Course on Design of Steel Structures
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Lecture 19
Module 4
Tension Members and Net Area

Hello today I am going to start a new chapter on new module that is tension member. So far we have discussed about different type of connections starting from bolted connections, welded connections and also eccentric connections. Now we will go one by one the member design. Member means either it is a compressible member or flexible member or tension member.

Now unlike RCC structure here tension member plays an important role like in case of RCC structure because of the depth load or self-weight generally structure undergoes compressions and may be rarely tension comes into picture that is why we use such type of members means we design as a means RCC design but in case of structures where tension occurs frequently in such cases we have to use the steel member so that the steel can take tension.

So in case of industrial building or bridges particularly trust members members are subjected to tension because of different type of loads including vehicle load in case of bridges and wind load, earthquake load for industrial structure etc we found that many members become means undergoes under axial tension.

So we means we have when we will be learning the design means design of steel structures we have to learn how to design a tension member. In case of RCC member many of us have not learnt that design of tension member in RCC but in case of steel we need to know as we know that wind when industrial structure is built when wind comes into picture or earthquake comes into picture some columns goes compression and other columns under tension.

And again because of reverse direction again the columns which were compression become tension and which were tension earlier may become compression. So we have to design the members for both tension and compression in case of industrial building or structures. So those things we will see one by one and you know tension members means may be of any type of cross sections it may be angle section, it may be circular section, it may be (())(3:03) sections any type of sections can be used.

However generally we use means because of its advantages geometrical properties we use circular section as a tension member or sometimes we use angle sections also, right.

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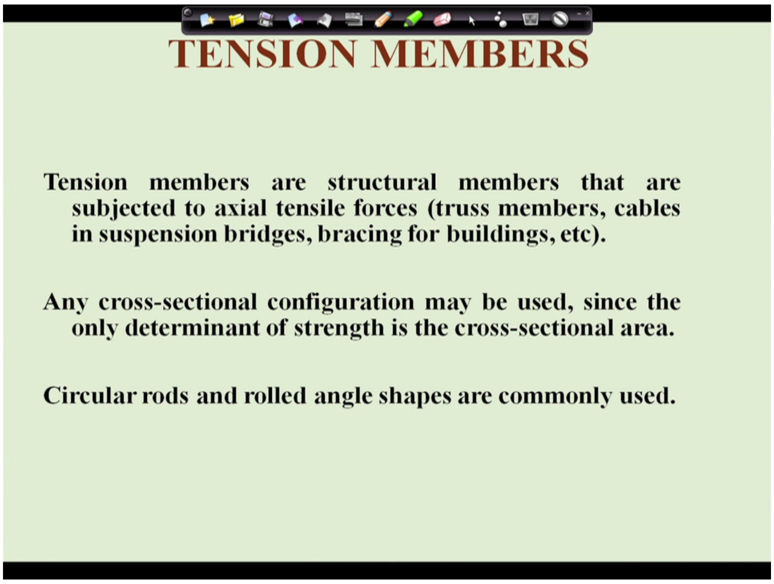

So if we see that truss member, cables in suspension bridges, bracings for buildings these are often subjected to axial tension forces who is next to be designed properly and as I told that any cross sectional configuration may be used where circular rods and rolled angle sections are commonly used.

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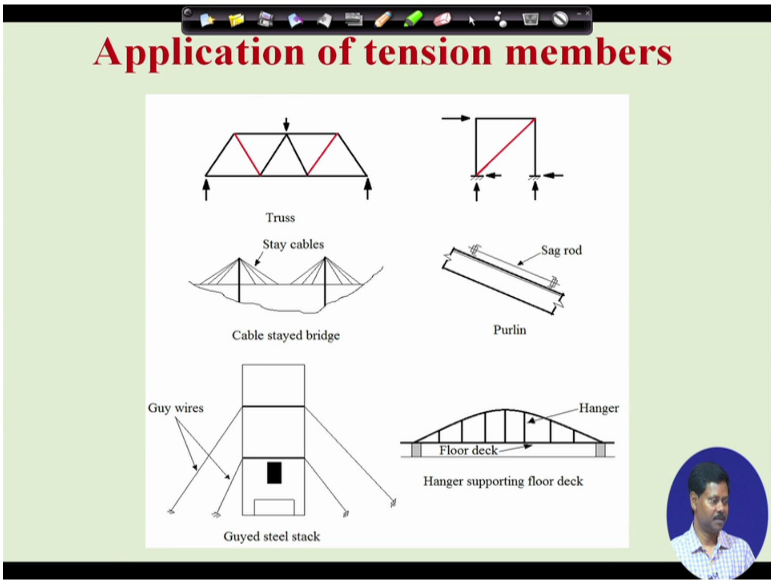

