Strength of Materials

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Lecture - 22

Hi, this is Dr. S. P Harsha from mechanical and industrial engineering department, IIT Roorkee. I going to deliver my lecture twenty-two on the course of the strength of material, and this course is developed under the national program on technological enhanced learning, NPTEL.

Prior to start this lecture, I would like to discuss, you know like the concept, which we discussed in the previous lecture, that if we have a spring, then you know like what kind of deformations are there and what exactly the types of string, springs are there. And if you are talking about, you know like the load application on the springs, irrespective of the radial load or the twisting moment, then how the deflection will take place. And once you know the deflection, you can probably get, you know like the stiffness of this spring as the force per unit deflection or we can say, we can simply get the value of the shear stresses for that. So, all that kind of you know like the discussion, which we made in the previous lecture.

So, we found that the you know like the spring has, you know like its own unique properties and it has lots of application, where you see where the breakings are there or the clutch operations are there or even in the automobile, you know like we have shock absorbers are there.

So, it is perfect because we have, you know like the three main types of springs, which we discussed in the previous section. One was, you know like the helical spring according to the helix angle and generally we are using and you will find that many of the application, even in your, you know like the pen where you know you want to control the motion of that lead, then the spring is there. Or right from that part to major, you see, like if we have, you know, like any, like aeroplane, when it is landing, it is just you see, when it is landing, the arc shock absorbing is there. So, it through tyre, you see and when the tyre is connected to that internal inertial frame, then the springs are there, the leaf springs are there in our automatic vehicle. So, there are you see, you know like right from the small application to the bigger application, lots of use, uses are there of the spring.

And if you want to design the spring, then first you see, if it is under the action of radial load, then you know like we calculate, that actually what exactly the deflection is. So, you see, you know like we found, that actually deflection is nothing but it is direct function of the mean diameter of the spring or we can say it comes when, you know like reciprocal relation with the small diameter d cube d to the power 4 or we can say, it is reciprocal relation with this number of coils or direct relation with the applied torque. So, all these bla, bla things, which we discussed in this previous lecture and also once you have the deflection, we probably you know, find it out the, this spring stiffness or the shear forces or angle of twist, whatever like that.

And then, you see we discussed, that actually when you have a spring and under, when it is under the action of not the radial load, when it is the twisting moment is there, then what is the maximum bending stresses are? So, you see, you know, like when the twisting moment is there, again it depends on, that actually how much twisting moment is applied. And due to that actually, what exactly the shape is there and we found, that this angle of twist, you know, like the one end is so close, it is coming so close to the another end. So, we are saying, that it is the windup angle and we also calculate that, we calculated the windup angle for the spring part.

So, this part we discussed in the previous section and we found, that you see, if you want to design the spring, then again, you see, you have to be very, very careful, that actually what exactly the influencing parameters are there through which you see, we can simply say, that yeah, this much deformation you will come under the action of these radial load or under the action of this twisting moments are.

So, now you see, again in and the last portion you see, we, we just wanted to, you know, like focus, focus that actually, if the spring application, if more than one springs are there, means if you have two springs. And if they are connection in the two ways, then how you see, you know, like the stiffness will come. So, again you see, I just wanted to start from that portion.

And that then you see we would like to go that actually when we have a beam or we have a member, which is subjected by flexural loading. Then, you see, how we can define and what kind of loadings are there and what types of these structures are. So, this, you see, kind of discussion, which we are going to discuss in this lecture.

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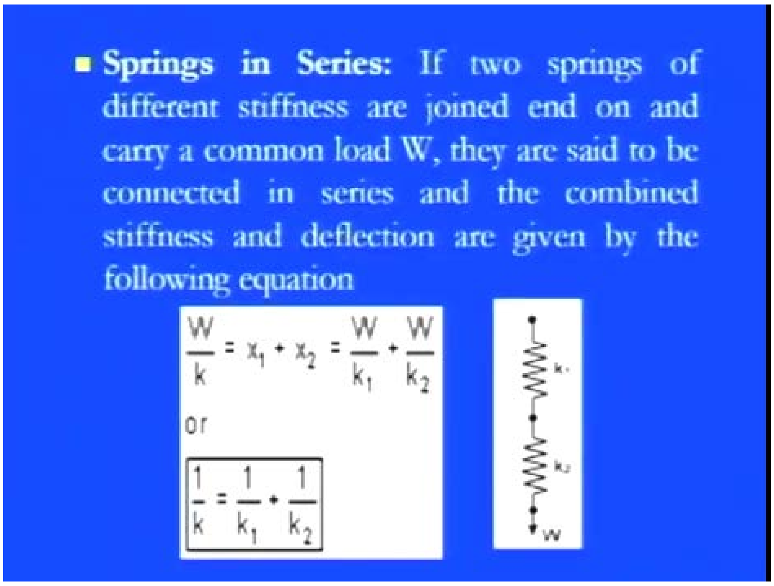

So, we are starting from the spring part, that if we have the spring, two springs are there, and if they are in the series form. So, if these two springs are there, and you know, like with the different stiffness, because you see, both are, both the springs are of the different material. So, they have, you know, like the different stiffness altogether and if they are joining just one by one at the two extreme ends. So, you see, these ends are there, they are joined to each other and they are carrying the same loads.

So, you see, if we are keeping radial load at the downward direction. They are said to be connected in the series and the combined stiffness. And whatever the deflections are coming, we can simply calculate as per W by k, which is nothing but you know, like as a deflection is equals to whatever the deflection in the first one plus the deflection of the other, another one.

Or we can say, that the x 1 is W by k 1 plus W by k 2. So, this is the resultant, you know, like the deflection is there, which is nothing but the summation of these two deflections, W by k 1 plus W by k 2. Or since the radial load is applied on both of the springs are same, so we can say, that 1 by k is equals to 1 by k 1 plus 1 by k 2 or k 1 plus k 2 divided by k 1 k 2

Or we can say, the spring stiffness, if two springs of the different stiffness, if they are, you know, like in the parallel region and the radial load is applied in towards the radial direction, then we can say, that the resultant stiffness of these two combination of the series spring are nothing but equals to k 1 k 2 divided by k 1 plus k 2. So, you see here this one this form is the, you know like this is the basic form we can say of the series in, of the spring in the series form.

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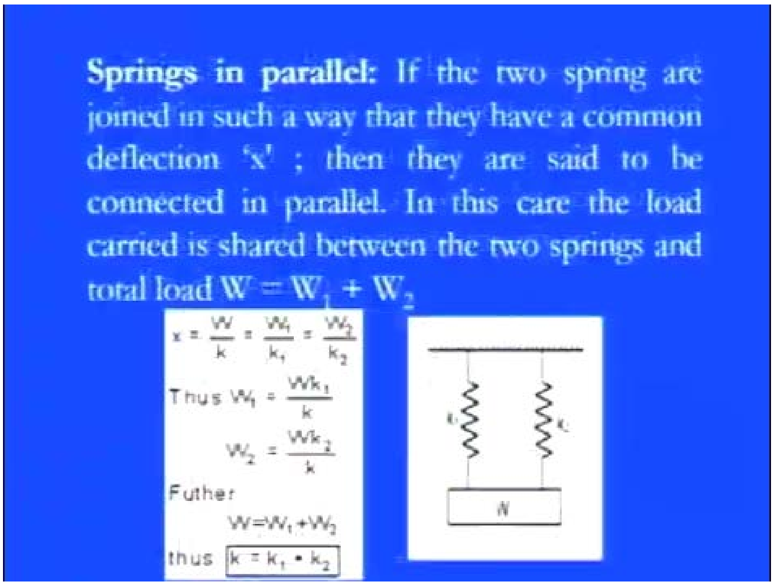

But if we have the another form, which is you know, like the parallel region in which the springs are connected in the parallel and at the both end of the spring, both springs, which have two different stiffnesses, if you see, the load is applied was such, you see.

So, if we have the two, two different springs and due to the load application if we have the same deflection, because you see, both are confined by this W here. If you can see this particular diagram, both ends are exactly, you know, like contacted at these two region and the radial load is applying exactly on the lower portion.

So, they are said to be connected to the parallel because this is the parallel actions are there on both of the springs. So, in this case the load is carried out, you know, like by these two springs are simply shared exactly. So, we can say, this W is nothing but equals to the W 1 in this spring and W 2 in this spring. So, x, the total deflection, is coming as W by k, which is the summation of these two springs.

So, if you are keeping those values there, what we have, the W, which is nothing but equals to W 1 plus W 2, as we are keeping here. So, we can say, by keeping those values what we have. The resultant spring is stiffness, is nothing but equals to the linearly summing up of these two spring stiffness. So, k is equals to k 1 plus k 2. So, the meaning is pretty simple, that if these two springs are connected in the series, then we have the resultant stiffness, is k 1 k 2 by k 1 plus k 2. And if these two springs are connected in the parallel way, then we have less spring stiffness. Resultant spring stiffness is k 1 plus k 2.

So, this, you see this part is, you know, like very, very important, that what exactly the spring formations are and how the load is applying and then, what is the resultant stiffness is coming. And through which you see, you know, like once you know the resultant stiffness, then you can calculate, that actually you know, under the application of this load how much deformation can be taken place. And then, corresponding, you see, how much deflection can be taken place. And once you know the deflection, then you can easily get the value of shear, this strain part, stress part. And then, you can you can simply design the safe, you know, like region for these kind of springs.

