Design of Steel Structures.
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Lecture-45.
Introduction to Flexural Member.

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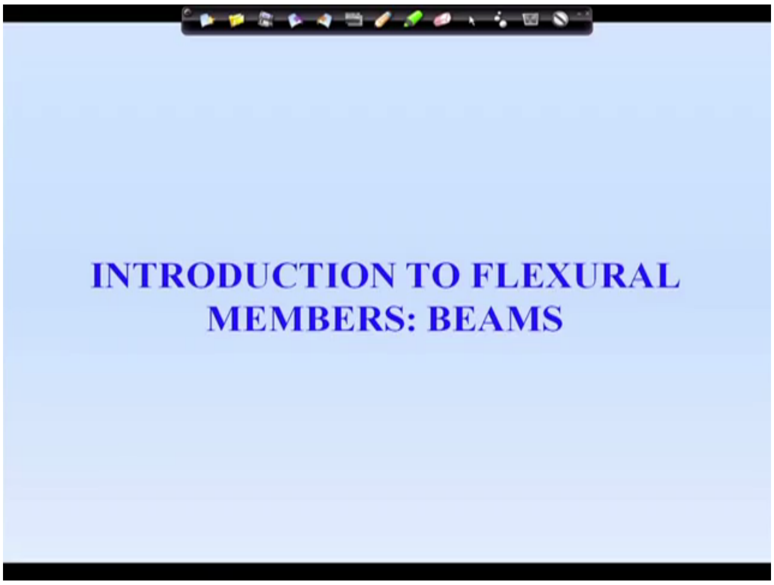

Today I am going to start a new chapter which is called Beam, at the beginning I will be giving a lecture on introduction to flexural member and beam is basically a structural member which is subjected to transverse loading, that means the load perpendicular to its axis. And because of this transverse loading the members produces bending moment as well as shear force. So when we will be going to design we have to design against bending moment and against shear force.

Now in an anatomy of a structure or a building system we have seen that apart from compression member of column, tension member the beam are also existing and beam is an important member in a structural system which carries load which are basically transverse load and the loads from the super structure which are coming to the column it comes mainly from the floor and floor to beam and then beam to column. So we need to know how to design the beam against such type of forces like bending moment and shear force.

Not only that in case of steel structure we will see the beam is not only failed due to bending or due to shear but also failed due to lateral buckling, due to local buckling, due to torsional moment, so many things will come into picture. Why we have not studied this since in case of RC structure because in case of RC structure generally we provide rectangular section, whereas such type of problems will not come. But in case of steel structure we provide certain rolled section where the thickness of the member is quite less means say for example I section the thickness of the flange the thickness web is quite less.

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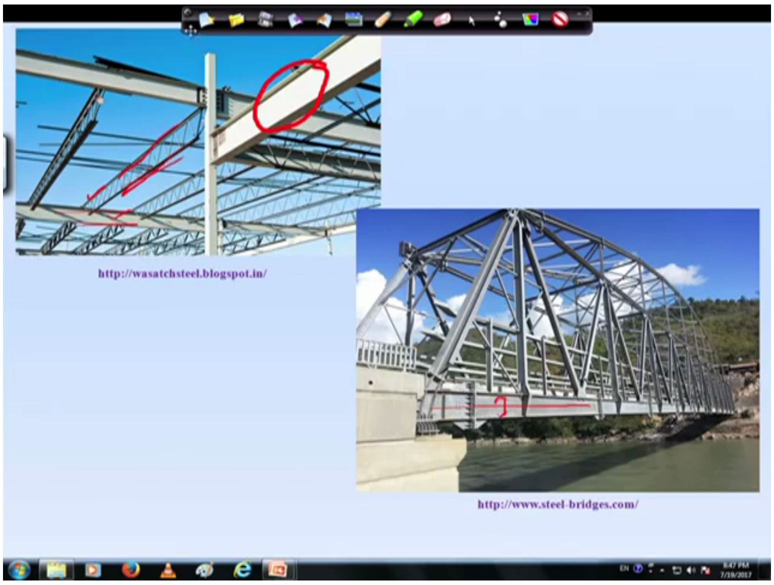

So there will be chances of different types of buckling local buckling of the flange, of the web which we need to take care, so all these aspects will be discussed in this chapter. So coming to picture here we can see that this is called a beam, generally these are the beam, this is a channel section which are used and here also we can see this is a horizontal section, this is a beam, this is a beam and some beams are connected to another beam, where we call this is as secondary beam and this is as primary beam.

