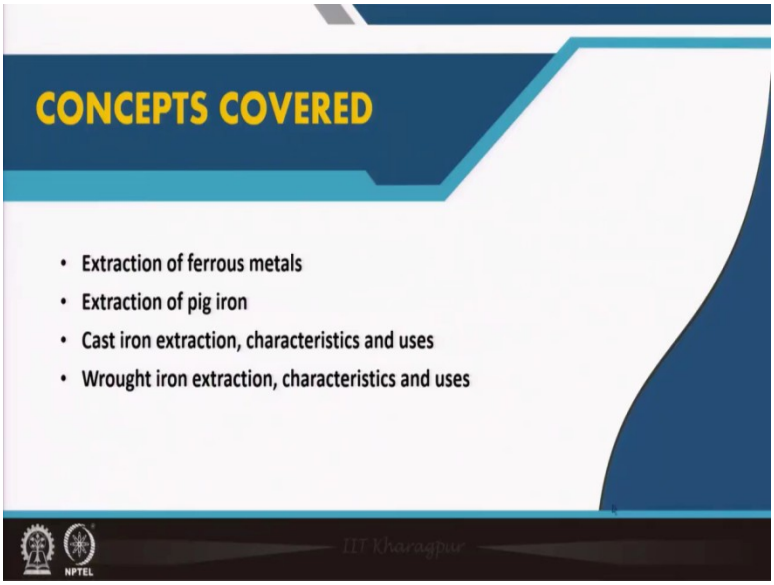
Building Materials and Composites
Dr. Sumana Gupta
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture No - 27
Ferrous Metal – 1 Cast and Wrought Iron

After the introduction lecture to this particular module on ferrous and non-ferrous metals, we will move on to the topic ferrous metals, particularly discussing on cast and wrought iron. Now what we understood in the first lecture is, metals are quite different than whatever other items we had discussed so far in the previous 5 modules. So there we understood that metals have much higher embodied energy it requires lot of exploration to get it.

So we get or retrieved the metal from the ore and then we have to go for high energy and hence the embodied energy increases. But yes it is 100% reusable, it has a larger life span and you can continuously use it without much loss; which was not possible for other all other materials discussed so far. Other thing is metals are malleable, ductile; they can take lot of tensile strength which was along with compressive strength, which was not much taken other than the item wood.

(Refer Slide Time: 01:59)

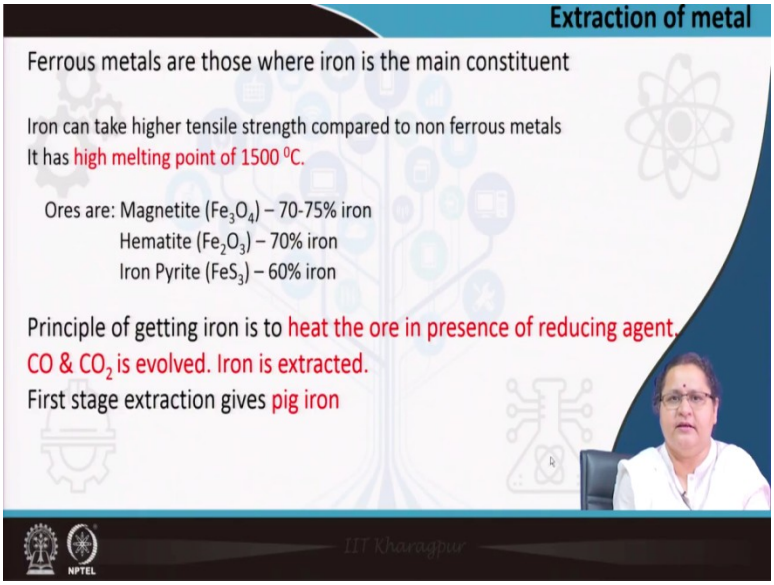


So we will move on to cast iron and wrought iron in this particular lecture because we find these two metals are used from the very preliminary times. I had shown you examples of the Eiffel

Tower which is made of wrought iron. The Statue of Liberty (inside of it) is made of steel. Wrought iron and Cast iron bridges were the very initial steel structures. So first we cover these two items in this lecture and then we will move on to the steel which is more used nowadays.

