Building Materials and Composites
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Lecture No - 26
Introduction to metals

So, welcome to module 6. So today is the first lecture of module 6 which is mostly on metals and particularly ferrous and non-ferrous metals which are used in the building industry. Now unlike the materials we had studied till date, that means in the previous modules we had brick, stone, wood, precast items, glass and they are everywhere. We understood that we had to make the item and then use it for the purpose.

We had concrete also. So everywhere one was giving you some advantage disadvantage and mostly they were compressive members other than the wood and bamboo which was also useful in taking tension. We had also discussed the reinforcement bars when we discussed concrete, which mostly referred to the reinforcement inside the concrete and that was as a discussion it came into the conversation.

So we will look into ferrous metals as well as non-ferrous metals only which we are concerned in the building industry.

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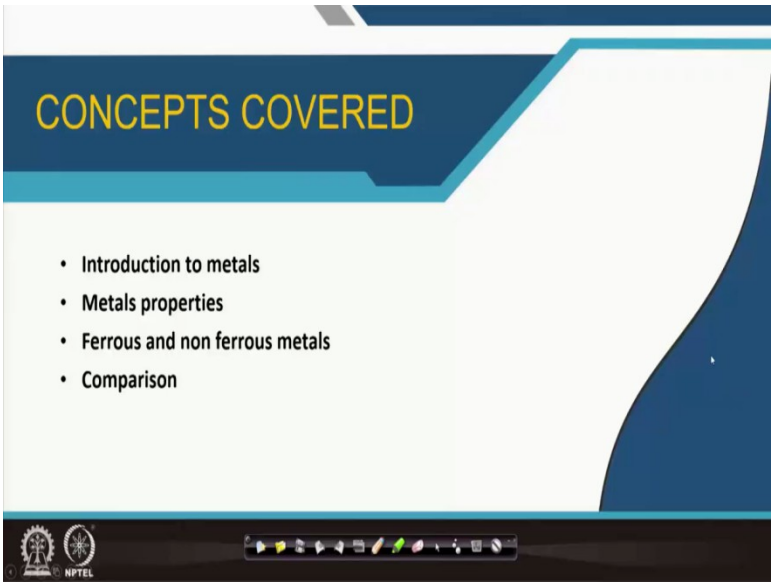

If we look into the content we have the introduction to metals, metal properties. Many of you may know these but we will try to again recapitulate that so that we can understand how it is useful in the building industry. We have the ferrous and non-ferrous metals and we will try to compare them to some extent considering their use.

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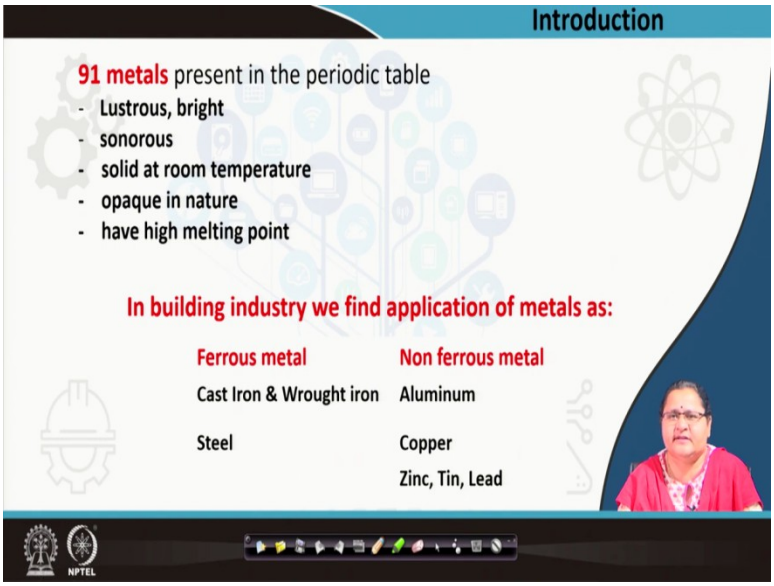

Considering the periodic table we have 91 metals along with all the elements over there. So we are not going to have all 91 metals for us but property wise or to identify them it is easy to say they have a luster. That means they have brightness, they make some sound when you actually strike two pieces or if it falls, you can get such sound which we if you can remember or recollect when we discussed brick.

