Basic Construction Materials
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Module - 7
Lecture - 35
Metals 2 - Part 1

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Hi, welcome to this lecture as part of the course on Basic Construction Materials. In this lecture, we will look at uncoated steel reinforcement.

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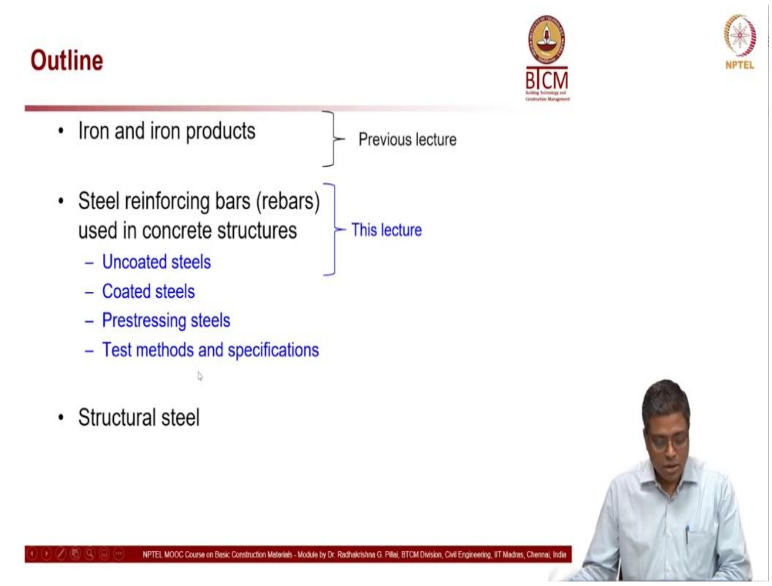

This is the outline of this module on metals. In the previous lecture, we looked at iron and iron products and how they are manufactured; cast iron, etcetera. And today, we are going to look at steel reinforcing bars, in particular uncoated steels we will cover today. And then coated steel, pre-stressing steel and some test methods and specifications, we will cover in the following lecture. Followed by, there will be one lecture on structural steel by Professor Arul Jayachandran.

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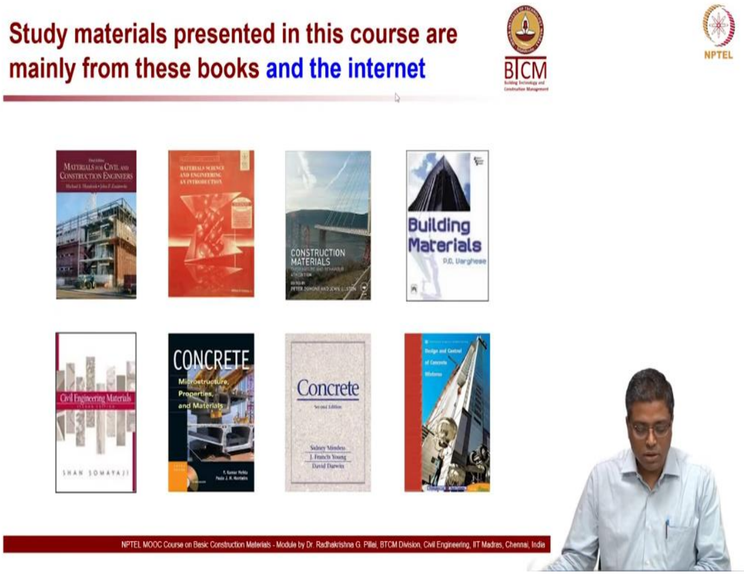

And these are some of the textbooks I used for this course. And as you know very well, lot of information from the internet has been used; photographs, etcetera, to make the course more interesting for you and easy to convey the messages.

