Basic Construction Materials
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Module No # 08
Lecture No # 40
Metals 5 – Part 2

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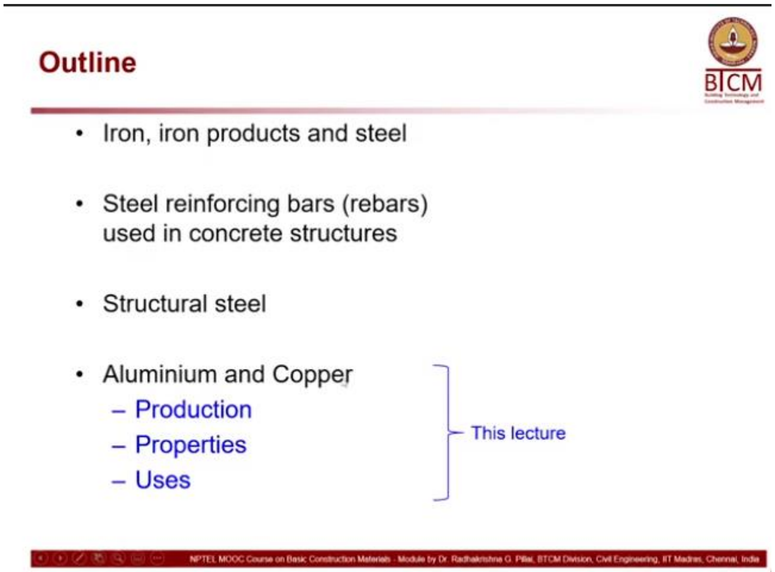

Hi, in this course on basic construction materials, today we will look at aluminium and copper and their production, properties and uses. In the other lectures we have covered iron, iron products, steel and then steel reinforcing bar and also structural steel and then now looking at aluminium and copper and their production, properties and uses.

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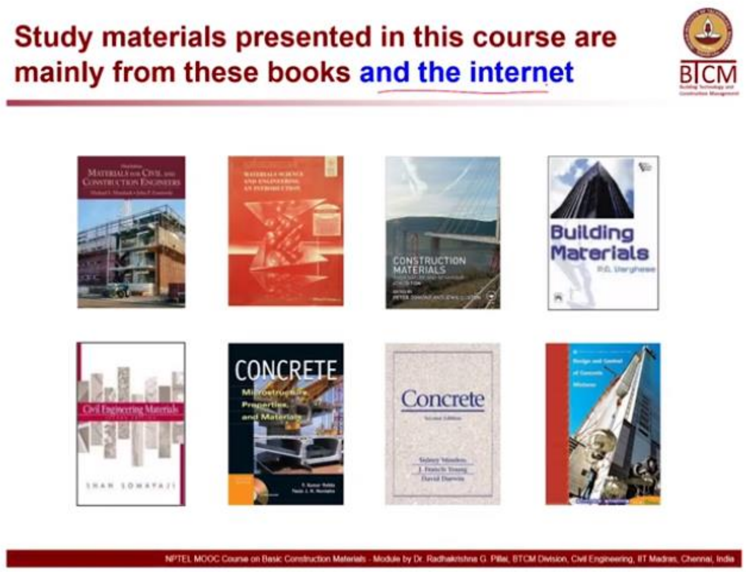

So these are some of the books that are used for this course and of course we have used a lot of materials from the internet.

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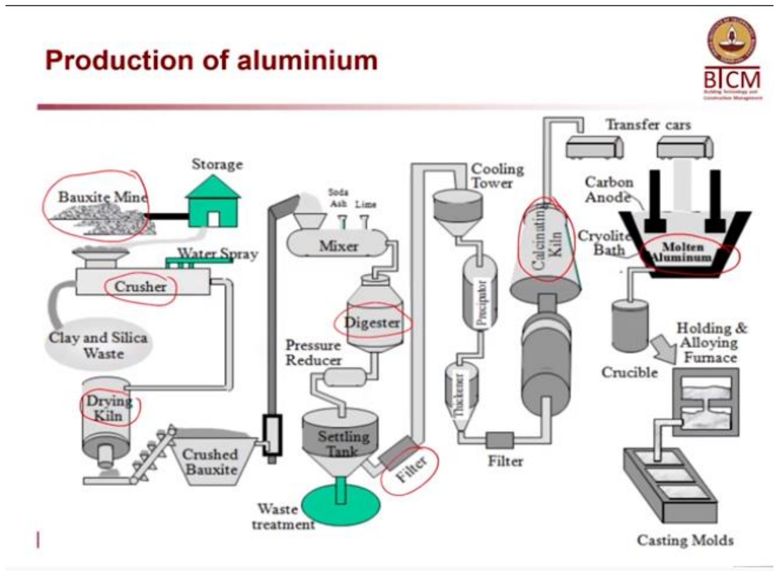

