Course on Design of Steel Structures
Professor Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 12
Module 3
Design of Plug and Slot Weld

Hello today I am going to discuss about the design of plug and slot weld in last three lectures we have discussed about fillet weld and then butt welds and I have told that three types of welds are there fillet weld, butt weld and plug weld or slot weld, now plug weld and slot weld is nothing but a type of fillet weld. As I have told earlier also that in case of plug or slot weld we are facing problem of limited distance and limited length of the joint. If the length of the joint is limited and if we have higher values of tension or compression force then it is difficult to adjust the entire length on this limited chart. So in that case we have to cut some portion of the overlapping portion in terms of slot or plug to make adjust of that additional length.

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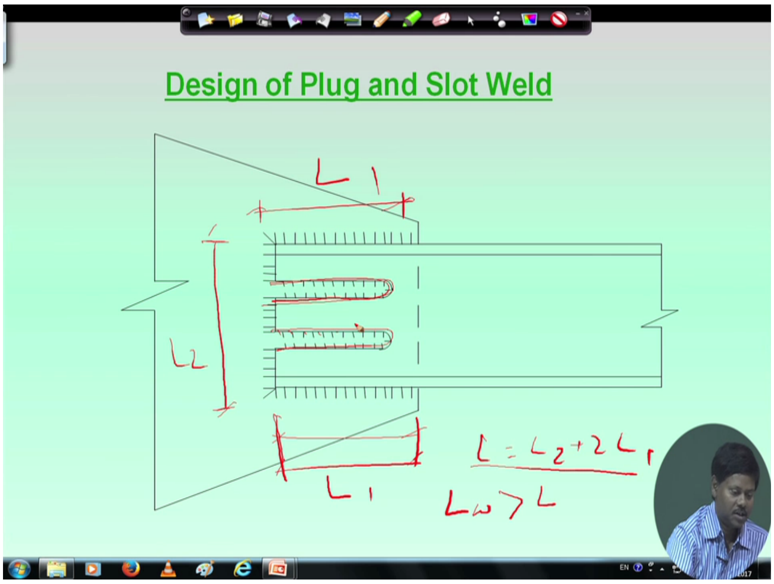

Now if we see here in case of plug or slot weld if we see here that here we have limited length say L right. So here we will get only this much length and this say if it is L1, L1 and L2 then total length we are getting L1, L2 plus 2L1 right.

So if we get the Lw value means required length is more than L then it is difficult to adjust because our length is limited, this L1 is fixed so to adjust a limited length in the limited length to adjust this we make some cut of the overlapping position. We cut some portion in terms of slot or plug and then fill with the welded material and this is how we increase the strength and accommodate the additional additional length.

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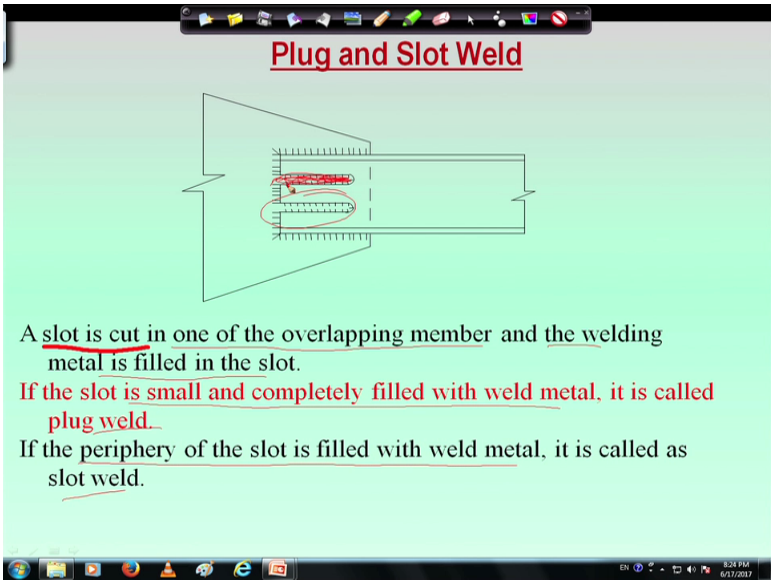

So if we see a slot is cut in one of the overlapping member and the welding metal is filled in the slot now what is slot and what is plug. When the slot is small and completely filled with weld metal then it is called plug weld that means if it is completely filled with the weld metal then this type of slot is called plug weld but if the periphery of the slot is filled with weld metal then it is called slot weld means periphery in this case periphery is filled with weld metal there so it is called slot weld but when it is completely filled with the weld metal then this is called plug weld. This is how slot weld and plug weld has a difference.