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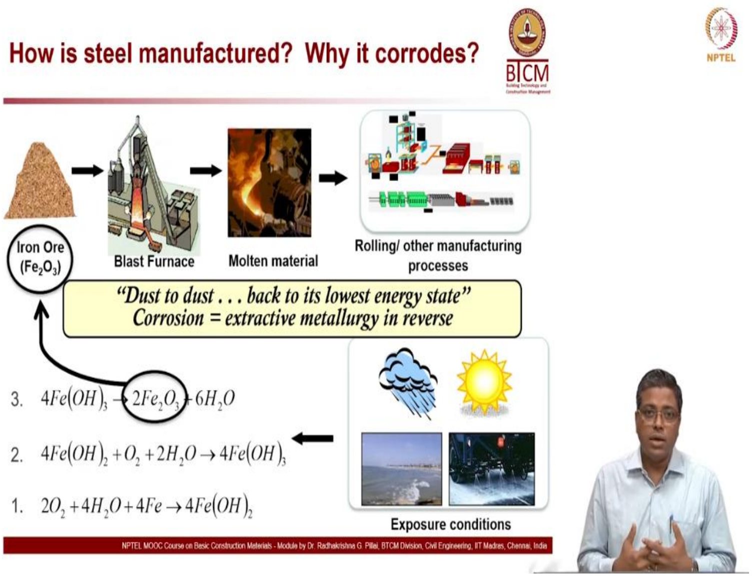

Now, how is steel manufactured? We already looked at it. And why it corrodes? We looked at it in the previous lecture. I just wanted to emphasize on one aspect here, that steel is manufactured from iron ore. So, because of the heat treatment and the mechanical treatment given during the manufacturing of the steel, the energy level of steel is higher than that of the iron ore. So, when we use this steel in concrete structures and the structures gets exposed to moisture, oxygen, carbon dioxide, chloride, and etcetera.

And in that exposure conditions, the steel will get corroded. And this corrosion is nothing but the extractive metallurgy in the reverse direction. And the corrosion product is having similar structure, chemical structure as that of iron ore. Also one more thing I would like to mention is that, it is that the iron ore is heavily used for manufacturing of steel in India even today. Majority of the steel manufacturers use iron ore as the raw material.

But if you go to most of the developed world, they have started heavy use of scrap metal as raw material for manufacturing steel. So, the use of iron ore is less, but more of scrap metal is used and in India, we are still using a lot of iron ore as raw material.

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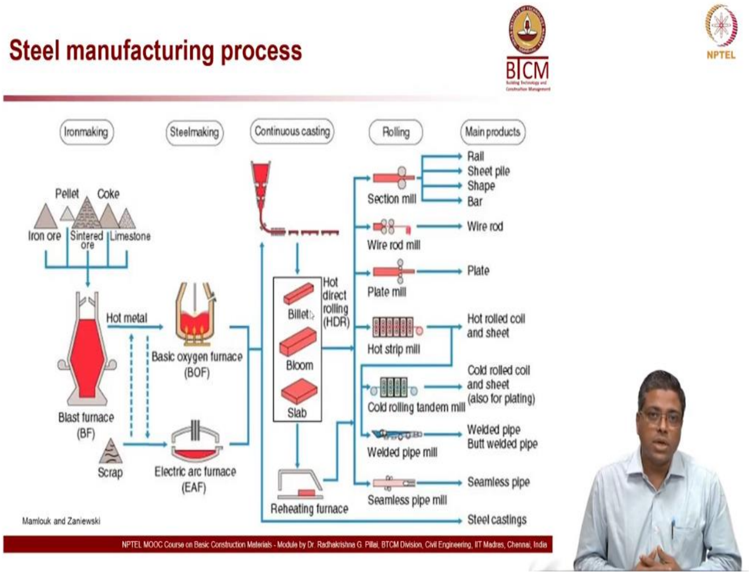

So, this is just a quick look at the manufacturing process. Essentially, the rebars are made from either billets. Billets are prism shape elements which are produced first and then they are put into some kind of roll to make different steel sections, including the rebars. Different types of dies are used for that.