Now let us see how we extract the ferrous metals. We will be very brief in it and then we will go particularly to see the extraction of pig iron, then cast iron and wrought iron with its characteristics and uses. We will try to cover these in this particular module.

(Refer Slide Time: 02:57)



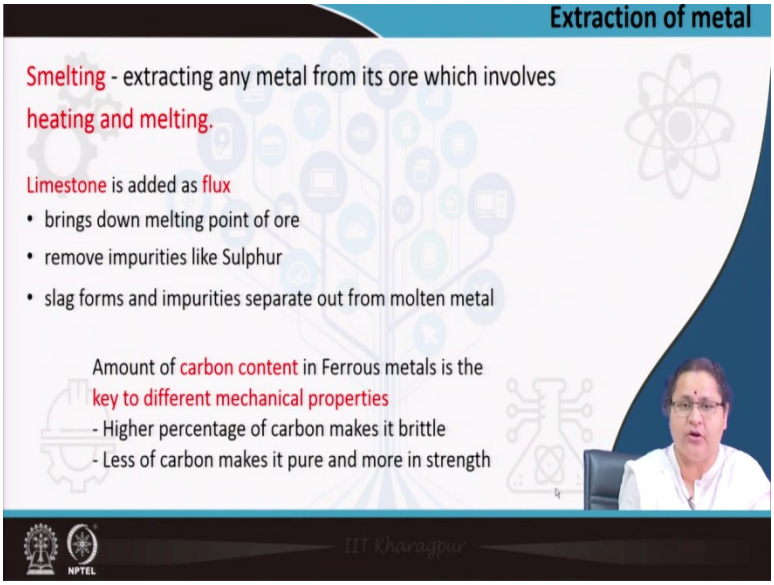
So ferrous metals are those which contain iron and iron can take higher tensile strength compared to the non ferrous metals. That is why we use iron so extensively in our buildings although it has many other drawbacks. So we will open up through this module on different aspects of iron. Now let us come to the melting of its ore. We have to know what the ores are. The important ores are the magnetite, the hematite and the iron pyrite. These three ores occur in majority and are found extensively in many parts of India. We get around 60% to 75% of the total iron content.

But how do we get that iron? So principle of getting the iron is simply heating the ore. In other words you are heating the ore in presence of a reducing agent. In the process you are reducing the ore and then carbon dioxide, carbon monoxide is evolved and iron is extracted in may be a

crude form. This first stage extraction is called pig iron which is the first product and this act as an input for manufacturing either cast iron or wrought iron or steel.

So pig iron is the first processed iron ore and it can be used for making other iron products. So pig iron is nothing but the initial to initiate the production of cast iron and wrought iron or steel we need to have this first extraction from the iron ore. So we treat it further and we get all other forms.

(Refer Slide Time: 05:07)



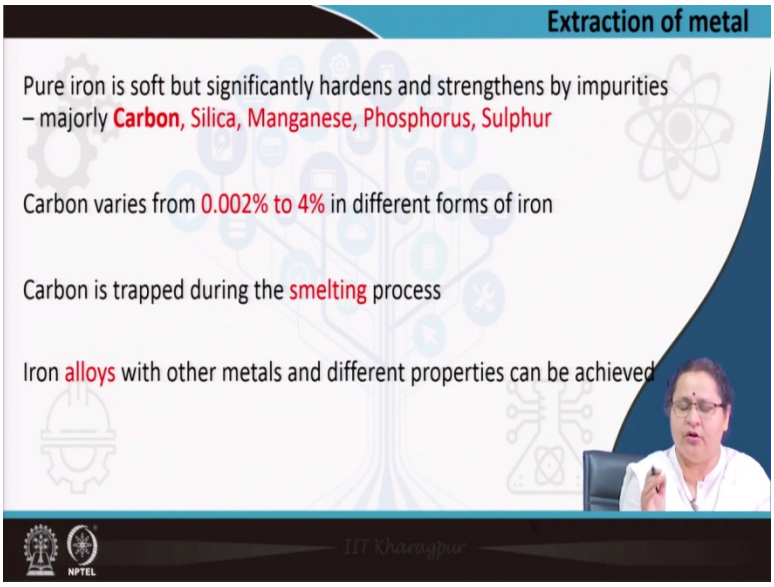
Now let us come to the process known as smelting. It is actually extracting the metal from its ore which involves heating and melting. So what we will do? We will take the ore and we will try to heat it up to that temperature where it will start melting. Limestone is added as a flux or an additive which actually reduces the melting point. It also has many other aspects: for example, it helps in removing the impurities like sulphur.