Now in the production of aluminium mainly the raw material which is used is nothing but bauxite. So bauxite is used and then it is crushed into smaller size and then it is dried after mixing with water and then you have further mixing processes or digestion processes and then filtration etc., and then eventually the material is heated or calcined and then finally you get the molten aluminium.

And then it is poured into different casting molds for the purpose of further usage. So this is the brief on how aluminium is produced. You can just pause for a few minutes and then look at various processes involved here. But we do not need to too much into the detail in this particular course.

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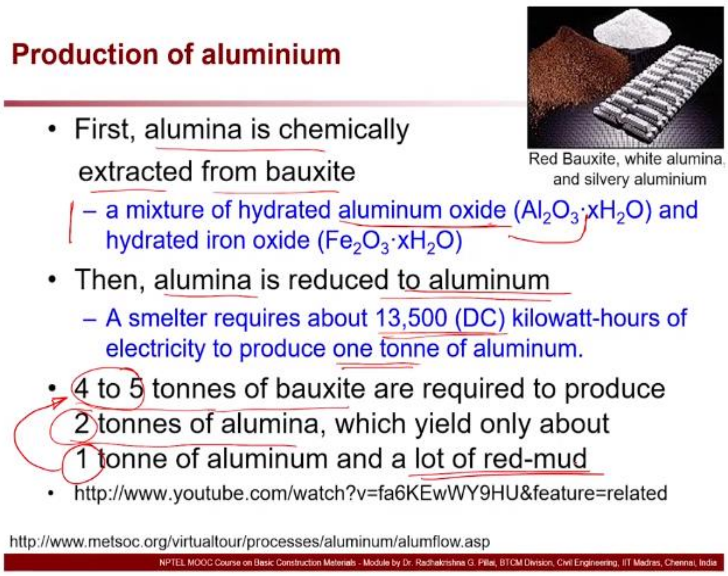

So let us very briefly look at whatever we just discussed on the production of aluminum. First step is alumina is chemically extracted from bauxite. Now what is there in bauxite? It is basically a mixture of hydrated aluminium oxide and hydrated iron oxide and there are also other oxides present in that like titanium oxide or also some silica etc. might be present in that ore material which you collect.

And then, this is our key element here, aluminium oxide. This alumina is then further reduced to aluminium. So alumina from this, it is reduced to your extracting the metal aluminium. So this process requires a lot of energy and how much is that? It requires about let us say 13,500 DC kilo watt hour, that much is the power requirement, so it very energy intensive process to produce just 1 ton of aluminium.

Now let us look at the other waste which is generated during the aluminium production. About 4 to 5 tons of bauxite is required to produce 2 tons of alumina. So you can see from 4 to 5 only 2 tons of alumina you are getting from which eventually you get only 1 ton of aluminium. So, 1 ton of aluminium is produced from about 4 to 5 tons of bauxite. So the remaining material is all the waste.

If I am assuming that 4 tons of bauxite is required, that is only 25% of the material is actually the final product. So you have 75% of the material as byproduct or waste and this red mud, we can look it as a waste product or byproduct but mostly waste product. Because it is not really being used today, it is actually pondered. I will show you some photographs. So main point here is there is lot of waste generated with the production of aluminium you can watch this you tube on this you know production process also.