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Now, let us look at the, how the steel industry kind of evolved. This slide show, the steel industry started with mild steel, in 1950s if you look at. I am not covering the things before, but just last few decades we are looking at. First we had mild steel in 1950, and then galvanized rebars were introduced. But later on, people stopped using galvanized rebar. Then HYSD or High Yield Strength Deformed bars, they were used.

Then epoxy coated rebars were introduced in 1970s and in 80s, we started seeing Cold Twisted Deformed rebars and then stainless steel. Then again galvanized or zinc-coated steel came into the market and then in 1990s, not much change. But after 2000, we started seeing TMT, mainly for ductility and corrosion resistance, higher strength also, without really modifying much of the manufacturing process, in the sense, not really too much cost, but it was a low cost option available to enhance the ductility and at the same time to get better strength also.

And also, low carbon chromium, which is corrosion resistant steel. And then, 2007, zinc polymer membrane steel, again coated reinforcement. Now, latest version, there is one more type of coating which is coming is called plasma coated steel. It is essentially again a galvanized coating, but done at a very different plasma level. That means, very fine microstructure level. So, these are just to show you a glimpse on how the steel industry kind of evolved over the past few decades.

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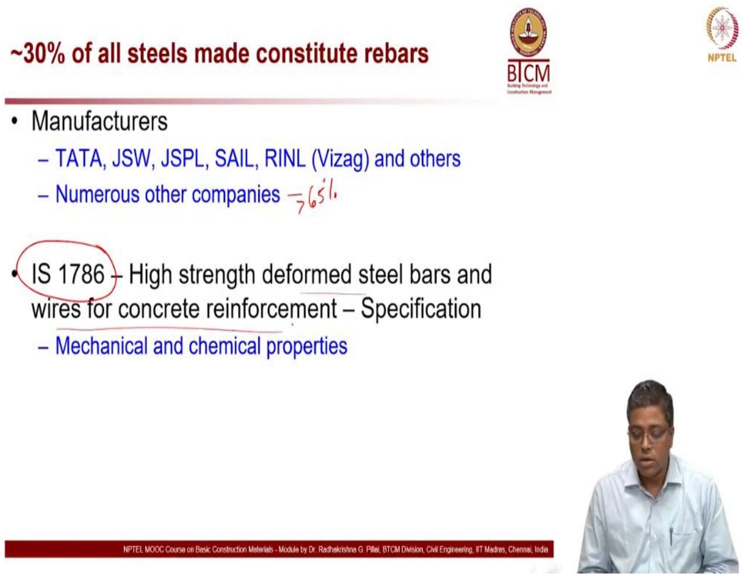

Now, 30% of all the steel that is manufactured, whether it is plates, sheets, rebars, whatever; all the steel we put together, 30% of that will be steel rebars, in India. In India, that is the kind of distribution. TATA, JSW, Jindal Steel and Powers Limited, Steel Authority of India, Rashtriya Ispat Nigam Limited, RINL, it is also called Vizag Steel. So, these are some of the major steel manufacturers, but there are numerous other companies which make steel.

In fact, the total production if you look, these numerous other companies, they contribute about 65 plus percentage of the steel rebars which is made. In fact, greater than 65%. So, you can see, so many companies are out there, which buy the billets from the manufacturer like the billet here, they buy and then produce the steel rebar. So, now, all these 30% of the steel which we are talking, they are all rebars.

All these rebars are kind of governed by this one standard specification: IS 1786, published by Bureau of Indian Standards. So, all the steel rebars have to meet these specifications, the mechanical and chemical properties which are given in this standard, so that they can be used. They are bound to meet these specifications. And this is for high strength deformed steel rebars, for bars and wires for concrete reinforcement.