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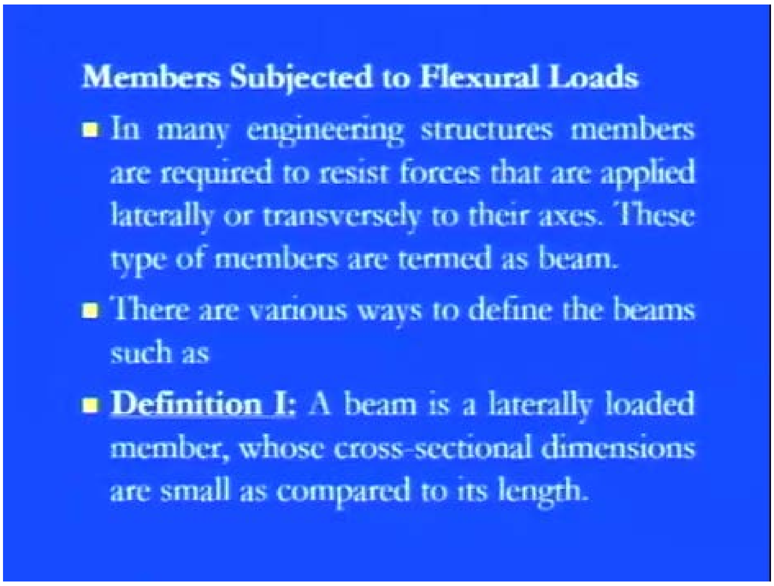

So, now you see, come to the next topic, which is, you see, when the members are subjected by the flexural load. That means, you see, you know, like if we have, you know, like the different kind of object and we are saying, that these object or this, you know, like the main substances, if they are just, you know, like under the action of various forces.

Just to resist those forces if we are applying, what are the kind of forces laterally or the you know, like transversely along the axis. That means, you see, if the force applications are there and through which whatever the resistive forces are coming along lateral direction or you know, like transverse direction, then these type of members are termed as the beam. That means, whatever the load application is there and if the resistive forces are coming in these two directions, we can say, these objects or we can say these bars are known as the beams.

So, there are various you know like the ways are there to define these beams. So, you see, here we are using the three different categories to define the beam. The first definition is a beam, is laterally loaded member whose cross-sectional, cross-sectional dimensions are small as compared to its length. So, you see, here as I am saying, that it is the laterally loaded. So, means, the whatever the, in, in lateral direction, the diameter or you see, you know, like the thickness or whatever you see, the other dimensions are, they are very, very small as compared to the transverse direction. That means, you see the longitudinal direction. So, we have more length and we have a small diameter or we can say small thickness or width or whatever like that. So, this is the first definition of beam is, that we have, you know, like a laterally loaded member whose cross-sectional area or we can say, the dimensions are very, very small as compared to its length. So, this is first definition of beam.

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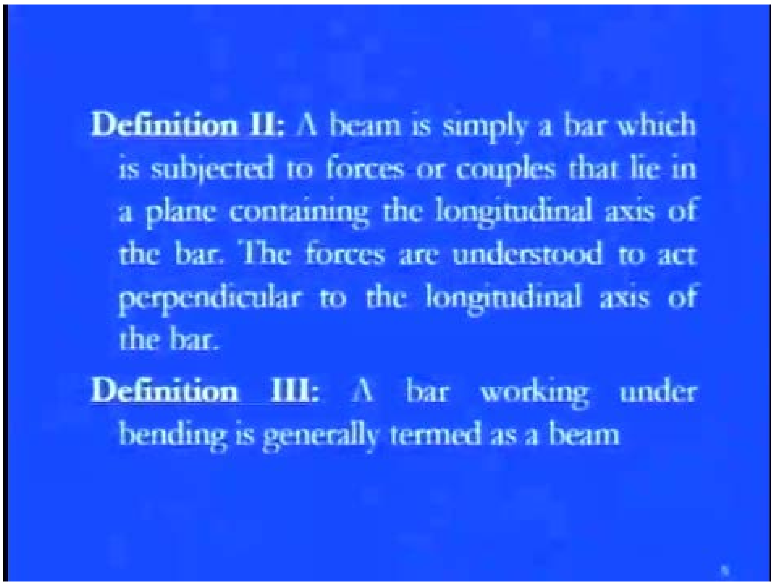

Second definition of beam is, a beam is simply a bar, which is subjected to the forces or we can say the couples, because you see, either it is the radial loads are there or it has, you know, like under the action of the couples, that lie in a plane containing a longitudinal action of bar. That means, you see, you know, like it is always simply fixed on, on a particular horizontal direction, or we can say the longitudinal axis.

And whatever the actions are coming, like in terms of the point load or we can say, in terms of the different variety of loads or couples or moment or torque, then even apart from that also it will always be in the plane of longitudinal axis only. And the forces, and the forces are understood to act perpendicular to the longitudinal axis of a bar.

So, whatever the forces are coming, they are always perpendicular in terms of compression or extension or in terms of, you know, like this kind of shearing actions are there. So, if we are talking about these kind of, you know, like the specimen, then they are termed as the beam. And the third definition is, a bar working under the bending is generally termed as the bending. So, you see, whenever we are designing a beam, the bending action is always taken place and we have to see carefully, that actually how much bending stresses are and corresponding, you know, like the strains are there.

And through which you see, if we are, if, if we want design safely, we have to be chosen, you know, very, very carefully, that actually how much load application is and under these load application what is the bending stresses and the strains are. So, bending is the perfect direction in the beam and we can say, that if these actions are there, it is the perfect definition of a beam is. So, these three definitions are there through which we can say, that whatever the object is there, it is exactly termed as a beam. So, now you see, once you define this cross-sectional area or the cross-section of any beam, then our main focus is, then what is the material of a beam.

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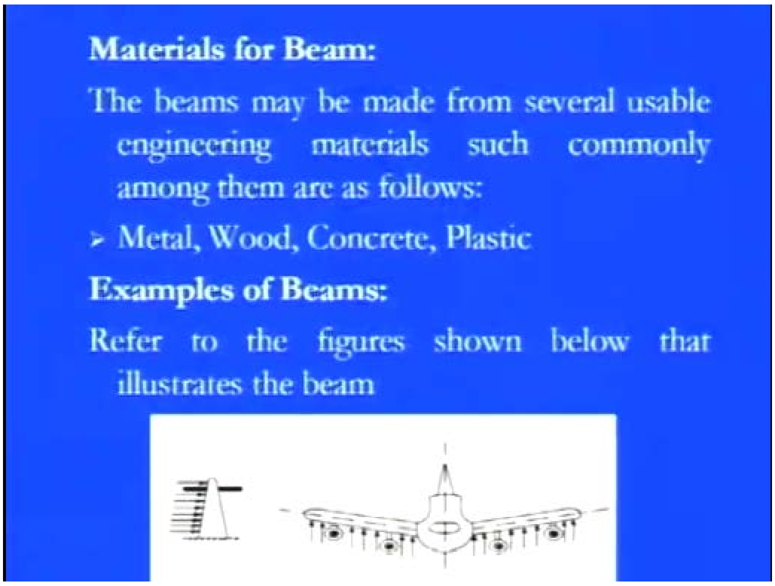

So, the beams may be made from the several usable engineering materials based on what exactly the applications are. That means, you see, where you are keeping the beam, whether you are keeping a beam on your wall just, you see, to sustain the load or whether you are keeping these beams in a, you know, like, just like you have, you know, like swing area, or whether you are keeping the beam in the aeroplane as shown in the below figure. So, where you are keeping, so corresponding the materials are coming just to resist the bending stresses.

So, you see here the commonly used materials are the metals of various kinds, the wood is there, the concrete is there and the plastics are there. So, you see, here even if you can find these beams where the rails are passing. And you know like they are simply absorbing, you know like the compressiveness of those things or whether you see, you know, like on the top of floor, you see, for the roof side, you will find that beam just to carry all the load.

So, you see, there are various materials are there available for the different kinds of beam for different applications. So, example of beams just referred to the figure below, you will find, that we have an aeroplane and under the aeroplane, you see, this beam is all along, you know, like it is just coming. So, whatever the drag and lift forces are coming, they are simply applying on these sections, you see, these beam, see, now subjected by, you know, like as I told you, just definition of beam, they are just along the longitudinal action.

So, you see, this is the longitudinal axis is there and whatever loads are acting, they are just perpendicular to the longitudinal axis. So, these load applications are like that. So, if you want to design these aeroplane files, you have to design as a beam. Or if you see this particular figure, then you will find, that you know, like here we have, you know, like cross-sectional beams are there and the load application is exactly normal to this action. So, probability is also termed as a beam. So, here you see, we have an example of beam and material is exactly based on what application of the beam is.