It also helps in a formation of froth or a slag which is lighter in weight and separates out from the molten metal. So the lighter material comes up which contains lot of impurities and that can be actually tapped out, whereas the molten metal sinks down because it is heavier. Since the density is higher it sinks down and that can be separated out. So limestone plays a key role in the extraction process and it is called as flux.

So what we see that during this process of smelting is that heating and melting process, the flux plays an important role and we get the item which is pig iron or cast iron or wrought iron or steel whatever it may be. But because of the heating process the entire material that is the metal in liquid form attracts lot of carbon in it. So we also need to look for to extract or keep the carbon lesser in amount and this carbon is the key player to make or change the properties of the metal iron.

So lesser the carbon, purer is the iron and it is more in strength. Higher amount of carbon decreases the strength. The items become more brittle in nature. However we have to have carbon in it because carbon helps or carbon contributes towards the strength of the steel also.

(Refer Slide Time: 08:03)



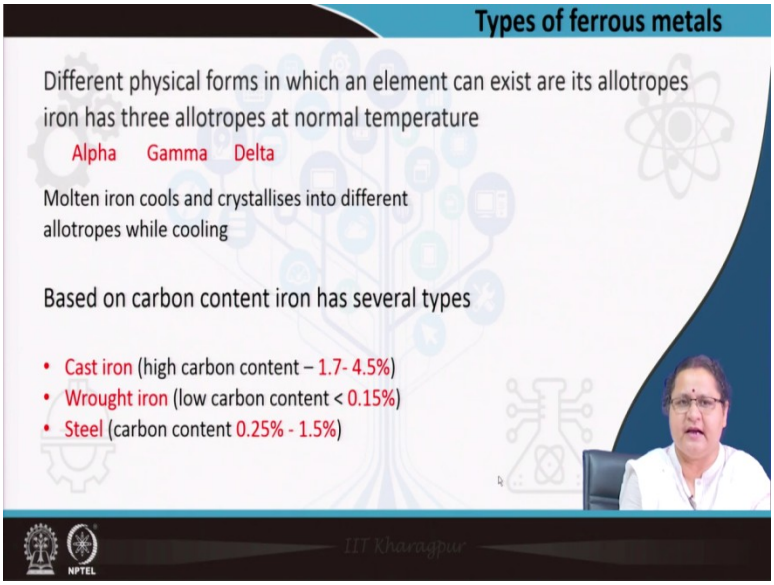
We are using the term steel iron but they may be understood as the same. So pure iron will be soft but will significantly harden due to the impurities. So carbon is the major impurity. Other than that there is silica, magnesium, phosphorus and sulfur. As I told flux, limestone attracts sulfur and it reduces the amount of sulfur or percentage of sulfur from the ore.

Carbon varies from the range .002% to 4%. So by varying different carbon proportion you will get different types of iron. And this carbon as I told you is trapped during the smelting process that is the heating process. And as you all know, all metals can alloy with other metals I have

discussed this in lecture one and you can get various properties. Another beauty is of metals you can treat it with heat and you can get different properties of metals.

So heat treatment can be done, alloying can be done, varying carbon percentage can be considered and we can get a large type of iron. So we need to know all of them.

