Course on Design of Steel Structures
Prof. Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Mod01 lecture 02
Steel as Structural Material

Hello, today I am going to discuss the different material properties of the steel, because we are going to use the steel as a structural material. So before going to use, that we must know what are the behavior of the steel for using that means for using as a structural material like steel, we should know the composition of the steel then how the composition are going to vary along with the structural properties, then what are the structural properties are there in case of steel material? What are the advantages of steel and disadvantages of the steel so that we can wisely use the steel as a structural material? So these aspects will be discussed.

Also we will see we know the steel is a to some extent ductile. So how it behaves under stress-strain curve means there stress-strain curve of steel we will see, how the strain is going to vary with stress, those aspects will be discussed in today's lecture. So before going to use the steel as a design material we will try to understand what are the advantages and disadvantages of the steel.

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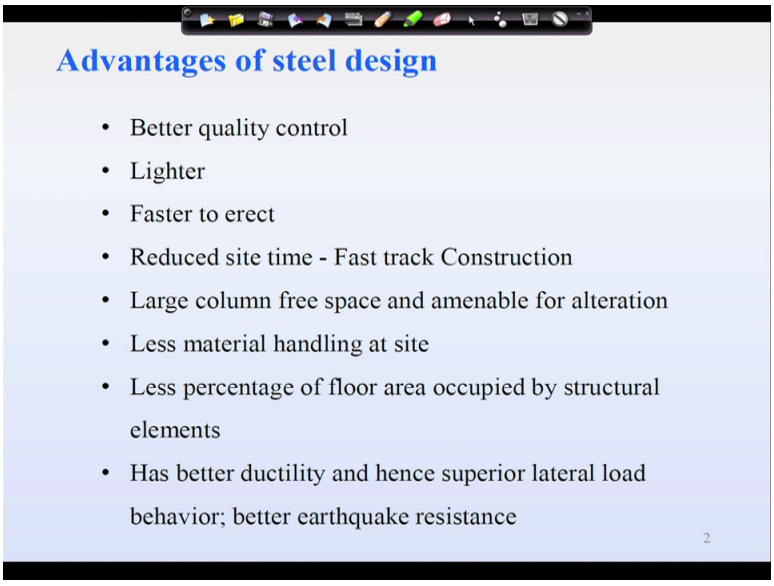

So if we look into the different type of advantages, one is the better quality control. This better quality control means the steel is basically factory product, so its quality is maintained in a better way, in with respect to concrete material. So therefore, its property will be uniform and its properties are well defined. So when we are going to design we know with confidence where these are the property we have going to get, unlike in case of concrete, we are not very sure what properties we are going to achieve, there will be gap between the target strength and the design strength, but in this case that gap is quiet less.

This is the advantageous property of the steel another property is the , it is lighter with respect to other building material, it is quiet light, light in the sense the strength to weight ratio is very high means steels weight is light in compare to its strength. So with less amount of space we can provide the member and that member can withstand large amount of load with a small free space unlike in case of concrete structure that is why it has certain advantages and also, as it is lighter, so dead load on the structure will be less. So if dead load on the structure will be less, so what it will create that consequently the size of the structural member for carrying out that load will be less. So the space in the in site will be comparatively high compare to concrete structures.

Now another aspect we have that faster to erect (())(3:46) means unlike concrete RCC structure, this can be erated (())(3:50) at site very quickly, because all steel load sections are available. So once it is transported to the site just we need the connections properly and then we can erect (()) (4:02) the structure as we as desire. Another thing is the reduce site time faster (())(4:08) construction means is very quickly construction can be made. So time of construction time will be comparatively less which is advantage for construction purpose.

Then large column free space and amiable for alteration. This is what I was telling; column free space will be getting less sorry high, because the size of the column in case of steel structures, size of the column will be comparatively less with respect to the RCC column. So the free space will be much more as respect to RCC and also as it is lighter, so the size of the column will be comparatively less in instead of using RCC, right.

Then less material handling at site, at site in case of RCC structure we have to handle, this is course aggregate, fine aggregate, cement then water and lot of material handle has to be done and lot of wastage also happens in that in the site, lot of hazardous come into picture at the site, but in

case of steel structure we will be free from those type of hazardous and has less material handling is there, so loss of means wastage will be comparatively less.