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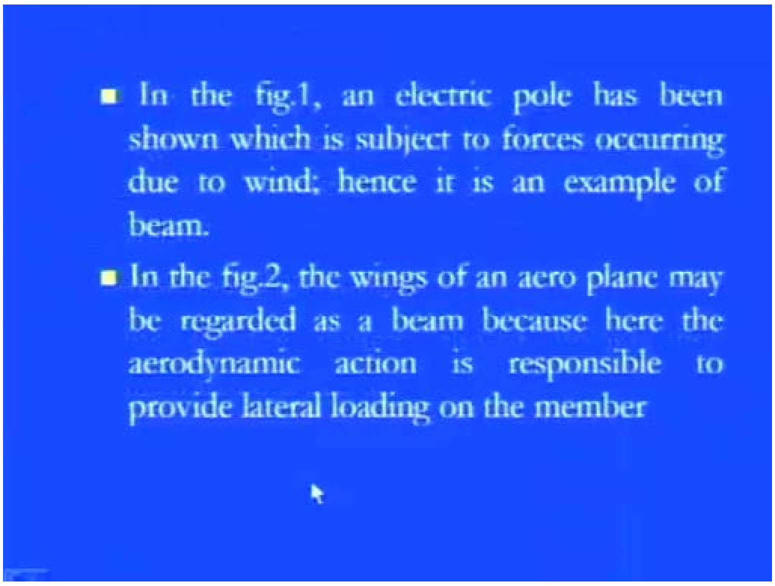

Now, in figure one, an electric pole has been you know, like shown there, on the top of that subjected to the forces, which is coming due to the beam, due to the wind. You know, like the forces are coming, this drag forces are there and they are exactly perpendicular to this pole.

So, as I, you know, like shown in this particular diagram, that actually when they are coming perpendicular to the plane of this particular subject, always we are termed as the pole or any substance is as a beam. Or in figure 2, the wings of the aeroplane may also be, you know, like regarded as a beam because whatever the aerodynamic actions are coming, the drag and this lift forces are coming. They are exactly perpendicular to the longitudinal axis.

Or we can say, whatever these responsibilities are there of this particular action, aerodynamic action is just to provide the lateral loading on these particular members of an aerophile. We can say, that either this aerophile section of an aeroplane or these, you know, like the poles or any kind of this cross-section, if they are under the action of these, you know, like the lateral, which this perpendicular loading in the lateral directions when it is just lying in a plane of longitudinal axis, these are termed as a beam. So, this is, you know, like the basic definition of the beam is and the material was there actually, which you can chosen, each it can be chosen at any way, just based on what applications are.

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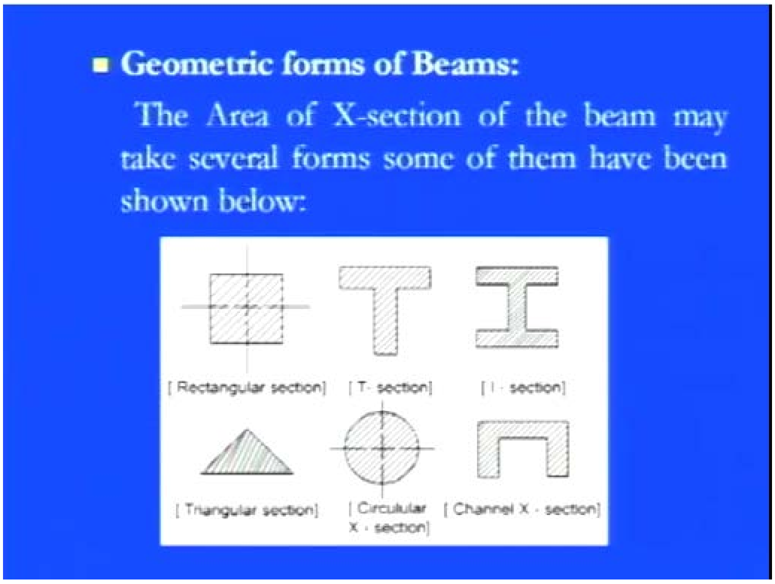

So, now you see, we have the geometric forms of a beam. So, the area of the cross section of a beam may be taken in several ways. So, you know like, and it depends on what area you have chosen, corresponding applications are there.

So, like you see, we can either chose the rectangular area cross-section that you see, you have a beam, which has the cross-section of the rectangle. So, you see, rectangle cross section always you, it will give you the clear feeling about, that actually how this central axis is to be there. That means, the central axis, which is passing from both of the way. It is just uniform.

So, if you want to design the just, you know, like any of the bending stresses, you know, distribution or you see, if you want to see, that actually how the shearing is taken place, you can simply see, that neutral axis is well-defined. You can simply define this neutral axis and you can, you know, like define the region of these bending stresses are whenever we have a rectangular cross-section. And a corresponding, you see, you need to chosen the effective, the dimensions to calculate that effective area.

So, this is one, you know, like the cross-section is there of beam, that is a rectangle or we can, you know, like we can choose also the T section. Or you, just what you, what we need to do here, we simply removing this material, so that you know, like once you remove the material you have less inertia because the mass is now removed. So, less inertias are there. So, if you, if you are designing a beam, which you know, like in which the weight is the main criteria, the T section or another, the I section always gives you, you know, like the minimum weight.

But as compared to even the T section and I section, I section is more, you know, like the symmetrical part because you see, here on this particular top and on this top we have the balanced way, and in between you see, there is a connection. But as compared to the T section, you see, we do not have this particular section. So, in some of the application it gives you imbalanced cross-section.

So, sometimes you see, whatever the bending stresses are forming under the action of these loads, they are not uniformly distributed. So, probably you see, for the safe design of any kind of beam where the load actions are there, always I section is very, very popular. And whatever the bending stresses are there, they are always coming in the very symmetrical way. So, this I section, because you see, here this much weight is removed, this much weight is removed as compared to this section. So, it has a less, you know, like the mass moment of inertia or we can say, it has a less weight. So, you know, like whenever this kind of motions or whenever this kind of analysis is there, this I section is very, very popular.

Then, you see, the another cross-sectional areas are the triangular cross-sectional area. So, you see, you know, like whatever the beams are there, they have a flight and this cones are there at these two corners and it is to be connected. So, we have this kind of beam or we have a circular cross-section, like if we have a circular prismatic bars are there and if it is under the action of the perpendicular load or any twisting is there. So, probably we can use this kind of circular bar or so...

Or if we have a channel, which is, you see, you know, like just this channel is there and there is a gap, means there is a group is there all across that particular, this length of the beam. So, whatever the cross-sectional area is there, corresponding dimensions are coming and corresponding, you know, like the affected area will be considered under the action of these forces. And these forces are always perpendicular to this longitudinal axis or the couples are coming, twisting, torques are coming.

So, we have to be very, very careful that actually what exactly the effective areas are there or the important thing in any of the beam is what is the cross-sectional area. Because you see, you know, like when you are talking about any force or any stresses, the affected, affected area is firstly concern. Because when we are talking about the uniform distribution of the stress, that in which area it is to be distributed and whether, you see, you know, like any kind of stress concentrations are there or not, we have to check it out those things.

So, that is what, you see, you know, like even in this also when the bending stresses are forming all along this prismatic bar or this kind of beams always we have to be very, very careful, that which area is to be chosen first for the safe design and how, you know, like these area to be, you know, like, considerable under the action of these forces.

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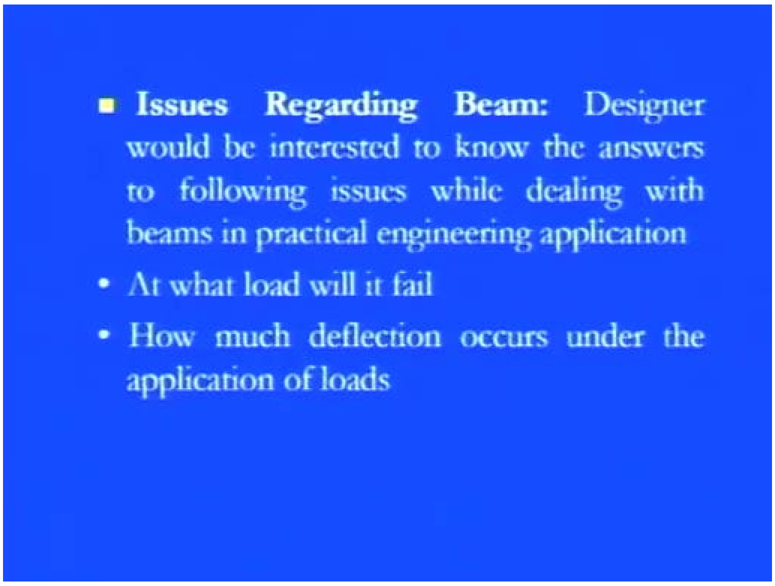

So, now you see, issues regarding with the beams are, you know, like whenever a designer would be, you know, interested to know the answer of the following issues while dealing with the beam or the practical, you know, engineering application because as I told you, it has lots and lots of application of a beam.

So, you see, first of all, at what load will it fail. So, first of all, you see, you know, like as we know, that it is, you know, like in the longitudinal axis and the perpendicular loads are coming. So, how much load it can bear and you see, how much, up to what extent you can, goes, go, that first it will go to the plastic deformation at the action of bending and then it will rupture, you know, like or the fracture will take place.

So, first of all, the first key issue is there, that how much of this particular beam, the load carrying capacity is. And the second question is again important, is how much deflection occur under the application of this load because you see, when you are applying the load, there is a different kind of, you know, like the distortion or we can say, the deflections are coming in this kind of beams. So, again you see, we would like to see, that at you know, like, which portion is under the action of tensile or which portion is under the action of compressiveness is. So, based on that, you see, we would like to design those beams are.

