in the red, square rectangle where we have a cracked epoxy. So this also will lead to crevice/ underfilling corrosion. So cracking of epoxy is not a good idea, whether it is due to mechanical damage or sunlight or whatever be the way. We should not have allowed this epoxy to crack.

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Here is another example where this is a picture from construction sites where these bars are exposed to the sunlight for months or even weeks. So when all these get exposed to the sunlight and sunlight has UV radiation, that will make this epoxy crack. And these cracks are not something which you can really see with your naked eyes until it is we know severely corroded.

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So I am going to show you some more cases where these bars are exposed. And you can see that there are many brown lines brown things which you see on these bars you see here it is all very severely damaged. However, they are unfortunately being used in our construction. So as a technology epoxy coating is done very well, it is not being used properly in our most.

And yet to see a construction site that is using good quality epoxy coating or epoxy coated rebar. So it is very high time that we worry about the quality of these structures. And the durability they will start corroding very fast

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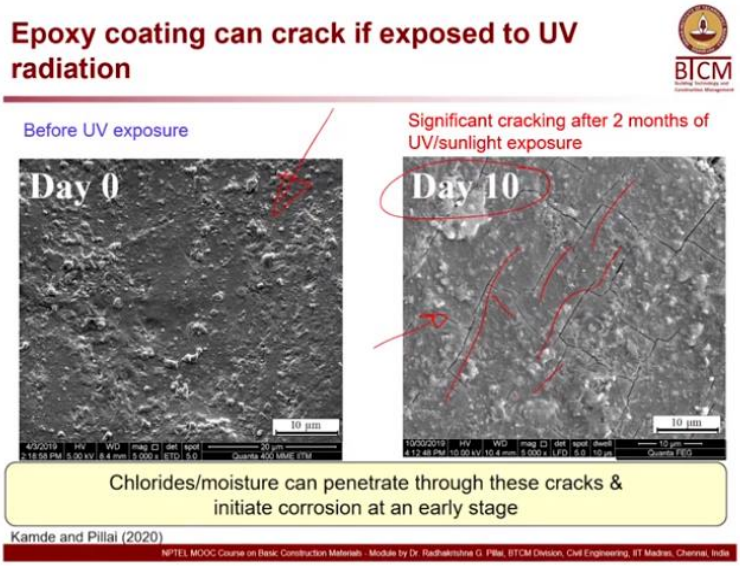

This is what happens; you can see I have been talking about this; they are getting cracked because of exposure to sunlight. So in some lab experiments, we saw that you know in very few like 10 days you know even if you expose it to sunlight in within a month, you will have a lot of cracking on the epoxy. So this is also a microscopic image or micrograph, which shows that initially there is no cracking and then after some time you will have many cracks on the, you can see this lot of cracks on this epoxy coating.

So this green color coating you see, even though you may not see the cracks with a naked eye. When you look through a microscope, you will see a lot of cracks on such re-bars on such coating when exposed to sunlight for a couple of weeks. So we must ensure that these bars are handled like babies; they should be protected from sunlight, and they should be protected from other abrasive actions.

You cannot walk because you cannot park vehicles on that, so a lot of care has to be taken when we use epoxy-coated rebars.

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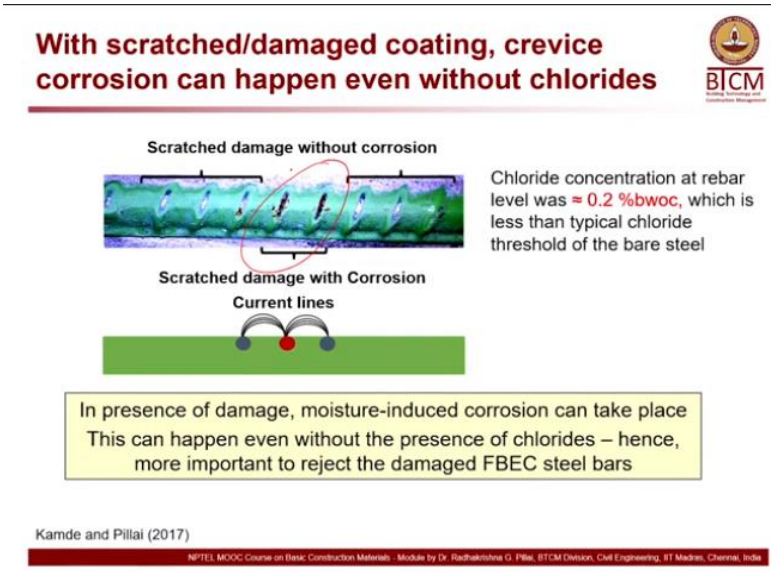

