Building Materials and Composites
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Lecture No - 29
Ferrous metals 2 – Reinforcement Bars, Corrosion, Light Gauge Steel

In this lecture 4 we will discuss on reinforcement bars which we did not discuss at all in the previous lecture. We were discussing mostly on rolled steel. Rolled steel is used independently. It can take tension, compression and it can itself act as a structural member. Coming to this particular lecture where we will discuss reinforcement bars, corrosion and light gauge steel. Now reinforcement bars as I discussed it will be embedded within concrete.

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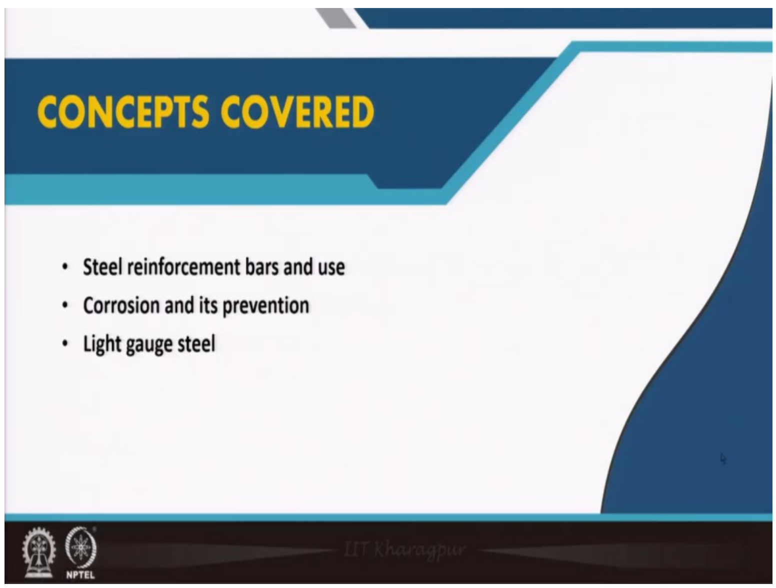

Next is corrosion which we will try to expose the defect or the drawback of steel or iron and discuss on how we can actually take care of corrosion. Because steel is so versatile in its use but it is having that property of being corroded and that is a defect. And if we can overcome that defect we can actually make use of steel in its best way and I will try to expose you to another item that is light gauge steel. This is now into our CPWD specification also.

This is not exactly 100% steel structure but light gauge steel can be used as a structural member for say 2 to 3 storey high, maximum up to 4 stories. It is a very cost-effective way of construction. So I will just expose you to light gauge steel very briefly and conclude the topic on ferrous metals.

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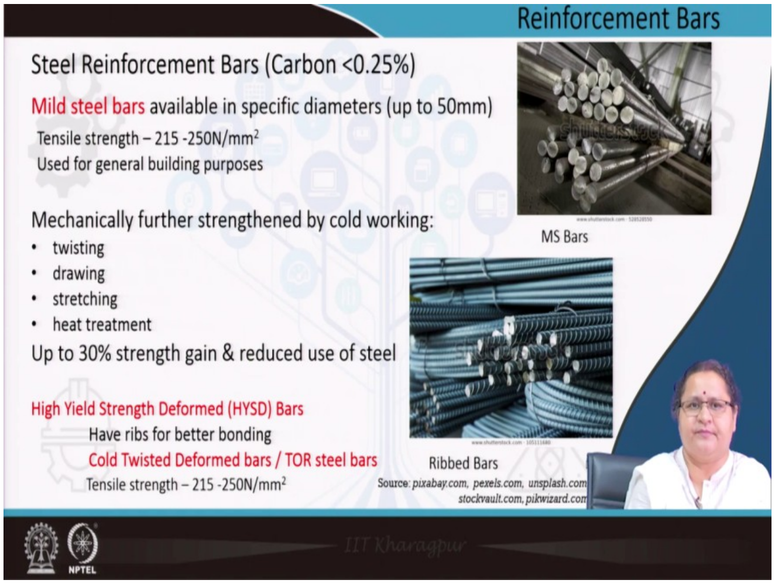

The steel reinforcement bars, which can be seen easily on construction sites. These are mainly rods and bars which are mild steel, having less of carbon. They are usually of different dimension starting from say 2 mm and go upto 50 mm. The available dimensions that are used for construction purposes are 2, 3, 5, 6, 8, 10, 12, 16, 20, 24 and 50 mm. So in your further classes you will understand the calculation part depending on the area of steel required to take the tensile load of any structure.

