Course on Design of Steel Structures
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Lecture 05
Module 1
Introduction to Bolt Connection

Hello in last lecture we have discussed various aspects of different connections which includes rivet connections, bolt connections and of course welded connections I have not discussed anything and as rivet connection is becoming absolute nowadays so I have not concentrated on that much, I have concentrated the bolt connections in detail and in case of bolt connection when we are going to design we need to know certain terminology that we have discussed. Today I will discuss about the bolt connections in particular where the different pattern of bolt connections we have discussed and in different pattern of bolt connections how the strength is going vary that will be discussed.

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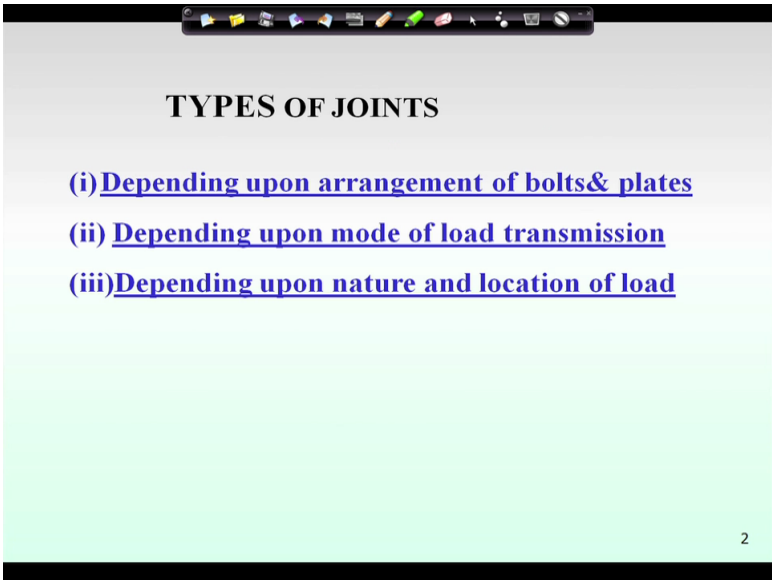

Now in case of bolt connections or in case of weld connections also we have different type of arrangements like depending upon arrangement of bolts and plates we can design the bolt, we can find out the strength of the bolt. Again depending upon the mode of load transmission we have to design and another thing is depending upon the nature and location of load, in nature and location of load also depends the design procedure.

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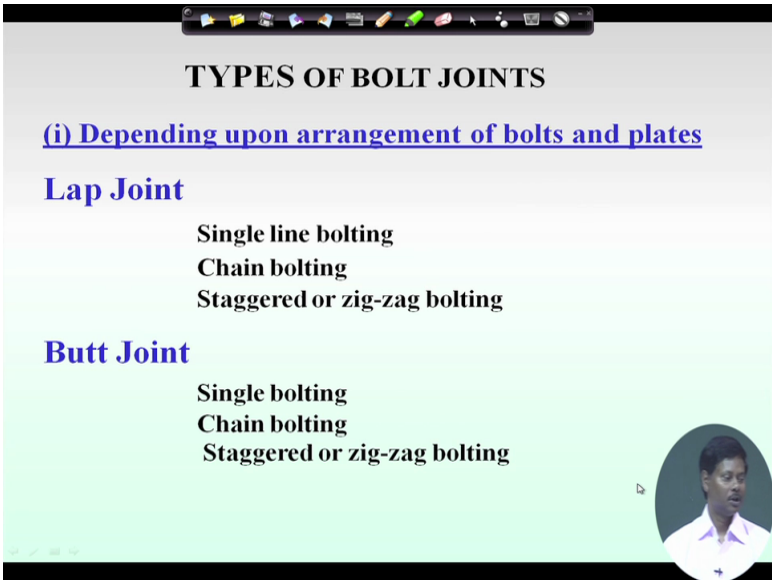

Now coming to depending upon arrangement of bolts we can see that we have two type of joint we can make one is lap joint another is butt joint. So in case of lap joint we have we have seen earlier also we can make a single bolting, chain bolting and staggered bolting. And in case of butt joint similarly we can have single bolting, chain bolting and staggered bolting. So coming to the different bolting pattern first let us come to the chain bolting.

