Basic Construction Materials
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Module - 7
Lecture - 36
Metals 2 - Part 2

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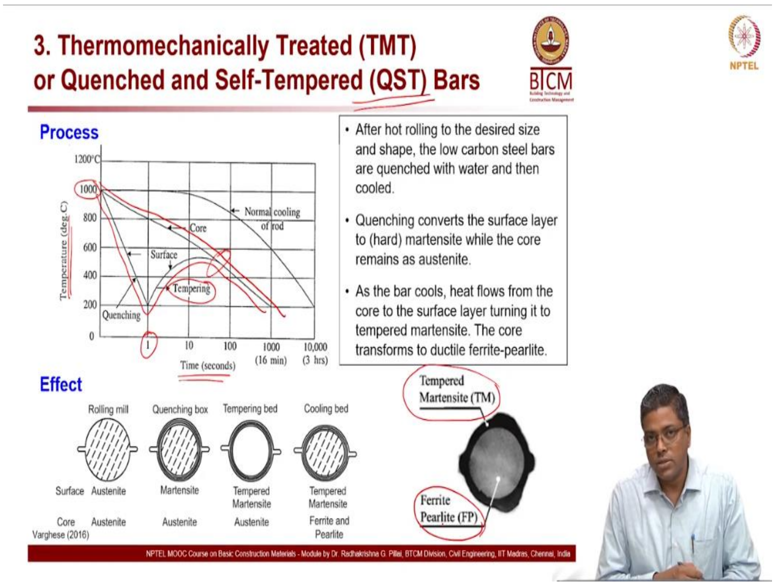

Now, the third type of rebar which I would like to talk about is the TMT or quenched and self-tempered, QST steel bars. This is a bar which is widely used in today's market. So, it is very important for you to understand in detail about this type of rebar. So, we will focus a little bit more on what are the important quality parameters, etcetera for this type of bar. Now, how is it made first? So, this bars, you can see here, 100 degree Celsius temperature.

This is the temperature scale and then this is the time axis. Now, time axis here is logarithmic scale. You can see here, 1 second, 10 second, 100 second, 16 minute and 3 hours. It is not linear scale, it is log scale. Now, what they do is, for making this steel, they pass when the steel is hot, it is coming out of the rolling mill, they pass it through a pipe with water or a water bath, very fast.

So, what happens? It gets quenched, like a blacksmith dips the knife into the water when it is hot and then he hammers it. So, the reason is mainly to make the steel hard and easy to handle. It will not get deformed very easily when we handle it in a very rough manner in our construction site. So, you need that hardness and at the same time you need high strength.

You need high strengths and also you need ductility. So, there are a lot of things which we have to worry about while making steel rebars. And that is why this beauty of this TMT or QST steel is you make this by quenching the rebar that is passing the rebar through a water bath. So, what happens is, the surface temperature follows this curve. So, when the moment the bar goes through the water bath, it gets quenched in the water.

So, the hot steel comes in contact with the cold water for 1 second. And then, suddenly it comes out of the water bath. Then the Centre of the steel is still very hot, the core region is still very hot. So, that heat also radiates outward and then it heats the surface again. So, that is what we call tempering process. So, you can see the temperature increases again and eventually, it match with the temperature of the core, which is this curve here.

So, this matching happens here. So, the surface temperature is different from the core temperature during the manufacturing process. So, the surface gets quenched and then it gets tempered because of the heat coming from the core of the steel bar. So, we call it self-tempering. So, that is why the name quenched and self-tempered steel comes from, QST. And ideally speaking, QST is the correct terminology and not the TMT.

TMT is the word like Maggie we say know, somebody started calling Maggie, and we all call Maggie. But actually, the correct name of Maggie is noodle. So, like that, if you really think about the technical term, it is QST which is the correct term. So, somebody in the early time of introduction of the steel, this type of steel into the market started calling it thermo-mechanically treated.

And so, if you really think there is no steel which is not thermally or mechanically treated. So, all steels are thermally or mechanically treated. So, it is really not a correct name, but we have to go with what others say. So, we will also join the same way. But you must remember that it is QST steel. During this process, what will happen is, the outer, this is when we quench this and self-tempering leads to a microstructure called tempered martensite for the peripheral region, because that surface is the one which gets water. Now, the core region or is cooled in a very slow manner. Now, that forms a microstructure called ferrite pearlite, FP.