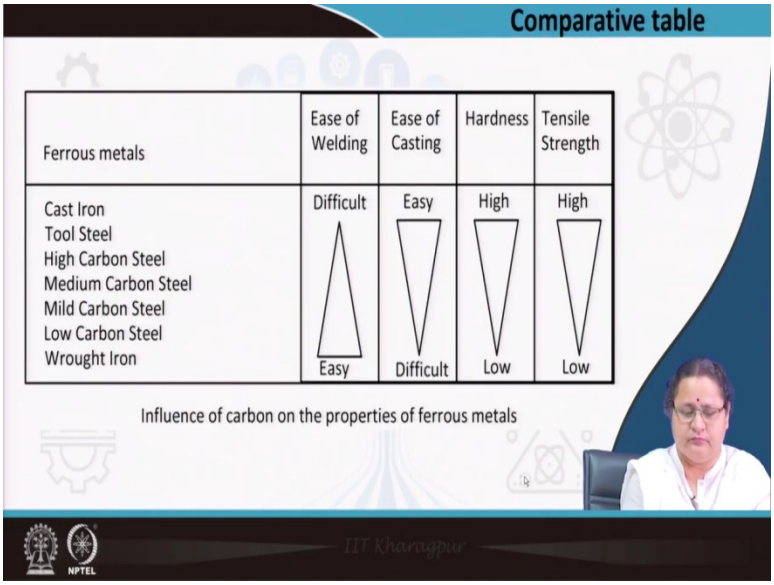
(Refer Slide Time: 09:50)



Now coming to the types of iron, how iron exists in its physical form. You have all studied in chemistry the term "allotropes". Iron has three allotropes alpha, beta, alpha gamma and delta at normal temperature. But we are not much concerned with this. These are more for the metallurgists. What we are concerned is on three type's cast iron, wrought iron and steel. There are mostly categorized based on the carbon percentage.

Now you see in cast iron the carbon percentage is varying from 1.7 to 4.5. As I told you the carbon content of cast iron is about 4%. Hence it is very brittle. Wrought iron on the other hand has less than 0.15% that is if you remember .0002% is the starting range which is not even 1%. For steel you see it is between 0.25% and 1.5%. So not all cast iron and wrought iron will be very much useful for structural purposes whereas steel where we see it is only a small window of carbon percentage from 0.25 to 1.5, there we get a lot of variety.

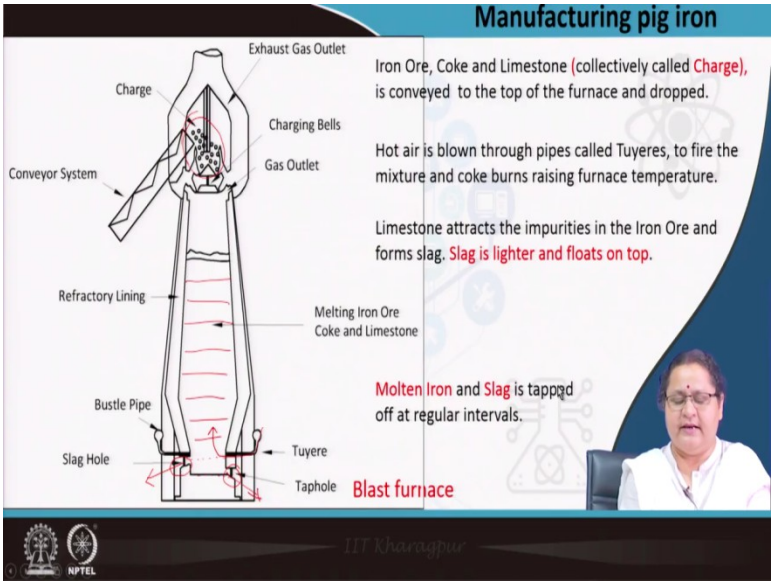
(Refer Slide Time: 11:26)



As we proceed we see that cast iron which is at the top of the table and wrought iron which is at the other end of the table and we see steel in between. So cast iron and wrought iron are totally opposite in their character and you see for the ease of welding, wrought iron is the easiest where else cast iron is easy for casting. Wrought iron cannot be cast hardness of cast iron is very high and tensile strength of cast iron is also very high.