Then less percentage of (())(5:36) occupied by structural element that is what I told already and the most important thing is that, it is a better ductile and hence, (it is) it can carrying the lateral load in a better way and that means it is earthquake resistant and resistance (())(5:52). Ductile if the structure becomes ductile then what will happen that earthquake energy can be absorbed and without failure, it can be transfer to the ground.

So if the structure is ductile we can have better resistant due to seismic excitation, also it will be better in case of cyclone. So these are the few of the advantageous property I discussed and similarly, we need to know the disadvantages of steel material, because unless we know the disadvantages we cannot make use confidently, we can make use properly. So when we are going to use steel we must know what are the advantages and disadvantages and then we can make use wisely the steel material wherever it is necessary.

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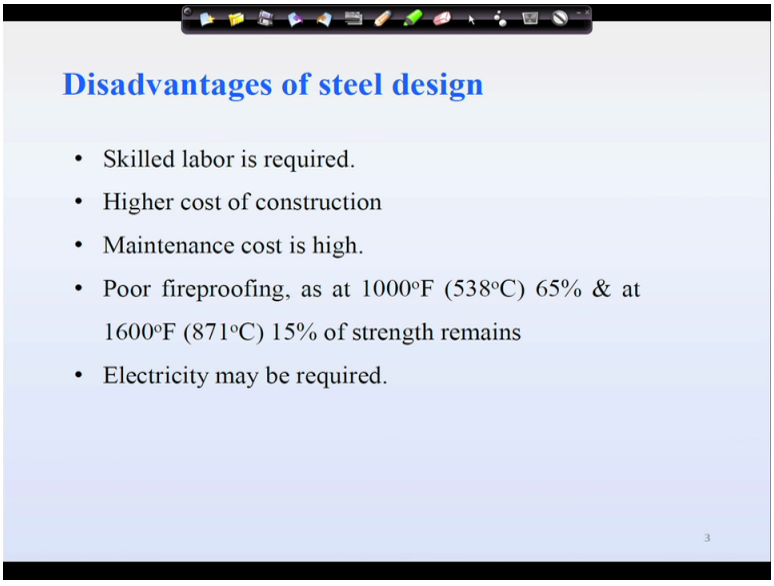

So one disadvantage is the skilled labor is required, unlike RCC structure here skilled labor is required for connections, because connections has to be made properly and that connections may be weld connection or bolt connection or may be rivet connection with the accuracy means with a higher degree of accuracy we have to joint, so that the load is transferred from beam to column,

column to foundation and also from secondary beam to beam, from slab to means floor to beam etcetera.

Another thing is higher cost of construction; actually material cost of steel is quite high as compared to concrete. So construction cost will be quite high as compare to concrete. So we have to make use of steel wisely, because unnecessary (())(7:44) if it is not required then we should not go for steel construction, because it will make costly. So this is another disadvantage, because it is high cost.

Then another thing is maintenance cost is quite high, maintenance cost is high means to after construction due to humidity and other problem, it get corroded, so because of corrosion steel strength get reduced. So time to time frequently we need to make painting we need to make maintenance. Therefore, painting means time to time painting can has to be done and, because of painting cost will means maintenance cost will be high, so unlike concrete structure here maintenance cost will be disadvantageous for (())(8:36).

Next is poor fire proofing as at 1000 degree Fahrenheit that means 538 degree centigrade, almost 65 percent strength remains. So 35 percent strength vanishes. Similarly, at 1600 degree Fahrenheit 15 percent strength only remains that means 85 percent strength got reduced. So therefore it is less fireproofing so we have to be cautious (())(9:05) about the fire safety while using the steel as a structural material.

Then another problem is that electricity may be required if we construct in a remote area where electricity is a problem then we may not be able to go for welded connection properly. So sometimes we need electric connection, which may not be available at the site, so in that case we means we have to face problem from that. So these are the few (advantages) disadvantages of the steel using as a structural material.