You have to first estimate the area of steel required and distribute it into the number of bars required. Now the cross-section of each bar is circular and hence you know the total area of such bars. So you have to divide it with the dimension of the bar of a specific diameter and find out number of rods that will be required. And you have seen in my previous lecture on concrete that dense network of reinforcement is there before any casting of concrete takes place.

So we are referring to these bars in this lecture. What is the advantage? These bars go embedded inside the concrete. You will never see in any structure that a mild steel bar is taking the entire load. Rather you can see an angle section, rolled section, tubular or circular section taking the load. But these bars mainly go into concrete for reinforcement. So these are usually used for general building purposes.

These bars have a tensile strength between 215 N/mm^2 to 250 N/mm^2 and to be precise there are different grades (grade 1, grade 2) of mild steel bars. So as you can understand these mild steel bars are plain on the cross section. If you see the picture (MS bars) carefully it is having a smooth surface on its longer face unlike the bars which you see in this picture (Ribbed Bars). The new picture here you see ribs or lugs these are called cold twisted deformed bars or high yield strength deformed bars.

These are mechanically further strengthened by cold working; meaning there is no crystallization pattern changes inside like hot rolling. So these bars can be twisted, drawn and stretched. These processes will result in developing high yield strength deformed bars and it has ribs on top. If it is twisted it is taut steel bar. So what is happening? The bars are having twists. What does it help in? What is the difference between the upper picture and the lower picture?

After the bars get embedded in concrete, it is very difficult to move this ribbed bar than that of a mild steel bars. You cannot pull it in both the cases. But the bonding strength between the ribbed bar and the concrete will be higher than that of the mild steel bar and the concrete. So this is more preferred and you see the tensile strength for this cold twisted deform bar is similar. What you are achieving? You are achieving higher bond strength between bonding of concrete with steel. And this can reduce the use of steel by a good percentage.

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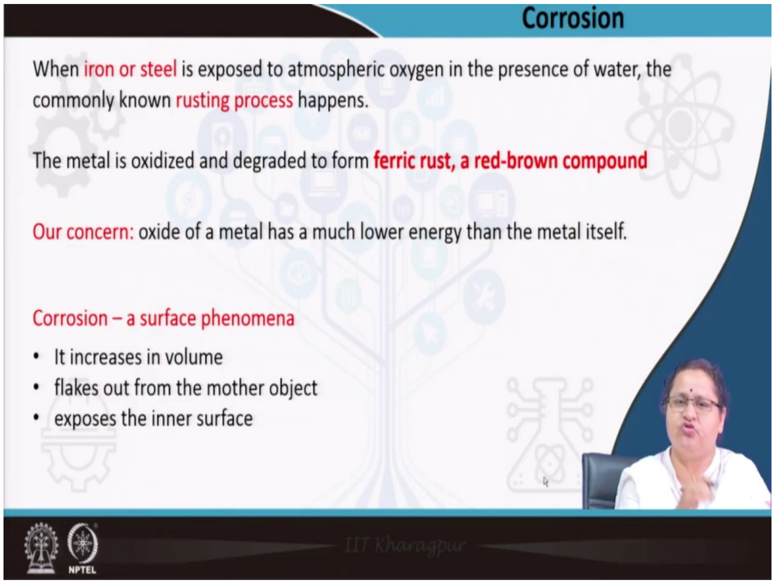

Another point you see which is separately written that was heat treatment. So here you see thermo mechanically treated bars; thermo means temperature. So you are allowing heating to change the property the mechanical property of T bar. Here short intensive cooling happens when it is dipped in water and then surface layer gets hardened.