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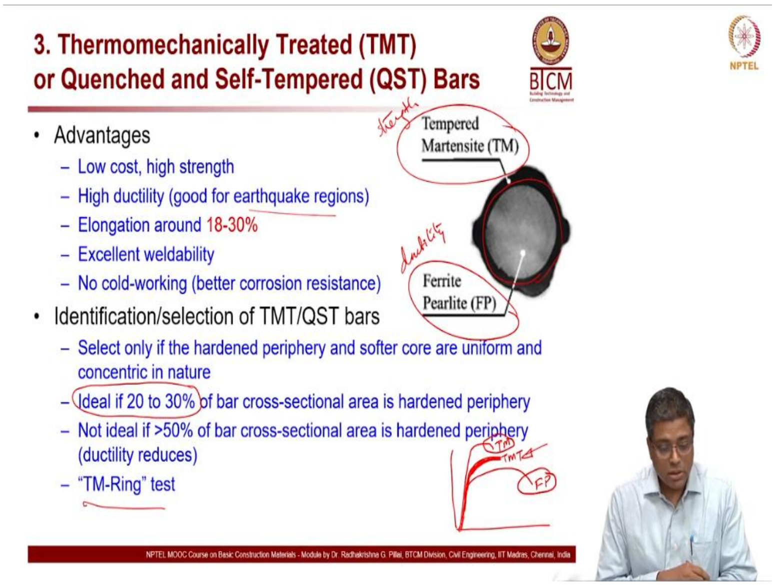

So, tempered martensite on the peripheral region and ferrite pearlite on the core region. And this colour here is not any Photoshop or anything; this is how you will actually see the bar. If you cut the rebar and then look with your naked eyes, you will actually see this colour difference with some acid treatment; I will show you that later. But you can actually see this on all the rebars, if they are good TMT bars.

Now, what are the advantages of this bar? Low cost, high strength, high ductility for earthquake resistant regions, you need very ductile rebar. Where is that ductility coming from? It is coming from this, the ferrite pearlite-ductility. Tempered martensite contributes heavily for high strength. The ferrite pearlite contributes for the high ductility of the rebar. So, this is essentially a composite rebar.

So, if I draw stress-strain graph of this ferrite pearlite and tempered martensite, I will see that, maybe something like this and then something like this and then this is the TMT bar. So, this is for FP, this is for tempered martensite, this is for TMT bar. The Centre one is like a composite. This is like the composite bar, rebar curve. So, this is for the core region, this is for the peripheral region and this is for the rebar.

So, you can see how the core and the peripheral region, the composite structure forming the rebars. Now, there are some specifications here. The bars are ideal if 20 to 30% of the rebar cross-section area is hardened periphery. A cross-section area is the tempered martensite and not ideal, if the dark colour region and the grey region, if they are not really uniform, these bars will not behave the way you want it to behave.

So, there is a test which is very good test. We call it TM-Ring test, TM -tempered martensite ring. You can see this bar here. There is a ring know, you can call this as a ring. So, we can call it TM-Ring test.

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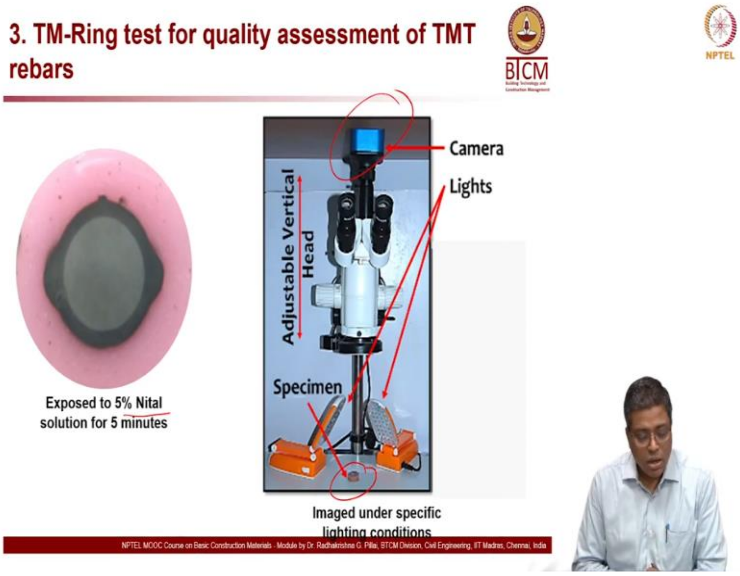