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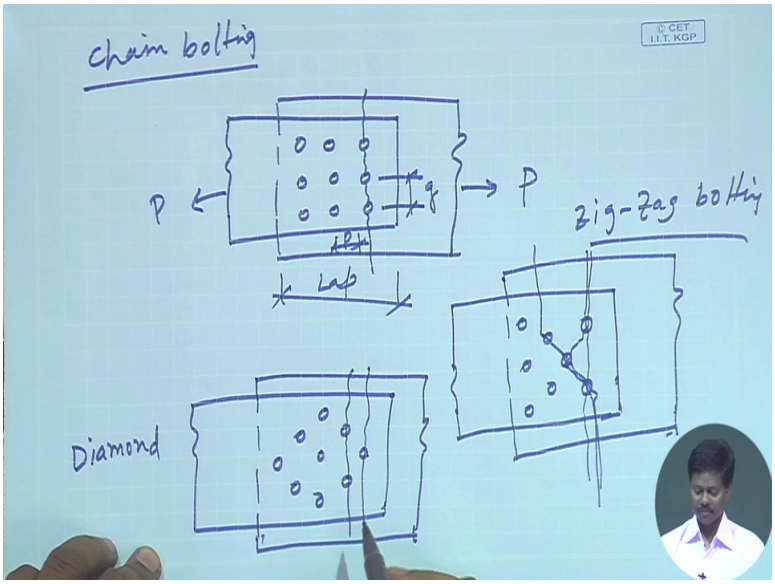

Let us see the chain bolting how it looks if we will consider say for lap joint as we see earlier in case of lap joint the two plates are overlapped together and are joined by different way of connection like bolt, rivet or welding so this is called lap. Now in case of chain bolting the bolt will be in same line, in same row and column bolt will be. So this is called as I told this

is called gauge and this is called pitch if force P is active in this direction, so this type of bolting is called chain bolting.

Now here you see the in case of chain bolting I will discuss later in detail that it can fail in this way caring failure may happen in the plate in this way, so in case of chain bolting it may happen. Now in case of zig-zag bolting, if position will be in a zig-zag way, so we have bolting here, then we have bolting here, may be again here, here. So the failure may occur in this direction, failure may occur in this direction, so different way it may occur that means another way of occurring is this so we have to calculate what is the weakest section and according to that we have to calculate the lowest strength of the connection and then we have to find out the requirement and in case this is called zig-zag bolting.

Another bolting we have which is called diamond bolting, in this case the bolts are number of bolts are in pitched towards the center, right. So this is called diamond bolting, so its failure may occur in this way, in this way by failing of this like this and different way it may fail and generally we prefer diamond bolting because it is much more efficient.

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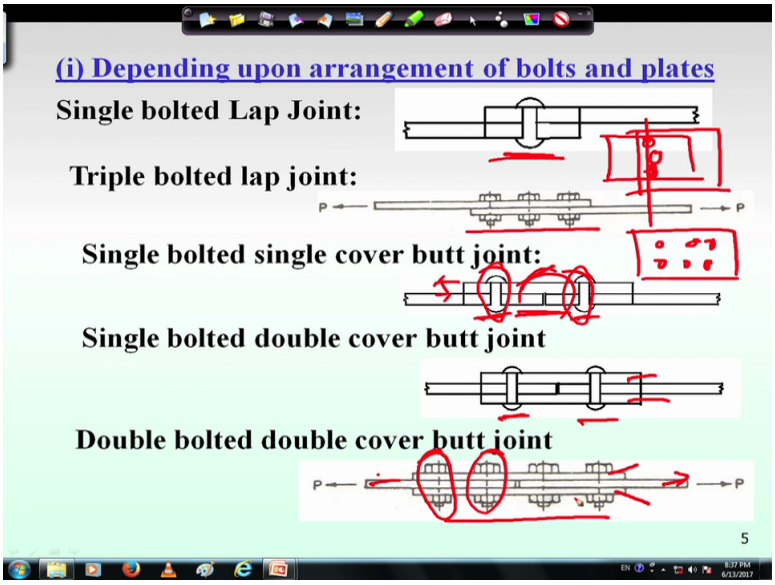

Now as I told that depending upon the arrangement of bolts we have if we see that one is single bolted lap joint single bolted lap joint means only one bolt is there, right. So if we see d plan we will see like this single bolted lap joint may be we have like this one line, right. Then triple bolted lap joint, double bolted lap joint also may have, triple bolted that means here we have triple bolted in three columns it is. Then single bolted single cover butt joint, we know butt joint that means two plates when are connected in same plane with an extra plate

this is called butt and then this type of joint is called butt joint. Now here we have cover plate of this thickness we have cover plate and we have one bolt here, another bolt here that is why in each plate we have a single bolt single row of bolt that is why it is called single bolted single cover butt joint.

And if we have two cover in top and bottom then this is called single bolted because one bolt in each plate single bolted double cover butt joint, right. Similarly here we can say double bolted double cover butt joint because we have two covers and in each plate this is one plate, this is another plate in each plate two bolts are there, two line of bolts are there that is why it is called double bolted double cover butt joint.