So as I was talking of the different types of steel through the time temperature transformation diagram. Here you see the outer layer which gets immediately cooled, gets a crystalline pattern changed. Whereas the inner core remains in its original form that is the pearlite core. So outside which was thermally treated and intensive cooling was done by dipping it in water. What has happened? The crystallization pattern of the outer layer has changed to martensite steel, while the inside is still hot.

The crystallization pattern of this martensite steel is still changing and this gradually cools in the atmosphere. The outer portion remains martensite while the inner remains pearlite, giving different kind of property. It gives higher strength and ductility and also high temperature resistant up to 500 ^{o}C. Why we mentioned this here because even if it is embedded in concrete, if the structure is subjected to fire these bars will get de-shaped if the heat rises and the structure will crumble. So having higher resistance to temperature is to be noted and is very important.

This thermally treated bars or the TMT bars can be welded and at the point of welding it does not have a loss of strength. We can get high strength starting from 415 N/mm^2 to up to 550 N/mm^2. Reduction of use in Steel up-to 40% can be reduced and hence recommended for high-rise structures. Steel is quite heavy and has density of 7.8 g/cc (gram per cubic centimeter).

So just recommending lot of steel structure is actually giving lot of weight to the structure. So the self weight increases. Hence using such kind of thermo mechanically treated bars a considerable percentage of the steel use will be reduced hence it is recommended for high-rise structures. Further you get the advantage of high temperature resistance and obviously high tensile strength. Another type of rebar in the reinforcement part is known as thermo mechanically treated high corrosion resistant bar (TMT HCR bars).

In this kind of bar the same thermo mechanically treated bar (TMT bar) has chemical changes inside it and that gives it the added advantage of having higher thermal resistance of up to 600 ^{o}C along with lesser corrosion. So these members will be further recommended for high-rise structures obviously. The strength wise it will be similar to TMT bars and they can bend without cracking. So we see the reinforcement bars are of different kinds including the mild steel bars. The mild steel bars are provided for regular use.

But with the advancement cold twisted deform bars or the high yield strength deformed bars in to the market that has higher bond strength, higher tensile strength, requires to be used in lesser amount, which makes the whole system cheaper. Further we have the thermo mechanically treated bars which have a outer layer of a different type of steel, inner of a different type of steel achieved through heat treatment and having higher resistance to temperature.

TMT HCR bars having lesser chances of corrosion. So these all these types of bars go embedded in concrete unlike the rolled sections. So what is the advantage of these bars? The advantage of these bars is they are not getting exposed to the atmosphere directly and that helps to resist or keep it in an environment away from the atmosphere and thus prevent corrosion. So we open up the topic on corrosion which is a very common phenomena.

I am very sure you all know rust. We mainly see irons items or materials getting rusted with time. What is that? It is the oxidation that happens to the body of the material. The iron reacts with the oxygen in the atmosphere. We cannot take out oxygen from the atmosphere so these re-bars which are embedded in concrete has the added advantage of not being exposed to oxygen. What helps in rusting? It is the oxygen, water and carbon dioxide. So this ferric rust or ferric oxide forms in stages which degrades the iron.

Ferric rust is as a reddish brown compound. Our concern is we have to stop this oxidation process since the metal oxide has lower energy or lower strength than that of the metal. So it is weakens the metal otherwise it would not have been a concern to us. Since the strength gets reduced, the oxide is increases in volume. Please note that corrosion is a surface phenomenon.

It is happening only on the top of the item i.e. the topmost layer which is exposed to atmosphere. It increases in volume and obviously it sheds off it comes out from the mother's surface and then it attacks the layer beneath. The volume increases and exposes the inside or the next layer which again experiences rusting because it is exposed to atmosphere and that particular area gets weaker and weaker along with the entire structure as our atmosphere has water vapor also.

So the three elements namely oxygen, carbon dioxide and water react with this iron through the different chemical reactions stages to form this rust. These rust flakes expose the inner layer and further rusting happens. So we need to take care of it. So what can we do to prevent it from the rusting process? We can modify the surface or change the environment as a possible remedy.