Clinging two first class bricks make a metallic sound, which was due to the right amount of iron in it. Now most of the metals (almost all) are solid at room temperature apart from mercury. So we can get the item ready for use. So it is solid form so you can use it directly. It is not like concrete which you need to give some time to set. So when you use metals you get it in its solid form. It is opaque in nature unlike glass, which is the only material which was transparent or translucent to some extent.

We have this material also similar to brick, concrete, wood etc. It is also opaque in nature. So the light cannot pass through it and it has high melting point. So with these few words let us come to

the building industry what are the metals that we find the application off. So we have under the ferrous metals we have cast iron, wrought iron and steel. Though there are other types of classification of ferrous metals say alpha beta gamma delta iron we are going into the cast iron and the wrought iron form which is mostly divided considering the iron content.

Why? We are looking into this from this direction because these actually took take care of the brittleness or the hardness or the ductility of the metal. So when we cover cast iron and wrought iron we go into these details. We will know them considering their contents or the ingredients which form it. Other than that we have steel which is extensively used in building industry, particularly the structural elements and that is the use of steel in ferrous metals in our particular trade.

Coming to the non-ferrous metals we have aluminum, then copper, zinc, tin and lead. Now obviously when copper is alloyed with zinc or tin you will get brass or bronze. We have special application of lead though earlier lead was much used in the building industry as the base for paints. But it has been found over time that it is not healthy to the habitants inside the building. So lead is gradually taken out from the list of metals and it is being replaced by other metal oxides.

So we find most commonly used non ferrous metal is aluminum, which is not comparable to that of steel as a structural element. Although we have some examples but aluminum is used for making frameworks. It is soft and we have plenty of use of aluminum, mostly it has replaced wood. We will go into further details when we come to each of them. Copper again used with tin or zinc to get brass and bronze which are again some prestigious metals.

Even copper by itself is a prestigious metal used as a building material. So we will come to them individually when we discuss.

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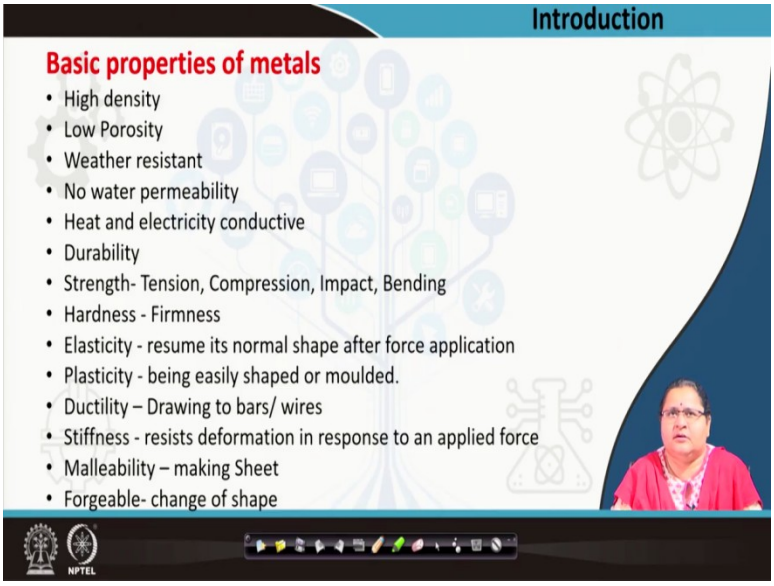

Now let us try to go through the basic properties of metals. Most of the metals have high density. High density means it is high in weight and it is almost non-porous. So we do not refer to some bulk density rather we report the density of the material. Whether resistant refers to how much it can take the extremities of the climate of which water, wind and temperature are the three factors.