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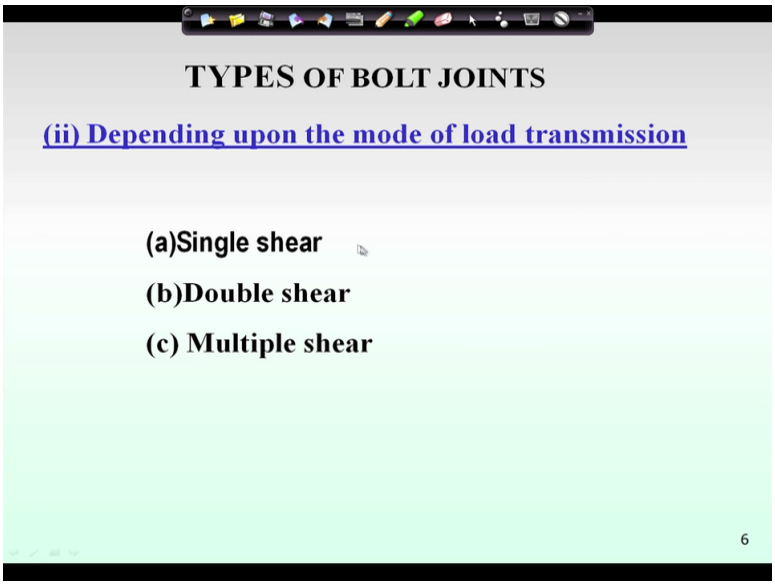

Now depending upon the mode of load transmission we can define a single shear, double shear, or multiple shear.

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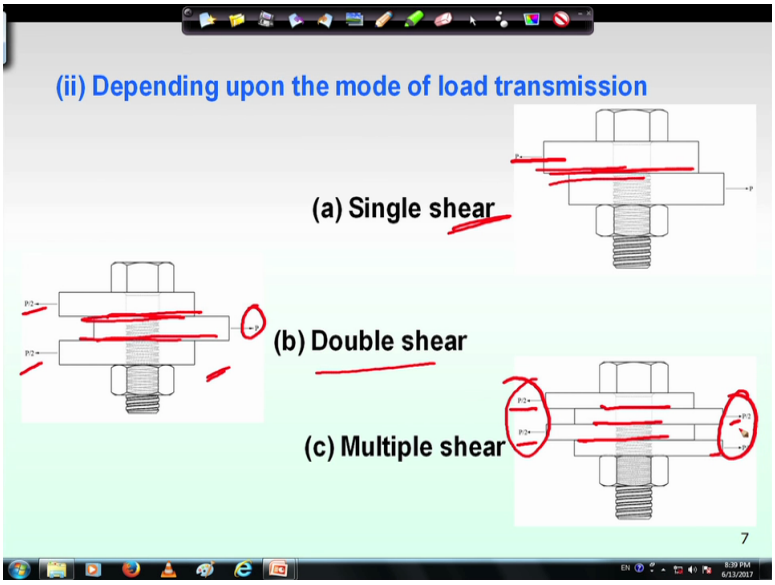

So the single shear when it comes here we see when the two plates are joint together this is one plate, another plate and it is joint through bolt then only one shear plane is there that is why this is called single shear and in this case if we see that one shear plane is here where it may fail another shear plane is here where it may fail, therefore this is called double shear.

And you see if the P is the force in this plate then it will be divided by P by 2 and P by 2 and multiple shear means number of plates if it is joint by the bolt and if number of shear plates is two then it is called multiple shear. So here we see one, two, three, three shear plates, right and from equilibrium equation we see this in this direction it will be P by 2 P by 2 and in this direction it will be P by 2 P by 2.

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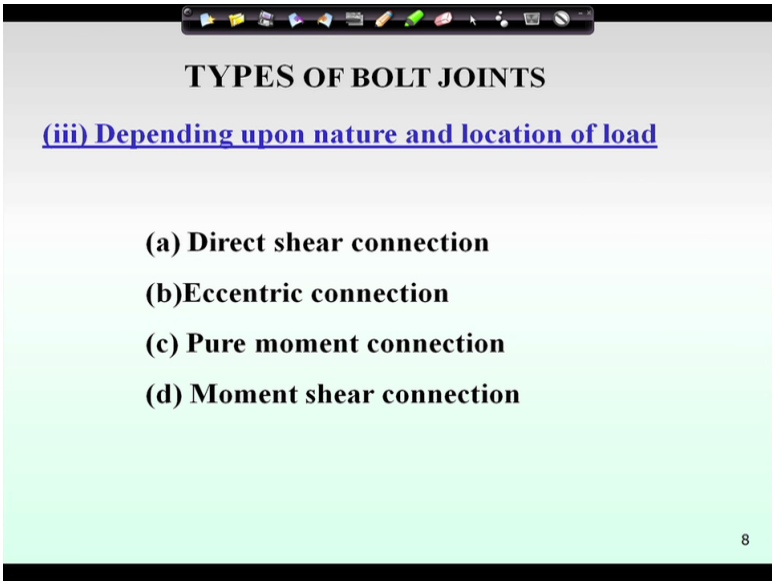

Now depending upon nature and location of load we also can find out different type of connections like direct shear connection, eccentric connection, pure moment connection and moment shear connection, so four type of shear connection we can see depending upon the nature and location of load. Let us see how it looks.