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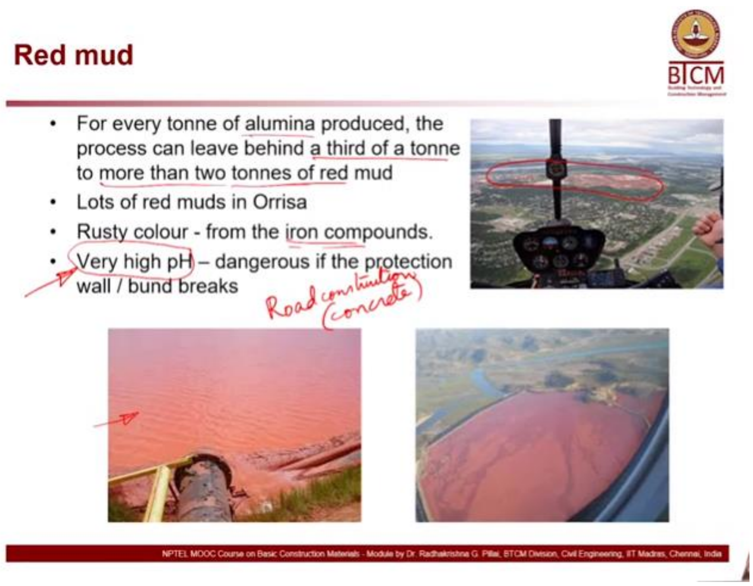

Now for every ton of alumina produced, the process can leave behind a third of a ton to more than 2 tons of lot of waste. That is a whole point; you can look at these numbers more specifically. But Orissa is the state where in India we have lot of aluminium production happening and there are lot of ponds like that. You can see this is the aerial view taken from aircraft or a helicopter, you can see this is the pond.

So you can see the size of that large waste where it is dump or you know red mud pond. Now what is the problem with this red mud? The first thing is it is a rusty in colour because the presence of iron compounds, but that is colour does not matter much. But this is the problem; it has a very high pH. Now when you have very high pH and you have a pond like this, imagine the barrier of this pond it breaks or the dam breaks.

This material if it just starts flowing outward, then that is very dangerous for all the things which are around that pond. So that is one danger thing about this. So now people are actually started looking at whether this can be used for road construction. So red mud is actually used for road construction, there are examples where people are used or basically concrete, a concrete made of red mud.

This is upcoming research area also. If some of you are interested, you can look at that aspect. So this waste like the fly ash waste which is there in the power plants people started using fly ash for concrete making. So similarly now there is lot of research going on, in looking at the use of red mud in concrete construction.

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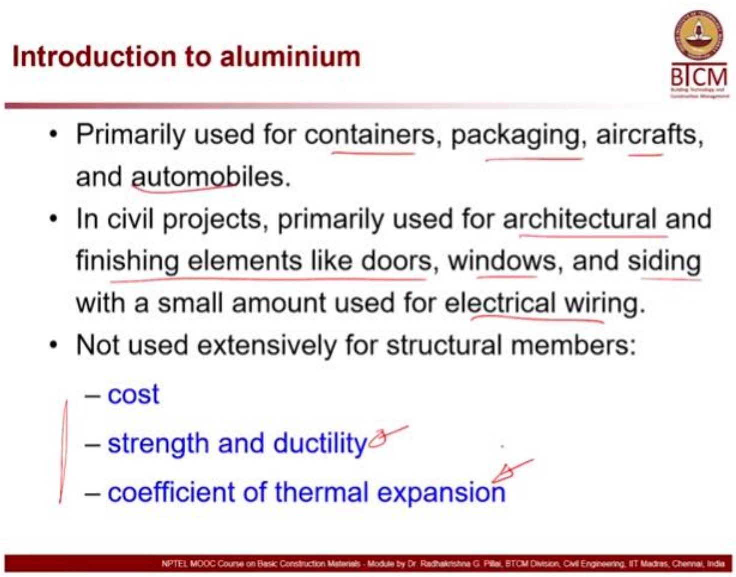

Now primarily aluminium is used for containers packaging aircraft or automobiles etc. Now in civil engineering, where do we use? We use for architectural and finishing elements like doors, windows, siding with a small amount used for electrical wiring also. But the volume wise if you look at, electrical wiring may not have significant volume. But other elements like doors, windows, if you look at it there is a large quantity of aluminum being used.

Now these are not very much used for structural members, but now we see that wherever you want a light element we are still trying to use it. But structural members still not mainly because of the cost associated with it, is very expensive. And strength and ductility strength is not as high as steel. Ductility you know elongation wise yes but because strength is not that high, then it has big limitation when it comes to structural element.

And coefficient of thermal expansion is also another reason why we cannot really use it in concrete etc.

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Now these are some of the examples to show you where the aluminium is used in civil engineering construction. So these are the first pictures on the top left this is just some frame structures etc., which may not have very high structural strength requirement. But so in other cases small loading capacity things we can make with aluminium. Then wall elements you can see here, these channels.