Now as you all know metals are good conductors of heat. So under strong temperatures or that is summer high degrees and high temperatures, metal itself cannot be the answer for a building envelope compared to the work which brick does. If it is done by a sheet of metal it will conduct the heat inside. So it will affect the thermal condition of the inside of the structure if a entire thing is made of metal.

So metal is mostly used as a structural element rather than as an infill element. Maybe you have all seen the shed of cycle stands- the top of which may be of some metal sheet and may have corrugations like this and it is a continuous sheet. So this kind of sheet can go as a roofing of a temporary structure. Even if it is the roofing of a house it is a temporary thing because you can always open it and you can re use it but remember it is when used as a roofing of a house it is exposed to the sun rays.

And it is trapping in lot of heat inside the house. So if it is the solution, you must remember that it will trap in lot of heat. So it may be weather resistant from the point of the sun rays but it is not that effective from the point of water or rain. Let us think it is a steel structure which is subjected to rain every day maybe you have noticed the phenomena of rusting. It may get rusted if it is not properly treated. So exposing a steel structure or any ferrous structure may lead to rusting when we are talking of being weather resistant.

So the non-ferrous metals may be a better answer to that or the other answer is you need to give some protection to a ferrous metal against water permeability. Many a time we had talked of impermeable water should not pass through and that is why we used sealing water to join bricks otherwise there would remain pores or gaps between the bricks to allow moisture or water to move in.

So every time we had to prevent the water entry. But if the entire wall is made of steel, no water will enter inside. Yes it may get affected by water but no water can come to the inside of the house. Now coming to the next point which is heat and electricity conductivity; the thermal conductivity as already discussed, we are concerned only with the solar energy that is the sunlight. Other than that if there is a case of fire etc. heat would be conducted very fast.

Coming to the next point which is durability: If we consider a brick structure and a steel structure or R.C.C structure also, steel structure may be more durable. But yes it has its negatives also that is corrosion etc. But with proper precaution we will see that steel structure or any non-ferrous structure would also be more durable. It has high tensile compressive strength.

It has high impact load. It can take impact more than that of brick, stone, wood, concrete even in bending also. It is hard and elastic: that means it comes back to the normal shape when even after application of force. So deformation is not observed unless it is a huge amount of force. It is plastic when it is in molten form, it can be multi molded and any kind of shape can be given. We will come to that when we get into individual metals.

So we can mould because it is plastic, free flowing when it is in its liquid state. Ductility refers to how easily it can be drawn into bars of any length. If you remember to get pieces of bamboo pieces of wood you had to go for proper carpentry proper cutting to get long pieces but here you can draw it into bars of any length. So when we also discussed of wood, it was seen that wood is available in the piece of the log length.

But if you want to have a higher length you had to do some carpentry or joinery to it and then again further strengthen it with some metal straps. But in case of steel, in case of ferrous metals or even in case of non-ferrous metals, you can have lengths much longer than as compared to that of wood or timber. So you can draw it or you can even roll it to get long lengths in the form of wire, may be of enormous length, you can actually use it for electrical purposes.

So for the wiring system we can use metals because it is a conductor of electricity. Stiffness is defined as its resistance to deferred deformation in response to an applied force. It is stiff, malleable, it can also be formed in sheets as we had discussed with the metal plate. Yes when we are making it into sheet and then we can make then we make it into corrugations. It becomes more stable but yes we can make malleable or we can make thin sheets.

We can even change shape or forge it just by changing little temperature by bending using proper appliances or tools. So you can get different shapes different patterns out of metals as out of ferrous as well as non ferrous metals.