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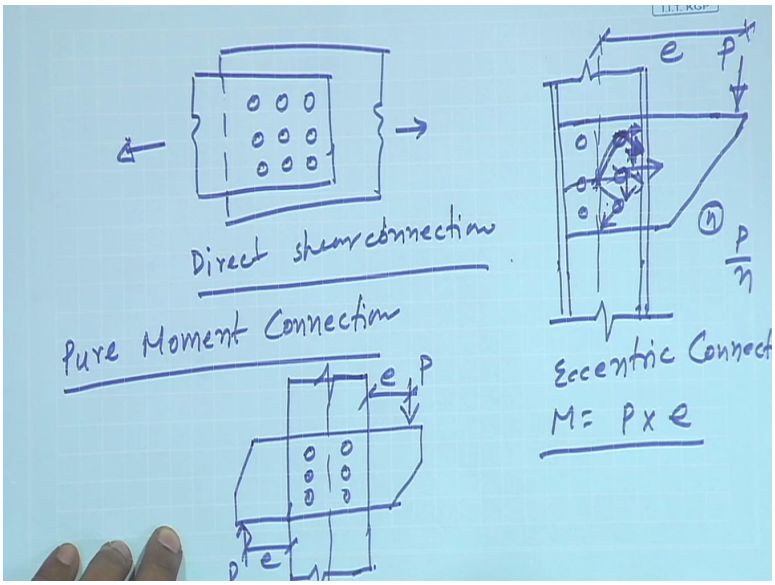

Say for example direct shear connection, in case of direct shear connection we can see that if two plates are overlapped together then this type of connection is called direct shear connection. So when such type of condition will come we will design the bolt accordingly due to shear it may fail so we can find out the strength of the joint.

Next is the eccentric connection eccentric connection means when a beam and column are connected together say for example a column is connected with a beam member and we have a member here may be connected through gusset, if we have a load P here, we can eccentricity e and if it is connected through bolt then such type of connection exerts moment because this is an eccentric connection.

So for eccentric connection here we will see the bolt will exert the direct load in this direction P by n so if n is the number of bolt then and each bolt the force will come P by n and also the moment will be P into e moment will be P into e. So because of this moment the bending stress will develop and because of that certain stress on the bolt will develop, in different directions it will develop, right in this case it will develop like this if it is center sorry in this case it will develop like this, in this case it will develop like this perpendicular from the

center like this, so for this case it will be developing like this, so this is how it will happen this is called eccentric connections.

Another case we have again which is called pure moment connection pure moment connection so for this sometimes two members are connected with a pure moment say for example like this this is P and this is also P means with e from symmetric loading is there. So here only moment will be developed in the connection, so this is called pure moment connection.

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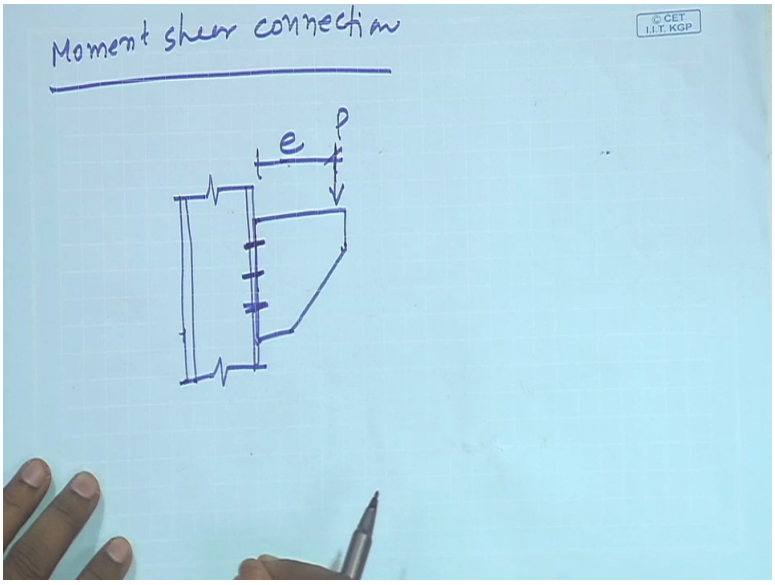

Then moment shear connection, in case of moment shear connection that is suppose say column may be I section and we have a bracket and this is connected in this way. So it is connected in this phase, right so bolting will be in this way. So in this case moment and shear will be developed this is e, this is P, so moment and shear will be developed so this is called moment shear connection.