These channels which are made are then used for electrical wiring. I am not talking about this pillar this is not aluminium that is definitely steel. But what we are talking is these wires, these electrical wires these are made of aluminium. So we are talking about these electrical wires or transmission lines that are made of aluminium. Also different type of sections or channel section of different shapes for making complex and architecturally aesthetic doors, windows, and frames etc., aluminium is used.

Also in the fence sometimes we use aluminum. But this galvanized iron is also widely used. This is another place where if you talk about the facades of buildings where you can see these channels are first placed on top, you will get glass facades. So those channels are also made of aluminium. So there are various places where aluminium is used, may not be necessarily as a structural element.

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Use of anodized aluminium - This anodized aluminum is something which is more corrosion resistant and at the same time you can have difficult colour to it. It is not just a painting the one on the right side or left side, these are not colored aluminum. But these are like a painted aluminum, these are coloured but not by painting but by a process called anodization.

I will cover that process later, but for now you understand that some of the time when you visit places you will see these different doors frames etc. You might look for, is there aluminium being used in that? So sometimes there will be plastic coating like this one here. You will have plastic coating on the bottom right image, but inside that there may be aluminium elements which are used mainly for ensuring the strength etc.

But at the same time we need material which is corrosion resistant also in such cases. So corrosion resistance is one good property and also in this anodized aluminium you can have different colored elements for artistic or aesthetic purposes.

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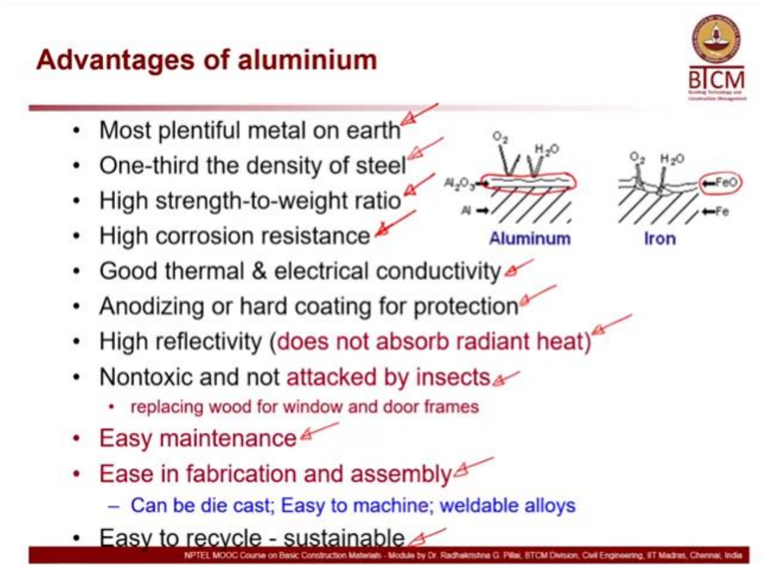

(Refer time: 11:12) So let us look at some of the advantages. It is most plentiful metal on earth abundantly available in many places and density is one-third that of steel so it is light weight that is why people actually prefer to use it even though cost is high. High strength to weight ratio that means for means for a particular section I can have more strength with less material being used. That is the idea of that. Definitely it has high corrosion resistance.

And then next point is good and how this corrosion rate is reduced. It has high corrosion resistance or rather low corrosion rate. So how is it achieved? Corrosion rate is reduced because there is less. Because the oxide film which is formed on the aluminium surface this one it is Al_2O_3 which is much resistance against or which can resist the entry or availability of oxygen and moisture to the layer below that.

So it protects the metal or the bare metal below the oxide layer whereas in case of iron or steel we have this oxide layer of iron. However we have seen many places steel actually corrodes, so the resistance of aluminium against corrosion is higher than that of steel. So if you have a highly corrosive environment, it is better to use aluminium than iron or steel. So that also adds value to the use of aluminium especially in the long run.

Now good thermal and electrical conductivity, that is also very good so because of high electrical conductivity we are able to use as electrical wires for transmission lines etc. And anodizing or hard coating, this is possible with aluminium. We can provide an aluminum oxide layer on top I will cover that process later. But that is also a possibility and which gives the high hardness to the surface and also color as we want and you know it is corrosion resistance also.