So secondary beam are rested on the primary beam and in case of bridge structure we oftenly tell that girder and this bridge structures are used means are designed considering beam as a plate girder, where the girder dimensions are decided on the basis of the bending moment and other forces.

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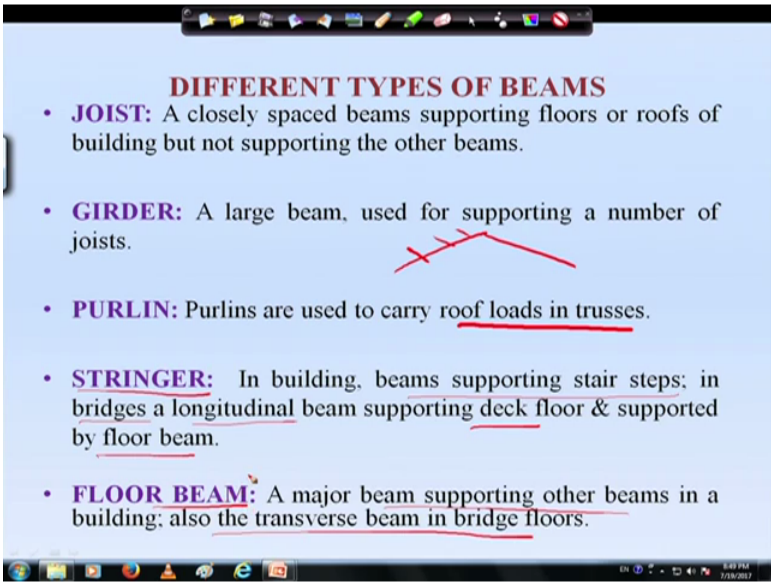

So in case, though we call this beam but these beam members are named different way at different places, like when like Joist, a closely spaced beam supporting floors or roofs of building but not supporting the other beams. This is called Joist. So sometimes the beam are named as Joist. Girder we call when a large beam used for supporting a number of joist. So in previous example we can see that if this is called a Girder, this is supported by the cross cross beam, this is supported by the secondary beam, so this structural member the flexural members are called different way in different places.

Like Purlin, Purlin also we call when it is used to carry roof loads in trusses, when the means roof trusses are there, then Purlins are provided so those beams are called Purlin, when it is carrying the roof load. And in building beam supporting stair steps or in a bridge a longitudinal beam supporting deck floors and supported by floor beam are called Stringer. And a major beam supporting other beams in a building and also the transverse beam in bridge are called Floor Beam.

So, we though we call different name but we will see in case of design we will design as a flexible member. So design procedure will be same for all the cases but their names are different to identify the use of different beam members in different places like Spandrel Beam.

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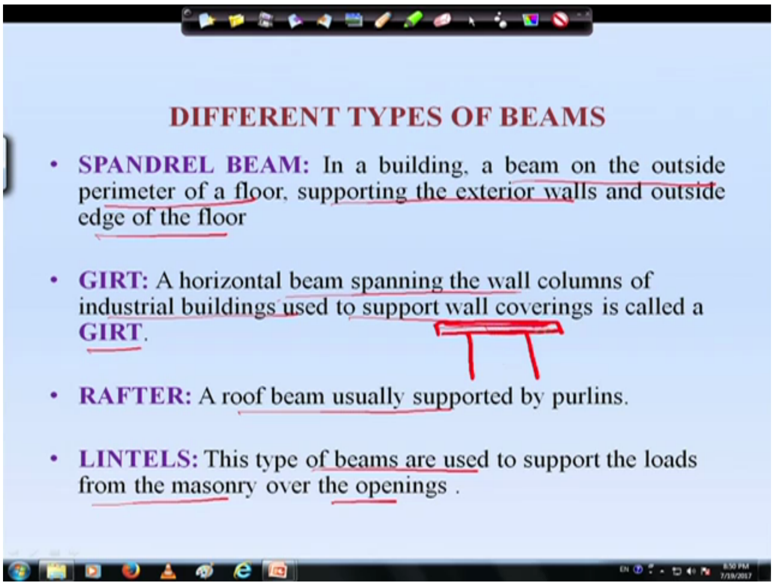