Thus, what is the corrosion mechanism like how they corrode? So this is an experiment we did in our lab itself; you can see here by doctor Deepak ((16:43)) see here this some of the scratches form or become anode whereas the other scratches become cathode. So in corrosion reaction, you know there is an anode and a cathode like a battery. You have an anode and a cathode. So anode is a location where it corrodes, and cathodes are the locations on the bar where it helps to corrode.

So what you know the point which you have to understand today is that if you use this coated non-metallically coated rebar, there could be a possibility of scratches or cracks on those epoxy coating which may or may not be visible with your naked eye. Moreover, some of those cracks or scratches will start corroding, while others will help the other scratches to corrode. So there is a point here is this going to happen even without sufficient chlorides. So it is more dangerous to use this kind of re-bars or damaged epoxy-coated bars.

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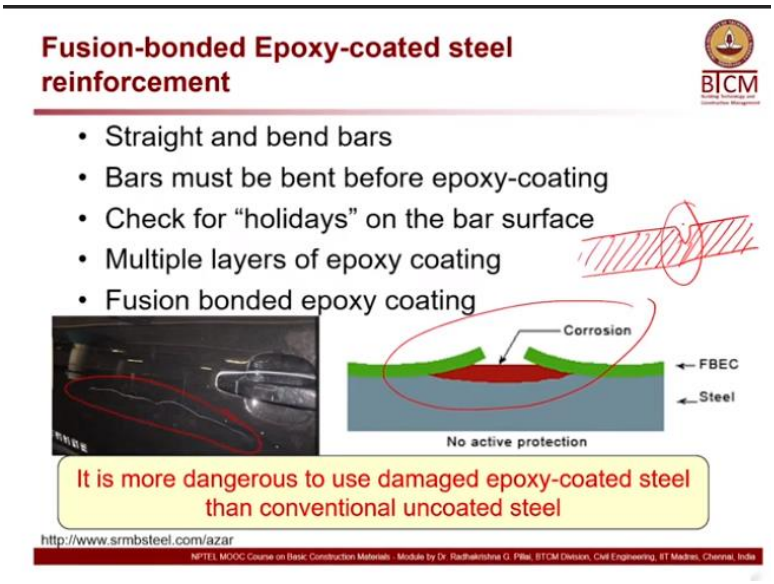

If you have, it is more dangerous to use a damaged epoxy coated steel bar than an uncoated steel bar. So look at these two pictures; what is happening? You know, if you have a vehicle like a crack like this, what will happen if it corrodes it corrode right at the crack alone. Moreover, that concentration will be high when you have localized corrosion. So similarly to the picture is shown on the right side.

Where you have that green is the epoxy coating and the red portion is the corrosion product. Thus, you have localized corrosion. So the cross-section of the rebar the remaining area available will be very significantly affected. So if you have rebar like this, it will corrode something like this so you have a localized corrosion attack. So this is the bar, this is the rebar, so you have a localized corrosion attack, so the steel capacity will be reduced significantly locally.

So some tips are that you should bend the bar before you apply the epoxy coating. And also, check for holiday scratches or cracks; do not expose them to sunlight, and multiples of epoxy coating are possible. And make sure that in your document, you write fusion bonding epoxy coating rather than chest epoxy coating.