These are some application of tension member where in case of cable stayed bridge we need to design tension the stay cables and similarly in case of truss members few members become tension, in case of bracings we need to design the bracings which comes into tension action, so in case of purlin, in case of hanger supporting floor deck, etc we have to design for tension.

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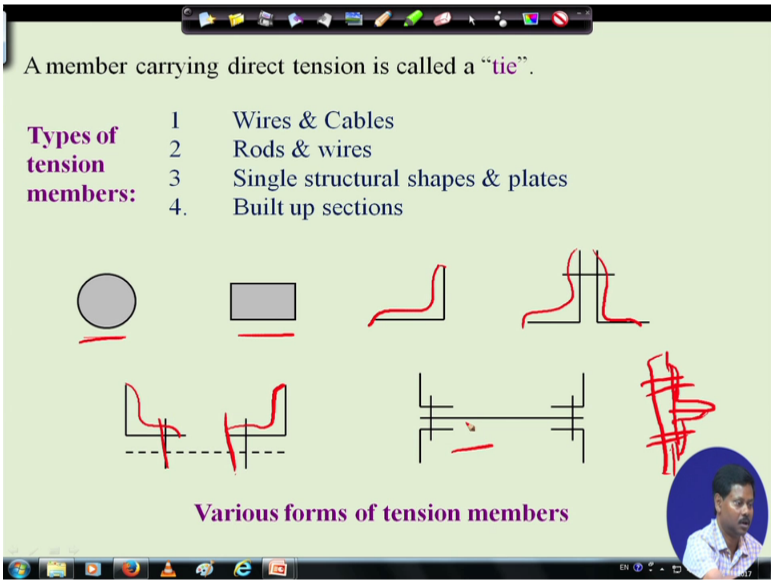

Now coming to tension member we will see that different type of section can be used one is circular sections that is we can use circular section, we can use rectangular or square section, we can use angle section if we see this angle section and of course angle section back to back angle section in a different way also we can make like we can make angle sections in this way also say this is one angle and this is another angle which is connecting with a gusset plate.

This this also sometimes we use then this is written here also if we see this two angle sections are connected with a gusset plate with bolt connection or four angle sections are also connected, this is the way we can make some angle sections.

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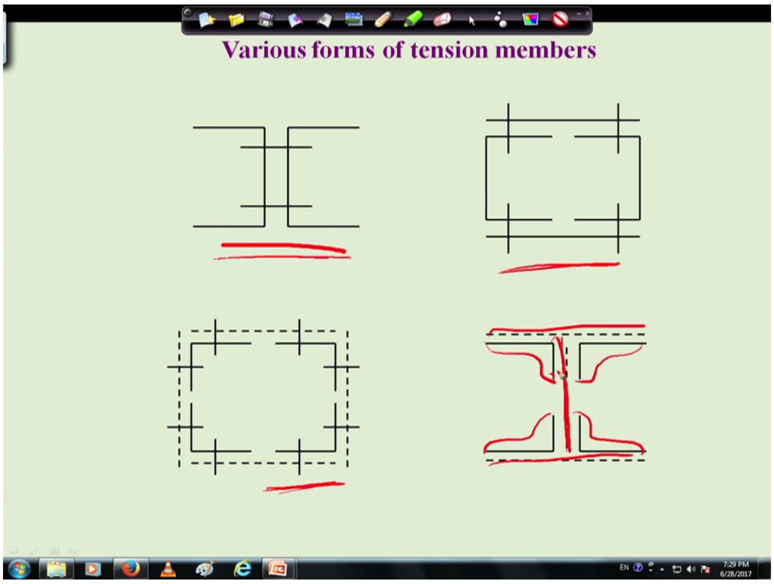

Then other various type of configurations as like this this two channel sections back to back that generally we use for column section means for compression member but sometimes we may need for design of tension member also. Again channel section face to face it may be connected again and angle section making a box this way also one can connect and angle section with the use of gusset plate and other additional plates we can make angle sections also means use angle sections for making a built of section which will be useful for tension member design.