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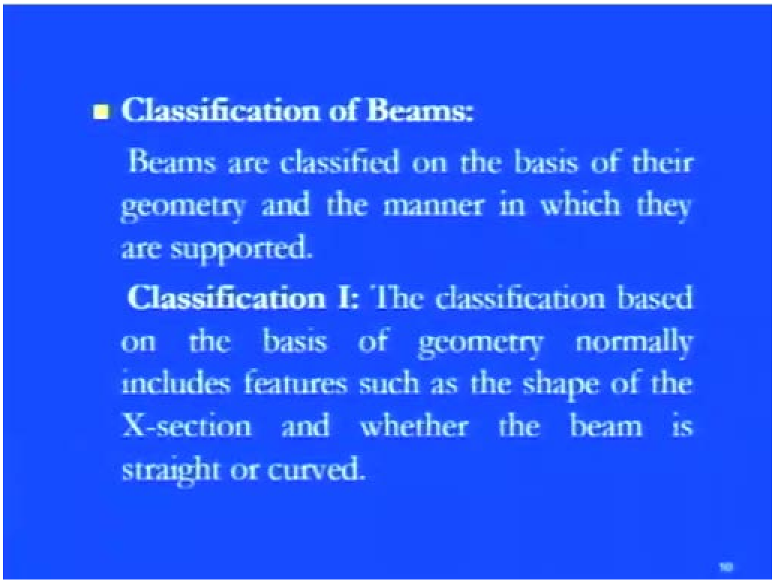

So, you know, like based on that again we would like to classify these beams because now, you know, the beam, you know, the material of the beam, you know, that what the loads are, these load can be applied and what the cross-sectional areas are there. So, now based on these things, you see, beams are classifying on the basis of their geometry, as i told you, the cross section as just in previous we discussed, and the manner in which they are supported.

So, there are two main issues. One what is the geometry of this beam is and second, under which you know, like what is the manner of the load application is or how they are supported, whether they are supported at both ends or whether one end is supported or whether it is, you know, supported on the roller end or rigidly support is there of both ends.

So, there are variety of, you know, like these kind of supports are available and based on that actually we can simply classify those beams. So, first classification is the, classification is basis on the geometry, normally includes the features such that the shape of the cross-section, and whether, you see, you know, like the beam is straight or the curved.

So, in general we are talking about what is the cross-section of the beam is, generally you know like. And we already discussed the various cross-sectional part of the beam, just like, whether it is a square cross-section or round cross-section or is I section beam, T section beam or whatever like that, you see, you know, like. So, first is this, what is the cross-section is there, means what the cross-sectional shape of that particular beam is and the key feature is that whether we have a curved beam like that or whether we have a straight beam.

So, if we have a straight beam, then all you see, the design criteria is different. If we have a curved beam, then all design criteria is different because you see, you know, like whatever the bending stresses are coming in the shape of a straight, straight beam or the curved beam is altogether different. So, this is the first classification.

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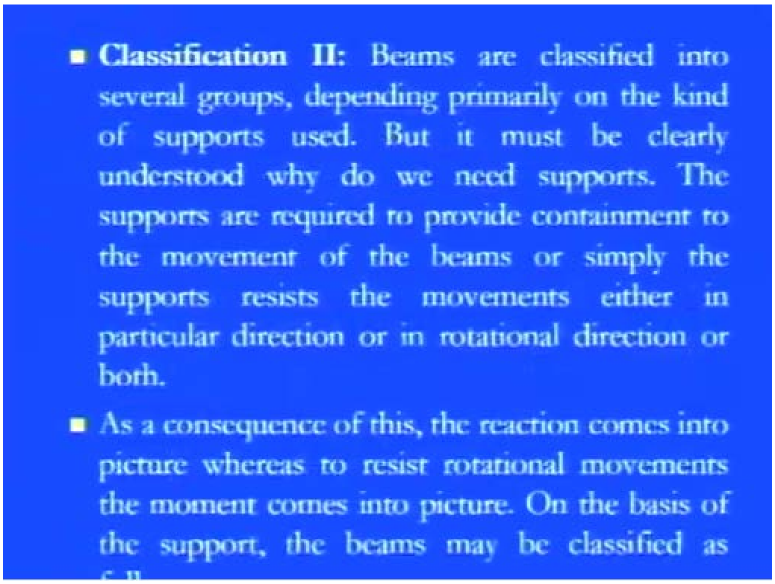

And the second classification says, that the beams are classified into the several groups depending primarily on the kind of support used, as we discussed, that actually what kind of supports are there at the two extreme corners. But it must be clearly, you know, like understood, that why do we need this support, means, what application is there, why you know, like the supports are there, whether you see, you know, like both ends are supported, whether one end is supported, what exactly the application is there, then what kind of loads are coming on that beam.

So, we have to first of all understand this kind of phenomena, then only we can say, that yeah, this beam is of this nature. The supporters are required to provide containment or we can say, you know, like the movement of the beam are simply supported, simply you know, like the kind of support resists the movement, either in the particular direction or the rotational direction or even the both.

So, this is the real feature, that actually, why we need the supporters? Just to withstand those things or just you know, like to provide these kind of resistances in terms of, you know, like movements or in terms of, you know, like in a particular direction, the kind of movement or it is a kind of rotational part. So, what exactly this supporters are doing there.

So, based on once you know, that this kind of, you know, like the applications are there and the corresponding changes are coming due to the supporters, we are simply classifying these beams are. And then, as a consequence of this, these reactions once, you know, like when, when you have the kind of the supporters, always the reactions are forming due to these supporters. So, what kind of reactions are coming into the picture, whereas to resist the rotational movement of the moment coming or we can say the bending moment, which is coming into the picture.

That is the key issue, that how these reactions are coming because when you are designing beam under the action of these bending forces, always one has to be very careful, that actually how this bending action is taken place and what the reactions are coming. And one has to consider the reaction very carefully.

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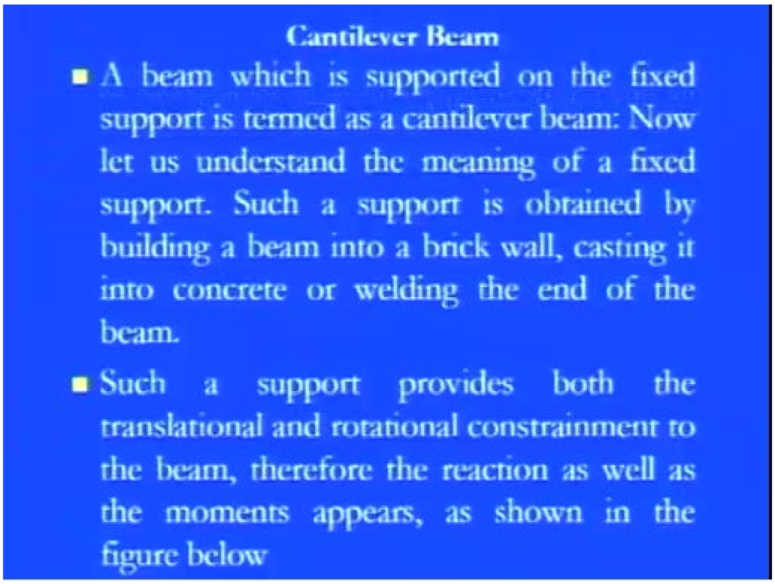

And on that basis, you know, like these particular support the beam may be classified as cantilever beam. First of all, cantilever beam is nothing but you see, here if we have a, you know, like the beam, which is the same definition as we defined, that it is, you know, like whatever the lateral parts are there, the dimensions are there, they are very, very small as compared to its length. So, we have a beam and if one end of beam is rigidly supported, so as the one this beam is supported on a fixed support is termed as a cantilever beam.

Now, let us understood the meaning of a fixed support. Such a support is obtained by, you know, building a beam into bricks wall or we can say, casting into the concrete or welding end of the beam. That means, you see, if I am saying, that the cantilever beam, that means, one end is rigidly, you know, like supported at one part. That means, you see, either this beam is going in, in, into the wall or this beam is casting into the concrete wall or we can say, we are simply welded, we have this wall and we have this beam. So, it is welded at this particular section.

So, this end is free and this end is rigidly supported. Such a support provides both translational as well as the rotational constraint to the beam. That means, you see, if you have this particular rigid support at this particular corner, then you cannot get any kind of translational motion or the rotational motion. So, it provides the rigid resistance against these two kinds of motion. So, it is the real constraints for translational as well as the rotational motion.

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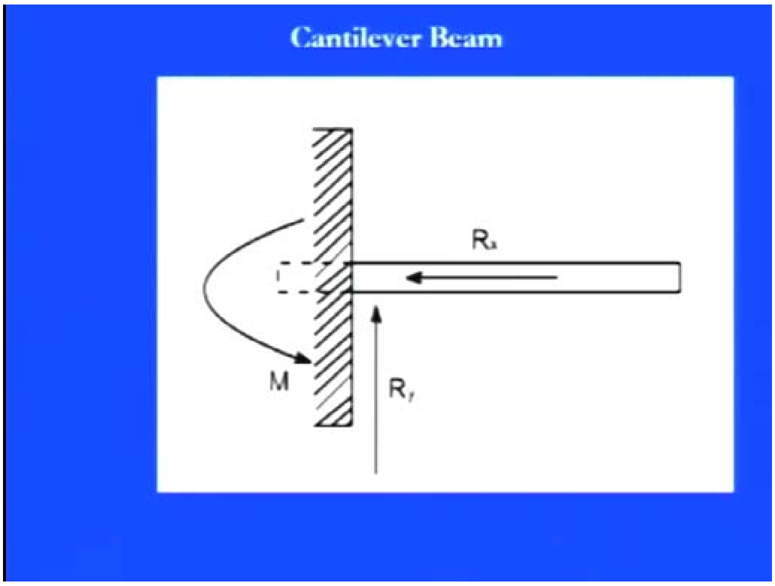

Therefore, the reaction as well as the moments appear are, just you see, we can show, that this is the kind of cantilever, we have a rigid support. This beam is rigidly fixed inside that. So, you see, it will always try to resist to whatever the kinds of, you know, like the translational as well as the rotational forces are coming on that. So, you can see, here if you apply any kind of load, it will sustain that kind of part, you see, either this moment or this kind of reactions in both of the way, this in horizontal way or this vertical direction.