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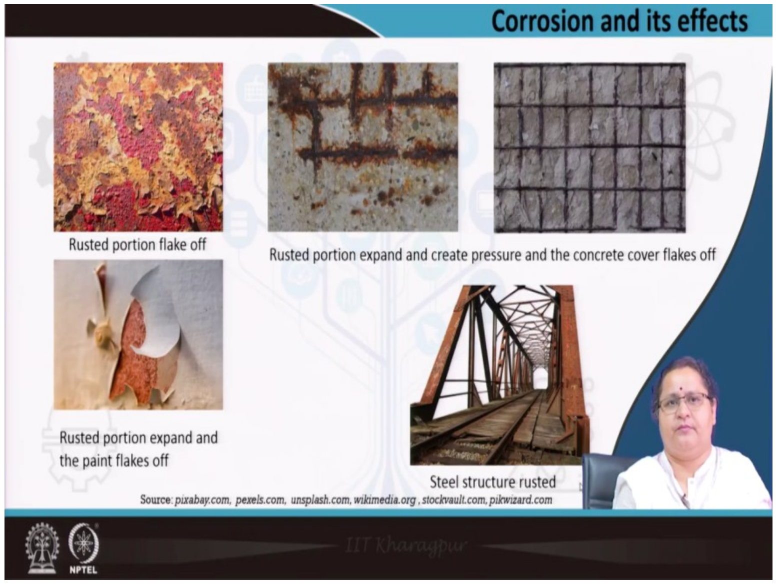

Let us see some pictures to get a visual idea about rusting. You see in the first picture, the layer is flaking off which I have told you just now. See these are the flakes that are the upper layer is coming out and exposing the inner layer. So in the next stage, the inner layer will get corroded or rusted. In the next picture you see here is a pipe, which has been painted. The inner layer is iron which is getting rusted by entry of water vapor or water leakage.

It may have internal leakage where from it is getting water and with the presence of oxygen and carbon dioxide in the atmosphere, the rusting has happened and it has pushed the layer of paint because it has increased in volume and the paint layer has come out. In the next picture you see the steel structure is completely rusted on prolonged exposure to atmosphere.

But there is a difference in these two pictures. On top these are rods embedded inside concrete. Concrete, if you remember, has a layer or a clear cover. So the rods were kept and the concrete was supposed to cover it. So this was at least 25 mm. So just think of the pressure this rusted iron creates that this 25 mm of concrete, which can come out.

So it is not just the paint layer that is coming out but also the 25 mm of concrete layer that has come out due to the pressure created by the increase in volume of the rusted iron. So you can understand this rusting has happened in absence of atmosphere but the trapped in air, trapped in moisture has led to such corrosion. There may be fine cracks which were not visible through which air has passed and this has taken a long time, which is a gradual process that has ruined the concrete.

So corrosion has a far-reaching effect on to building even if the reinforcement even if the steel or iron is embedded inside. We have to be very careful on that.

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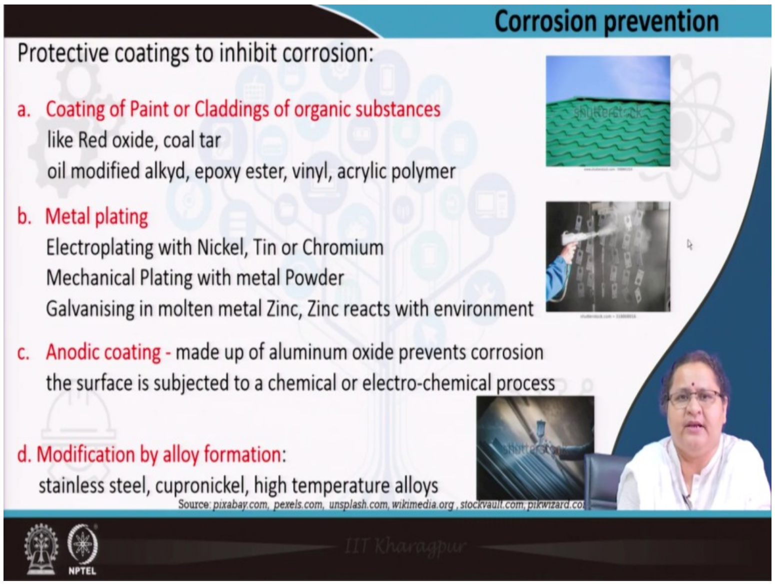