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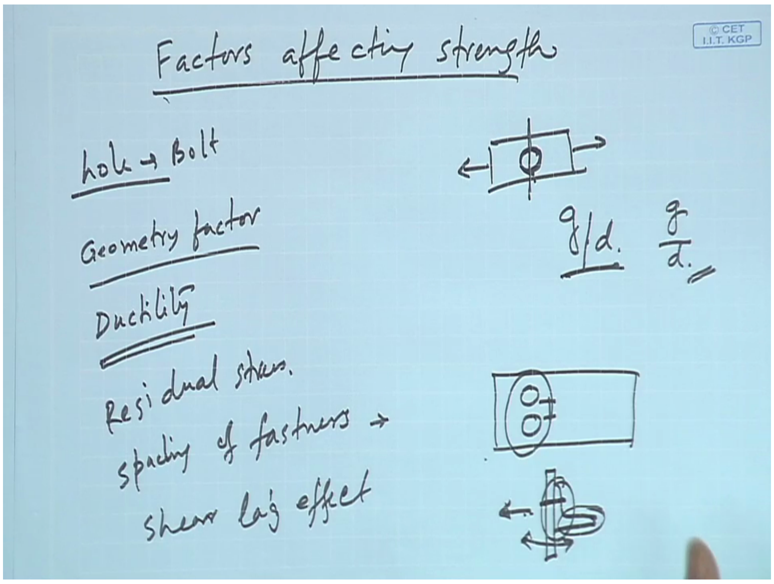

Now we will discuss about various factor affecting the strength we will discuss about factors affecting strength strength means the tension strength. So here one is the hole means bolt hole

hole due to bolt. So if we have a plate and if we make a connection with a hole then the net area of the section is going to be reduced that is why when we will be calculating the net area or the for calculation of the tensile strength we have to reduce the bolt hole area because this bolt hole cannot take tension that is why the strength will be decreased in case of presence of hole.

Then another factor is geometry factor geometry factor of the member geometry factor is that a lower ratio of guz length to its diameter guz length means g and diameter d results in contentment of contraction at the net section and hence it is more efficient that means when g by d ratio will be low then it will be more efficient so this also we have to keep in mind.

Then another is ductility factor if the members become ductile ductility factor if the members become ductile then it increases its strength because even distribution of stress because of the ductility of the member distribution of stress becomes even and because of that we can get more means more strength if the member is ductile.

Then residual strength if we have residual stress in the member in case of residual stress have a more pronounced effect where fatigue is involved in case of fatigue we have to count the residual stresses also how much it is present so accordingly it has to be taken care.

Then spacing of fasteners spacing of fasteners this is also if the spacings are closer than relative to the diameter then block shear will lead into failure that means when a member is connected then compared to its diameter if spacing is less than chances of block shear failure will be there so that has to be also taken care.

Next is the shear lag effect this is very important in case of tension member design shear lag effect in fact sometimes member total members are not connected to the gusset plate or to the system.

So when the members are subjected to tension so all the portions of the element or the member are not directly connected as a as a result are not directly are not directly under tension.

So therefore tension force are not distributed throughout its cross section properly, so there is a scope of shear lag effect. So that because of shear lag effect the strength of the member gets reduced. So when it has it occurs say suppose in case of a member say a angle is connected to a gusset plate.

Now when the tension force is applied so this portion will be under tension directly as it is directly connected but this portion is under tension but at a time it will not occur there will be some lag lagging. So because of that lagging shear lag effect will come into picture and because of shear lag effect the strength of the member will be reduced.