So, this, this is the basic form of the cantilever beam. So, whatever the load applications are there on this particular free corner of these, you see, on any of, along this particular length, any of the part, this can be easily, you know, like sustained by these kind of rigid support. And this form of the beam is known as the cantilever beam.

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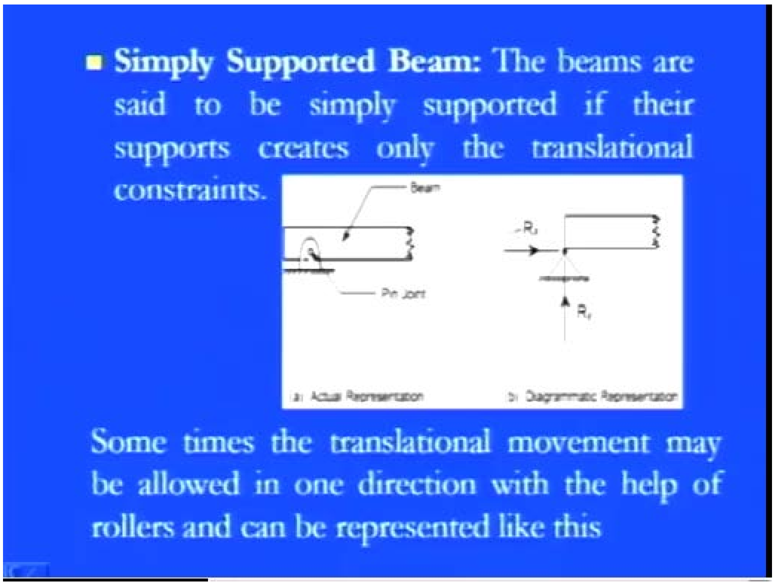

Second, you see, based on what kind of supports are there. Second category comes as the simply supported beam. The beams are said to be simply supported if this support creates only, you know, like the translational constraints. That means, you see, you know, like just you see, whatever the translation motion is there if we are keeping the supports, that actually they are, just provide the resistance against, you know, like that kind of motion, we are saying, that we have the simply supported beam.

So, you can see here, we have, you know, in this diagram we have a straight prismatic bar or we can say, the beam is there and we have a pin joint. So, the pin joint is simply, you know, like given this kind of motion here. So, whenever, and a kind of load application is there, the reactions are coming in terms of this vertical, as well as the horizontal direction.

So, you can see here, that, that how we can, this, represent this kind of forces and this particular pin joint. So, if we have this beam and if these pin joints are there, this particular, so the reactions are forming under the action of any load in this vertical direction is known as the R y reaction and the horizontal direction as the R x reaction.

Sometimes the translational movement be, also be allowed in one direction with the help of the rollers that can also be presented in the next, you know, like the figure, that you see. We have the roller and you see, we can allow, you know, like moment of this particular beam in the only x direction.

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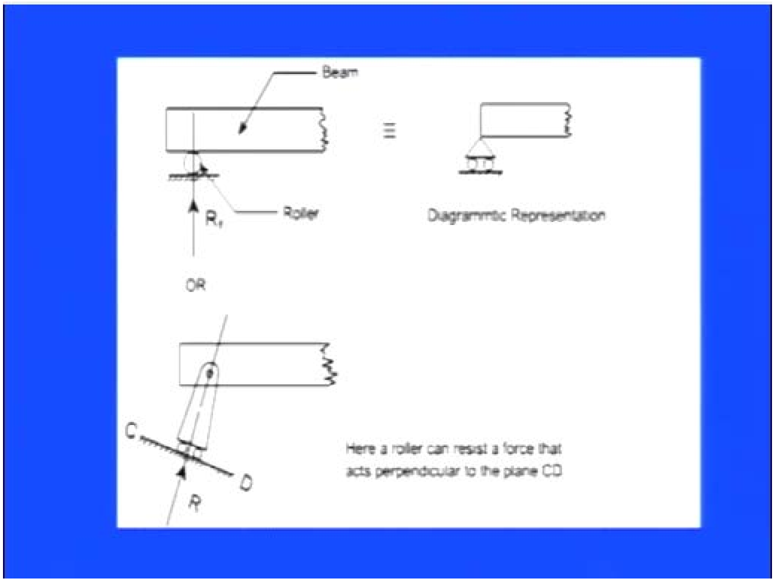

So, once, you see, we have the roller. So, this is the roller, you see, or we can say, this is the kind of roller is there. So, in that only the vertical forces are dominating in that or we can say, the reactions are coming. So, we need to show this kind of thing. So, we have a beam, we have a roller and this reactions is there on just to provide the resistance.

So, that is why you see, Ry is there in the vertical direction or we can simply shown in the different picture, that we have, you know, like and which is the general representation of these beam under the roller. So, you see, here this, these rollers, you know, like always allow this beam to move in the x direction, either of both side, either this side or that side according to what load applications are there. Or we can say, here a roller can resist the force that acts perpendicular to the plane of CD.

So, you see, here it is not, that a straight one is there even if it is at a twisting angle. These, you know, like pin joints are there, this pin joints can be acted as a roller at this particular way and you see, the reactions are there, which are coming along this particular line of action.

So, here you see, which is exactly, you know, like perpendicular to this particular plane CD. So, these reactions will be going along with them, so along with this line particular. So, you need to resolve these reaction forces in just by taking theta because this is a straight line, the theta. So, R cos theta and R sine theta. So, how these theta, you know, like will come into the picture R cos theta or R sine theta and how they will, you know, like at, as on a reactive forces one has to consider.

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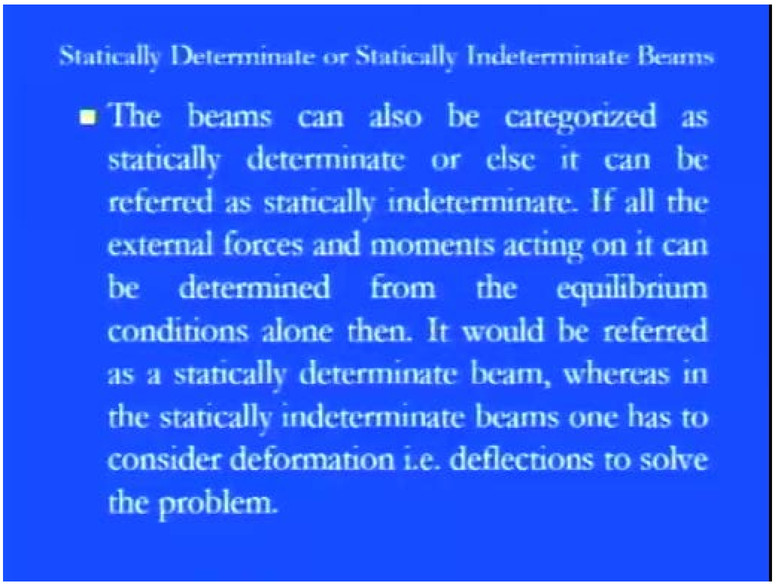

So, this is, you see, the simply supported beam was there. So, now, you have the two main forms of the cantilever beam, beams based on what kind of supports are there and that is why, you see, we are classifying accordingly. One, we have a cantilever beam in which one end is rigidly support, nothing has to be happen in terms of translational or rotation, and one end is absolutely free. So, either we can apply any kind of moment, point load or whatever the kind of things are there, concentrated load, like that.

And other is, you see, we have a simply supported beam in which the reactions are there if we have, you know, the pin joints at both the end. So, this will, you know, like allow this particular beam into the kind of moment under the application of load, either it is going in the bending side or the shearing part. So, we can simply take the reactions forces in x as well as the y direction, is two mutually perpendicular reactive forces.

And the another form of the simply supported beam is, that if we have the rollers on that, then definitely, you see the reactive forces are coming in the perpendicular direction, irrespective of whether this pin join is the straight one on the roller or this pin joint is the tilting part. So, these two forms of the beams, which we discussed here.

Now, you see, would like to discuss the statically determined or we can say statically indeterminate beams are. The beam can also be categorized as the statically, means under the action of the static force, determined or else, it can be referred to a statically indeterminate form if all the external forces or the moment acting on it can be determined from the equilibrium conditions all along that. That means, you see, you know, like if you are and this is the biggest assumption in all the beam theories is, that under the application of all the loads and the couples or the twist, you see, this beam is the well equilibrium manner. That means, you see, it is well balanced.

Then, when you apply the load, when you apply the torque, it is, you know, like going under the action of bending stresses. So, how this bending stresses are being set up along this particular beam. And you see, if you are saying, that they are well balanced, that means, you see the counter balances are there of this stresses and accordingly, this balance theory is there, and that is what you see. We are saying, that these beams are nothing but the statically indeterminate beams.

And then, you, it would be referred as statically determined beams, whereas in statically indeterminate beams, one has to consider the deformation or deflection to solve the problem and that is what you see we are categorizing two main ways. One, if you are talking about the statically indeterminant form, then all your main focus is on the stress and strain.