Now a high reflectivity because of this white or grayish color, it reflects the sun light. So it does not absorb the radiant heat. Then non-toxic and not attacked by insects like wood or anything if you want to compare. If you have wooden door and frames there are possibilities of termite attack. But if you go for aluminium frame you can forget that those kinds of problems in the long run.

And for maintenance also it is relatively easy, mainly because it is light weight and then you know easy to work with etc. This is easy to recycle so this material is very sustainable in that way you can re-melt it and produce another product just like steel also easily recyclable. If you are able to collect it, you can use again for making new steel and like I mentioned in the some countries I brought you know 90% of steel is made by scrap steel.

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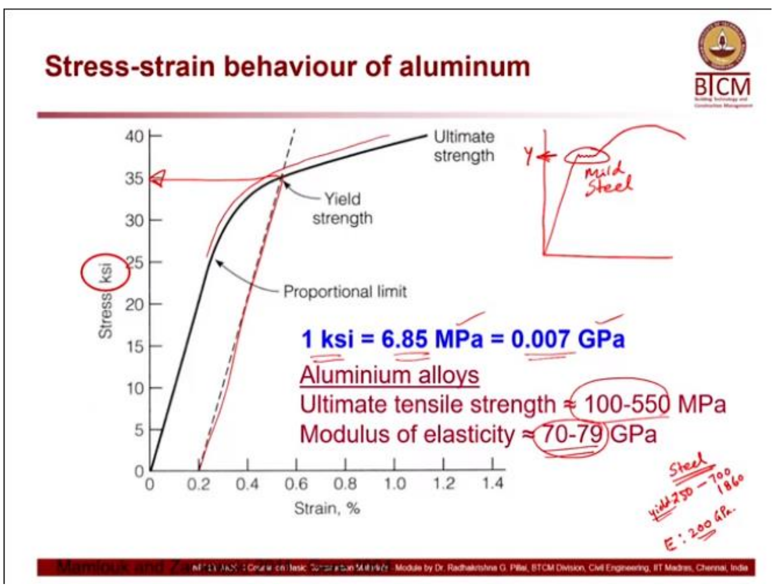

Now let us look stress strain behaviour of aluminum. So you can see here this thick black curve this curve here. Now this curve is strain versus stress. Now when you take 0.2% offset, if I go parallel line this, you are getting a proof stress of about 35 ksi. Now how do you convert that ksi to GPa or MPa the equation is given in the blue thing here 0.007 GPa if you want to convert ksi to either MPa or GPa you can look at these conversions.

So yield strength is this and one thing is note here is there is no definite yield point. It is very gradually changing, that is a particular feature of aluminium. When you have mild steel, you do not get like this. In the case of mild steel, you will have a curve which goes and something like this and then it goes like this. So this plateau region is missing in case of aluminium, especially if you are talking about aluminium alloy you will see only like very gradual change in the slope of the stress strain curve.

So in case this is for steel, in particular mild steel and this is the yield point. So what is the typical ultimate tensile strength of aluminium, it can range anywhere from 100 to 550 etc., depending on the type of alloy you are talking about. Modulus of elasticity, it can range from 70 to 79 or let us say 80. That is a typical modulus of elasticity which you are talking about. Now let us look at a comparison here, so in case of aluminum alloy is like this let us say, for steel what will be?

For steel you can have tensile strength you know ranging from 250 to 600, 700 like that this kind of steels are available. If you are talking about pre-stressing steel it is 1860 like that, so very large. This is not ultimate and I am talking about this is yield strength. Now modulus of elasticity 'E' of steel it ranges from about you, know we typically assume the number 200 GPa. This is what typically we assume for modulus of elasticity of steal.

Now modulus of elasticity of aluminium is 70 to 79 so it is much less. The tensile strength, yield strength, modulus etc., are less for aluminum. So we have to think about that while suggesting it for some use.