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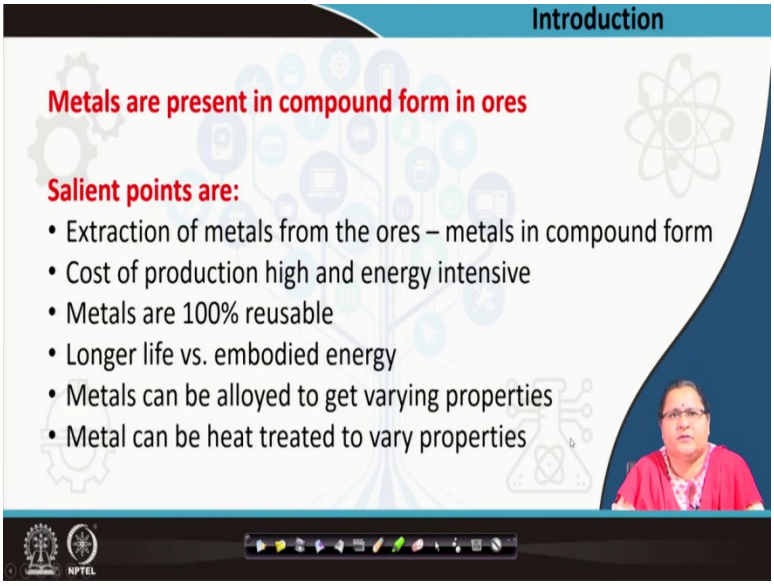

So if we move forward metals are unlike whatever materials we have covered, they are present in ores in compound form. Metals are electro positive in nature hence many of the metals are present in they are in oxide forms, in forms of compounds where from you have to extracted. So extraction of metals from the ore forms the key point to get the metal in its purest form. So first is for getting any metal we have to find the ore mine. It has to be taken out if you remember the stone query from where the stone was taken out.

But stone was itself available after dressing. But here the ore is having the metal inside it mostly in its oxide form or in any other compound form like lead sulfide. So you have different ores and there you have to actually reduce it to get the ore get the metal out of it. And obviously you have to melt the entire ore and as it is metal it has high temperature, high melting point, it is energy intensive, you have to use or burn a lot of fuel to get the metal to melt and proper processing needs to be done.

So we will come to that when we go into each of them and we will try to cover the salient points of getting the metal or extracting the metal from the ore. But once it is done it has a long life and it has it is 100% reusable. So the embodied energy though it seems to be quite high for its present form but considering its age like how long it can be used, it becomes very negligible considering the life of a brick or that of any other building materials.

So that is why only looking into the energy may not be the right decision point, rather one should also look into the length of its life metals can be alloyed to give variations in properties. We can see aluminum added with other metals into it gives it more strength, even retaining its property of light weight. Similarly for iron we can take care of its negative property which is corrosion.

So we will go into each of the metals when we will discuss it further. We can heat treat metals and get varying properties too. So we have to keep these points in mind that whenever required we will see some treatment is done and either it is alloyed or it is treated or it is heat treated and then different properties are obtained because we need different properties when it is being used for different purposes.

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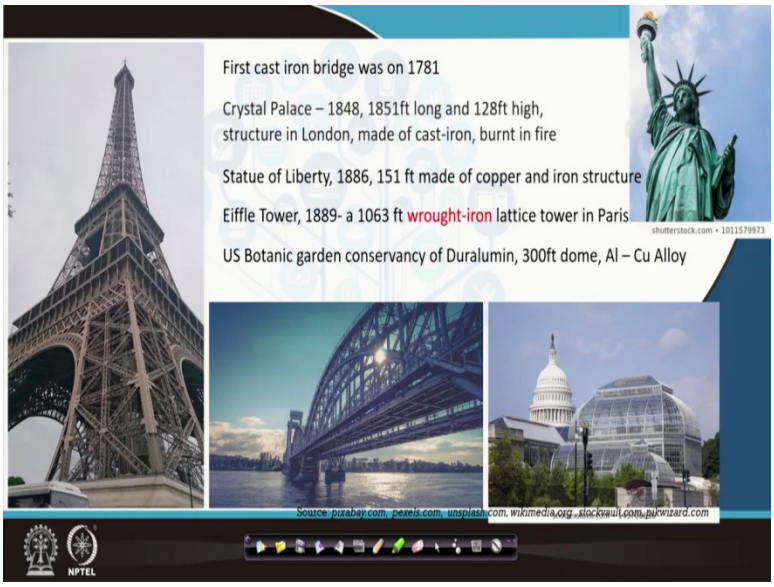

Let us now look into some examples of metals used in building. The first use of metal as cast iron was in bridges and we can see way back in 1781. Though the uses of metals are historic because Iron Age and Bronze Age. If we take a close look at the structures, although it is not falling under the building domain, cast iron was extensively used. The Crystal Palace bridge in London which has been burnt in fire was in 1848 which was also a huge spanning structure where glass and steel together was exhibited it was to hold exhibition.