And then, corresponding you see, all you know, like that how this bending stresses are forming and what is the bending moment is there and how we can calculate all blah, blah things based on the different cross-section.

But if you are talking about, that if your beam is, is statically in determinant form, that then, you see our main focus is how the deflection is there and then, you see the deflection theory is there. So, it is altogether a different chapter altogether, a different concept is there. So, you see here we are categorizing the two main ways one is statically determinant beam or second is the statically in determinant beam is.

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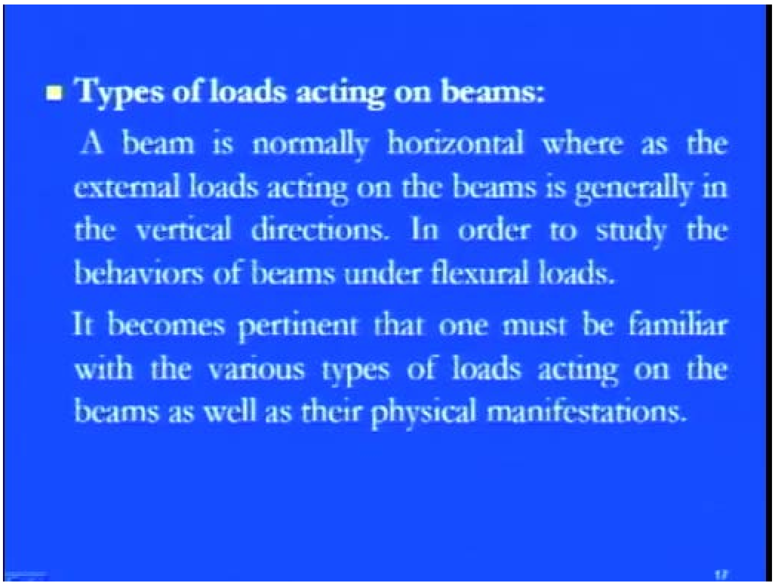

So, with the statistically determinant or statistically indeterminant beams, now you know, like, we would like to see, that whether you know, like whether it is under the deformation or under the deflections are there. Now, we would like to categorize those beams based on what type of load actings are, because you see, as in previously, you know, like we have discussed, that actually whether it is, you know, like cantilever or simply supported beams are.

So, now beam, which is normally horizontal where as the external load, which are applying or acting on these beams generally in the vertical direction. And we, you know, like that is what the definition of the beam is, that the beam is always lying in the longitudinal axis and you know, like this loads are just perpendicular or normal to this particular axis are there.

So, always this is a pretty common nature of the loads are there, that they are always perpendicular to the longitudinal axis is there and in order to study the behaviour of the beam, you know, like under these flexural loads, we have to be very, very careful chosen of this kind of loads are there, there, that they are mutually perpendicular. It means, this axis is this and they have to be acted on perpendicular axis or the normal to this particular beam.

And it becomes pertinent, that one must be familiar with the various types of loads, that what types of load are acting on that particular beams as well as their physical manifestations, that actually how they are appearing. And due to that actually what kind of, you know, like the deformation or we can say, the stresses of beam forming the bending stresses or the shearing stresses due to that particular thing. And since you know, like we are, we, we know, that the bending stress is nothing but the combination of the tensile as well as the compressive stresses.

So, you see, you know, like again we would like to classify this kind of beams on the basis of the types of load. The first type is the concentrated load, means, you see, it is a kind of load, which is considered to be act as a point, like you see, we have, you know, like the ((Refer Time: 33:41)) there or hanger to be, you know like. Or we are simply keeping some, you know, like the points loads on a particular just section where all the load is to be concentrated.

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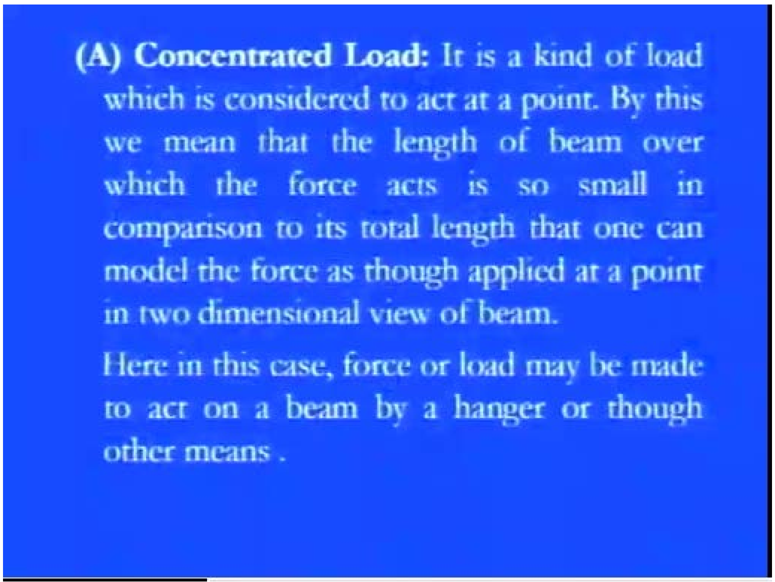

So, this kind of load is known as the point load or we can say, the concentrated load. By this we mean, that the length of the beam over which the force acts so small in comparison to the total length, you know, like means, actually this is simply acted as a small, small portion as compared to the bigger length of that, one can model those force as applied as a point in two-dimensional view of a beam.

So, as I told you, that actually, you know, like if we have, you know, like let us say, this 2 meter, this length of beam is there. And this, you know, like the point, this load is just, we are simply keeping the load and this effective area under this load is, let us say, just

10 centimeter. So, in comparison to the 1 meter or 2 meter load, tens, 10 centimeter or even the 5 centimeter is nowhere comparable.

So, we can be treated this concentrated load as a point load and generally, you see, we are saying, that the point load is acted vertically downward or upward like, that you know, like and the constant magnitude is there.

So, you know, here in this case the force or a load may be made to act on a beam by either hanger or through by various means, as a, as I told you, you know, like just keeping the effective load there or by you know, like just putting exactly, that actually what the kind of, you know, like distribution is there, the load just concentrated on that particular point is there.

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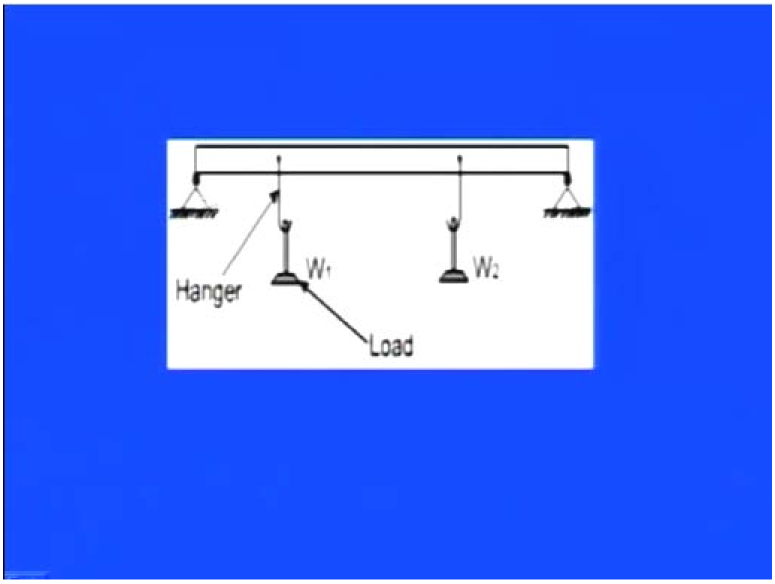

So, we can see even, you know, like here, that we have this, the simply supported beam. So, here you see these two pin joints are there. And if you see this particular figure, then you find, that this beam is, you know, like spread all across this particular, these two, you know, like this fixed supported beam. And at these two points, you just see these two point here, what we are doing here? We are simply keep the hanger and in the hanger we use, we are simply keeping the load. So, the effective area under this load is this much.

So, as compared to this entire length of beam, if you compare this particular area you will find, that there is a very tiny part as compared to this or either this one or even to W

2. You see, you will find, that this effective area under which these loads are applying is very, very small.

So, we can be treat, you know, like these, these loads as a point load and generally, we are saying, that the concentrated loads are the point loads and simply, you know, like we can justify those things by giving, you know, like the indication, just point indication towards downward direction here as this point load W 1 and here point load W 2 for this simply supported beam.

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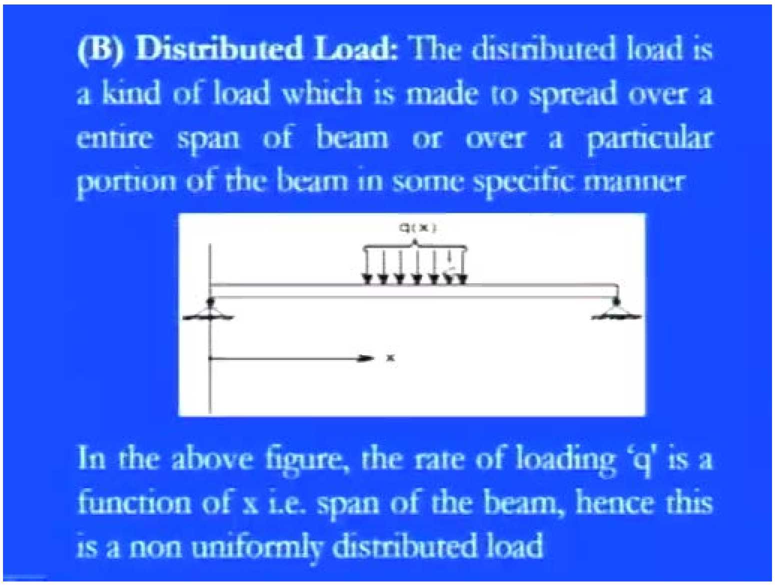

Then, you see, you know, like the second kind of loads are the distributed loads. The distributed load is a kind of load, which is made to spread over an entire span of a beam or a particular portion of a beam in a specific manner. That means, you see, here in the previous part we have seen, that only the concentrations were there. That means, you see, only the effective area was very, very small.