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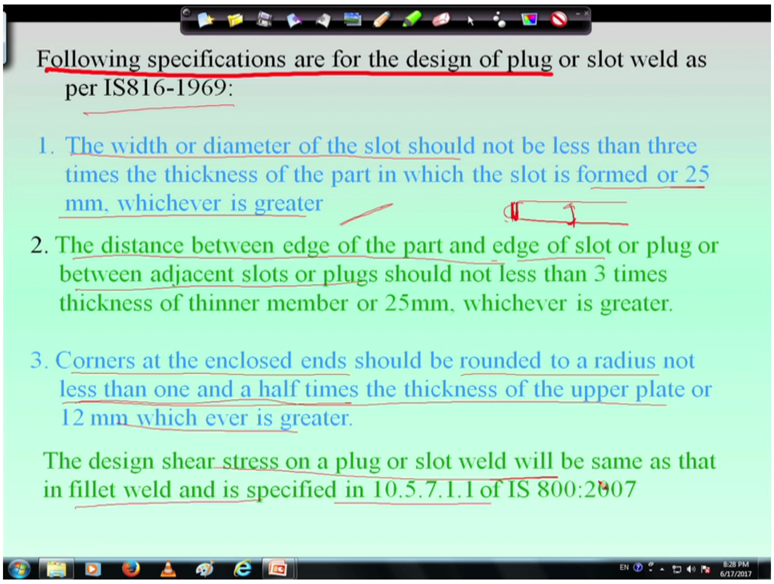

Now IS816-1969 certain specifications are given which we need to follow for design of plug or slot weld so what are the specifications we need to see which is given in IS816-1969. Say first the width or the diameter of the slot should not be less than three times the thickness of the part in which the slot is formed or 25 millimetre which is greater this we have to keep in mind that is the slot diameter or width. Slot diameter means when we are making a slot so this diameter or this is width this diameter slot diameter or width should not be less than three times the thickness of the part in which the slot is formed or 25 mm at least 25 mm.

So this diameter will be at least 25 mm or at least three times the thickness of the part in which the slot is made so this is what we have to remember and diameter of the slot has to be fixed in this way. Another thing is the distance between the edge edge of the part and edge of the slot or plug or between the adjacent slot or plug should not be less than three times the thickness of thinner member or 25 mm whichever is greater.

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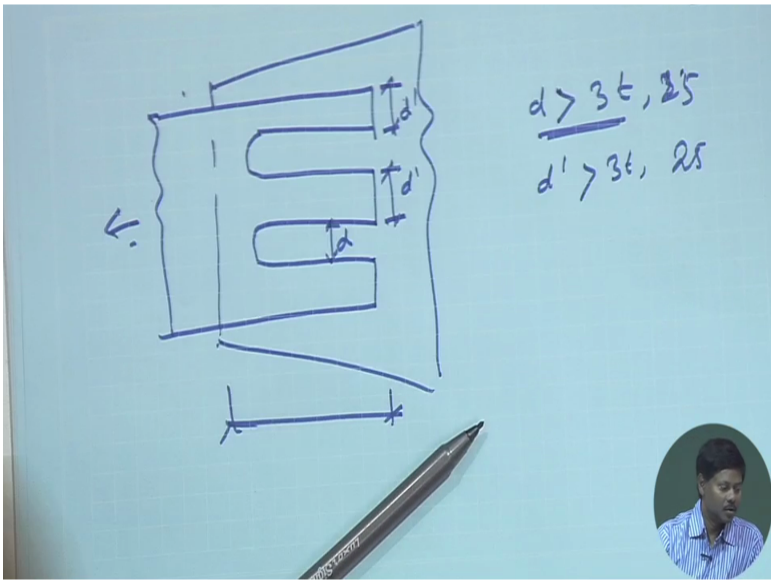

Now if we draw the things then it will be clear say suppose we have a slot here and because of this limited distance, we have to make some slot so if we see so first point is telling that the diameter or width this has to be sooner be less than three times the thickness of the plate in which slot has been done at least it should be more than three times the thickness of the plate right this is one point, second point it is telling the distance between edge of the part and edge of slot that means distance between edge of plot or edge of slot like this or adjacent to slots should not be less than three times the thickness of thinner member or 25. This is also so this distance if we say called d dash the d dash also has to be less than three times or 25 whichever is less here also three times of 25.

Then another point we have to remember corners at the enclosed ends should be rounded to a radius not less than one and a half times the thickness of the upper plate or 12 mm whichever is greater. So corner at the enclosed end means at the enclosed end we have to make the rounded corner with a radius not less than one and half times the thickness of the upper plate or 12 mm thickness whichever is greater right so these three points we have to keep in mind and the design stress on a plug or slot weld will be same as that in fillet weld and is specified in clause 10.5.7.1.1 of IS800:2007.

So as I told that design criteria will be same as we have done in case of fillet weld because this is nothing but a type of fillet weld only thing is because of limited distance we have to introduce some slot so that the additional length are adjusted.