And this is how a bar will look like. And this is a small test setup. You can see the rebar piece here at the bottom of the photograph. There is a camera here and then you take a photograph, simple thing - it is nothing very complicated. Anybody can do this in any of the field construction sites. So, all you need is a 5% Nital solution. Nital is nitric acid plus ethanol.

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(Video Starts: 08:26) This is the test. You can see the video. The one on the left side is a poor quality bar. The one on the right side is a good quality rebar. And then, you can see, the one on the left side, you will start seeing that the ring formation is very bad. But on the right side, you can see a full ring formation. You can see here. On the left side, it is incomplete, but on the right side you have full ring. So, left side is a bad quality rebar and right side is a good quality rebar. You can very clearly see that ring test. **(Video Ends: 09:02)**

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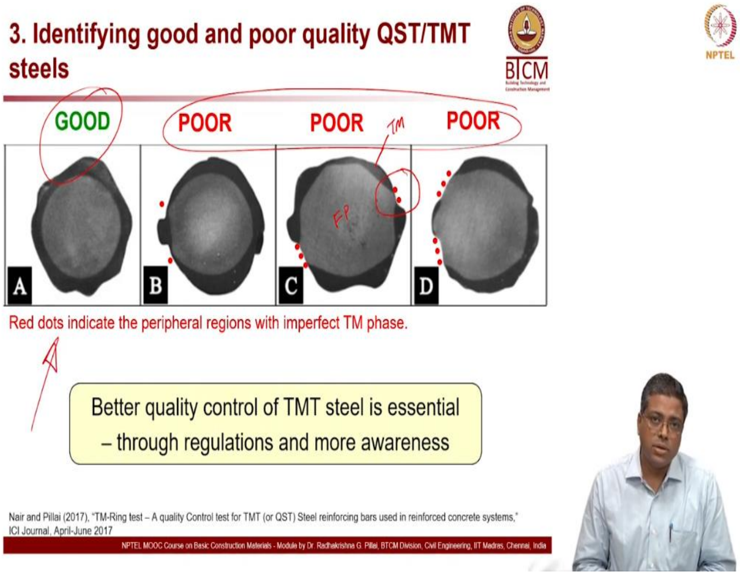

Now, these are examples. Again here, this one is a good one and all these are poor quality. All the 3 photographs on the right side, they indicate poor quality rebar. And unfortunately we have a lot of such rebars in the market. What is the problem here is, I have indicated the red dots here. So, for example, you look at here. You will see that, that region, you have the tempered martensite which is the dark grey colour, ferrite pearlite; and then this is TM.

So, there is a discontinuity in the ring or the ring thickness is not uniform. So, these are all the problems. Why this is happening is because, the steel manufacturers, sometimes they do not quench the steel properly. If the uniform quenching is happening, then you will get a bar like this, the one on the left side, good quality bar with full ring, and very good quality in terms of corrosion resistance also.

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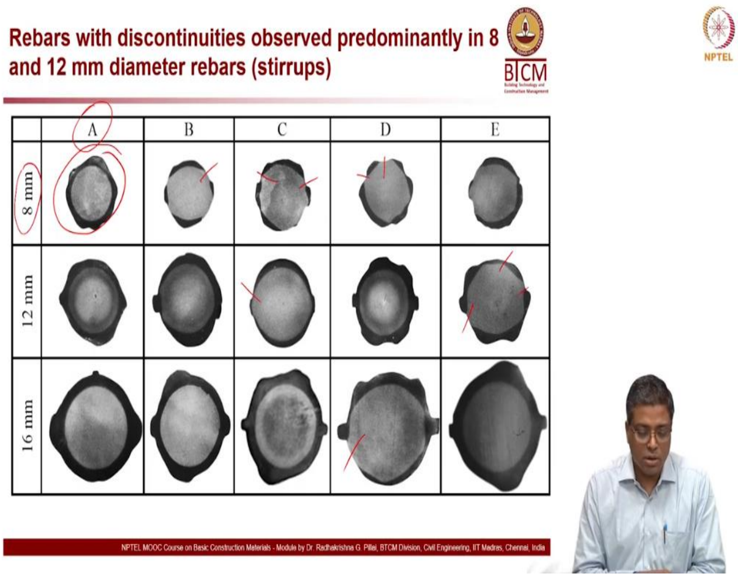