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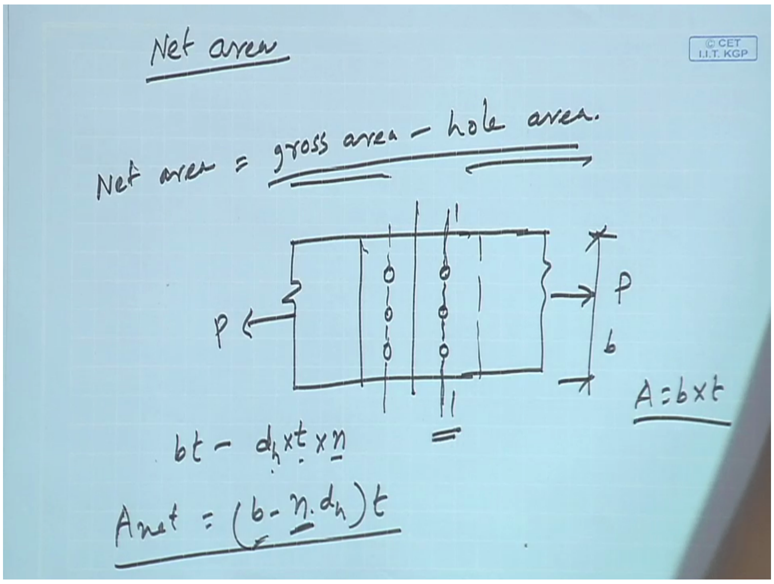

Now coming to net area calculation because in case of tensile member axial tensile force the net area plays analysis important role because when we will find out the yielding of the section or rupture of the section means the member when it is under tension rapture may come into picture along its critical section.

So for that we have to find out the net area net area means basically the total area minus the hole area because of the presence of bolt the members are (())(11:37) so that hole cannot take tension. So when we are going to calculate the net area we have to reduce that area not only that its means we have to calculate that in which section it is going to fail, there are several options will come into picture through which there is a chance of failure failure means rapture failure it may.

So we have to calculate the different options and then we have to find out that which one is the most critical and according to that critical section we have to find out the what is the strength due to rapture. So this is how we will make it.

So basically net area means gross area minus hole area, so this is the formula which we can use however case to case it will little change, say this is true when the plates are in chain bolting. Say we know the when two plates are in connections and under tension say P and say bolting connections are made with a chain bolting. So there will be chance of failure along this direction because in this direction say 1-1, right or along this direction.

So in this direction along this path the net section area will be less, if I consider here the net section area will be b into t, if this is b the width of the plate is b and thickness is t then gross area will be b into t, right but the area along these sections will be less, that will be gross area minus hole area hole area means if diameter of the hole is dh and if t is the thickness then dh into t into if n number of holes are there then this bt minus dh into t into n, that means gross area means hole area.

So I can find out Anet that net area is equal to b minus n into dh into t, this is how I can calculate the number of means net area where t is the thickness of the plate, dh is the gross diameter of the hole and b is the width of the plate and n is the number of bolts in one line in one line number of bolts in this case it will be 3, so this is how we can calculate the net area in case of chain bolting.

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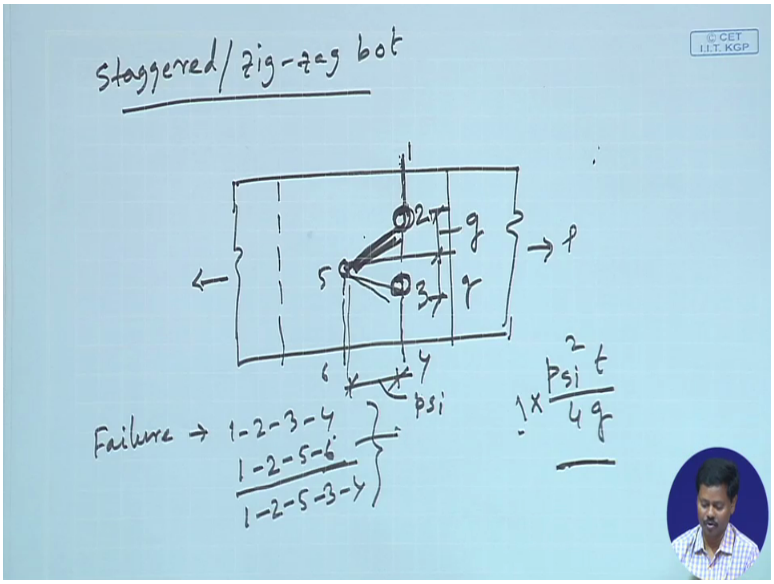

But in case of staggered bolt we have different formula in case of staggered or zig-zag bolt, we also call zig-zag bolt there the bolts are not in a particular line it is distributed in a zig-zag manner so we need to know how to calculate the net area and net area calculation means we have to see how it is going to fail. So here we can see that suppose the bolt connections if it is like this then it may fail in this way in this way say I can give a name that 1-2-3-4.