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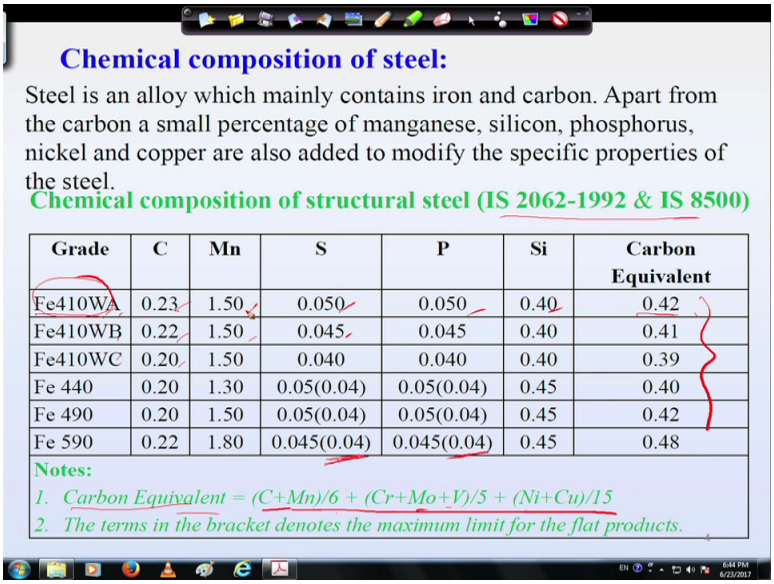

Now coming to chemical composition of the steel, basically steel is an alloy which maintain mainly contains iron and carbon, apart from the carbon a small percentage of manganese, silicon, phosphorus, nickel and copper are also added to modify the specific properties of steel. Here, in IS 2062-1992 and IS 8500 the chemical composition of structural steel have been (())(10:17) given. So some of the chemical composition of different structural grade of steel has been reported in this table like Fe410 of grade A, B,C the percentage of carbon might been shown. So different percentage of carbon, manganese then sulpher, phosphorus, silicon and carbon equivalent has been given it.

So with the different ratio of this we can achieve a particular grade of steel that means a particular weight of steel means a particular strength we will be able to achieve. Here, carbon equivalent means basically, the carbon plus manganese by 6 then chromium plus molybdenum plus vanadium by 5 and nickel plus copper by 15. So this summation is called carbon equivalent, which is given here, right and the terms in bracket denote the maximum limit of the flat products. This bracket in bracket whatever it is giving, it for it is for flat product. So if we want to produce means if we want to know in a particular weight of steel what are the composition that can be found from this table.

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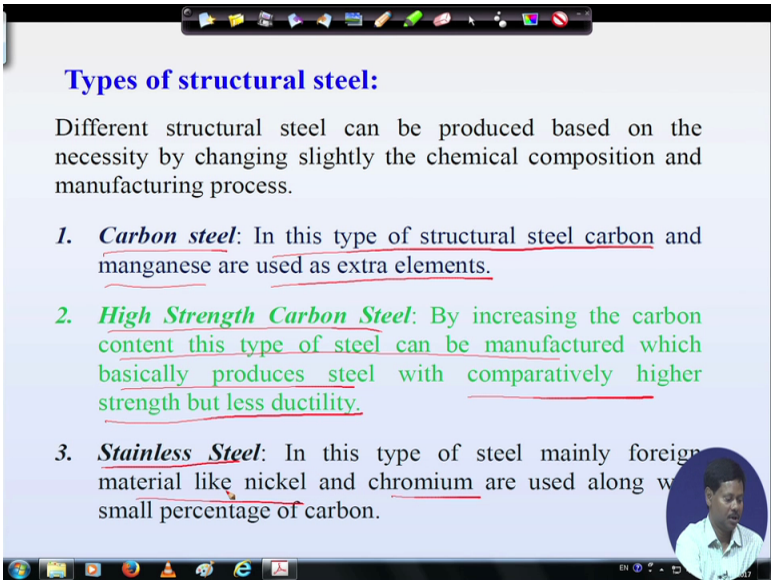

Now coming to types of structural steel we can see that one is carbon, basically different steel have been produced based on necessity by changing the chemical composition and manufacturing process. So in case of carbon steel the structural steel carbon and manganese are used as extra element and another type of steel is high strength carbon steel. By increasing the carbon content this type of steel can be manufactured, which basically produces steel, with comparatively higher strength, but less ductility. So for this type of steel you will get high strength, but less ductile. This is high strength carbon steel, another steel is stainless steel, in this type of steel mainly foreign materials like nickel and chromium are used along with small percentage of carbon.