Now, you see here, only the Type A is good in this. All others, you have incomplete or inappropriate rings, not consistent, they are sometimes disconnected. You can see everywhere here, disconnected, not uniform thickness. So, all these problems, in a photograph they might look good, but they are not actually good. They look like flowers know, in some cases, but they are not actually good quality rebars.

So, for a good quality rebar, you need something like this (A). Full ring is required. And also one more thing to note down is, in this picture itself if you see, the smaller diameter bar on the top row, 8 mm, is having more problem than the larger diameter bar. So, if you ask the manufacturer and do this TMT ring test, they will actually do it on a larger diameter bar and you may not be able to capture the problem.

What you should do is, you should test the bar with the same diameter which we are using, not a different diameter. The ring test should be done on the same diameter rebar and you should look for the proper ring.

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If you do not have a proper ring, what will happen is, you will have lot of cracks like this, when you bend the bar. And in the site, we always have to bend the rebars and when you bend the rebar, the cracking should not happen. So, the picture on the left side is a good quality bar. I have put this in a green and this bad is red. So, a good quality bar, like a proper ring, even if you bend it, there will be no cracks.

On the right side, a bad quality rebar, when you bend it, there will be lot of peeling off of the peripheral region, which is very dangerous for the structure. And this I think is one of the reasons why we have lot of the new construction start corroding faster. Because this kind of cracks, if they are happening, you do not need chloride, only water and oxygen is essential; that is all what is required to cause corrosion, because the mechanism of corrosion is called crevice corrosion. This is what is going to happen if you use this kind of bars. So, you must do this TM-ring test on all the bars which you get.

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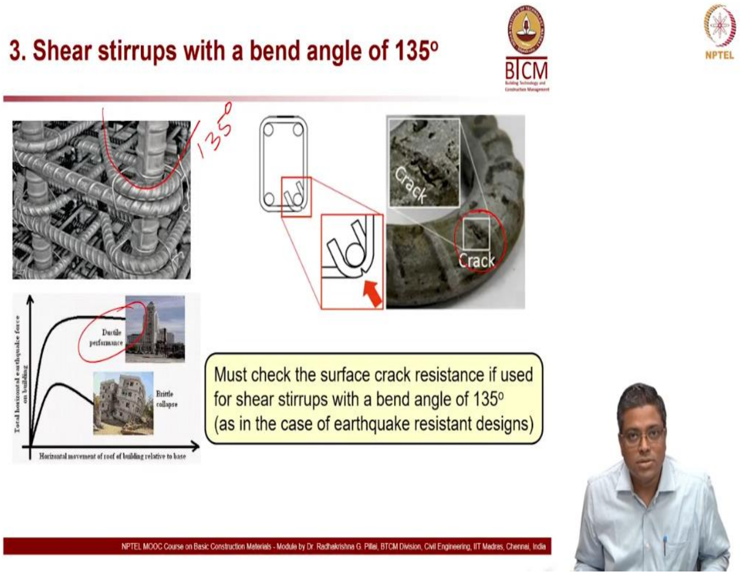

Now, we bend the bars at the site and then, while bending, this kind of crack should not happen. Why do we use this bar? We use this bar for getting ductile performance for our structures. That is why we use TMT bars. The core region is more ductile; I told you know, ferrite pearlite is more ductile, the peripheral region gives you the strength, which is tempered martensite.

So, the ductility is the key thing here. And for achieving ductility, we always bend these bars by 135 degrees. So, when you bend it like that, the bar should not crack. So, like I showed in the previous picture, if you do it, bend it like this, bar will not crack if the ring is for proper. If the ring is inadequate, it will crack.