In a building a beam on the outside perimeter of a floor supporting the exterior walls and outside edge of the floor is called Spandrel Beam. And a horizontal beam spanning the wall of columns of industrial building used to support wall covering is called a Girt and Rafter is a basically roof beam when supported by Purlins. So Rafter is a roof beam supported by purlins and Lintel we have already come across through RCC design, that is the this type of beams are used to support the loads from the masonry over the openings. Means when say suppose window is window is up there then we provide here certain lintel to carry the load in this place so this is called Lintel.

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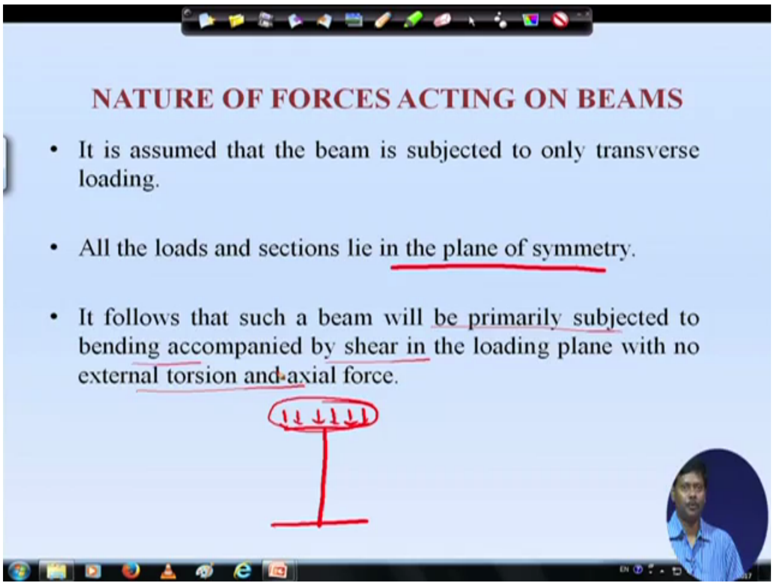

Now nature of forces acting on beam, if we see that basically the nature of the force is transverse load. In beam the transverse load are subjected to the member and all the loads and sections lie in the plane of symmetry that means say suppose a I section is there, now when loads are coming across its cross section it is consider that it is a symmetric loading. That means that there is no twisting and it follows that such a beam will be primarily subjected to bending accompanied by shear in the loading plane with no external torsion and axial force. Though in case of beam the axial force may come into picture sometimes and sometimes torsion also will come into picture because of unsymmetrical loading.

But generally we use to tell beam as a member when only the symmetry transverse loads are acting on the member has so in case of only symmetric in case of only transverse loading the member is called beam and design accordingly. So if we see say suppose a beam is having certain load then it goes deflection like this and it has it produce certain bending moment and it produce certain shear force. So the primary objective to design the beam against this bending moment and shear force.

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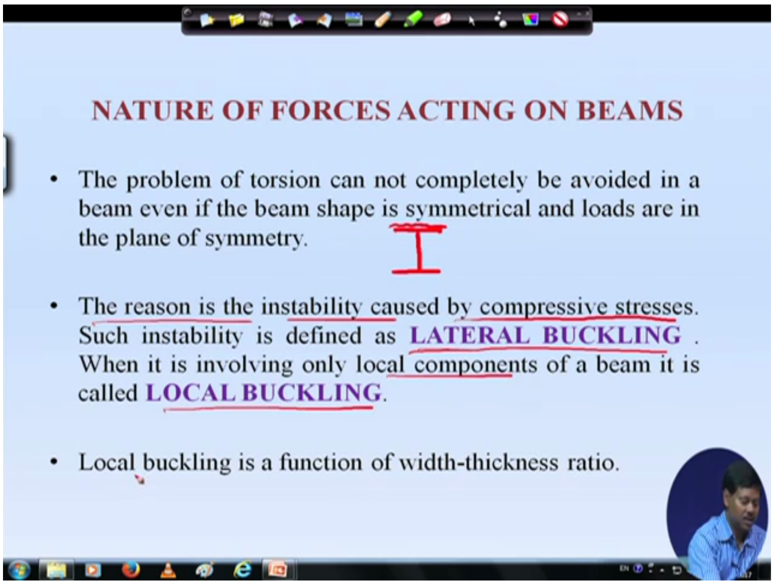