So failure may occur failure may occur along 1-2-3-4 again failure may occur in this direction also if this is 5, this is 6 means 1-2-5-6. So in this direction also it may fail 1-2-5-6 also it may fail 1-2-5-3-4 that means it may connect like this like this then then this then this. So three alternatives are there through which the failure may occur.

So what we need to know we need to find out what is the net area along this three alternatives root and finding out the net area the least one will be the most critical one so the failure will happen first on that line so that is why we have to calculate. And in case of staggered joint that direction will be that direction will be say if I consider that 1-2-3-4 then direction will be here 2 hole 2 hole area but if I have 12-5-6 for this case I can see that direction is 2 but there is a chance of gaining strength in this so that has to be taken care, that will be consider the sectional area holes will be consider as psi square into t by 4g, so this portion we have to take ps square i by tg.

So that means here psi is this one that in case of staggered pitch that psi is the pitch distance psi i for means 12-3-4 like this number of staggered pitch and g will be this distance this is g that means this is g. So number of staggered means diagonal path each one so this will be n into means 1 into this this will be added.

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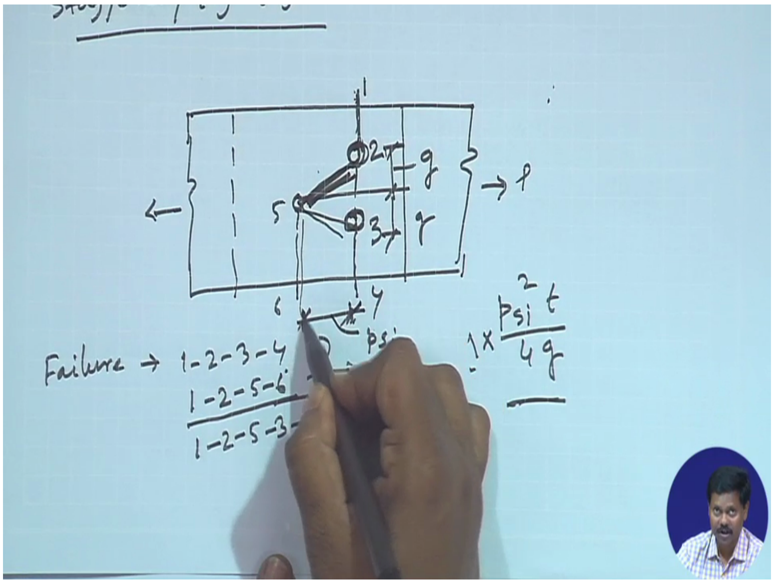

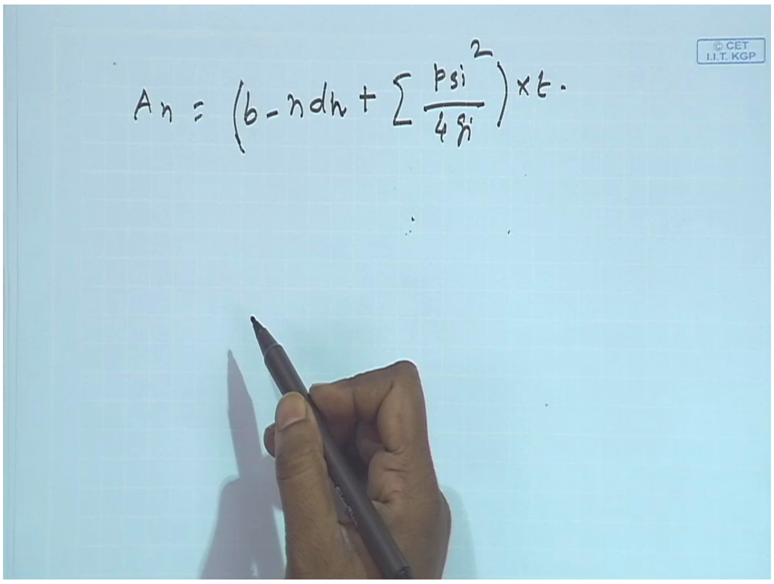

So in this case we can find out the net area as like this An will be b minus n into dh means in which path it is going according to that how many bolts are coming into picture we have to see and accordingly n will be decided and then summation of psi square by 4gi i is number of staggered line or that inclined line through which it is passing, so here into t.