But here, you see, now intensely we just want to spread this load over just across the length of the beam, so that, that particular area is to be affected by that much load. So, you see, here you know, like if you want to describe those things here, the figure is on your screen. We have a kind of simply supported beam.

And you see, here what we are doing? Here, we are simply, you know, like put the concentrated, put the distributed load. So, this, you see, this is, this load is not concentrated. This entire load, which has a magnitude, the rate of loading is q of x. q of x is nothing but, you see, this load q is distributed for this length x. So, this q is a function of x. So, it is, you see, uniformly distributed in this particular area.

So, generally, you see, we are treating this load as the uniform, this, this disturbed load and this is always be given in terms of q of x or we can say, rate of loading because the Newton per meter or millimeter, that how much you see in how much millimeter or a meter or centimeter. This 10 or 20 or this load is spreading out.

So, you see, we will find, that this is the effective area under which you know, like on which these loads are acting and we are treating it as a distributed load.

So, in above figure, the rate of loading q is a function of x, as usually you will see, the distributed load is always a function of x, that is, the span of a beam. And hence, you see, it is a non-uniformly distributed load because you see, we, if the impact of this load here is more here, it is less here, it is less. So, we can say, that this is a non-uniformly disturbed load is.

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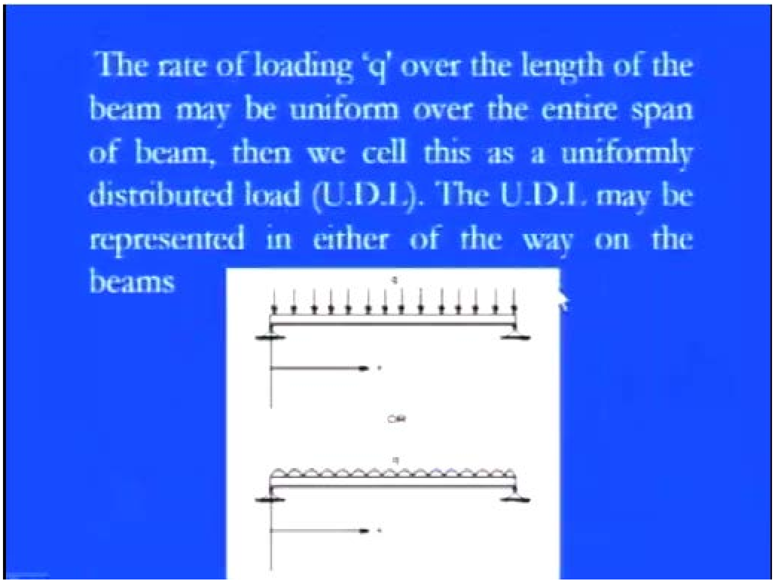

But if, if we are taking the load, rate of loading, this q, our length of beam may be uniform if you are just taking the entire span of beam. That means, you see, in this figure if you are taking, you know, like the simply supported beam and the total, you know, like this beam, this area of the beam is affected by this q load. So, this q is now, you know, like just applying on entire span of the beam, either we can represent by this point loads on those, those total, you see, or we can say, this is the, this load is, you know, like spreading on all across the length of the beam.

So, we can say, this kind of load where the load is total, you know, like affected the whole area of the beam, this load is known as the uniformly distributed load, UDL. And the UDL may be, you know, like represented here by both way, either the point load all across this particular, you know, like length.

This is the point, points are there or we can say this spiral parts are there through which we can say, that the q of x is there. And the q of x is always, it is a rate of rate of loading of either the distributed load or we can say, the uniformly distributed load. And always it is coming as q Newton per meter or kilo Newton per meter or Newton per millimeter, whatever you see the units are there. That means, you see, what is affected length is there or which this, this load is coming, always the unit is like that actually Newton per millimeter or meter is.

So, you see, here this is the another kind of loading is there in which the entire span or a specific reason is affected by the load is, it is not the concentrated load where only the small area or the segment is affected.

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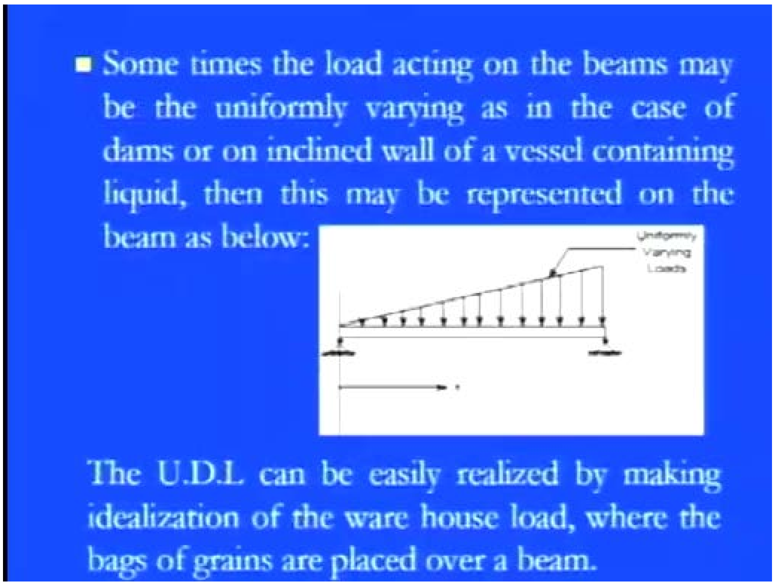

So, now you see here, this is the second, this was the second kind of load. Now, sometimes you see, the load acting on the beams may be uniformly varying as it in case of the dams or we can say the inclined wall is there, on a vessel containing the liquid.

So, you see, if you are, if you are, if you just want to analyze, you know, like the dams where you see, you know, like the, you know, like this water is just having a varying height. That means, you see, you know, like at the very close section the heavily loaded part is there and at some end, you see, you know, like the water is just in the, just touching on the surface of that.

So, if this kind of loading is there, we are always saying, that this is the triangular loading or we are generally, you know, like taking if we have a vessel in which the liquid is flowing and will find, that always liquid is at some hard, you see. If it is in the inclined part at some portion, it is heavily, heavily, you know, like the hydraulic pressure are there, rho gh is there. And at some part you see it is just touching to the road. So, this kind of loading is known as the uniformly varying load.

Or we can say, that triangular load is there, which has, you see, the tendency at one, you know, like the simply supported beam. Always the maximum load is there and it is simply varying. So, it is not uniformly varying, it is varying in uniformly, this, this tapered section way. So, we can say, that this kind of UDL, you know, like or we can say, now this kind of load is known as the triangular loading.

So, the UDL can be easily, you know, like realized by making idealization of the, you know, like the warehouse load or where you see we can say, that the bags of grains are simply placed all across the beam. That means, whatever the grains are there, within that particular beam, they are absolutely placed within their own places. So, whatever the distortion or deflections are there, it has to be uniform and whatever the bending actions are there, they have to be uniform.

But in this case, where you see this kind of loading is, there we have to be chosen, that actually varies the, this concentrated part is there. That means, you see, where the centre of mass is there through which these bending loads are, these bending can be occurred, and then corresponding, you see, we need to chase. We need to check the effective area and which these bending loads are because you see, here if you are considering this portion and if you are considering this portion, one has to be taken care, that actually what is the effective area is there and how much load is to be applying on this area since this load is varying with the length.

So, you see, need to, we need to check, that actually where is the centre of masses of this particular load is. So, that is what, you see, know, like this is the third type of load is in which the triangular loading is there and it has general application. Now, you see, we are going for the next one, that is, the concentrated moment is.

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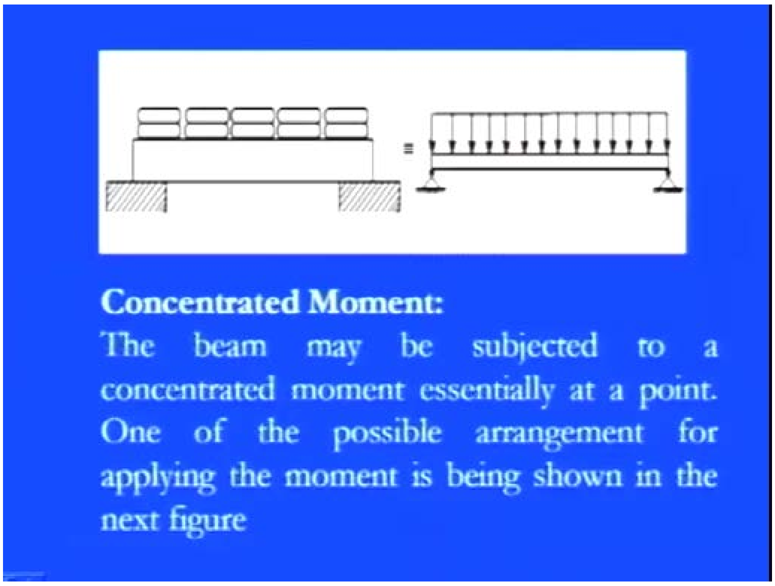

So, the beam may be subjected to a concentrated moment. It is essentially at a point because you see, it is a moment is there and the concentrated moment will just tend to move this, this beam in a particular direction. So, you see, the complimentary moment will come just to balance this move.