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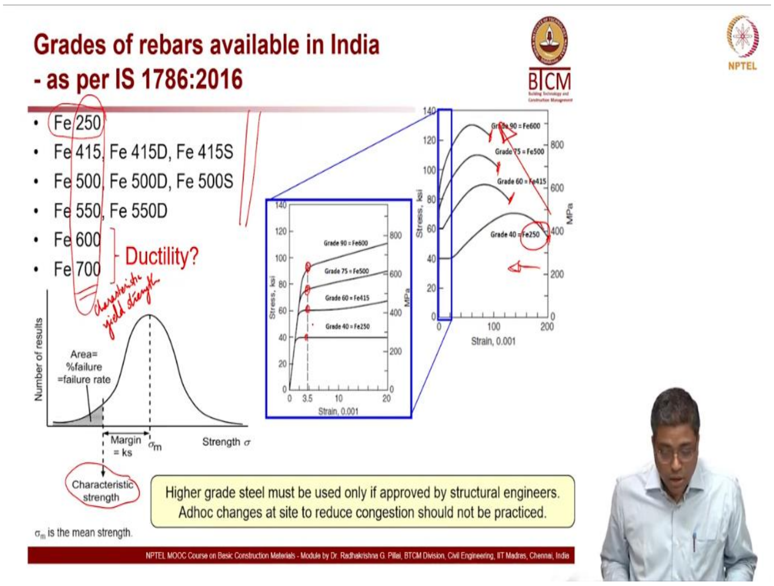

Now, what are the different types of grades available or to be precise, the strength grade available? So here, you have studied already stress and strain and all that. So, there is something called yield strength which we studied. So, this is one of the grade, let us say Fe 250. Fe stands for iron. So, we have so many of these grades available in the market, Fe 250, 415, 415D, 415S.

So, I will cover these things in the next lecture, a little bit more detail. However, what is this 250? 250 is the yield strength of the steel. So, there are different, the steel rebars with different strength grades are available or steel rebars with different yield strengths are available. And they typically range from 250 to all the way up to 700. But this 600 and 700 are not widely used, very rarely. They are also not much available too.

But 415, 500, 550, etcetera are available. So, these are the bars which are available in the market today. If you look at the graph on the right side, you can see that, as the strength increases, the 250 here, as it increases, the ductility is decreasing. So, the point here, the endpoint of this, they are actually moving to the left. That means ductility is decreasing. So, ductility is essentially the width of the stress-strain graph.

If you want to really look at it, it is width of the stress-strain graph, essentially in the plastic zone. But what you see is, as the strength of the reinforcement increases from 250 to let us say 600, as shown on the graph, the width of the graph is decreasing; that means ductility is decreasing. This is something important to look at also. Now, what are these numbers? All these 7, all these numbers are characteristic yield strength.

We looked at this characteristic strength in the early lectures and so, these are the characteristic yield strength of the bar. I am talking about these points here, characteristic yield strength.

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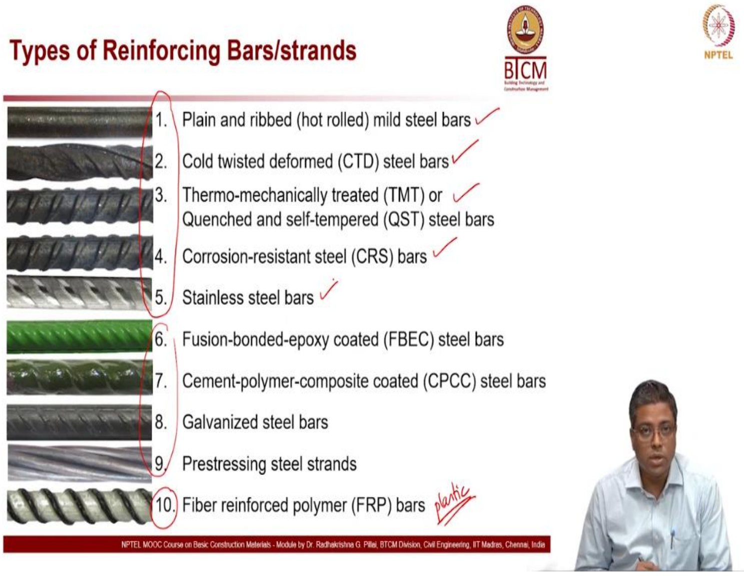