So here b is the width of the plate and t is the thickness of the plate and dh is the hole diameter that means bolt diameter plus 2 or 2 millimeter in case of directly punched hole and g is the gauge length between the bolt holes and ph is the staggered pitch length staggered pitch length I have shown between line of bolt holes as shown in the figure earlier that means in this figure staggered pitch this will be the staggered pitch.

And n is equal to number of bolts lying in the critical section and i is the means number of inclined lakes that means in case of this in case of this this will be if I consider 1-2-5-6 1-2-5-6 then n is 1 and in case of 1-2-5-3-4 1-2-5-3-4 n is 2. So this is how we will consider.

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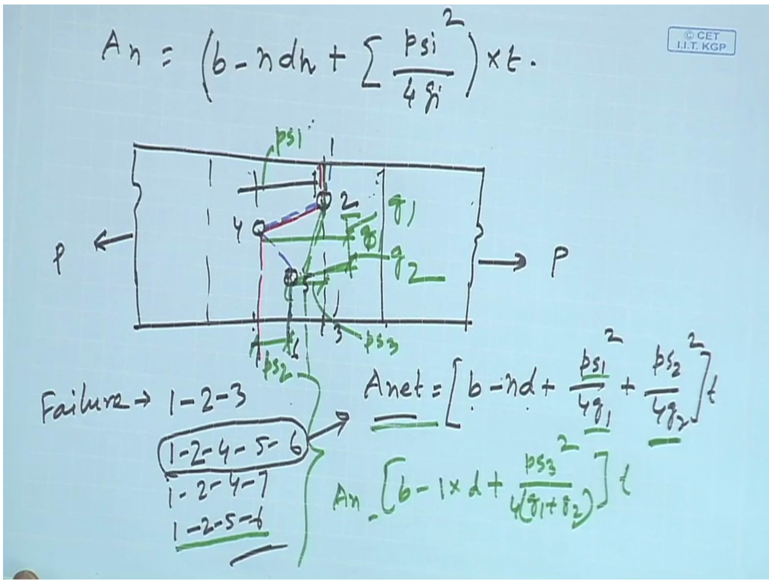

Now if the gauge distance and staggered pitch distance are different then how to calculate there is another case I consider where pitch distance and gauge distance are different. So for example this case where two plates are connected with a lag joint P is the tensile force acting and there is a bolt here, this is another bolt, this is another bolt that means it may fail along this 1-2-3 so failure may happen if I see failure will happen along 1-2-3, this is one case.

Then another case will be 1-2-4 4 means this one 4 and this if I consider this is 5 and this is 6 and this is 7, so 1-2-4 then 5-6 that means this way 1-2-4-5-6 in this way, another scope is that 1-2-4 then 7, 1-2-4-7 1-2-4-7 and another also 1-2-5-6 that means it may fail in this way also I am showing. So there are four options say 1-2-5 then 6, so four options we have and we have to find out the net area along this 4 line and then I have to find out the minimum one and minimum one will be the net area for which it may fail.

So I will calculate one by one and then I will try to find out the net area. So how do I calculate the net area in this case say Anet so in this case it will be say b minus nd plus ps1 square by 4g1 plus ps2 square by 4g2 into t, right. So this case is actually this is 1-2-4-5-6 in this case this case will be the new one. So what we are seeing here here we are seeing that b minus nd here n will be 3 and ps1 is this one ps1 this I can say ps1 and this is ps2 because after this 1-2-4 then from 4-5 it is coming so it is ps2, right.

So ps1 by 4g1 this is g1 and if I consider sorry this is g1 g1 and this is g2. So if I consider that 4g1 and then ps2 square by 4g2, so this is how I can calculate but if I consider that it is failing along 1-2-5-6 that means 1-2-5-6 then in this case it will be b minus nd n means 1 into d plus then in this case I should consider say this is ps3 say ps3 square by then this will be g1 plus g2 that means 4g1 plus g2 into t for this particular case An will be this. So case to case we have to consider what is the An value and accordingly we have to find out the most critical one, right.