One of the possible arrangement for applying moment is just, you see, you know, like we are going to see in that way. But prior to that you see, if you want to balance those things, always what we are doing here? We are keeping those, you know, like the kind of beam in that way such, in such a way, that these two reactions, whatever the reactions are coming, they will balance, you know, like they will balance whatever the unbalances are coming due to the applied load.

So, this is, you see, the kind of uniformly distributed load and if you have the triangular load, we will just to, try to counter balance the remaining load, so that the balancing will be formed and we can say, that it is the statistically determinant beam is. So, now you see, you know, like in the concentrated beam we can see, that what we have.

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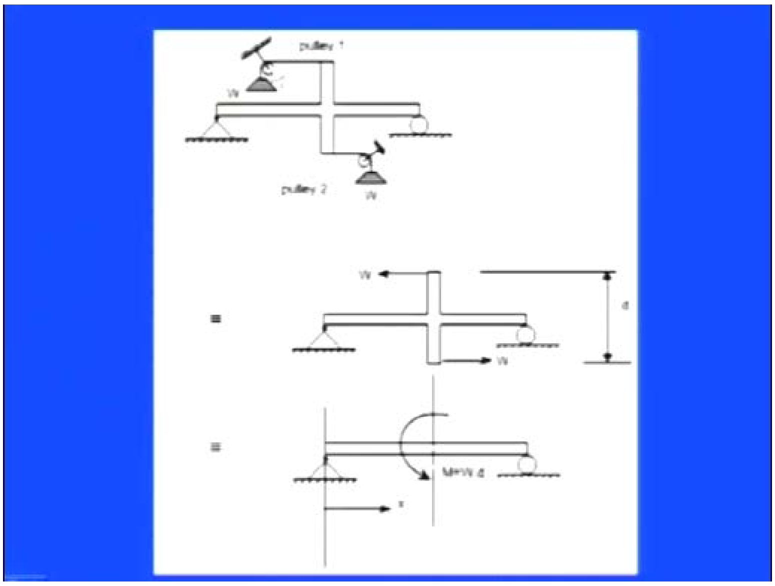

We have a simply, you know, like this kind of beam is there at one end, you see, you know, like the simply supported beam. So, when we apply the moment at these two ends and you know, like it will just try to tend in such a direction, that actually, you know, like it will, just moving this beam into clockwise direction and then, this beam will try to tend. Or we can say the, you know, like this consequence, consequences are coming in such a way, that this has reactive forces in this opposite direction or we can say, the clockwise direction.

So, what will happen in that case? This beam has a tendency to move in this direction. So, we need to design in such a way, that whatever the shearing action is there or shearing action is taken place or whatever the couples are forming, at what point this couples are formed, because you see, if you see this particular point, just concentrate on this particular figure you will find, that you have, you know, like this couple and the origin of the couple is this. So, whatever the couple is coming, it is coming due to this, you know, like the reactions. So, you see, here this, due to this forces it is tending to move in this anticlockwise direction.

So, what will happen? This, this portion will be under the action of the tension and this portion is under the action of this compression means, it will just tend to move in the upward direction. So, you see, this, this due to this couple this bending will take place. That means, it is going in this direction and we need, you see, the counter balance of this kind of couples to balance that.

Or if we want to compute those things what we have? We have, you know, like if you just replace this pulleys by these forces, we have, you see, you know, like the force direction in this direction and another force in this direction. And you see, when you have, you know, like this force and when you, when you have this, you know, like, like the distance, then we can simply compute the moment, which is nothing but equals to force into the distance. So, this moment will be acted at this point.

So, this is, you see, the exact, you see, the axis of the action though which this moment will be applied and this moment will be, you know, like going in this direction. So, whatever the resistances are coming, which will be coming in the anti-directions.

So, you see, here in this chapter what we defined? We defined, you know, like the main, if a subject is under the flexural loading, then how you can define those, you know, like the structure. And those structure we are simply defining, that actually it is known as a beam irrespective, whether it is a straight beam or curved beam.

Generally, you see, in this chapter only we discussed about the straight beam only where we have the length is very, very large. But what are the lateral dimension is irrespective of the thickness or diameter is very, very small. And then, we discussed, that actually this particular kind of beam having various kinds of cross-section depends on what kind of application is.

So, you see, if you are talking about, you know, like that where the weight criteria is very much and you see, we just want to reduce the weight with the same kind of bearing, bending actions, we are always preferring the I section. And we, we know, like in the next lecture also we are going to derive, that actually why this section modulus or this bending stresses are really uniformly distributed in the I section and why I section is fruitful. But you see, we had, we had a variety of the section is, that the rectangular sections are circular sections, triangular section, I section, T section. So, you see, all you know, like channel section. So, all these section have their own unique features and corresponding to what kind of applications are, we are choosing these sections.

So, that is what you see we discussed about these, you know, like this straight beams and this kind of sections. And then, we discussed an important issue, that how we classify the beam? We can simply classify based on how they are mounting or what kind of supports are there in that. If you are saying, that one end is rigidly fixed and one end is free, this is a cantilever. So, in that, you see, whatever the constraint motions are there in the rotational as well as the translational direction, it is to be rigidly fixed by one end.

So, there will, it, it would not allow these beam to move or translate any kind of motion in one direction So, but one end is free where we can apply any kind of, you know, like the loading and we can check, that actually what exactly the bending moment or the bending stresses forming within that kind of beams.

And second beam, which we classified in that category is the simply supported beam was. And this simply supported beam, you see, you know, like whenever the kind of loading is there, there are always two reactions are always forming in the horizontal as well as the vertical direction. So, Rx and Ry is there.

And in that also there was one more category was there, that if you put the, if you are allowing this motion in the longitudinal direction or you know, like the transverse direction, then you see, only one reaction will be formed. That means, whatever the resistances are coming from these supports or only in one direction, that is the Ry. And then, you see, you know, like we, we checked it out actually, if you have this pin joints in a particular angle, then how reactions are taken place. So, that is what you discussed about these either the cantilever beam or simply supported beam.

And then, you see, we discussed, that what kind of loadings are there through which we can even classify the beam. So, you see, here the main two types of loading will, which we discussed. One, the loading is the concentrated type. So, you see, here if you are keeping the hanger or if you are keeping direct loads on a particular area, so under the, under these, you know, like effected, effective area, under these loads are very, very tiny as compared to the entire length of the beam. So, that is why, you see, the concentrated loads are sometimes termed as the point load. And generally, you see, we are simply notating this kind of load by a simple arrow towards either the vertical downward or vertical upward directions. So, this was, you see, the concentrated or we can say, the point load was there.

And the second category, which we discussed in the load condition is the distributed load. So, distributed load is always the distributed on the entire length of the beam, either for a short span or for full span of the beam. So, if it is the short span of beam, then it is the non-uniform distribution of load because the impact of the load over, over this total length of the beam is non, non-uniform and whatever the stress are forming, they are always in the non-uniform way. But if you see this whole, this, this load is, you know, like spreading all across the length of the beam, then we are saying, that it is the uniformly distributed load across the span of the beam, the full length of the beam.

Then, you see, we are, again we are denoting by UDL or it is a just showing by the ((Refer Time: 50:01)). And this kind of load is always not coming in the Newton form, it is, it is always coming in the rate of loading. So, they have, you see, either the kilo Newton per meter or kilo Newton per millimeter.

And the third kind of loading is, if you have, you know, like this kind of the figure, which is showing on your screen. If you have, you know, the kind of twisting or the moment is there, then again, you see, you know, like the two different actions are taking place at two extreme ends, like one is at, at you know, like this tensile and one is the compressive one.

And how to design those things? You see, again we need to check it out the, what the point of application or we can say what is origin of this kind of moments are. Once you know the origin, then you can say simply, you know, like found the, you know, like we can easily form these, you know, like the moment by taking what are the load into the distances. And then, you see, form you know, like from this end, the left end or the right end, how these bending stresses are forming within this, you know, like this beam can be easily evaluated and then corresponding designs to be taken care.

So, in this, you know, like chapter we discussed all those issues about the basic issues about a beam. Now, you see, here we would like to see that if a beam is under the concentrated load only and if it is the cantilever beam or a simply, simply supported beam, then you see, how these, you know, like the bending moment will take place and how we, we would like to calculate those moments with the kind of reactions are there and we would like to draw the bending moment diagram.

And also, you see, when there is a bending action is there, you know, like when, when there is bending formations are there, always shearing actions are forming because you see, they, these two, you know, like even if you are talking about simple supported beam or a cantilever beam, the kind of reactions are coming from the bottom and top from the top action, you see, the load action is there. So, shearing is there at these two corner.

So, how you see the shear forces are coming and due to that you see, how the shear force diagram we can draw. So, these two are the real good diagrams to see the feasibility of the load. And what the, you know, like we can say, that how these loads are forming and due to this load how these, you know, like this beam is behaving, that kind of, you know, like the phenomena, which we would like to see in our next chapter.

Thank you.