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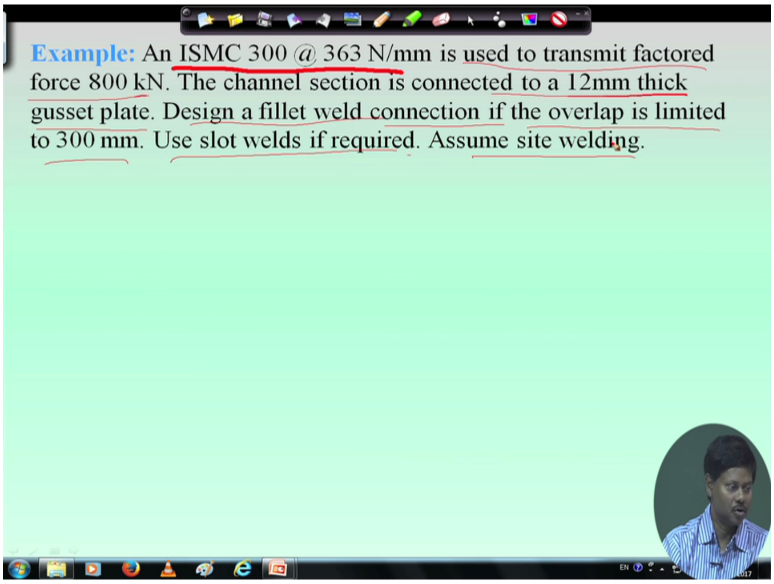

Now with this we will go through some example so that we can understand how to design a slot weld with the product provision whatever we have understood means whatever we have discussed and then we will be designing the member.

Say for this case we have a problem like this that is an ISMC300 at 363 newton per millimetre is used to transmit a factor force of 800 kilonewton. The channel section is connected to a 12 mm thick gusset plate so channel section is connected to a 12 mm thick gusset plate. Design a fillet weld connection if the overlap is limited to 300 mm. So overlap distance is limited to 300 mm we cannot make more than that so use slot weld if required and assume site welding. So with this data let us try to design the slot weld.

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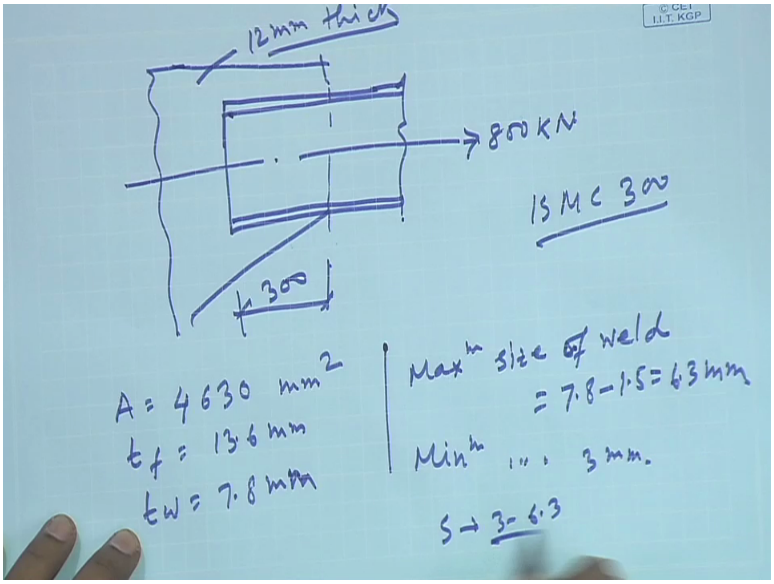

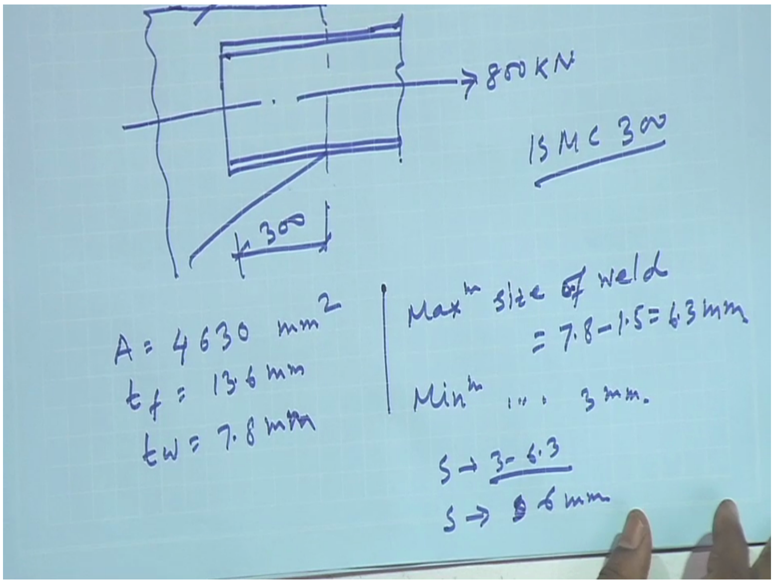

So if we see this is a channel section and say suppose we have limited distance of say this is 300 mm available distance is 300 mm means over lapping distance and it is carrying a load of 800 kilonewton, tensile force of 800 kilonewton kilonewton and ISMC300 right. This is the channel section and it is connected to a gusset plate which have thickness of 12 mm thick right now we have to design a fillet weld to adjust this.