Now the torsion cannot completely be avoided. In a beam if even if the beam is symmetrical beam shape is symmetrical and load are also in plane of symmetry, that means suppose a I section, say it is a symmetrical I section now load also asymmetric. If it happens in such case also means if the loads are also in plane of symmetry and beam shape is also in symmetrical position, then also torsion may come into picture. This is because the instability, the instability caused by the compressive stresses.

The reason I am reading once again the reason is the instability caused by the compressive stresses. So such instability is defined as Lateral Buckling right and when it is involved only local components of a beam it is called Local Buckling. So while going for design of a beam member we have to see whether it is going for means whether we need to design for lateral buckling and local buckling and this local buckling is a function of width to thickness ratio.

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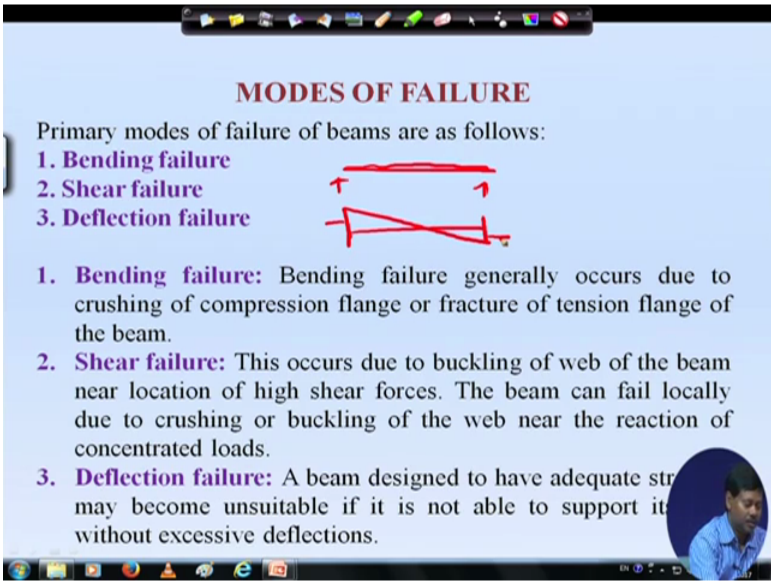

So depending on the width to thickness ratio the local buckling will be considered. So if we see the mode of failure as I told that mode of failure will be basically three type of failure primarily will come one is bending failure, another is shear failure and another is deflection failure. Bending failure generally occurs due to crushing of the compression flange or fracture of the tension flange, because if we draw the bending moment diagram means because of certain load so bending moment diagram will be like this, that means tension will develop at the bottom and compression will develop at the top of this such case.

And crushing of the compression flange will occur because of the load and fracture of the tension flange will happen. So this type of failure may happen, so if we see along the depth of cross section the stress will vary like this. So here it will be compression, here will be tension. So the extreme fibre of the member at top will be under compression and it may undergo crushing failure and the extreme bottom of the member will be under tension and it may failure to fracture of tension flange.

Similarly shear failure may come into picture and this occurs due to buckling of the web of the beam near location of high shear forces because we know if we see the bending moment diagram of such type of loading will see the shear force diagram will be like this. So maximum shear force will be developed at the support and the beam can fail locally due to crushing or buckling of the web near the reaction or concentrate load right.

So this is another failure which we need to take care, another failure may occur due to deflection excessive deflection. So we need to design the beam to have adequate strength but it may not be suitable if the if it is it is having excessive deflection. So excessive deflection will make discomfort to the user therefore we need to restrict the deflection also. So the code has provided certain deflection criteria that means limiting deflection of of the beam.

So when we are going to design the beam we have to also check the design criteria, deflection criteria, that means the section whatever we are going to choose under a certain load whether it is under permitted deflection or not that has to be checked, if not if deflection is excessive then section may not fail but we have to redesign the section to make it under limit state of serviceability. That means from serviceability criteria we have to fulfil the permissible modes also.