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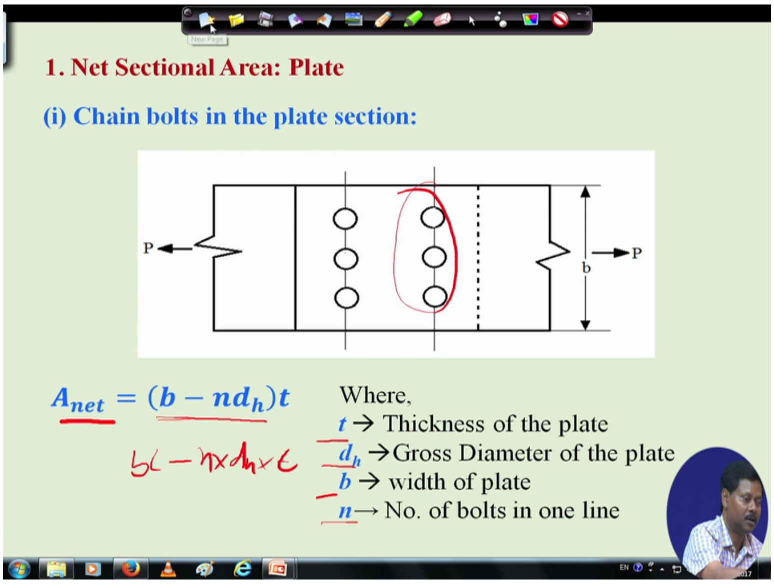

So now I will show the same thing in this picture so that one can understand so just to give the summary of the things whatever I have discussed we can say that the net area Anet we can calculate as b minus ndh into t where, t is the thickness of the plate, dh is the gross diameter of the plate, b is the width of the plate, and n is the number of bolts in one line, so this is what number of bolts in one line means in this line how many bolts. So in this case it will be 3.

So for chain bolting I can easily find out the net area as the gross area which is b into t minus n means hole area n into dh into t, so this is how I can calculate but the problem start when we have to calculate the net area for zig-zag bolting.

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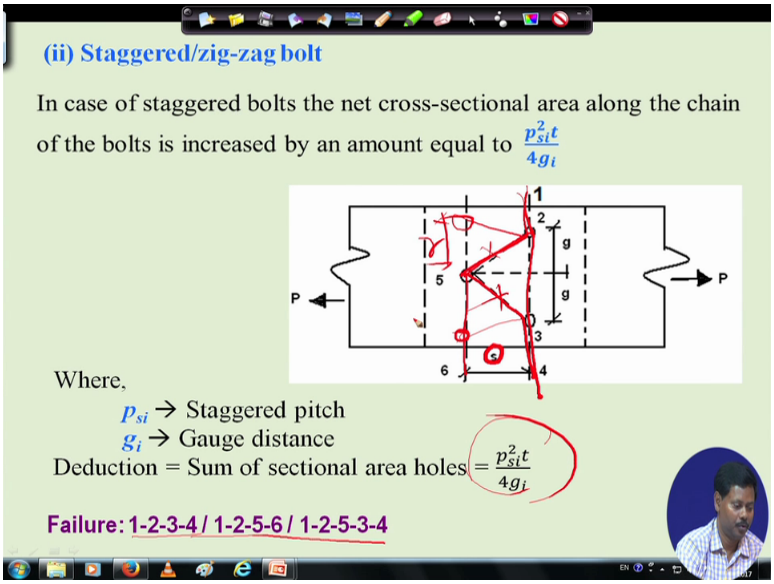

So in case of zig-zag bolting we have discussed two things one is one is that if the psi this is psi or s whatever we can say if this is same that means if again this is here so it will go like this again if this is here it will go like this that means here s is same and if g distance is equal also then I can write that sum of sectional area holes that will be that is psi square by t into t by 4gi and failure as I told that failure will occur along 1-2-3-4 so 1-2-3-4 in this direction, failure may occur 1-2-5-6 again failure may occur 1-2-5-3-4.

So if I consider failure along 1-2-5-3-4 then n will be 2, because number of inclined line are 2 so n will be 2. So in this way we can calculate.