So what we will do we will try to fast find out the properties of ISMC300 that is what will be the area say 4630 we can find out from SP 6 area is 4630, now thickness of flange is 13.6 mm and thickness of web is 7.8 mm so from this the thickness of web is 7.8 mm so maximum size of weld we can find out, maximum size which is allowed. Maximum size of weld will be 7.8 mm minus 1.5 as per clause 10.5.8.1 that will be 6.3 mm and minimum size will be, minimum size of the weld will be 3 mm from table 21.

So weld size is varying from 3 to 6.3 we can assume the size of the weld as in between say 6 mm right so size of the weld we are assuming as 6 mm.

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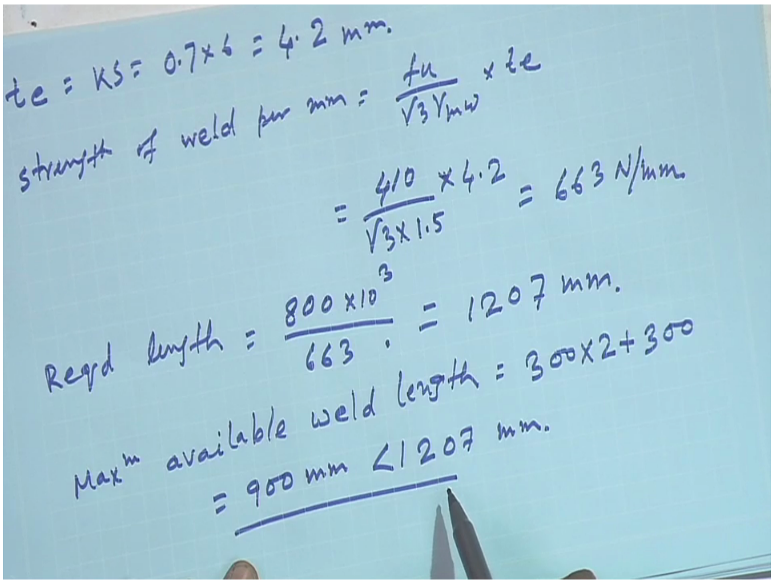

So throat thickness te effective throat thickness will be K into S that will 0.7 into 6 4.2 mm. So strength of weld per millimetre we can find out, this will be fu by root 3 gamma mw into te so that will be 410 by root 3 this is site weld so gamma mw will be 1.5 into te as 4.2 so we can find out as 663 newton per millimetre right.

So if strength of weld is known now required length we can find out required length of weld we can find out that is P by this weld strength, P is the factor load which is 800 kilonewton by weld strength 663 so from this we can find out 1207 millimetre. And maximum weld length which can be available maximum weld length maximum available weld length this will be 300 as maximum over lapping distance is 300 so 300 into 2 plus ISMC300 so depth is 300 mm, so this will be 900 mm which is less than 1207 mm so we have to put some slot weld because 900 mm is the distance which is less than the available length available sorry required length is 1207 mm and we need we need 1207 mm length and we have available 900 mm.

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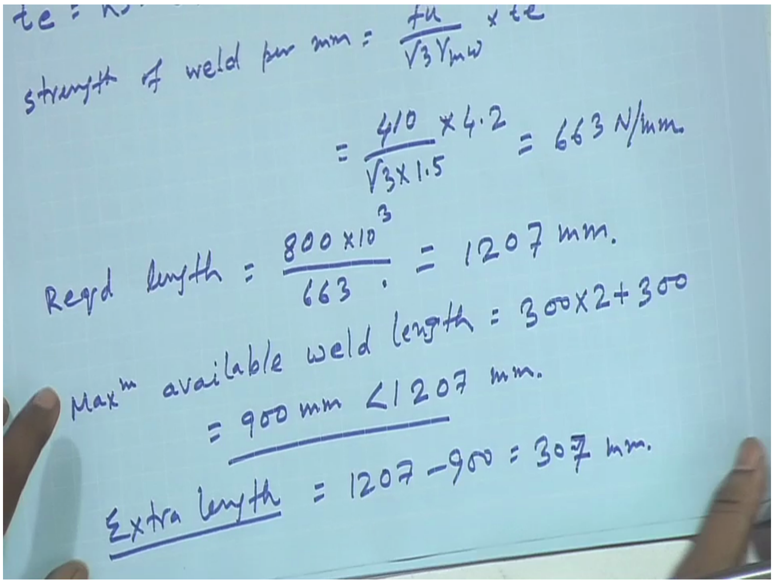

So extra length we need is additional length we have to this extra length we have to adjust that is 1207 minus 900 so 307 ok.