Now, these are different type of reinforcing bars and strands available in the market. First 1 to 5, we will cover today in this lecture. In the next lecture, we will cover 6, 7, 8 and 9. And 10, we will cover in the lecture on composites. I just wanted to mention that there are these fiber or plastic rebars are also available. Plastic rebars are also available, very lightweight, but they are still yet to capture the market, because it is relatively new; and steel is well time tested and proven; we know it is going to work.

So, in this module, we will only focus on metals. So, we will not talk about the fibre reinforced polymer rebars, but we will cover the items 1 to 9 in this particular slide. Now, item 1 is plain and hot rolled or mild steel bars. 2 is cold twisted rebars. Number 3 is the one which is widely used today, TMT bars. Then corrosion resistant bars and stainless steel rebars. These are the 5 type of reinforcement bars which we are going to look at in the coming slides.

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Now, plain and ribbed or hot rolled mild steel bars. Plain bar means something like this. It is smooth and there are no ribs on the surface. The steel has to get very well bonded with the concrete, but sometimes, in some places, you do not want that bond also. One example is, dowel bars which we are using on highway construction. If you are interested, you can just search for this word dowel bars.

So, you will know where this plain bars are used. It is used in the highway construction, concrete highways, and etcetera. It is used where you want the bar to slip like this in the concrete. But in most of the other concrete construction, we want the bar to be in contact and the relative movement between the steel and concrete should be 0. So, that is when we use ribbed bars with very high bond strength.

So, these are the ribbed bars, you can see the ribs. Next time when you see the steel rebar on construction sites, you can see it, there will be these ribs, like we have ribs on our body. So, like that, they have also ribs. They help in preventing the slipping of bar inside the concrete. Now, other type of bar, these are also mild steel. Typically, these bars are of Fe 250 grade. And there was a demand for increasing the strength.

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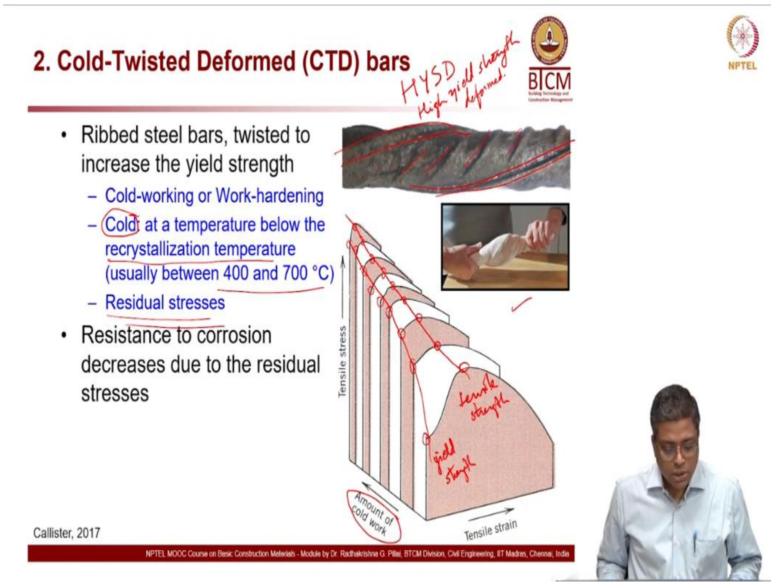

So, people tend to do, go for strain hardening or this is the next generation type rebar which came are cold twisted deformed bars or high yield strength rebar. So, also sometimes called HYSD, High Yield Strength Deformed, HYSD rebars. Now, you can see, there is a difference in the rib pattern on this and the one I showed in the previous slide. So, you notice this, this I kind of call it a seam, like in a cricket ball.