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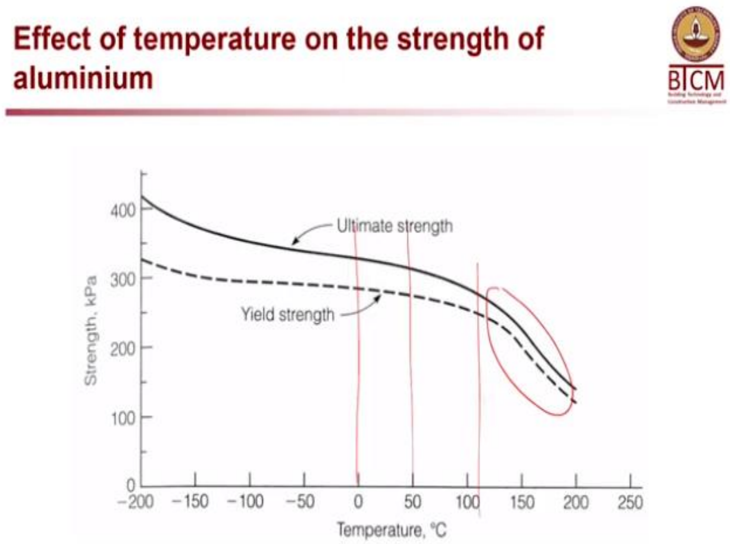

Now what about the effect of temperature on the strength of aluminum? So let us say for typical environmental temperature condition, let us say 0 to 50 degree Celsius you do not see much variation, it is ok. But if the temperature goes let us say 100+, why this is important is this kind of limits with the use of aluminum for many of the chemical plants etc., where you can have fluid with high temperature going etc.

So this kind of limits some of the applications. There is a significant reduction in the properties after, let us say 100 degree Celsius or something. So you have to look at when you suggest to, use aluminum for some whatever purpose you have to think about the temperature effects also.

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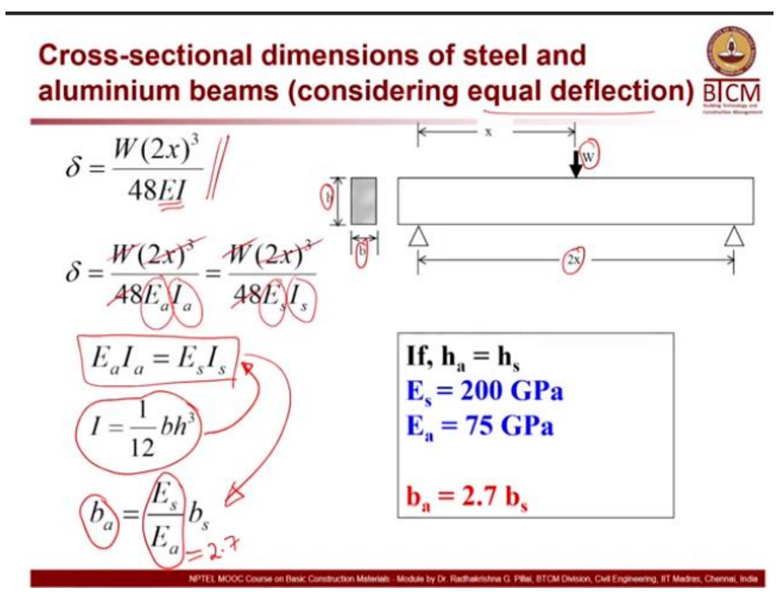

Now cross sectional dimension of steel and aluminum beams considering equal deflection. So this is a beam you can see on the top right it is a beam with height of the cross section h and width b. And length of the beam is considered to be 2x. Now if you apply a load w at the center then I can calculate the deflection as using this formula.

$$\delta = \frac{W(2x)^3}{48EI}$$

What is EI? E is the modulus of elasticity and I is the in a moment of inertia. If I say for aluminum I am going to call it E_a and I_a and for steel E_s and I_s. Now if you compare that,

$$E_a I_a = E_s I_s.$$

Now what is I? It is a rectangular section so we can say,

$$I = \frac{1}{12} bh^3$$

Now from that if I substitute that into this so I can get this equation which where I say width of the aluminium with that section required will be something like this. Now let us look at these numbers if ha = hs or in other words same height consider for both steel and aluminum, then assuming the modulus of steel to be 200 and modulus of aluminum to be 75 what we eventually get is ba = 2.7 times bs.

That means this term here is equal to 2.7. So what is this mean? If I replace a steel section with aluminum section, I will have to go for 2.7 times the width. So aluminum section will be 2 almost 3 times more in volume. So that is one reason and also costly. So it is not really good for structural applications. Structural means large beams, large columns wherever you know like in railway stations etc., you will see steel truss members etc.

There you cannot go for aluminum because you will need much more material. But there are so many other places where doors windows, frames etc., where we can use aluminum for construction purpose.