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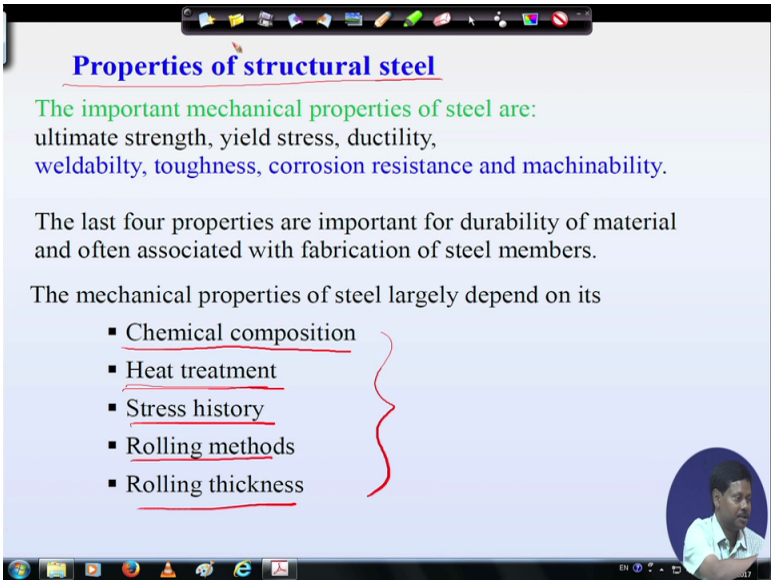

Now being a structural engineer we will try to see what is the property of structural steel. Now properties means different type of properties structural steel have, but being structure engineer or a steel designer, we will be focusing on ultimate strength, yield stress and the ductility. These three things are very important. This is mechanical properties this is ultimate strength what will be the ultimate strength and what will the yield stress and then ductility whether it is ductile or not.

These are very important for using the steel and also weldability, toughness; corrosion, resistance and machinability are also some of the properties mechanical properties and in this last four properties are important for durability of material and often associate with fabrication of steel members. So for durability consideration, this last four properties are very important we have to keep in mind and mechanical properties of the steel largely depends on this five things, one is the chemical composition.

So we have to know what is a carbon percentage is given and other different elements what are the percentage of that are present. So depending on that the mechanical properties of the steel will vary and that the heat treatment. How the treatment going to be make for producing steel then stress history, rolling methods and rolling thickness. So these are the few things few parameters which we have to keep in mind for getting the structural properties of the steel, because these structural properties of steel largely depends on this.

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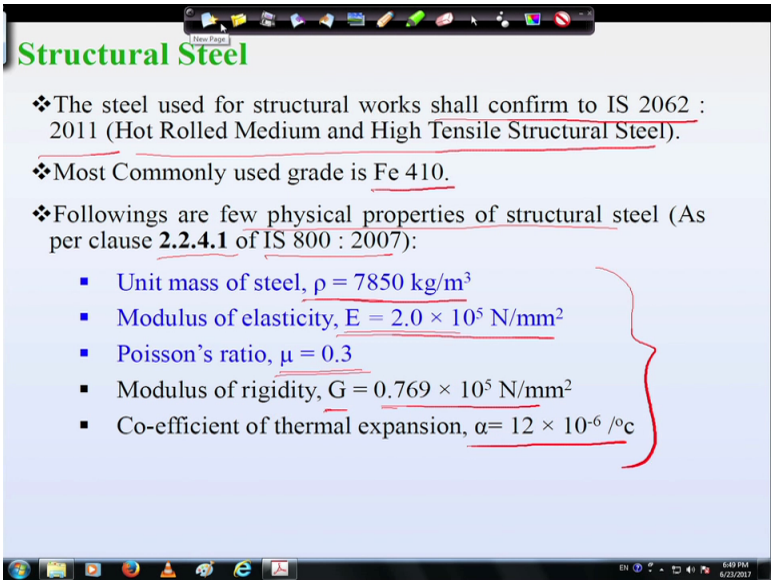