But remember I told you because of high percentage of carbon cast iron is brittle in nature. So whatever high beats tensile strength it may fail without any notification to the structure. So you can make a cast iron item having high tensile strength but it may fail because of its brittle structure and vice versa wrought iron would not we will come to that.

(Refer Slide Time: 12:47)

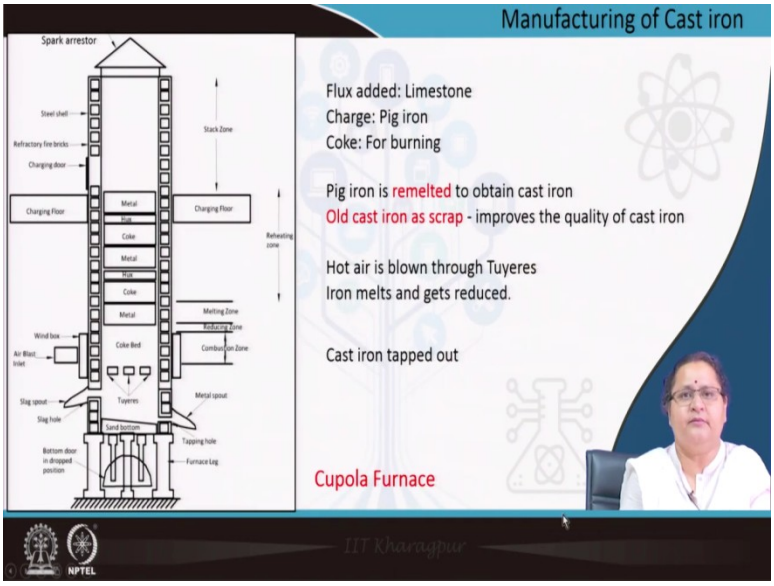


Now let us to the manufacturing process of pig iron. You see this is a picture of a blast furnace. What I told you the ore is first put in. If you see the ore or the charge which we already discussed, is pushed up with a conveyor belt. These items are very heavy, so the conveyor system is there which puts in the charge at the top of the furnace. And you see here in this portion the iron ore is the charge is getting accumulated and here are the tiers through which the hot air comes in.

If we see this hot air is blown into this charge which is limestone iron ore. And so this hot air is actually heating the entire charge and this eventually melts the iron ore and the coke gets burnt and the limestone separates out a number of impurities. So what you see here at the bottom is a slag hole and the other side is a tap hole. The slag hole is at the upper level whereas the tap hole is at the lower level.

This is to tap out the metal and this is to tap out the slag. So if we go see that limestone is attracting the impurities and slag being lighter, floats on the top. The slag on the metal is tapped out which is called the pig iron or the first extraction. It is taken out from the tap hole. So this molten iron and slag is tapped at regular intervals and the charge is continuously poured from the conveyor belt at the top and the process goes on.

(Refer Slide Time: 15:10)



So we get big iron which now goes into the manufacturing of cast iron. Here you see a similar picture where the metal, the flux and the coke are charged from this charging floor. So there are stacks on top, where from these items are charged one after the other to form a mixture. And here also the same process is followed. The pig iron is re-melted and the air is blasted inside through these tiers and you have a slag hole and a tap hole.

So this is called the Cupola furnace. After this second round of extraction, which is kind of purification and re-melting you get cast iron. Some old cast iron items are added into the charge so that the cast iron gets forms very quickly.

(Refer Slide Time: 16:42)

As I told you cast iron has a crystalline structure let us see the structure. You see it is mostly a very grainy structure with columnar grains and oriented in a single direction. So you can break it just like a biscuit. So here you can see that at any point it can crack or break and this is the problem with cast iron although it has very high tensile strength. Now coming to the properties of cast iron. The melting point is lower because higher the carbon lesser is the melting point.