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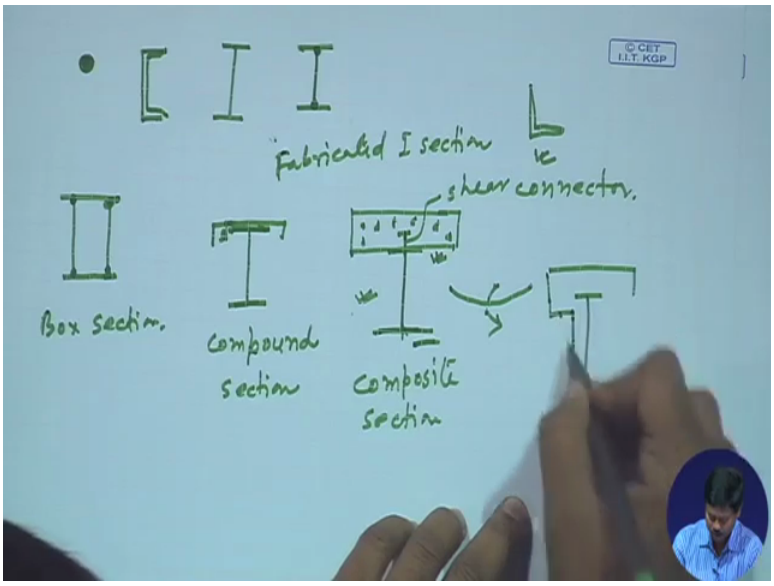

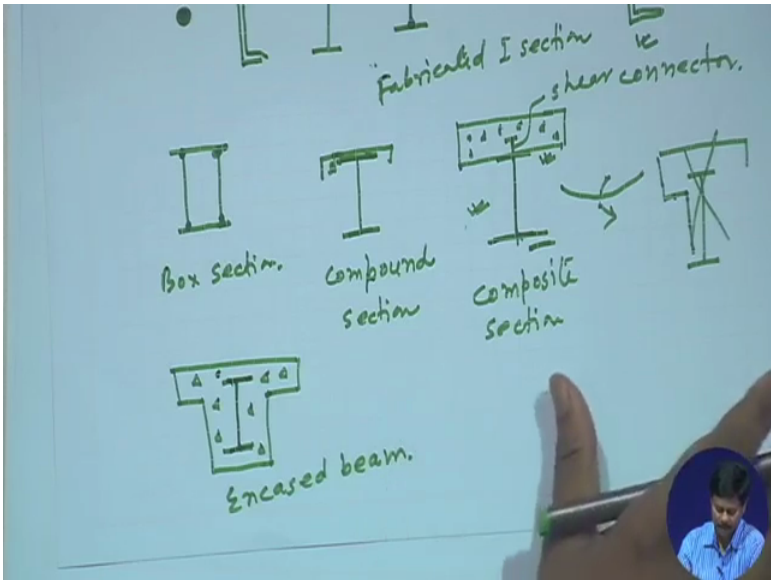

Now type of steel section, so in case of beam we may use different type of sections say one is say solid section we can use right and different type of rolled section like channel section we can provide, again thin walled open section roll open section I section can be provide right, this thin walled open section and sometime fabricated I sections also provided means we have provided means, we have considered a plate then we have fabricated means we have welded here, we have welded with other plates and this will be the this is called fabricated I section.

This is used frequently to fulfil the requirements and sometimes we provide the thin walled close section also. This is I think like this these two plates are fabricated like this so we make welded connections here and this is called thin walled close section. This is also called box section, so box section can be used sometimes angle sections can be used, angle sections for light weight transverse load angle sections may be provided, however for this case asymmetric building will come into picture which need to be take care. And sometimes compounds sections also we provide.

Compound sections means combination of two sections. Say for example this is an I section, steel ruled I section and along with that say if the compression is quite high compared to tension then we may provide sometimes channel section at the top right. So this is called compound section which is made of two different section, here it is I section and channel section combination of I and channel section.

Then also we use composite beam, composite beams mean made of steel and concrete say for example this is 1 case, this is I section and over the I section we provide the RCC slab or beam and connect with the shear connector we connect with shear connector. This is called shear connector shear connector right and this is concrete. So this type of section is called composite section, this has certain advantages in the sense we know the concrete are good in compression and steel are in tension.