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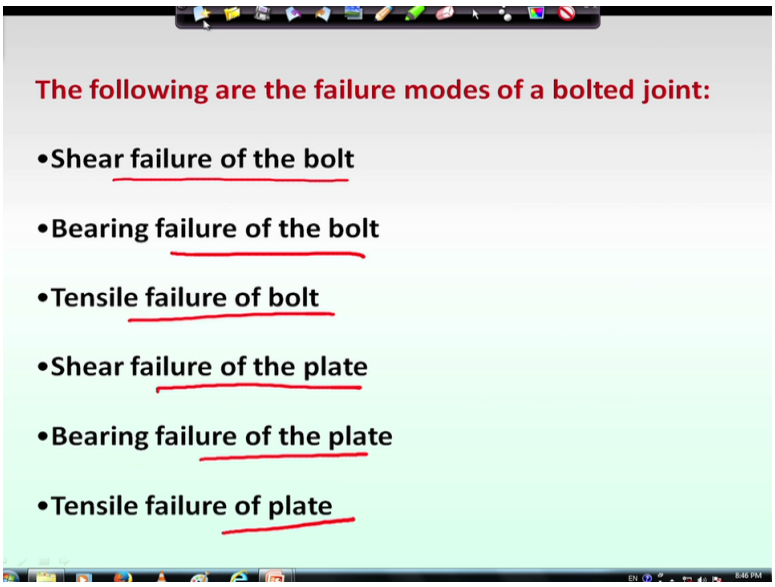

Now we will discuss about the different type of failures because when we are going to design a bolt, when we are going to find out the strength of a bolt, or strength of the connection as a hole we have to find out what are the type of failure may occur and to arrange those failures what are the mathematical equations are developed and how we will calculate the strength.

So if we see the failure of a bolt joint we will see the failure may occur in this way, one is that shear failure of the bolt shear failure of the bolt, then bearing failure of the bolt, another is tensile failure of the bolt, so these three types of failure may come in case of bolt. Similarly the plate also exert shear failure, bearing failure and tensile failure, so we have to see the different failure and the least strength of a different failure will be the bolt strength, so this is how we calculate the bolt strength.

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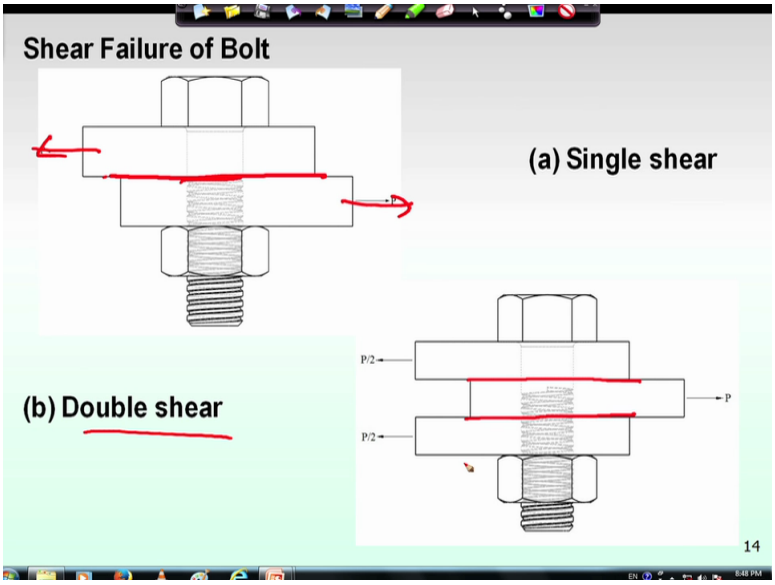

Say first let us come to a failure which is called shear failure, so this is a shear failure for different case with single shear and double shear. Now if you see for single shear that means only one shear plane is there between two plates only one shear plane is there, that is why it is called single shear failure so how the failure may occur that due to shear of the bolt at this point it may fail.

Then in case of double shear we have two planes two shear planes this is one shear plane, another shear plane is this. One is passing through the threaded portion another is passing through the shank portion. So here it may happen means double shear failure may happen. So when calculating the strength shear strength of the bolt due to single shear or due to double shear we have to know means how the plates are connected that we have to know after knowing that we have to find out whether it is going to be single shear or double shear, if single shear strength will be calculated accordingly, if double shear strength will be calculated in that way.