Now the structural steel whatever we are using, it should conform the IS 2062-2011 is hot rolled medium and high tensile structural steel. So it should conform to this code and we use mostly the Fe 410 grade of steel. Most commonly used weight in general we can see that it is Fe 410 and few physical properties of structural steel, which are given in IS 800-2007 in clause 2 .2 .41, because this is also this properties also will be required for some times like unit mass of steel, rho the density of mass density of steel is 7850 kg per meter cube. This is required, because when we are going find out the self-weight of the structure then we have to find out what is the weight of the steel? In that case we have to know the mass density of the steel unless we know that we will not be able to get the proper load, self-weight what is coming due to the steel member.

Next is the modulus of elasticity, this is also important to find out the thickness (())(15:58) of the steel member and this we consider that 2 into the 10 to 5 newton per millimeter square. Poisons ration also is important, which we consider in general 0.3 and modulus of rigidity G , G we considered as 0.769 into 10 to power 5 newton per millimeter square and co-efficient of thermal expansion for heat related problem, we have to consider this thermal expansion that is alpha is equal to 12 into 10 to the minus 6 per degree celsius, because steel we can expand or contract and because of the stress may develop so that thermal stress whatever is going to be developed that has to be calculated and that traditional forces has to be calculated while analyzing their structure. So in that case thermal expansion coefficient is important.

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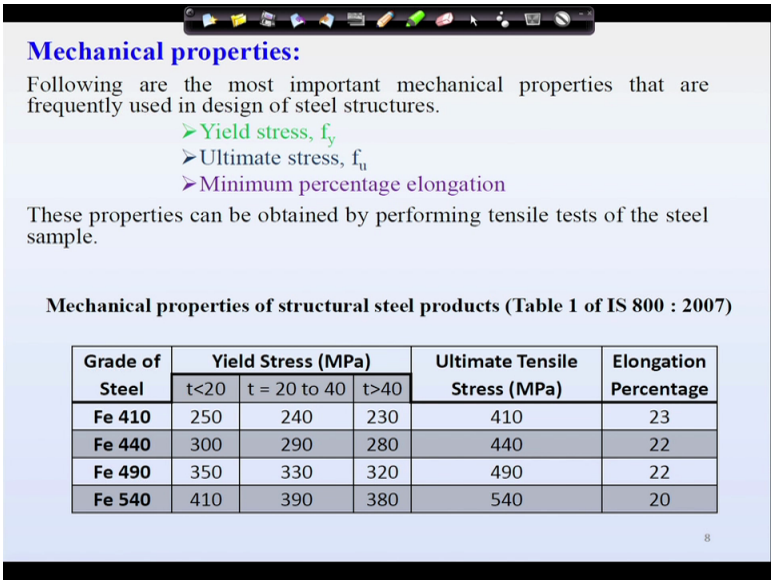

Grade of Steel	Yield Stress (MPa)			Ultimate Tensile Stress (MPa)	Elongation Percentage
	t<20	t = 20 to 40	t>40		
Fe 410	250	240	230	410	23
Fe 440	300	290	280	440	22
Fe 490	350	330	320	490	22
Fe 540	410	390	380	540	20

Now coming to mechanical properties as I told, the three things are very important that is one is yield stress, what is the yield stress of the steel? What is a ultimate stress and the minimum percentage elongation? Minimum percentage of elongation, so these we can find out, in table 1 of IS 800-2007 mechanical properties of structural steel like, we use Fe 410 grade of steel. So in that case, the yield stress is put as a 250 and ultimate stress is 410 in MPa and elongation percentage is 23.

