Course on Design of Steel Structures
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Lecture 54
Module 11
Purlins

Purlins are basically a flexural member in which transverse load comes into picture, in case of purlins the moments from both the axis come into picture as a result purlins are need to be designed by biaxial moment. So we need to check the bending moment carrying capacity in both the means against both the axis and then we have to check the interaction formula so that the purlin is designed and these purlins are basically connects the trans members in the roof structure to support the roof seeds and other materials and these purlins are are placed on the rafter.

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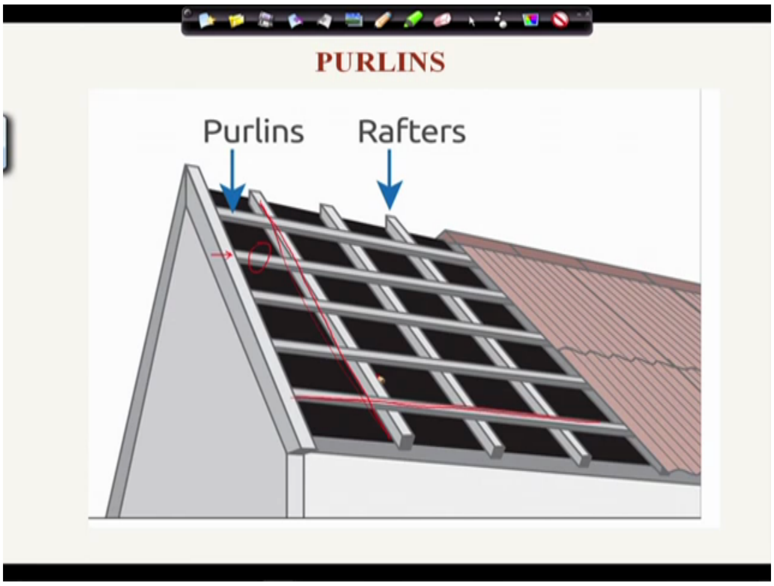

Let me show a picture through which we can see that if this is a roof truss then we can see that trusses are connected with this purlin member, these are the purlin members and these purlin members are placed on the rafter, this member is called rafter and the between two (purlin) two truss members purlins are connected and if you see these purlins are in an inclined means are placed in an inclined position and these purlin sections are basically means whatever we use is channel section or angle section because load is quite less and as a result we generally provide some lighter section like channel or angle section, sometimes also we use I section also.

Now we will see how to place the channel section or, how to place the angle sections in a inclined roof that we will see which is the recommended configuration.

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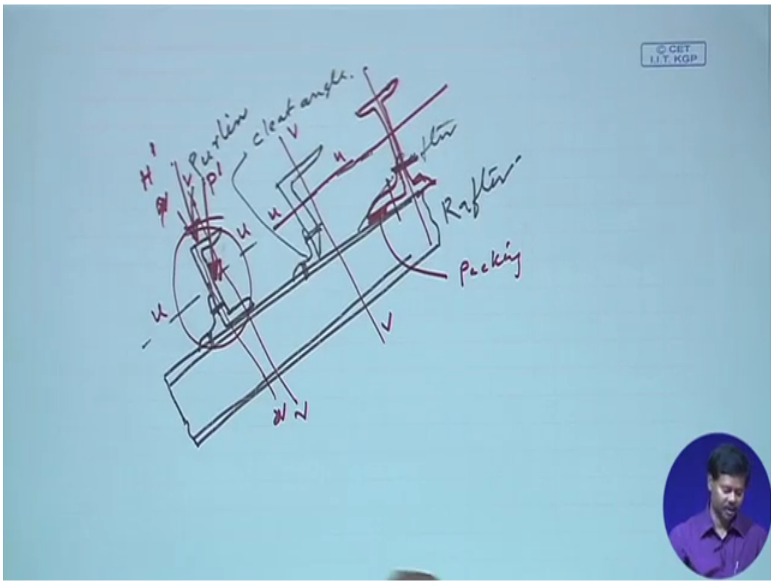

So now if this rafter is like this which has slanted say this is end section, say I section we have a rafter then the if we use channel sections we can use in this way not in the reverse way. So its flange will be towards up, right so this will be the axis and similarly if we use say now we have to connect this purlin to rafter with some angle section in this direction, so this is connected like this so here we can provide bolt or weld and here we can provide bolt or weld. Then we can make the connection between the rafter and the purlin.

And if we use say for example angle section then angle section should be placed like this angle section should be placed like this where it will be connected with another angle to the rafter through this, right so which is called cleat angle, so this is called cleat angle and this is rafter, this is purlin and the load will be coming one is the load which is the wind load on the roof, so wind load we assume that it is normal to the roof it acts wind load acts normal to the roof and the gravity load due to self-weight and snow load or other sort of load are acting vertically downward, right so this is one load and another load is this.