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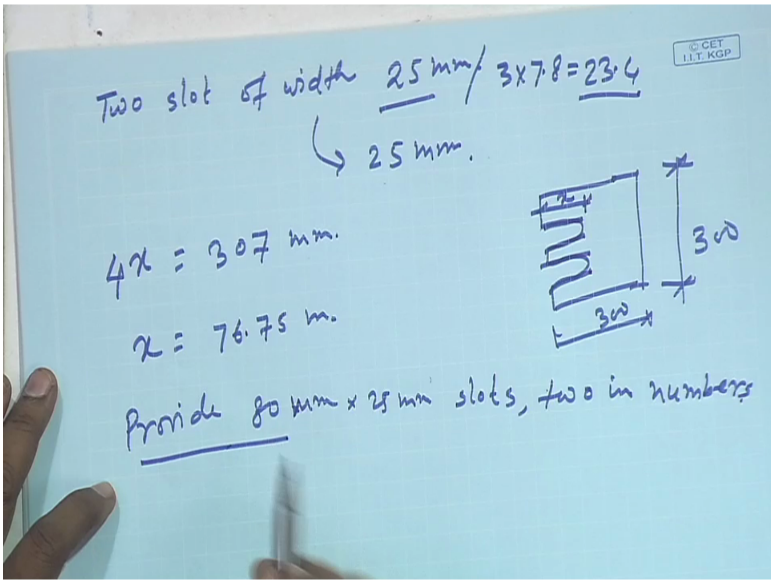

Now let us provide two slots we can provide some slots say two slot let us provide of width as we have seen from the codal provision minimum width will be 25 mm so 25 mm or 3 t 25 mm or 3 into t t is 7.8 so that is coming 23.4 whichever is greater so 25 and 23.4. So width we can find out as 25 mm right and length we can find out if if we find out length is this way if this is X right, this is 300 this is 300 and we have available length as 900 and we have to adjust additional length of 307 mm and this 25 mm width of slot if we use and if we use say 4 slot means 2 slot so there be 1, 2, 3, 4 total 4 that means additional length if this is x say 4x will be equal to 307 mm, so I can find out x as 76.75 mm x as 307 by 4 so 76.75.

So we can provide say 80 by 80 mm by 25 mm slots and this is two numbers two in numbers ok. So now this is over means when we are doing the example up to this it is fine but when we have to give for drawing we have to give the details.

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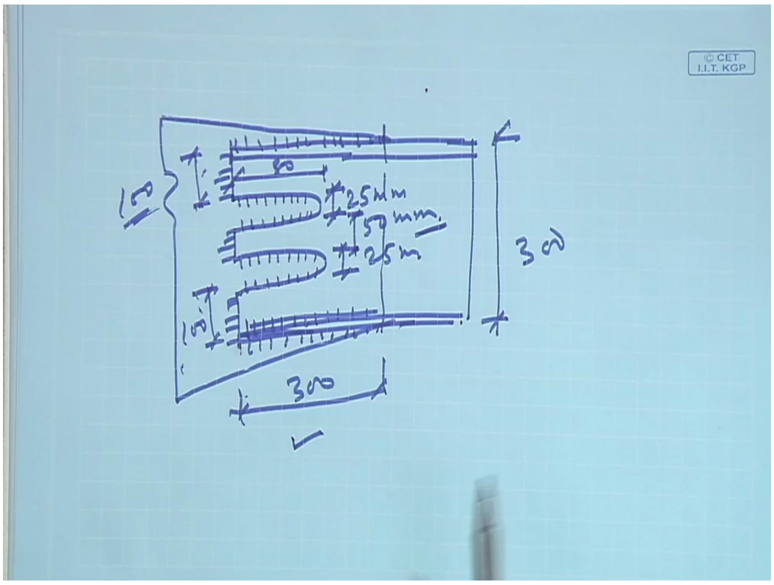

So in terms of drawing we have to make it say for example this is the slot weld say this is channel section and this is what gusset plate was, and this is 300 this over lapping distance was 300 so we are providing welding here sorry weld here.

So this distance are coming 900 and now with this we are providing distance of this x which was 80 mm, so this is 80 80 mm and we can as we have calculated this is 25 mm diameter of slot or width and this total is 300 so we can provide a at least a distance of 50 mm and so 50 plus 25 plus 2500 so here we can provide 100 mm and here also we can provide 100 so this this this will be the distribution or we can change means we can increase this value and decrease this also or equally we can distribute. So this will be the sketch of the slot weld and we have to provide to the site engineer in terms of this right. So this is all about the design of slot weld or plug weld.

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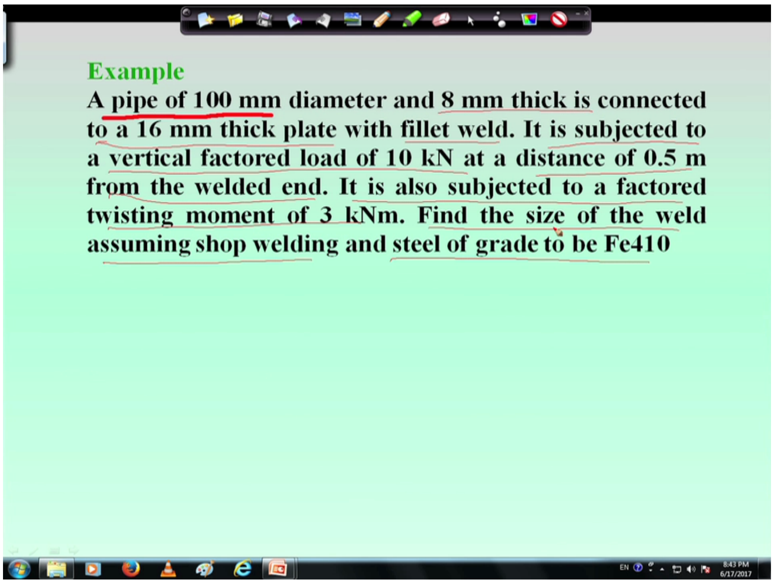