Here, you see another yield stress is given for thickness from 20 mm to 40 mm for this 250 we can achieve if thickness is less than 20 mm, but t if t is 20 to 40 then 240 and if t is this thickness is more than 40 mm then the yield stress is going to be consider as 230 MPa. So for Fe 410 grade of steel what we use we use yield stress either 250, 240 or 230 and ultimate stress as 410 and elongation percentage as 23. Similarly, Fe 440 grade of steel we can find out yield stress as 300 and ultimate tensile stress as 440 and elongation is 22.

So in this way we can find out the important properties like yield stress, ultimate stress and percentage elongation from the grade of steel, if a particular grade of steel is given then we can find out what is the yields stress, ultimate tensile stress and grade of steel, right. Now coming to ductility, a very important parameter in case of steel design is ductility.

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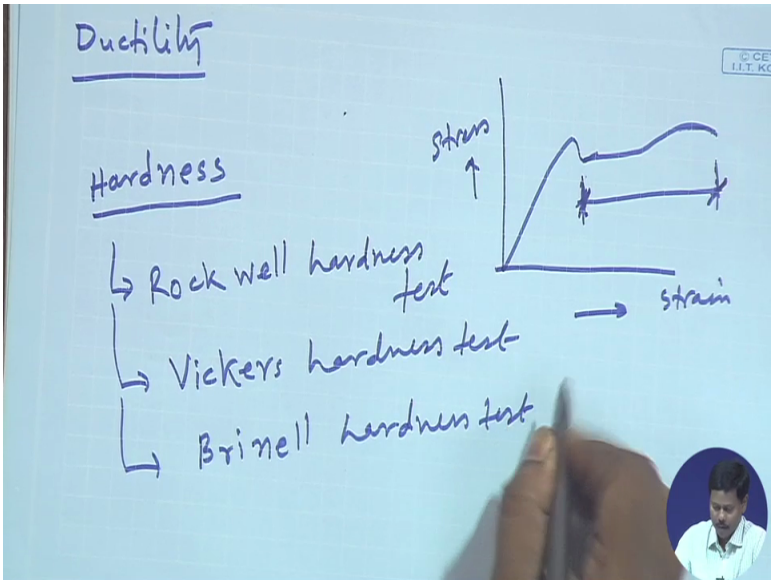

So I will discuss little more about ductility. It is a ability to deform under tensile force. Ductility is basically the ability to deform under tensile force and it undergoes large emulatic (())(19:33) deformation in case of ductility ductile material (())(19:38) deformation happens and emulatic (())(19:41) deformation means permanent deformation without loss of strength under the application algorithm. So if we see something like this, the stress-strain diagram of the material if this is strain and this is stress then this portion is basically the ductility portion where stress is not developing as such, but the strain is going to be increase and if we release the load, it will be coming to its earlier position of course of in not in same path, because it is inelastic (())(20:20), but it will come to its earlier position with deformation. This ductility means if the material is ductile that means it will be much more seismic resistance. So we prefer ductile material so that deformations are allowed without failure.

Then another property we also come across which is called hardness. Hardness is one of the mechanical properties of steel by virtue of which, it offers resistance to the (())(20:59) and scratching. So hardness we can be measure by different test (the) like rock well test rock well hardness test. Another test we make which is called Vickers hardness test and then another test through which the hardness is measure is called Brinell hardness test. So through this one can test the hardness of the material and another property also we come across is called toughness.

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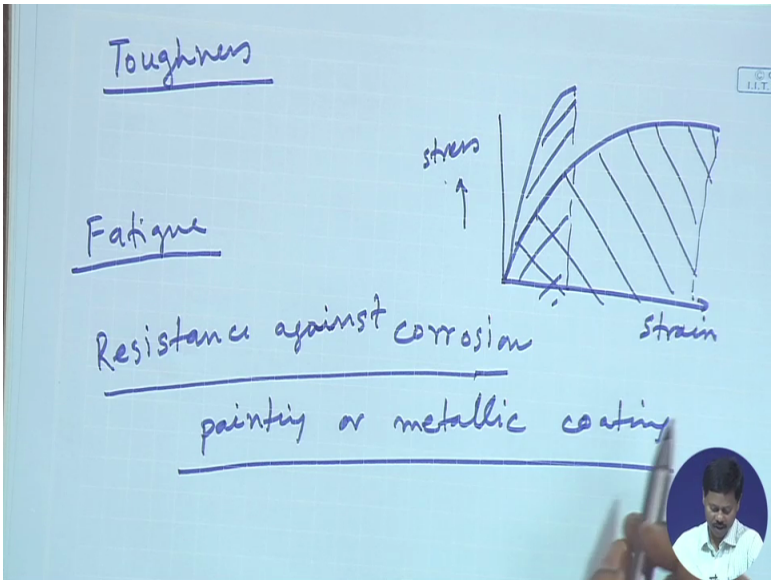