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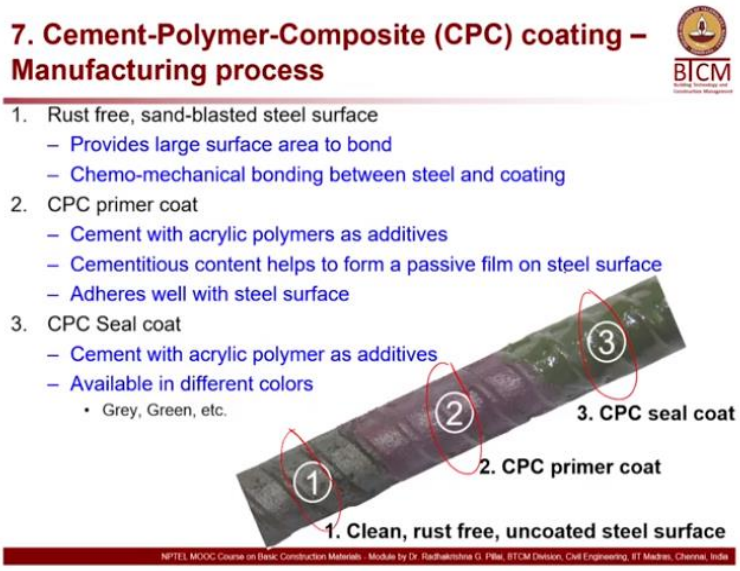

If you do not do things properly, this is going to happen; this is a picture from a bridge which is about 5 years old in Florida. Moreover, where they found that in 5 years itself, see how much corrosion is there. So, in fact, there are many places abroad where they have banned the use of epoxy-coated rebars, especially in the developed countries, but unfortunately, in our country, we are still using a lot of this rebar.

So I say that we are not ready in to use these bars because we do not have that much quality concern at our construction sites. So the message here is we should not use these bars unless we can ensure that these bars are taken care like babies. We do make sure that when we go out in the sun, babies will be protected, then we handle them very carefully know like that these rebars also need that baby-like treatment.

Otherwise, they will not perform, they will not have any corrosion resistance, and in fact, their corrosion-resistant is going to be poor than an uncoated reinforcement, so do not waste money because this kind of damaged rebars costs 20 to 30% more money and if you do that. You do not get the return. Then it is of no use. So another type of coating is cement polymer composite or CPC coated re-bar.

So you can see there are all again one here is a cleaned surface of the rebar, and then you have a polymer primer coating, and then on top, you have a seal coating, so as I said it is a double layer system. Now how does this one is the rust-free, we have to clean the steel surface We call it

sandblasting. What is sandblasting? We take sand and spray the sand on to steel surface. Take the sand and spray it at high speed very fine sand and that will clean the steel surface. If any loose particles present or some rust is present, it will clean up all that. So you get a very clean surface for item number 2, which is the primer coat to get bonded with the steel. Furthermore, on the top of the primer coat, you apply the seal coat then we get this. However, all this is done mainly at the construction site itself.

Imagine how difficult it is to keep a steel surface so clean, so because of that, and you know at the site you may not apply this coating on all places etc. So because of that, there is a lot of challenges in maintaining the quality of these bars.