Now as we have time will through another example which I have discussed in last lecture In case of butt weld or in butt weld lecture we have discussed that is how to calculate the equivalent stress of the weld joint means when it is under shear and normal stress or shear or bearing and normal stress. So how to check that design strength of the joint when it is subjected to axial tension or compression bending and shear, so I will go through one example with this.

Example is this that, A pipe of 100 mm diameter and 8 mm thickness is connected to a 16 mm thick plate with fillet weld it is subjected to a vertical factored load of 10 kilonewton at a distance of 0.5 metre from the welded end. It is also subjected to a factored twisting moment of 3 kilonewton metre. Find the size of the weld assuming shop welding and steel of grade to be 410, so this is the problem will be going to solve.

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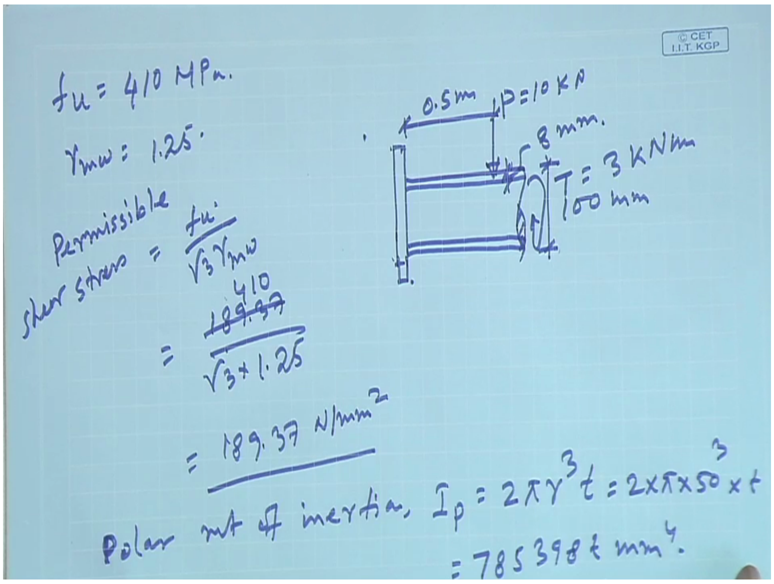

So if we draw the diagram let us see that a pipe is attached to a steel plate and the diameter of the pipe is given, diameter of the pipe is at 100 mm diameter and this thickness, thickness was 8 mm 8 mm thick pipe of 100 mm diameter and a load is acting say P of 10 kilonewton acting at a distance of 0.5 metre 0.5 metre distance it is acting and another twisting moment a twisting moment is also acting in this direction so T is equal to 3 kilonewton per metre 3 kilonewton metre, so twisting moment is also acting right so now we have to find out the equivalent stress and we have to check whether the weld joint whatever has been made is ok or not right.

So here first we will find out as the grade of steel Fe410 so fu we can find out at 410 Mpa and for shop welding gamma mw is 1.25, so permissible stress permissible stress, stress means shear stress will be fu by root 3 gamma mw this will become 189.37 by root 3 into gamma mw is 1.25 this is becoming 189.37 sorry this is 410 189.37 newton per millimetre square. So permissible shear stress of the weld has been calculated as 189.37.

Now here we have to find out the polar moment of inertia also polar minimum moment of inertia can be calculated as Ip for circular pi it would be 2 pi r cube into t if t is the throat thickness or effective thickness of the weld then we can find out 2 into pi into r means here it is 50 into t, so this will be 785398 t millimetre to the power 4. So polar moment of inertia we can find out.

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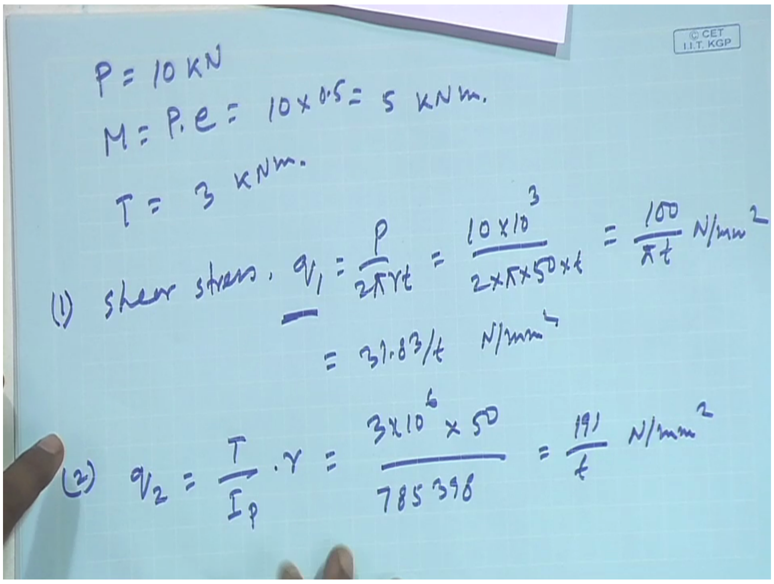