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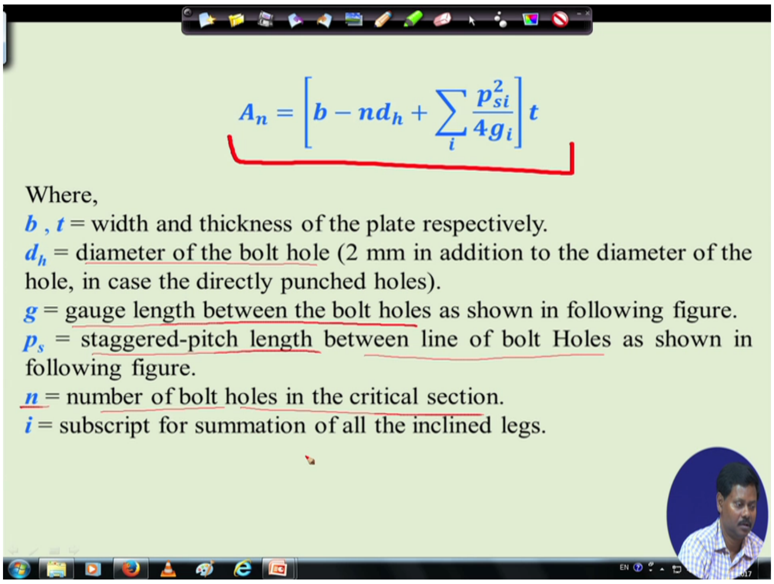

And the formula we know that An will be equal to b minus ndh plus psi square by 4gi into t. So the parameter name I have told the variables like n is equal to number of bolt holes in the critical section means which sections I am passing according to that I can find out number of bolt holes and ps is the staggered pitch length between line of bolt holes as shown in the figure and g is the gauge length between d bolt holes and as shown in the figure earlier we have shown the figure and dh is the diameter of bolt hole and b and t is the width and thickness of the plate respectively therefore the net area can be calculated.

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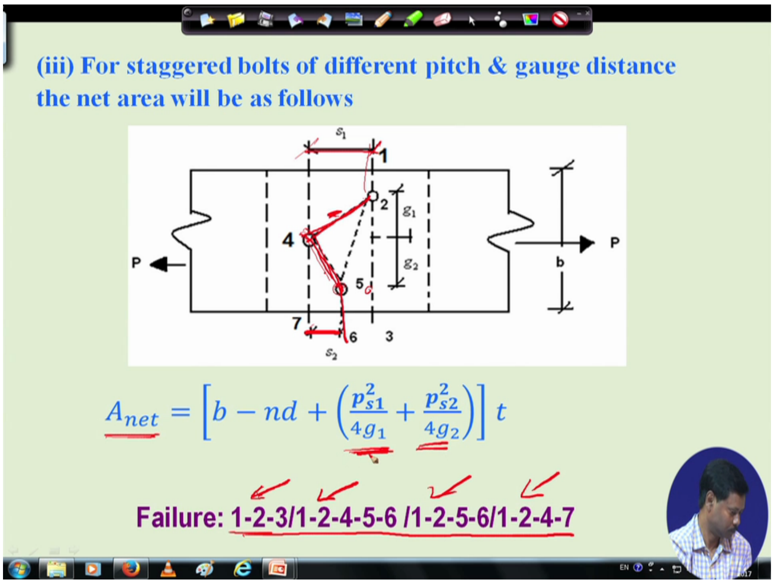

Now if the staggered pitch is different for different cases say for example this case. So in this case this is ps2 or s2 and this is ps1 or s1 we can notice and if we see here s1 and s2 are different that means these bolts are not in this (direction) means in this line in 1-2-3 it is not situated.

So in this case we have to calculate net area considering individual staggered distance. So if I consider the net area along 1-2-(5)4-5-6, so there is two inclined line so one is this one for this I have to make this ps2 square by 4g2 and for this I have to add ps1 square by 4g1 and net area I can find out in this way.

So this will be b minus nd plus ps1 square by 4g1 plus ps2 square by 4g2 into t, right and failure may occur in different way and so for calculation of net area I have to find out the critical path or line of calculation of net area for 1-2-3, 1-2-4-5-6, 1-2-5-6 and 1-2-4-7. So I will calculate the net area for these four cases and the minimum one will be the critical one through which the failure will occur, right. So by seeing we cannot tell that in which line it is going to fail, so I have to calculate and then I have to find out which one will be the most critical one.

So with this I would like to conclude todays lecture as time is not permitting. So next day I will go through one example and we will show how the net area is going to be calculated thank you.