Corrosion can be prevented by coating. You can see the picture of roofing where it is coated. Coating with maybe some red oxide paints and Coal tar (jet black) can be adopted. But if you paint you are getting rid of corrosion only. To get rid of rust flakes, you may apply oil like modified alkyds, epoxy esters, vinyl or acrylic polymers. It is a cladding or putting a dress on top of the iron member. You can also have plating, electroplating with nickel tin or chromium.

Mechanical plating is done with metal powder and the other is galvanizing. You all know galvanizing is usually involving zinc galvanization where zinc is put as a molten metal that is coated on top of the iron object and zinc actually reacts with the atmosphere very slowly and hence it protects the mother material. So you are doing a metal plating on top of a metal to prevent it from its oxidation process.

Anodic coating is another where aluminum oxide prevents corrosion; the surface is subjected to chemical or electrochemical process. And you have already noted that in the alloy formation you can have stainless steel, copper, nickel and high-temperature allies made with one of the major components as steel and you can actually go for corrosion resistance. However we find coating as very easy plating and alloy formation process. It is practiced but not much used in the building industry.

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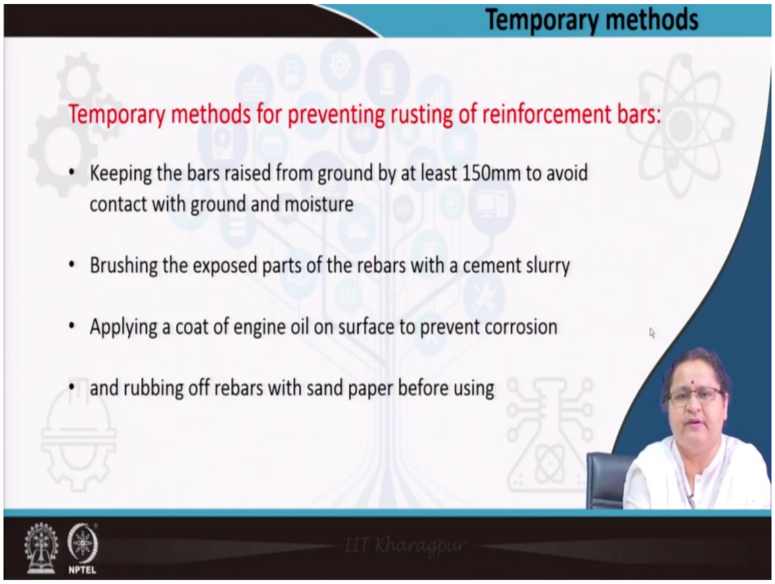

We also need to know the temporary methods as we had talked extensively on re-bars. If you visit a construction site, you will see lots of reinforcements lying here and there or clustered together. So how to maintain those iron materials when they will be used after sometime (say one month)? So will they be left exposed to the weather and let the corrosion/rusting take over? There are some temporary methods to prevent it from corrosion. First important point is to keep them raised from the ground.

You can just put brick as a support below at an interval and raise the entire steel bars and keep it free from the ground. So that it is free from water and then you brush the exposed parts with cement slurry. Why cement slurry? Cement slurry is coated because the rods will be embedded in concrete sometimes at a later stage, where cement will be one of the components. So it does not need to be taken out and you are only putting the exposed part. You are not opening and individually painting it with cement slurry.

You can either put cement slurry on top of it or you can also coat it with engine oil on top on the exposed surface to prevent corrosion but when you use it you must wipe it off with sandpaper otherwise this engine while oil will prevent bonding with the concrete. So these are the two things which can be done one is painting with cement slurry other is coating with engine oil but the first one is preferred.