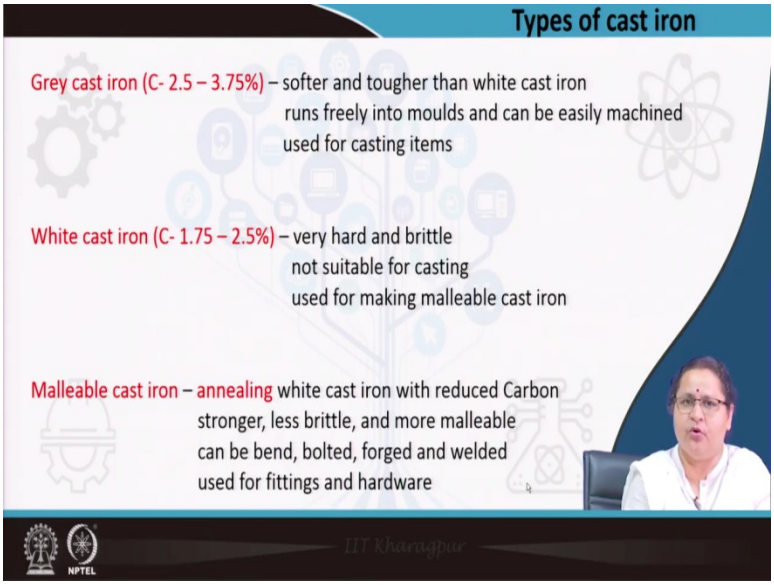
The carbon percentage varies from 1.7 to 4.5. It is strong in compression and weak in tension when compared to its compressive strength. But you will see wrought iron has lesser tensile strength (40 N/mm^2) than cast iron (150 N/mm^2). It is brittle and hard but it does not absorb

shock. So it suddenly fails without warning. You may see some cast iron and pipes in old buildings with a part of it is there and part of it is detached.

So, those are actually failure of cast iron where no warning is given. Hence it is used for such rainwater carrier which would not affect the system much as it is not used as a structural member usually. But it is strong in compression. It takes quite high compressive strength. It can be cast into various shapes and it has shrinkage. So when it is cast into a mould, it shrinks and it comes out very easily and you cannot do any kind of joinery. We will elaborate it later. With cast iron operations like Riveting, bolting and welding is not possible.

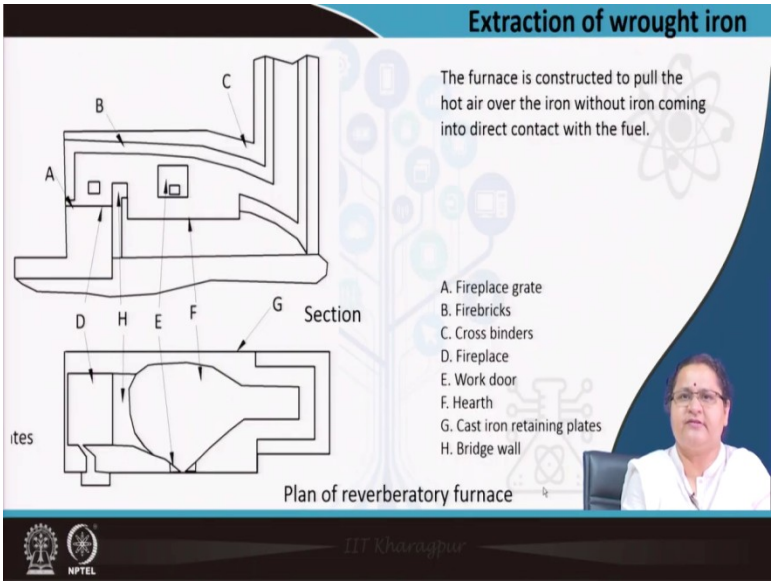
It cannot be forged; that means it cannot be bent or hammered or have its shape changed. So these are the salient properties of cast iron.

(Refer Slide Time: 19:14)



There are three types of cast iron; these are to mention grey cast iron will contain more amount of carbon, white cast iron is having lesser amount of carbon and malleable cast iron is having further less amount of carbon. Malleable means it can be pulled out, it can be rolled out, it is less brittle. It resembles more towards wrought iron as it is having lesser carbon content.