The Statue of Liberty is greenish in color and it is made of copper. But what is the structure inside it is made of iron. And iron when got rusted it was positioned in 1886 and on the river it was continuously getting corroded and the iron structure is gradually being replaced by steel.

But still the 151 feet high structure is intact and it attracts a lot of national and international tourists. Similarly the Eiffel tower is a wrought iron lattice structure built by Agustav Eiffel 1889. The same Agastav Eiffel actually also made the inside structure of the Statue of Liberty, which was later covered by this copper veil. So you can see copper is so malleable that it could be converted to a thin kind of coating or covering on top of this structure to give this kind of this kind of statue or a monument.

Now this wrought iron was used for making this entire Eiffel tower but later on when it is getting damaged at certain points it is replaced with steel. Here at this corner you see another structure which is totally made of an alloy of aluminum and copper known as duralumin. It is a 300 feet dome like structure in Washington. It is the US botanical garden conservancy. So these all are not steel structures and we can always use different metals and we can exhibit or show that yes it can take lot of height, lot of span and it can be used as a structural material in building.

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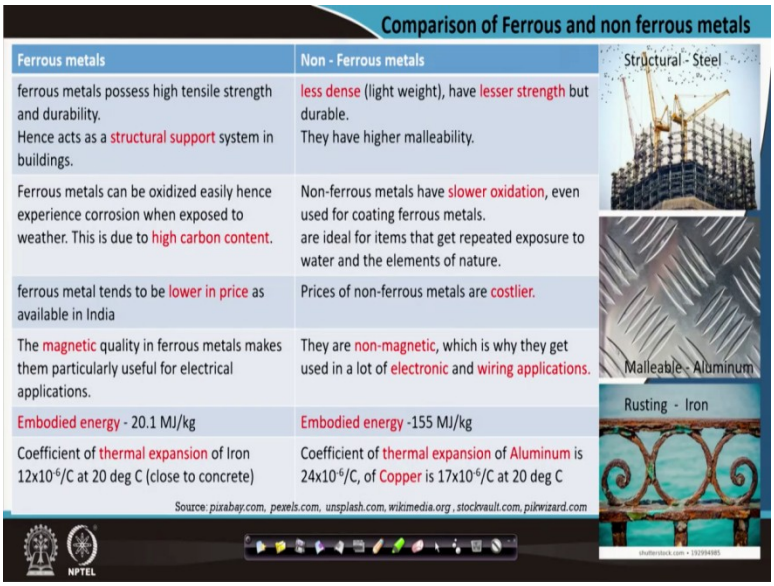

Now let us come to the comparison between the ferrous and non-ferrous metals. Ferrous metals possess high tensile strength compared to that of non-ferrous metals and both are durable. This

high tensile strength and high density of the ferrous metals gives it mostly its use as a structural support system in buildings whereas this less dense less weight lightweight material is mostly favorable for malleable structures or as a framework for any internal purposes mostly aluminum.

You can see this sheet made of aluminum which is malleable whereas for ferrous structures this is the structural system entirely made of steel. Ferrous metals can be oxidized and hence it experiences corrosion when exposed to weather; this is due to its high carbon content. So if we can reduce the carbon content we can reduce the process of corrosion.

Similarly the non-ferrous metals oxidize but very slowly and hence they are sometimes used for coating ferrous substances. Ferrous metals like iron need to be galvanized with zinc. So to overcome the continuous exposure to water or the elements of nature, we may select non-ferrous metals as the building material. From the cost point of view, ferrous metals are lower in price whereas non ferrous metals are costlier, although the ores are abundantly available. Extraction process is actually affecting and controlling the price.