So I am discussing some property, mechanical properties and other properties of steel, which is important to know for designing the structure and when we are going to design a member we must know what is a behavior of the member under load, say for example, if we make stress-strain diagram of a material, say stress and strain, so brittle material means it will be like this and suddenly it will fail brittle material and ductile material means it will not fail, it will undergoes strain. So this is ductile material.

Now toughness is a ability to absorb energy up to facture. Toughness is called the ability to absorb energy up to fracture and this toughness is measure by the area under the stress-strain curve. So stress-strain curve of this material and stress-strain curve of this material, the area we can find out and we can measure the toughness. So the ability to absorb the energy up to fracture is called toughness. It is a one type of mechanical property of steel. So basically it offers resistance to fracture under the action of the impact load. So this is one property another is fatigue. Fatigue means the repeated loading. it is means damage is cause due to repeated loading repeated fluctuation of stress and which leads to productive of cracking of the structure element (())23:42) and due to cyclic loading damage and failure of the material may happen which is called fatigue.

And another is resistance against corrosion means what is a resistance property against corrosion that also we have to keep in mind. In presence of moisture, corrosion of steel is means corrosion

of steel happens. So to avoid that what we can do? We can go for painting or metallic coating. So either of these two can be made to take care the corrosion. So this is one property which we have to keep in mind and then another property is residual stress.

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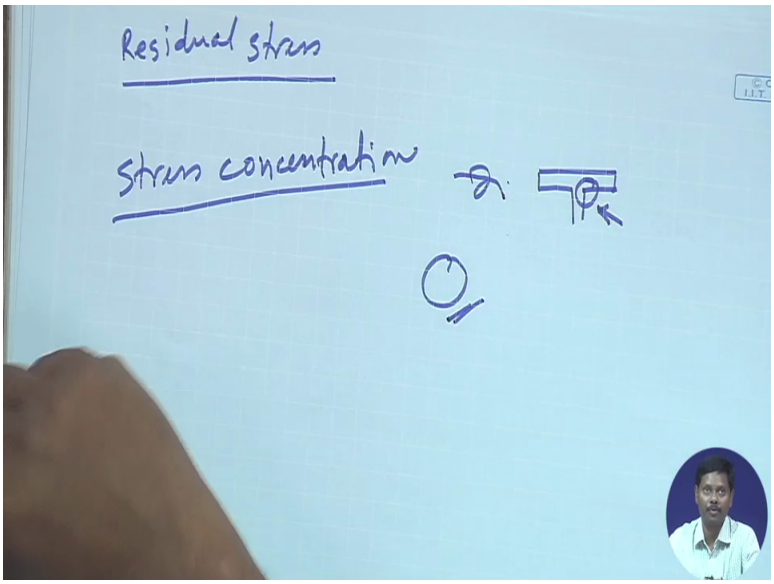

Residual stress come into picture, because of unable (())(24:55) heating and cooling, the residual stress is in the member develop. So how the material has been produced depending on that (()) (25:07) what are the residual stress there that we can calculate we can found and accordingly the design of the member can be done. Then another is stress concentration when certain changes of geometry properties are there, say stress concentration. It is basically a highly localized state of stress where at particular location stress is concentrated and, because abrupt change of the shape, in the vicinity of notch where say, suppose a member is like this, so sudden change at the vicinity of notch can make the development of stress concentration and also during near the hole the stress also generated several times greater than the actual stress and for that we have to take care that means when we are going to design there may be chances of failure at certain localized point, because of concentration of stress. So we have to make the section in such a way there stress concentration can be avoided.