(Refer Slide Time: 19:56)

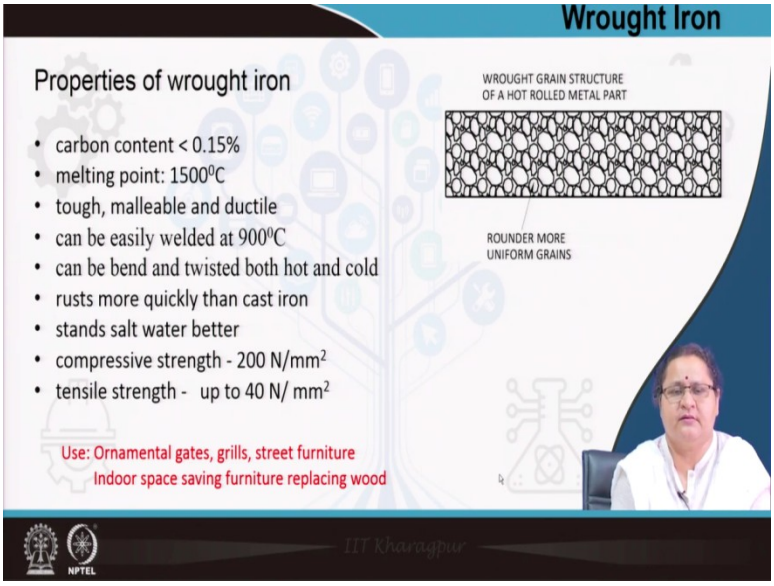


Now let us move into the extraction process of wrought iron. You see here it is a reverberatory furnace. So what is happening? The coal is actually not with the charge. So here this portion you see D is the fireplace where the coal is burning and this is the portion where the iron node is kept that is the pig iron is kept.

So this heat is generated and it is continuously falling on the pig iron. So this coal or the coke is not coming into contact with the iron ore. This is an indirect way of heating and hence what happens is that the carbon from the coke is not getting entrapped into the pig iron or the molten iron. What is the benefit then? The carbon content is much lower because it is not contaminated by the coke. This was happening in case of the blast furnace and the cupola furnace.

So that is why this is called a reverberatory furnace because the heat is reverberated or it is coming again and again from the ceiling of this furnace and melting the pig iron and the iron is extracted in its purest form. So once the pig iron here gets molten, it is getting gradually extracted out and this is how the wrought iron is obtained. So what you understood is the reverberatory furnace is such a furnace where the pig iron is not coming in contact of the coke and hence pure form or the purest form of iron is obtained which is called wrought iron.

(Refer Slide Time: 22:47)

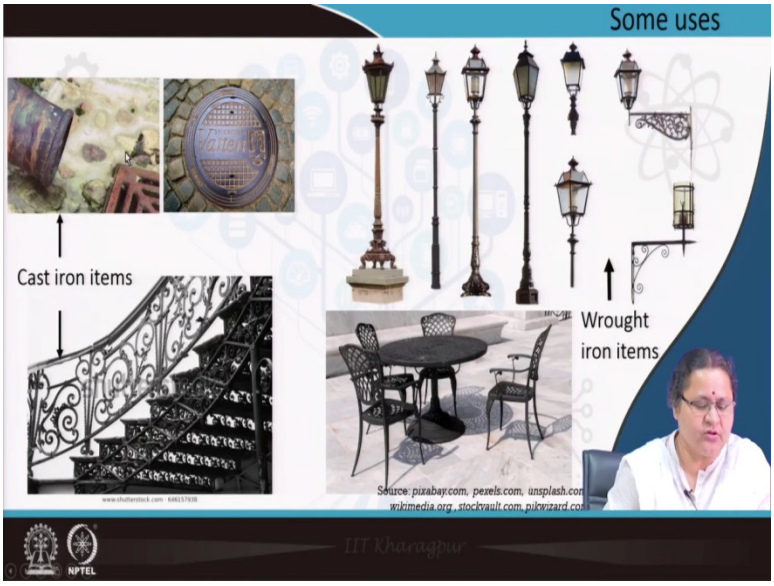


Now let us see some of the properties of wrought iron. If you see the structure, this is more of a rounded uniform structure. You can now distinguish between the cast iron structure and this wrought iron structure. So obviously there is a change in the structure of the iron with the changing percentage of carbon. The carbon percentage is negligible in wrought iron and as I told you the melting point of wrought iron is higher (1500 ^{o}C) than cast iron (1250 ^{o}C).