You have also seen the angle section in the case of rolled sections we had seen the angle section. Normally it is advisable to keep such sections or place such sections on structures in the direction where the water accumulation does not happen in these portions. Now water is not supposed to get accumulated because you are having a slope but yes some dust, dirt particles may come here which can retain the moisture and allow rusting.

So if you use such T sections in this direction you will always get an advantage of the water getting drained out. So a clear instruction should be that these sections should be placed in such a way that water accumulation and dust accumulation is to be avoided. We have to be very particular on this point of corrosion. If we can actually check and ensure this, then actually we can do a good justice to the use of steel in the building industry.

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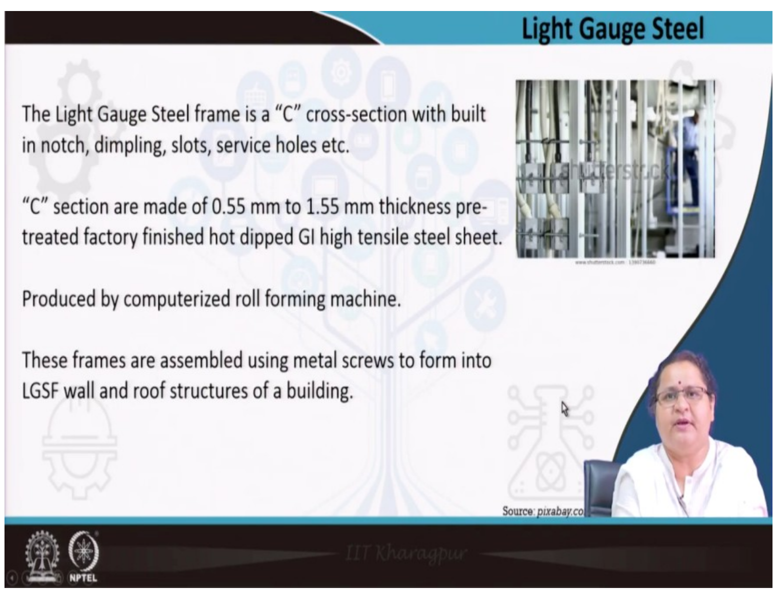

Now let us briefly discuss on light gauge steel. BMTPC which I have already discussed in my previous lecture on precast items, they have now introduced this item in our Central Public

Works Department (CPWD) specification. So this light gauge steel is using steel structure instead of the regular concrete and making the structure light in weight and cheaper. These are nothing but C-sections meaning channel sections, which has different slots on its web part.

It will have slots on its web at different levels; that is like floor levels, sill level and lintel level where it can be bolted with its perpendicularly with horizontal member to create a framework as you can see in the picture. The dimension is of 0.55 mm to 1.55 mm thickness which is pretreated factory finished, hot dipped and galvanized iron high tensile steel sheet is made from that.

So these are actually made from very thin sheets and these are folded in such C shaped and they are having you see notches, dimpling slots, service holes, etc., all pre-designed. These slots will bear the joints and will create the framework on to which the cladding material or the covering material i.e. the precast panels which will be bolted on top of it.

So the entire assembly will be light in weight and it will be fast process of construction and these special screws will take in the loads whichever they will be experiencing. These slots will be all computerized while it is formed because each of these slots will have the galvanization to prevent rusting and these are to be maintained as a structural member for a considerable period of time. So rusting cannot be afforded.

So everything is pre-planned, pre-designed and the framework is made of this light gauge steel. So this is a new advancement of steel structures. But these are mostly practiced in countries abroad but in Indian context, the Government has started building some Anganwadi body projects etc. using light gauge steel structures. Some are there in Orissa (in Bhuwaneshwar).

But we do not have a light gauge steel production factory. Therefore we have to bring in from abroad i.e. import it from outside hence it is not that cost-effective. But yes if we actually start building with these light gauge steel, we can actually get cheaper lightweight structures. With this we finish the ferrous part and in the last lecture of this particular module, we will cover the non ferrous metals. Thank you.