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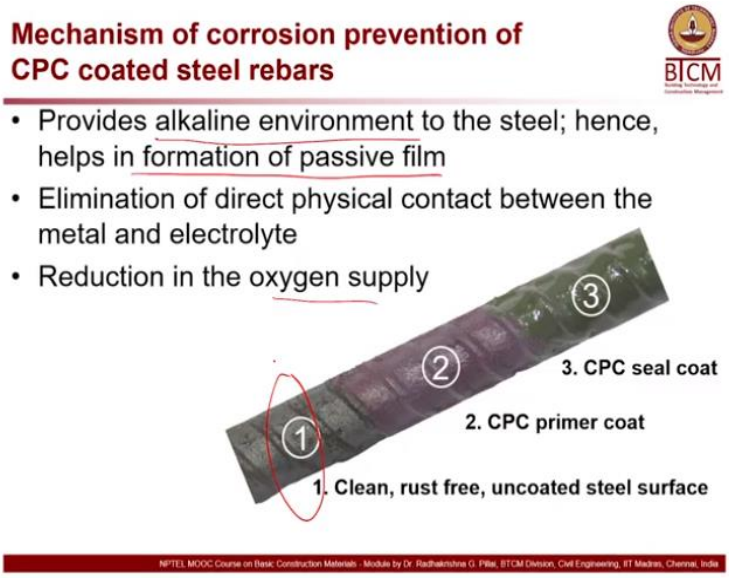

So now so what does it do? What is the protection mechanism is? This provides an **alkaline environment** to the steel. Because this material itself which is used, it has cement mix in it. So it provides a better alkaline environment than the epoxy, coated rebar, which we talked about. So because of the alkaline environment, passive film formation is possible, which is a protective film, or the oxide layer of the steel is possible.

Moreover, it eliminates direct physical contact between the steel and the concrete, and also there is a reduction. So it is like a physical barrier again; it would have a barrier effect. However, at the same time, there is a little bit of passive film formation, but if item number 1 clean surface if that is not properly ensured. Then the performance is not going to be as you expect.

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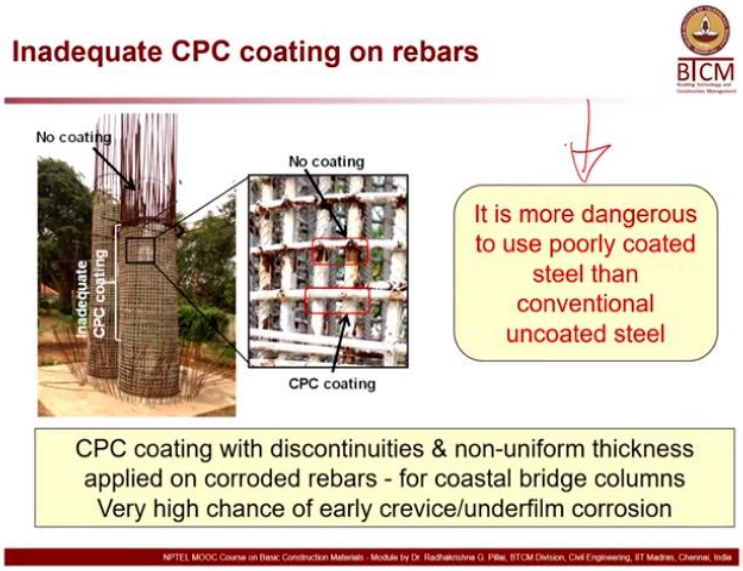

And also, this is a picture from one of the site where you can see this kind of coating is applied. But there are many places. I have put red rectangles here in the zoomed-in photograph where you can clearly see that some joints or the intersection between that vertical and horizontal bars are not painted. So when you have this discontinuity in the coating, you will again there is a possibility of a battery to be formed, or a corrosion cell can be formed.

We are creating a more vulnerable scenario like inadequately applying the coating. So in any coating for the general principle for you understand any coating which you provide on a metal surface, it is always better to provide a good coating. If you do not provide a good coating, it is worse than providing no coating. So if you are providing a coating, make sure it is of good quality; otherwise, it is better not to do anything just leave it uncoated at least you will not have the concentrated corrosion.

When you have the coating with damage, scratches, or inadequate coating like this, what will happen? You will have a lot of localized corrosion under film corrosion will happen. Localized, crevice, or under filmed corrosion will happen. If there is no coating, then there is no possibility of under film or crevice corrosion. So the message is that it is more dangerous to use poorly coated steel than conventional uncoated steel. So do coating if you can do a proper coating; otherwise, do not use it.