And then, you have ribs here. In the previous one, these are the ribs here. Now, there is a seam which goes like this also and this particular line is twisted now, twisted in case of CTD. Now, let us see how it gets twisted. You see here, this is what I am talking about. You can see here. So, they are twisted, just like when you twist a towel. You can see in this picture here, just like that. That is the process by which it is made.

So, when we do this cold working or work hardening or strain hardening of these rebars, it is done at a temperature which is called cold, but not cold for you. That temperature is about 400 to 700 degree Celsius. So, it is essentially the temperature below the recrystallization temperature of the steel. So, when the molten metal gets cooled and once the temperature reaches this 400 to 700, that range, at that time, it is colder than the recrystallization temperature.

So, at that temperature, the rebar is taken and then twisted. And then, we get this type of cold twisted deformed bars. And problem with this bar is, there are some residual stresses. Now, because of this residual stresses, resistance to corrosion also decreases. Now, before we go more into that, let me just tell here, when the, we do this deformation or this cold working; this graph here indicates that.

So, tensile strain, as the strain is more, then more and more the tensile strength or the amount of cold work. You can look at this amount of cold work, as it is increased, the yield strength is increased. If you take this point as the yield strength, they also tend to increase. So, you can do something like this, yield strength increases. Also tensile strength, the peak value is also increasing.

So, this is the tensile strength curve and this is the yield strength and also ductility decreases. Anyway, point is, these bars were heavily used for couple of decades in 1970s, 80s, etcetera, but now not much in use. Now, resistance to corrosion also decreases due to the residual tensile stresses.

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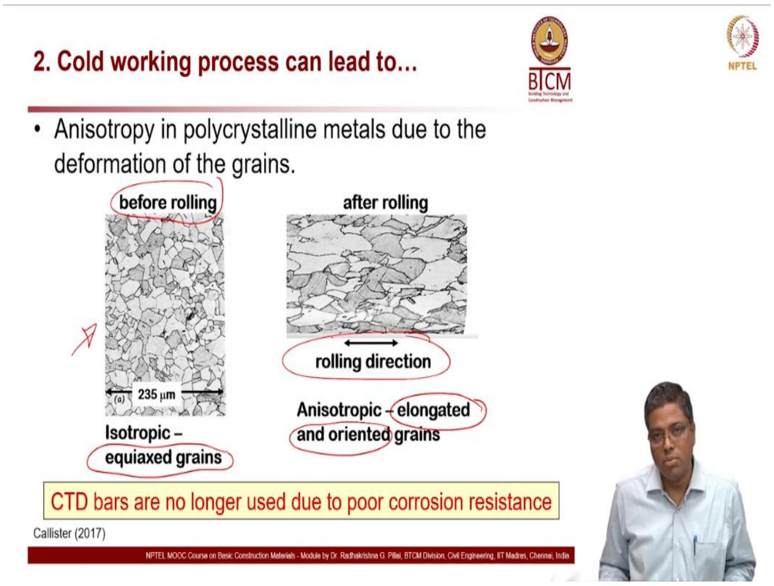

Now, cold working process, it can lead to anisotropy in polycrystalline metals due to the deformation of the grains. So, what is happening? While you do this cold twisting, the microstructure, you can see this grain structure. We thoroughly studied all this grain formation, etcetera in polycrystalline metals. So, you can see these, before rolling they have equiaxed grains, means, the size of this axis of these grains are more or less similar in all directions.

However, after the rolling, they get elongated or an oriented grains in the rolling direction or in the horizontal direction, as you see in the picture. So, the grains kind of get elongated. The point is, because of all this, there are some residual stress on the surface of the steel and when there are a stresses at the surface of the steel, then CTD bars kind of tend to show very poor corrosion resistance.

So, now these bars are not really made in the market. It is now the TMT steel which is being made. But if you go to structures which are like some 20, 30 years old, you will see all these kind of CTD bars were used. You can look for this, the shape of these ribs on them or seams on them.