Now also because it will be means the pipe will be under twisting moment under moment and under shear means this weld joint. So three types of stress will come into picture one is due to moment another is due to shear and another is due to torsion or twisting. So first we will try to find out so here three type of forces are there one is direct load that is 10 kilonewton which will act as a shear to the weld another is moment it is P into e that will be 10 into 0.5 so this is 5 kilonewton metre this moment and twisting moment was given three kilonewton metre right.

Now we can find out the stresses say for example first shear stress shear stress shear stress due to direct load so q1 I can find out that will be P by 2 pi r t, so this will be 10 into 10 cube by 2 into pi into r into t so this is coming 100 by pi t or 31.83 by t newton per millimetre square. So shear stress due to direct load we can find out next we will find out the shear stress due to twisting moment shear stress due to twisting moment q2 I can find out as T by Ip into r, so T is 3 into 10 to power 6 newton millimetre, r is 50 and Ip is 785398. So I can find out as 191 by t newton per millimetre square.

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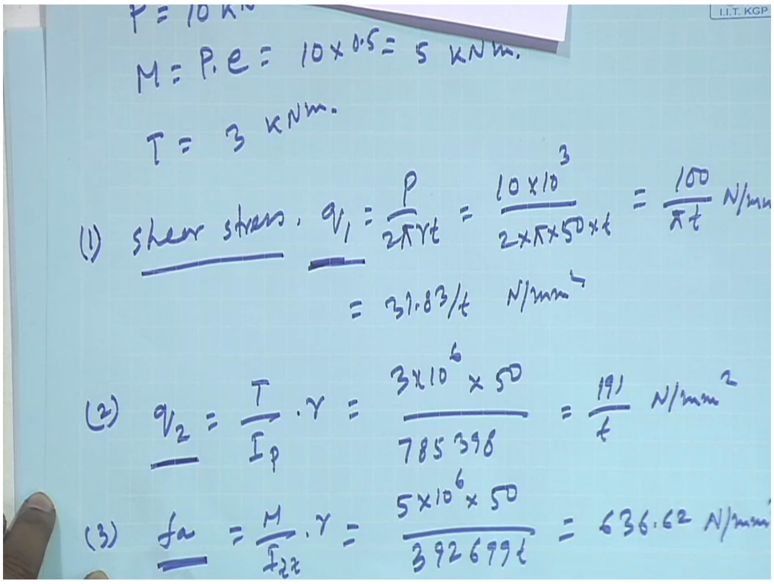

Then another stress will come that is normal stress due to bending. Normal stress due to bending that is M by Iz into Y Y in this case it is maximum will be r so M we have calculated as 5 kilonewton metre that is 5 into 10 to the 6, r is 50 and Izz we have calculated which is Ip by 2 so that is 392699 t. So this is becoming 636.62 newton per millimetre square ok. So shear stress due to direct load shear stress due to twisting and normal stress due to bending has been calculated, so three types of stress are acting together.

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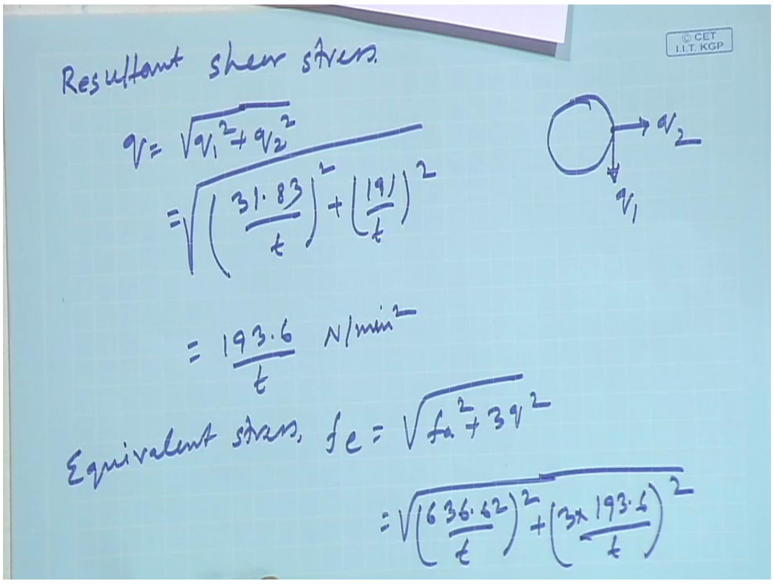

Now we have to find out the equivalent stress. Now first we we find out the resultant stress resultant shear stress shear stress, resultant shear stress q will be basically root q1 square plus q2 square because in the circular pipe, one shear stress is acting along this due to normal force P and due to torsion another stress is acting in this way.