Now if we see some other failure, so we have shown shear failure in single shear and double shear.

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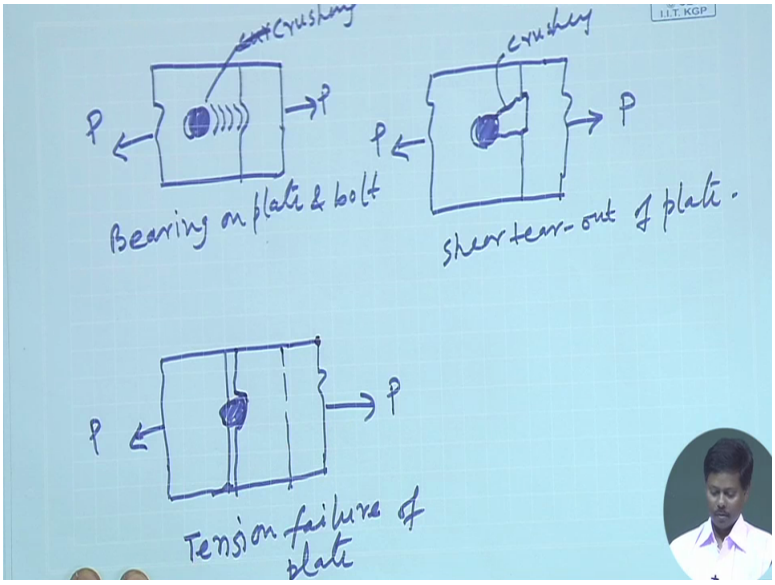

Now we will see bearing on plate and bolt, bearing failure how it happens. So if we see the two plates if it is connected and this is a bolt then due to bearing on plate it may fail that means it may fail like this is crushing. So this is one type of failure which is called bearing on plate bearing failure, plate and bolt.

Another type of failure may come in to picture also which is called shear tear-out of plane that means this is somewhat it will look like this this is crushing shear tear-out of plane. So such type of failure may also occur when force P is in this direction.

Another failure may come which is called tension failure of plate because when two plates are under tension and we are going to join through bolt by insertion of hole then along that hole line tension failure of plate may happen. Suppose we have bolt here now what it happen it may fail like this in this way the two plates may tear out in this way due to failure of plate, this is called tension failure tension failure of plate, right. So this is another sort of failure, so different modes of failure of bolt joints we are observing.

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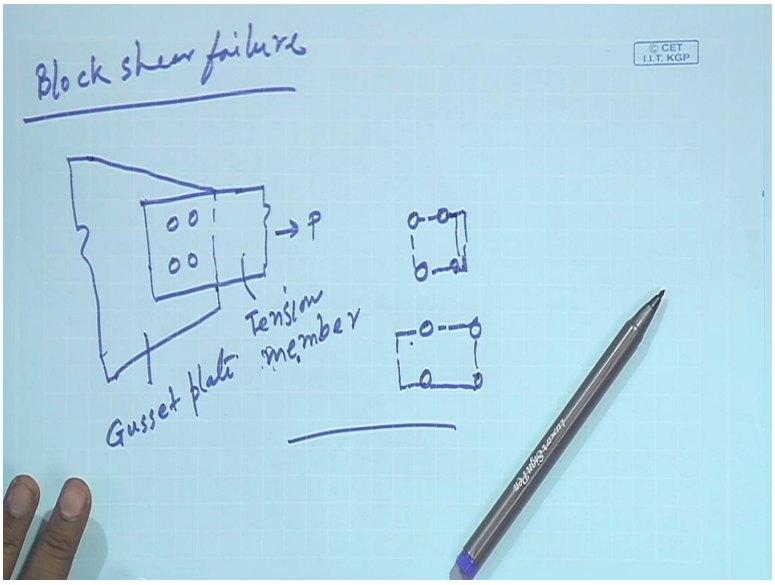

And another failure is called block shear block shear failure this may happen in this form say a plate is connected with another plate say for example gusset plate and a force P is acting now if bolts are like this then this is a tension member say this is a tension member and this is gusset plate so this block shear failure may happen in this way say as a hole it may fail this is one way or sorry this is one way or we have this is another way. So this is called block shear failure.