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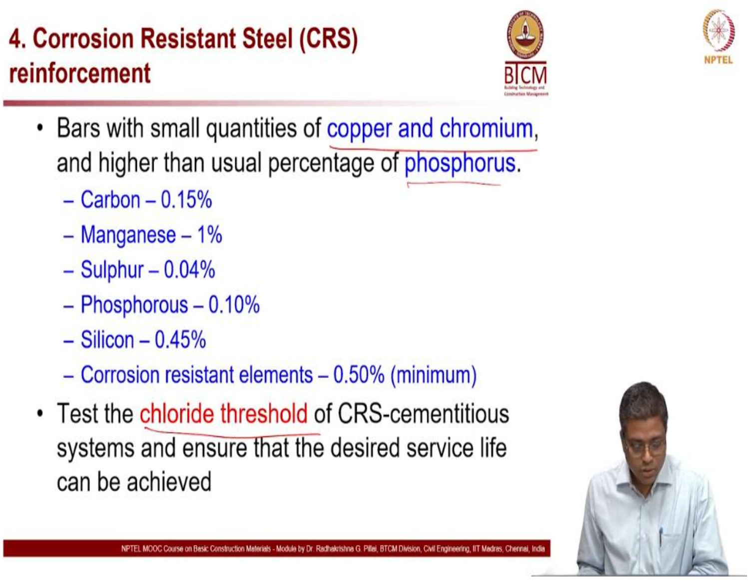

Now, another type of rebar is corrosion resistant steel, which is essentially made by addition of a little bit of copper and chromium and a little more phosphorus. So, these are the 3 additional ingredients for the steel. And then you get this rebar called corrosion resistant steel. Here, one important thing I would like to mention is that test the chloride threshold of this steel.

Because, if you look at the durability or service life of the structures, it is the chloride threshold which is more important than corrosion rate. Why I am saying this is, most manufacturers, when they sell this corrosion resistant steel, they will say that corrosion rate is low. But that is not the key parameter to look at when we look at long service life of the structures.

There is a more important parameter which is chloride threshold or even pH threshold, if you look at carbonation. So, chloride threshold is the parameter which you should look at. What is chloride threshold? It is the minimum amount of chloride which is required to cause corrosion. We will just leave it at that level, do not need to go too detail.

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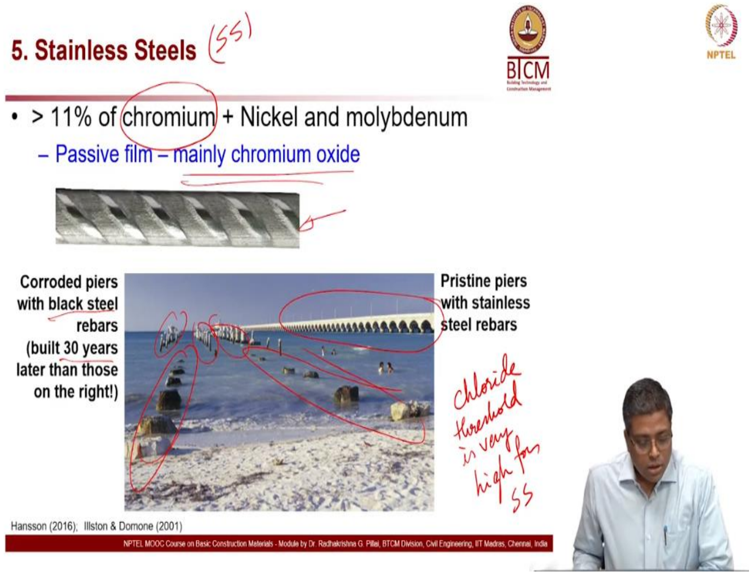

Now, stainless steel is another type of rebar, which is also getting more and more popularity. What is stainless steel? 11% of chromium plus nickel and molybdenum, if they have them, we kind of call it stainless steel. Now, passive film is the main oxide layer, mainly chromium oxide. Passive film of stainless steel has chromium oxide, because you have lot of chromium present in the stainless steel.

Now, this picture below. This is an example, photograph of stainless steel; looks shiny bright grey colour. So, picture on the bottom line will tell you very clearly how important or how good or useful is the stainless steel. You can see, these pillars here, they actually belong to a bridge which was constructed after the bridge on the right side. So, they are corroded piers with black steel. Black steel is the conventional steel rebar.