So resultant stress means this is q1 and this is q2 then q the resultant shear stress will become this q1 is 31.83 by t plus 199 by t right. So from these we can find out as 193.6 by t newton per millimetre square this is the shear stress and we have normal stress so equivalent stress, equivalent stress fe we can find out that will be fa square plus 3 q square so if we put this value we can find out fa was 636.62 by t plus 3 into 193.6 by t square, so this will be the equivalent stress.

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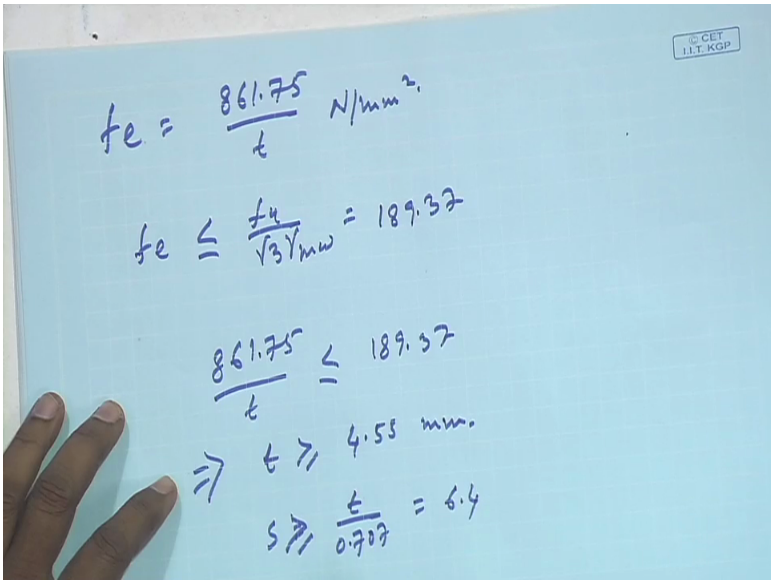

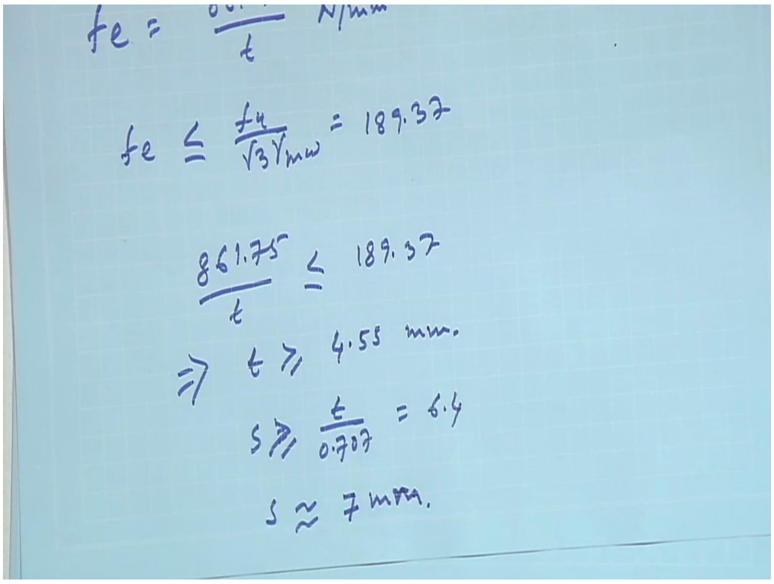

So equivalent stress if we calculate will get this value as fe as 861.75 by t. Now this fe has to be less than the weld strength means allowable strength in weld so if we make equal then we can find out the value of t right. So this fe should be less than or equal to fu by root 3 gamma mw that means this is 189.37. So 861.75 by t should be less than or equal to 189.37 so from this I can find out t should be greater than equal to 4.55 mm or S should be greater than equal to t by 0.707 that means 6.4, so S we can find out as S we can find out as 7 millimetre.

So the size of the fillet weld we can consider as 7 millimetre right if we provide size of the weld as 7 millimetre then the joint can with stand the external load whatever it has given. So in this example what we have seen that we have shear stress and normal stress, we have two types of shear stress so shear stress we have made equal and we have also normal stress then we found the equivalent stress and it has to be less than the weld strength which is 189 newton per millimetre square and from that criteria we can find out the minimum required weld size and in this case we can find the size of weld has to be at least 7 mm right.

So in this few lectures we have discussed about the different type of connections starting from rivet connection to bolted connection and then finally weld connection again weld connection, fillet and butt weld has been discussed and design criteria has been discussed how to calculate the design strength of the fillet weld and butt weld these things we have discussed and accordingly we have solved certain number of examples, I hope this will clear the it will clear or designing methodology how we have done and we will be able to design different type of joint using bolt or weld, thank you very much.