Wrought iron is tough, malleable and ductile. It resembles more properties of steel and it can be welded at 900 ^{o}C. We will come to welding where we will discuss what are the different the types of welding and how the joinery happens in metals. Another important point is that it can be twisted both in hot and cold condition. So wrought iron can be forged and that is why you can make many ornamental items just by forging or twisting wrought iron.

Again wrought iron is used for making street furniture; wrought iron gates are being made. It rusts more quickly than cast-iron and but it can stand saltwater better than cast-iron. You see here the compressive strength has gone down from 600 N/mm^2 in cast-iron to 200 N/mm^2 in wrought iron. Also the tensile strength has also gone down to 40 N/mm^2. But its properties of metals are more in wrought iron.

(Refer Slide Time: 25:28)

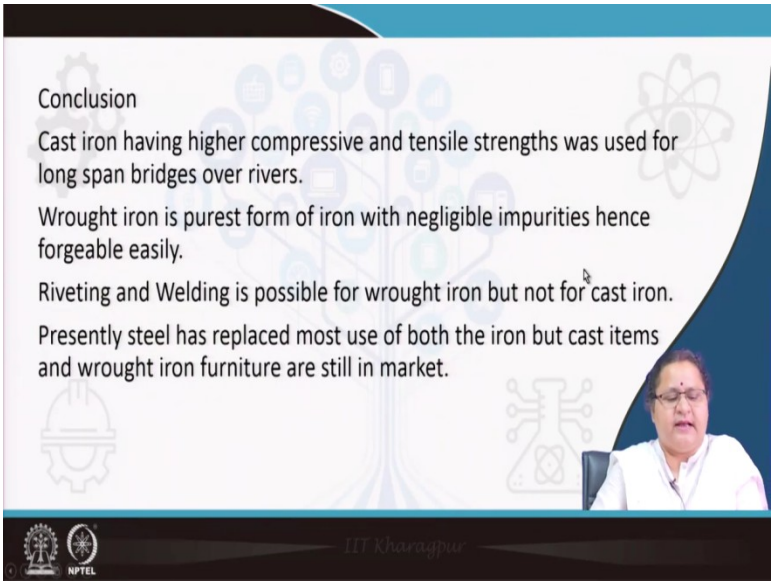


So here are some uses and we can see a number of pictures of cast iron. In rain water pipe the cast iron finds its application. You can see the grating is also of cast iron, where the water is coming and getting accumulated. Many of you have seen this kind of manhole covered on roads even at your residence. These are cast or made out of cast iron. So this is sitting on a surface people can walk on top of it.

Even if it breaks or cracks it would not create any problem. So it can be used for such purposes where it is not directly affecting you or your day today activities. Another application of cast iron is usually found in spiral staircases in old buildings. And sometimes one or two of its steps just fall apart. So it stands and appears beautifully at its place but may break without giving any warning. On the other hand you see the items made of wrought iron you can see ornamental street furniture, the lampshades, and the projecting brackets.

These are all twisted and made out of wrought iron. You can see wrought iron gardens, here tables and chairs, the street furniture on road, those are usually of wrought iron. So any kind of ornamental works can be made with wrought iron.

(Refer Slide Time: 27:42)



So we can conclude that cast iron has higher compressive as well as tensile strength and earlier it was used for bridges, large spans. Wrought iron is the purest form of iron with negligible impurities. Hence it is forgeable easily; works like riveting, welding and bolting can be done on wrought iron, which is not possible in case of cast iron. But presently we see steel has replaced most of it but these items some which are which I have discussed as shown you in the previous picture are still being practiced made of cast iron.

We can get lots of tools made of cast iron and hence it is not erased completely but yes its use has lessened to some extent with steel taking its place. So we will move to steel in our next lecture, thank you.