So when the members are used under gravity load, the beam members are used so then it bends like this, so bends like this means the compression occurs at the top and tension occurs at the bottom. So if we use such type of composite section, then compression will be taken care by the concrete section and tension will be taken care by the steel. So we can make advantageous use of the concrete properties and steel properties. Also sometimes we use encased beam encased beams means we provide certain I section, then periphery of the I section we cast with concrete so this is also sometimes used.

Sorry sorry this I am drawing once again, say I section and then it is casted like this, so this is called encased beam, encased beam. These are the concrete material and encased with the I section which is of steel. So these are certain type of section which we oftenly use for beam member right.

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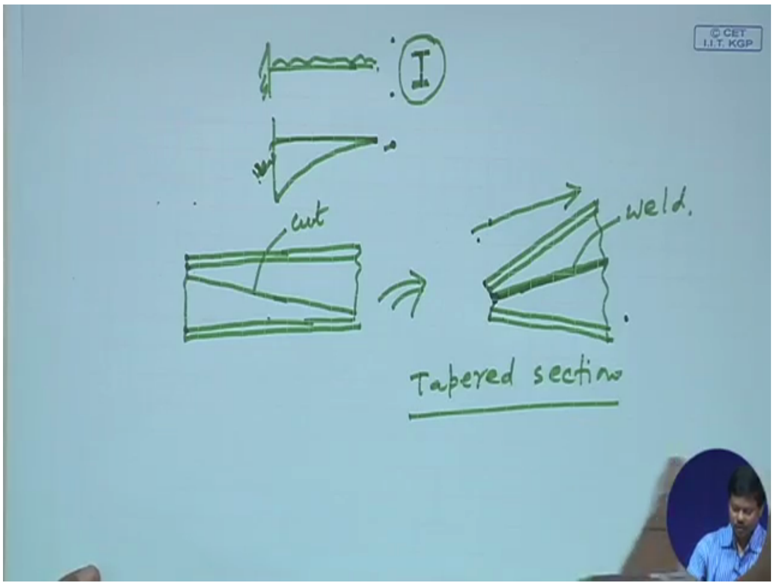

Another section we can use that is suppose a cantilever beam is there having certain UDL load now we can see the bending moment will be something like this, that means bending moment will be maximum here and minimum here so if we can if we provide a same section that means we have to provide the section considering this bending moment right.

We have to provide the a particular section considering the maximum bending moment and throughout the section we use which would be uneconomical. So to make economical we can provide the cross section means section with varying cross section. So that in different way we can make one way is say suppose we can provide a means we can consider a I section right we can consider I section and then we can cut say this is an I section then we can cut this through this ok.

So if we cut it then we can make it reverse and then we can make it weld so if we do that we can see that this can be made like this. This is one and this is another one right, so and in this phase the two sections are welded, right, this is welded. So as a means this is basically called tapered section, if we see the tapered section then along its length the cross sectional properties are impinging cross sectional dimensions are impinging. So if we use such type of member in case of cantilever beam it will be economical.

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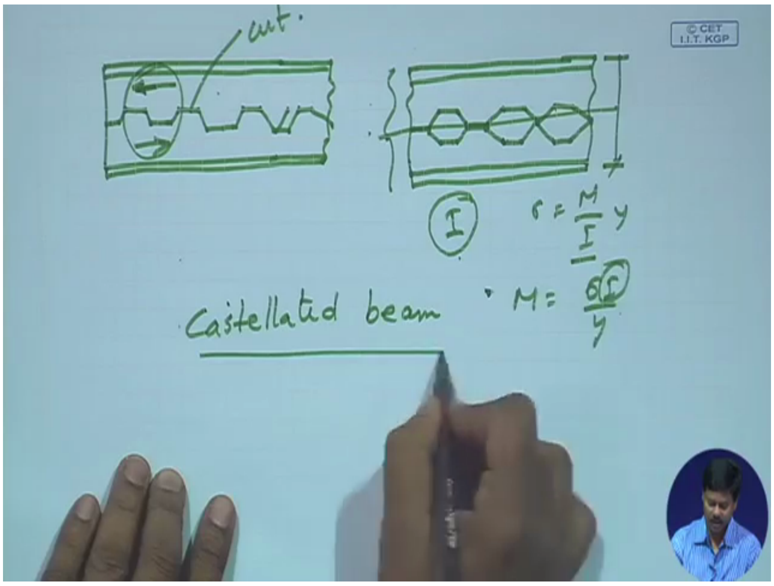