So, these piers are all corroded. But this bridge was constructed 30 years later than those on the right. This is a bridge with stainless steel rebar. So, same marine environment or chloride rich seawater environment you have, but when you use stainless steel, it does not corrode. So, it has very high chloride threshold than the regular steel. What is chloride threshold?

It is that amount of chloride which is required to initiate corrosion of the steel. For stainless steel, you need much more chlorides than the regular steel. Chloride threshold is very high for SS or stainless steel.

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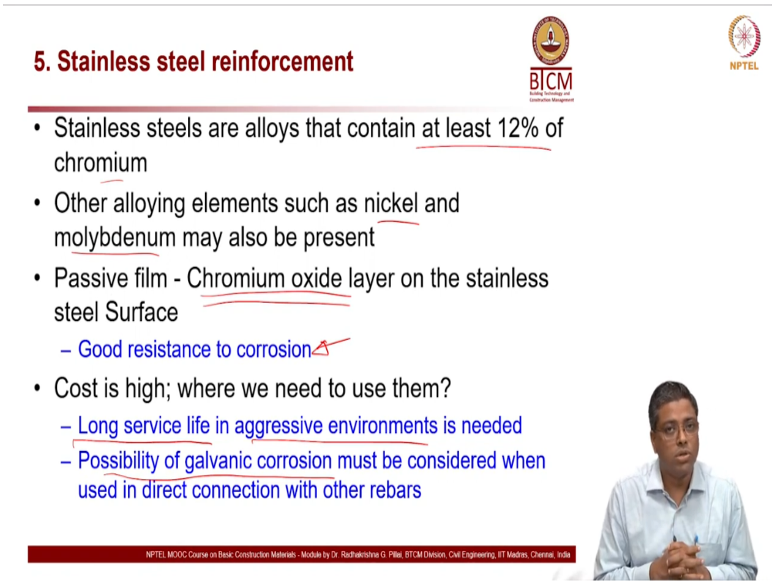

Now, what is stainless steel? They are alloy that contain at least 12% of chromium. Other alloys such as nickel and molybdenum are also present. And passive film, essentially it has a significant quantity of chromium oxide in that. That provides the corrosion resistance. But cost is a little bit higher, 6 to 7 times more than typical steel. But we have to see, it is not the capital which is, we have to worry about, we have to think about the lifecycle cost.

So, if you want a very long service life for the structure and in aggressive environment, probably stainless steel is the way to go for. But you have to see, you have to do this cost analysis, lifecycle cost analysis and then only you have to make that choice. Also there are some cases where people say, you can use some portion for stainless steel and some other portion for other normal steel.

Or the more vulnerable locations in a structure, like they are very near to the surface of the concrete, you can use stainless steel. So, in that case, we have to look for something called galvanic corrosion. Galvanic corrosion is nothing but, when you put 2 metals together, one metal will corrode in preference to the other or before the other, when they are in direct contact.

At home also, you might see this. Sometimes, you will see that in door hinges, etcetera, you will have a metal which is stainless steel and then screw will be mild steel. So, what will happen? Or the other way. So, 2 different metals are used. What will happen is, at that intersection, if you look carefully, you will see that there is some corrosion happening. That is because of the contact between the 2 metals.

So, 2 dissimilar metals come in contact, and then there will be a battery will form and that will cause the galvanic corrosion. So, when you put stainless steel in combination with the other steel, you must check whether there will be galvanic corrosion or not. That is something important to check.

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These are some examples where stainless steel rebars have been used for bridge construction. But in India, we are still not much into these, because this is in Toronto and New Jersey, very cold climate where they have severe chloride; they spray chloride onto the road surface, so that you can drive during the winter. Otherwise, there will be scales of ice will form on the road surface and you would not be able to drive your vehicles.

So, they have lot of deicing salts. They pour and they spray chloride solution onto the road surface to melt the ice, so that vehicles can drive. But fortunately, we do not have that problem in most part of our country. So, we have to still see where we need and what are the types of structures where we will require stainless steel rebars to be used.

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Now, to summarize today's lecture, we looked at history of steel rebars and then, we also talked about the plain and ribbed rebars, then CTD rebars and then TMT and QST steel rebars and then corrosion resistant steel and stainless steel.