Because ore wise we have large extents of iron as well as aluminum if we consider one as the ferrous and the other as the majorly non ferrous item. We have magnetic quality in ferrous metals which are not seen in non-ferrous metals. This is the reason why non-ferrous metals, being non-magnetic, are used for electronic purposes wiring appliances etc. For magnetic quality, ferrous metals have particular uses only for electrical appliances. In case of embodied energy, you can see ferrous metals have much lower embodied energy.

From the cost point of view, you can see extraction of ferrous metals is easier, that makes it cheaper too. It is of the order of 20.1 MJ/kg (mega joule per kg) whereas that of non-ferrous metals where it is referring to only aluminum as it is the most commonly used non-metal. It is 155 MJ/kg. When we will be discussing the other metals I will also give you the figures for the embodied energy of copper or zinc.

Coefficient of thermal expansion of iron is $12 \times 10^{-6}/^{o}C$ initally. This is the reported value for $20^{o}C$. Now here you see this thermal expansion value is very close to the thermal expansion

value of concrete. Just compare it with the non-ferrous metals. The coefficient of thermal expansion of aluminum is 24 x 10^{-6}/°C at 20 °C and for copper it is 17 x 10^{-6}/°C at 20 °C.

So why did I refer to the coefficient of thermal expansion of steel or ferrous metal versus that of concrete? This is due to the fact that in concrete we embed steel or embed the iron rods or the reinforcement. So if their thermal expansion behavior is not the same due to thermal changes internal cracks are going to happen one will try to expand more the other will expand little less and that will create internal stresses.

So that is why we have concrete and steel together to give reinforced cement concrete where no other metals are used. If it would have been aluminum you see concrete is having almost 10 x 10^{-6}/°C and it is 24 x 10^{-6}/°C at 20 °C. So if there is a change in temperature the concrete will expand less whereas the metal inside will try to increase more, thus creating a break internally. Internally the member will try to expand more, the other thing will try to will expand less and try to stay in its position and it will lead to internal cracks. So we have to remember this point very well.

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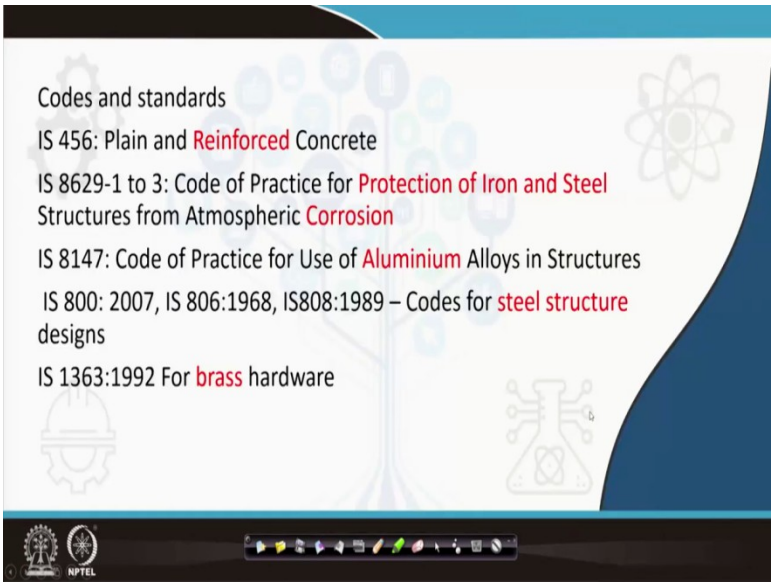

Coming to codes and standards for plain and reinforced cement concrete we refer to IS 456. We refer to IS 8629 for protection of iron and steel from corrosion. Similarly the other codes of practice are specified for aluminum, steel and brass. So with all these we end today's

introductory lecture and we will move on to the ferrous metals in the next lecture of this module, thank you.