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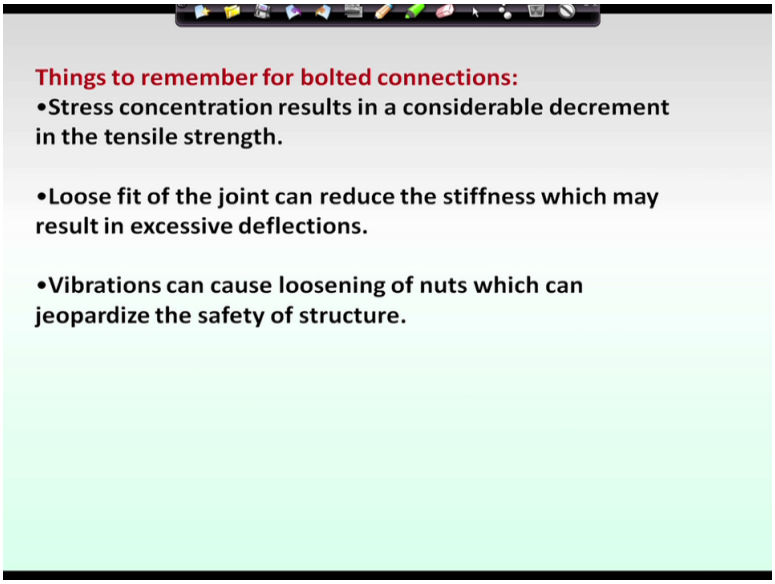

Now we have to remember certain things for a efficient connection using bolt that is one is the stress concentration results in a considerable decrement in the tensile strength so we have to try to avoid the stress concentration. Then loose fit of the joint can reduce the stiffness

which may result in excessive deflections. So that has to be taken care that means we have to tighten the bolts properly so that the loose fit does not occur and joint does not get reduced instantly.

Then vibration or loosening of nuts which can jeopardize the safety of the structure, due to vibration or so it may occur so this has to be taken care means we have to keep in mind while designing a joint using bolt.

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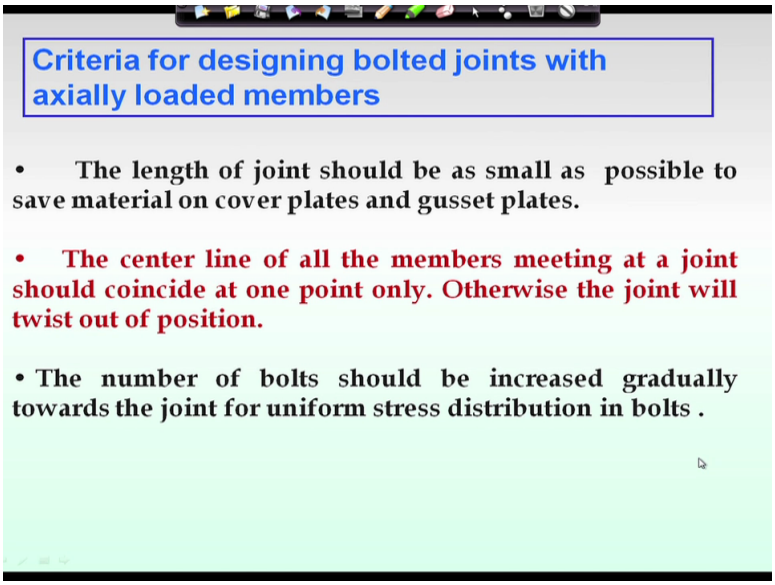

And certain criteria we have to remember for designing the joint under axially loaded members. First of all the length of joint should be as small as possible to save material on cover plates and gusset plates.

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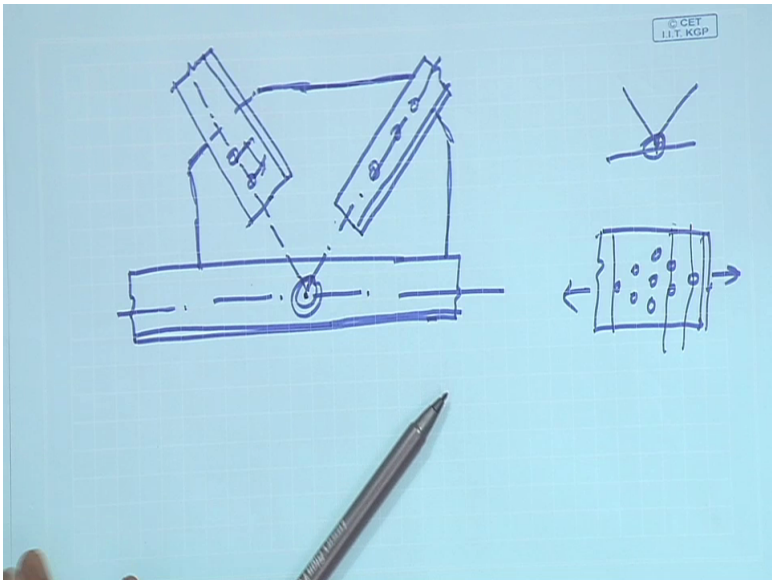

Say for example we have a gusset plate connected with different type of members say for example a truss member is connected like this. Now it is meeting at a point, ok. So how do we joint this so joining is possible say for example we have a member here horizontal member say angle section we have another member is cg is passing through this so we have to join in such way that cg of each members pass through a particular point otherwise eccentricity may develop then the moment due to eccentricity may come into picture.