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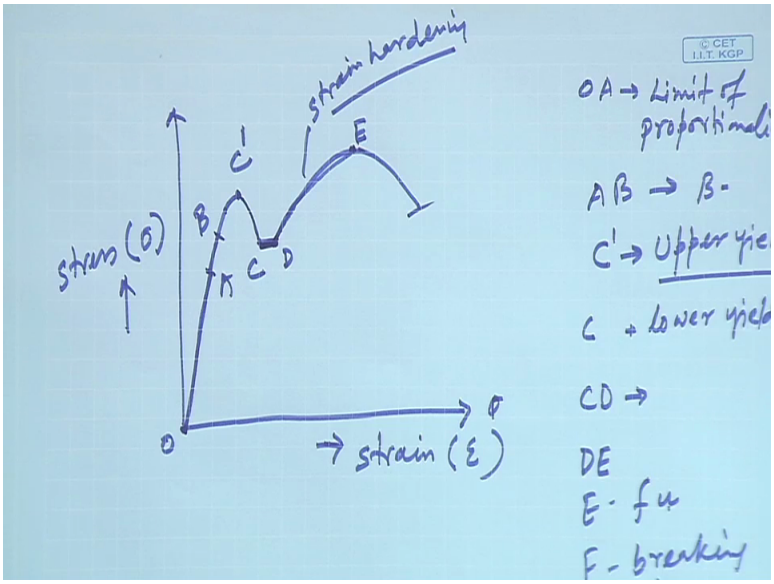

Now we will come to the stress-strain curve. So stress-strain curve of the mild steel we will see first, say this is strain which is called epsilon and this is stress, which is called sigma, right. Now in case of mild steel an ideal curve is looks like this, right. So this is the origin from where stress-strain curve develops. So and this is point A, this point A up to point A that means up to O means from point O to point A is called limit of proportionality. This portion is called limit of proportionality that means proportionality, right that means up to this, it is linear and it obeys the hooks law.

So OA is basically call the limit of proportionality then from A to B actually after reaching point A, change in strain is rapid compared to that of stress, but still the material behaves elastically up to elastic limit of B. It behaves elastically, but change of strain is rapid compared to stress up to point B means part AB, right. So this up to point B is elastic limit then point C. Point C is the upper yield point means if we go on increasing the force then we will observe that yield point means it reaches yield point upper yield point. So after upper yield point again, it will come down to say sorry, this we call C dash and this is C. So C is the lower yield point, right. This observation of C dash and C point depends on the rate of loading it means depending on the rate of loading we can observe the point C and C dash.

Then CD part, so beyond yield point, the material start flowing plastically without any significant increase in the stress and material goes large deformation. So CD part is basically

plastic part. So it means it flow like plastic and without any increase of the stress, the strain increases then up to point E DE, De means after reaching point D strain hardening occurs in the material and who is (())(30:16) here, the requirement of higher load to continue the deformation. This phenomenon is call strain hardening that means it resist deformation and needs more load to deform.

So after CD means where load was not increasing, but after that point, it is starts resisting deformation. So strain hardening occurs, so with the increase of stress, strain also is going to increase up to certain level, which is highest point E and E this E represents the fu the ultimate stress, right and after that the stress going to be reduced and at a certain point it breaks. So f is a breaking stress, right f is the breaking stress, so this is how the material behaves.

So what we need to know that when we are going to design a steel member we have to know what is a properties of steel under load that means stress-strain diagram how it varies, in case of mild steel, it varies in a way in case of torque (())(31:39) steel it varies another way, so we have to know and accordingly we have to find out what is the fu value and what is fy (())(31:46) value and what will be the strain at fu and strain at fy, right that means how much ductile this material is depending on that means we can think of designing the member properly.

So when we go to the design procedure the member when member is going to be design under certain procedure like working stress method or limit state method or ultimate stress strain design method we have to know the stress-strain diagram, stress-strain behavior of the material so that we can understand that up to what level we are going to allow the deformation and then how we are going to find out the maximum allowable stress and then according to that design criteria would be decided. So this is all about the todays lecture about the steel as a structural material, thank you.