So another section is called means we provide which is called castellated beam here basically what we do say one I section we cut through its web, say this is an I section and we can cut this through its web in this way right like this. So this is a cut right, now these two sections if we can displace say this we can displace towards this and this we can displace towards this, then we can make a sections like this.

So what we can make this will become something like this ok. So this will be opening in the web. What is the advantage, advantage is that if we slide these 2, then the depth of the cross sectional will increases right. If the depth of the cross section is increased then the moment of inertia about I means about this direction will increase moment of inertia.

If moment of inertia increase then we know stress will be decreased because stress is M by I into Y. So with the same section without increasing the material if we reoriented this through cutting through its web, then we can increase the moment carrying capacity right. We can increase the moment carrying capacity by increasing the value of I because moment carrying capacity will be sigma I by Y, so I am going to increase I by increasing the depth of the cross section of the material. So this type of beam is called Castellated Beam right.

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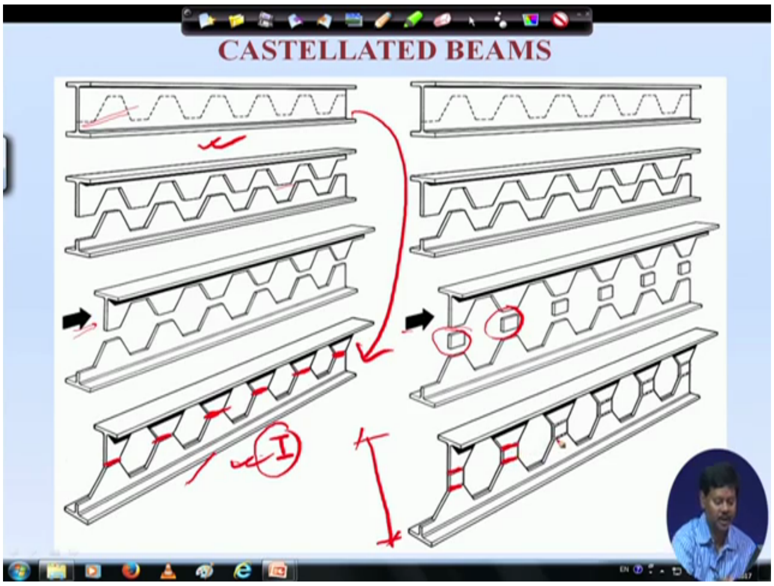

So this type of beam is called castellated beam. Now this looks like this so here you can see what I have shown is this one, first we are cutting through its wave and then one we are sliding to this and then we are getting this type of member and we are welding in this right through welding joint we are making a single section. Whereas the depth of this section will be higher than this, the original one though the weight of the material will be same because this is same but the depth will increase and if depth is increased then the section properties like I the moment of inertia will increase.

Another way of making castellated beam is weld making this we will insert a plate here right, with a certain thickness and depth right. So if we insert this then we can see the length is becoming much much higher than the original one, so through this I can achieve the moment of inertia to a large extent right and here we need to weld to make a monolithic. So this is one another example of castellated beam.