So another member say suppose is this another member is joint through this, right. So by joining such type of structure we have to see that the cg of all the members are meeting at a particular point, right and the length of joint should be as less as possible to reduce the material amount of material that means we have to join through say suppose gusset plate to this structure.

Now if we have more number of bolts here then we will not be able to reduce the length of joint that means we cannot reduce the amount of material required for gusset plate, that is why we have to keep in mind that as less as possible the length of joint should be. Another thing as I was telling the center line of all members meeting at a joint should coincide at one point only that means only one point it should coincide otherwise the joint will twist out of position.

The number of bolts should be increased gradually towards the joint for uniform stress distribution in bolt I have shown one figure if you remember that for diamond bolting we prefer diamond bolting that number of bolts will be increased towards the center, ok.

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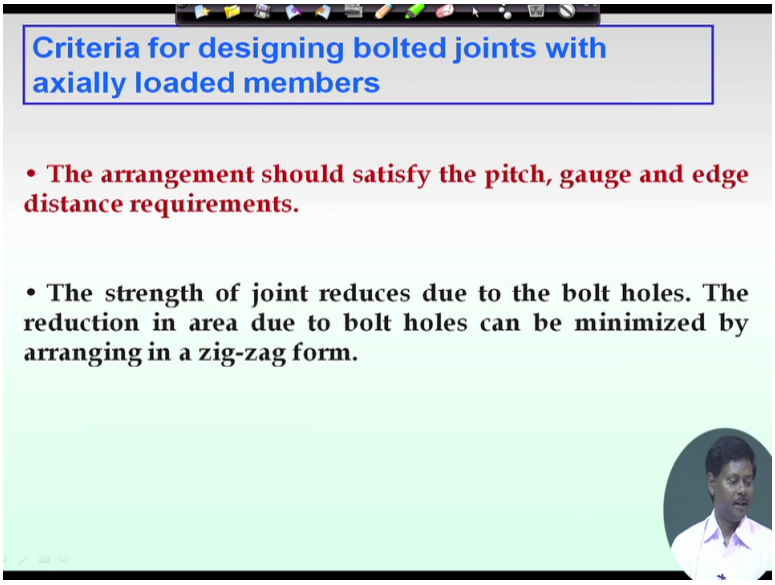

Then the arrangement should satisfy the pitch, gauge and edge distance requirement, that means the pitch distance what will be the pitch distance, what will be the gauge distance, what is the edge distance all the things has to be satisfied. Next is the strength of joint reduces due to the bolt holes. So the reduction in area due to bolt holes can be minimized by arranging a zig-zag form zig-zag form or diamond form if we make then arrangement can be made in such a way so that the strength can be increased.

So in short while designing a connection using bolt we have to remember certain criteria one is the length of the joint should be as less as possible as less as possible that is possible if we increase the diameter of bolt, we should not make use of large number of bolts we have to try to reduce the number of bolts so that the number of holes become less so the tensile strength of the member becomes high as well as because of less number of bolt the length of the joint will be less and thereby the gusset plate require for joining plates will be less. So the amount of gusset plates can be minimized through this.

Another thing is the members meeting at a point should be designed in such a way that cg of all the members are coinciding at a particular point, otherwise due to eccentricity the additional moment may generate that also has to be keep in mind. Another important things we have to keep in mind that the whether we are satisfying the pitch and edge distance properly pitch and edge and gauge distance because as per codal provisions we have to consider the minimum pitch and maximum pitch. So the pitch distance whatever we will provide we have to be in between that also we have to keep in mind.

So with this I would like to conclude todays lecture saying once again that when we are going to design a bolt connection we have to keep in mind what type of connections we are going to handle and accordingly what type of load may come and whether we are going for lap joint or butt joint, whether we are going for eccentric connections or concentric connection we have to see and accordingly we have to calculate the external forces and then we have to find out the bolt strength once we get bolt strength we can find out the number of bolt and we can design accordingly with the use of codal provisions for pitch distance, edge distance and gauge distance.

In next class we will discuss the bolt strength due to different failure means different aspects like bearing failure, shearing failure, tearing failure what will be the bolt strength that we will calculate as per the codal provisions, thank you very much.