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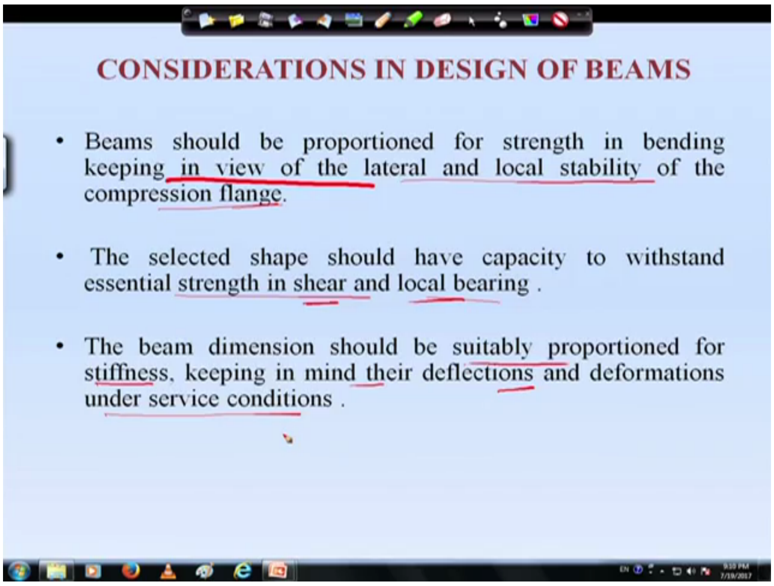

Now we will find out some consideration for design of beams, like when we are going to design a beam we have to consider that beam should be proportional for strength in bending keeping in view of the lateral and local stability of the compression flange. Because the compression flange have lateral instability can have, so that has to be keep in mind. Now the selected shape should have capacity to withstand the essential strength in shear and local bearing. So whatever shape we will select because different type of shape we can select so that shape maybe I section, maybe channel section, maybe other section.

That shape should have capacity to withstand essential strength in shear because the shear will be taken by the web so web thickness should be sufficient enough to take care the shear force and local buckling. Then the beam dimension should be suitably proportional to stiffness, keeping in mind their deflections and deformations under service conditions. So dimensions has to be made in such a way that it should be means the deformations under the service conditions should be under limiting value.

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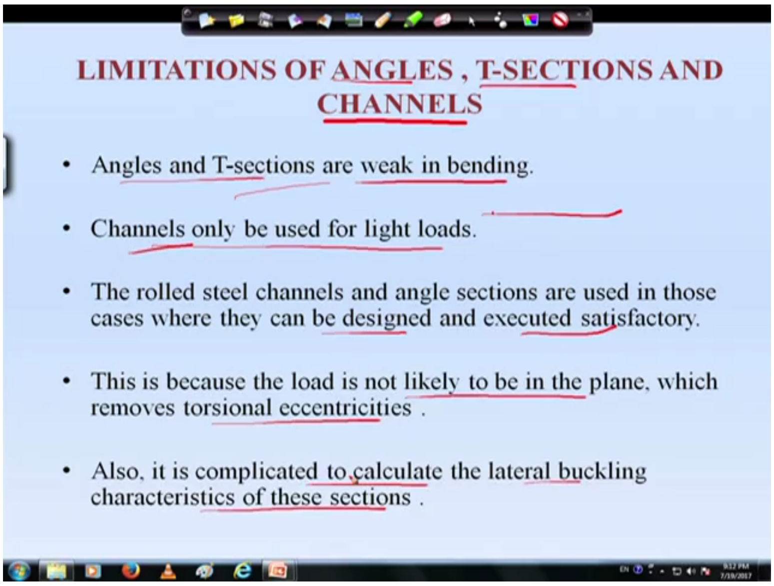

Now another thing we have to see that different types of sections, we have discussed that we can use channel section even we can use angle section or T section also, but these type of sections have certain limitations, like angles and T sections are weak in bending. So unless the load is transverse load is less, light generally we do not go for angle section or channel section or T sections. Then channels only be used for light load light load, that means when the length of the member is quite high but load is less, then in such type in such of case we can use channel section.

The rolled steel channels and angle section are used in those cases where they can be designed and executed satisfactorily, so that has to be also keep in mind. Now, this is because the loads is not likely to be in the plane which removes torsional eccentricity. So while using such type of section we have to keep in mind that torsional eccentricity may come into picture. Also it is complicated to calculate the lateral buckling characteristics of these type of sections.

So we have seen here certain demerits of using channel sections angle sections or T sections, later we can see that in case of flexural member I sections will be the best one right, because I sections are symmetric and it can take both compression and tension equally. Therefore we will show later in next class that why I sections are best, because its moment of inertia about that z-z axis is also quite high right. So we can achieve the greater amount of moment of the section which can withstand the large amount of load.

So today we will like to conclude here and next day we will see why I sections is better and then will see what are the failure may come into picture and then how to develop a design methodology. Thank you.