So this is say H dash the wind load which is coming perpendicular to the axis of the purlin and the vertical load which is due to dead load and other snow load and other loads dust load etc so that is vertically downward say may be we can write as P dash, right. And this we can use as u-u axis and this we can use along the direction say this is v-v axis, right this is the v-v and in fact this will go through this means cg of this v-v axis, right. Similarly here it will be like this some as here like this u-u and v-v.

Similarly I sections also we can provide I sections maybe we can provide like this say for example this is an I section which we can provide where u-u axis will be this and v-v axis will be this and in case of I sections the angles will be means provided the cleat angles will be provided with the help of packing say for example this we can provide like this and this will be packing, this is called packing and we can connect this.

So this is the recommended configuration for purlins and as I told that reverse direction we do not generally recommend.

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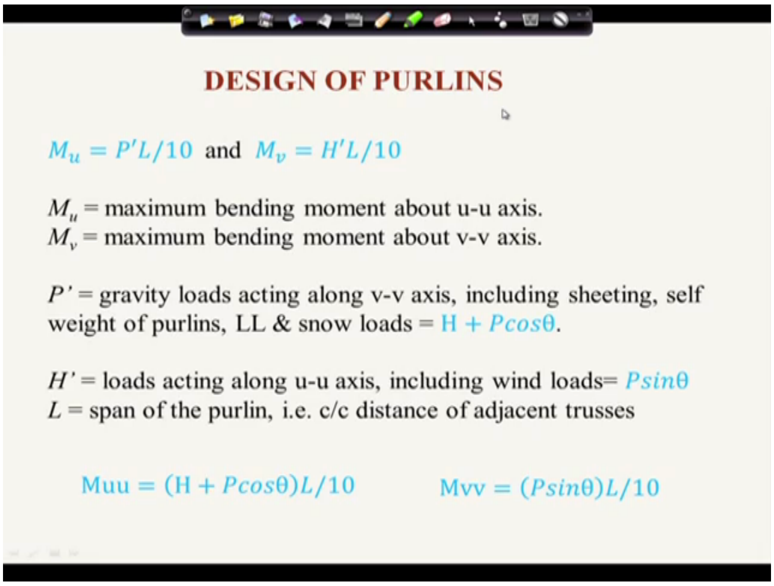

Now for purlin design we need to know what are the load coming into picture.

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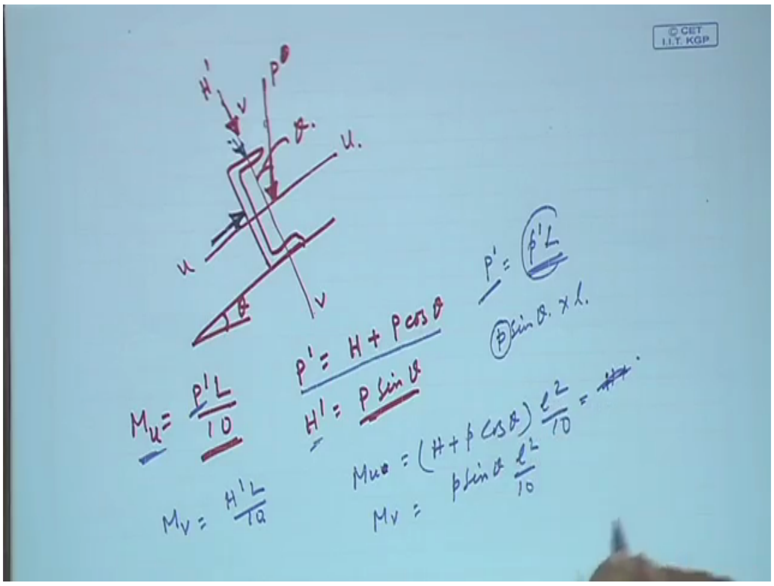

So if we see for an example say for channel section if we see here that load is basically two type one is the wind load which are acting perpendicular to the roof we assume that winds are acting perpendicular to the roof H dash and another is acting vertically downward vertically downward that is due to self-weight, dead load, snow load, etc this is P dash, right. So the the purlins are assumed that means the codal provision says that we should design purlin as an continuous beam because purlins are connected the truss members in different places and it is assumed as continuous beam.

So the moment can be calculated as P dash by P dash L by 10, where P dash is the gravity loads acting along v-v direction v-v means this is the v-v, right and this is u-u so P dash is the gravity loads acting along the v-v axis and which includes the sheeting self-weight of purlins live load and snow load, right. So M we can the moment u we can calculate as P dash L by 10, where P dash can be written as horizontal load due to wind plus P cos theta because if this is theta this angle of inclination is theta then we can consider this value as theta. So the P dash value will become so sorry this is P so H plus P cos theta.

Similarly I can write the H dash value as P sin theta, this is basically the along u-u axis so this will be this will be along u-u axis and this will be along v-v axis, right. So we can find out P dash as H plus P cos theta and H dash as P sin theta, therefore we can write Mu as P dash L by 10, and Mv as H dash L by 10, right. So here P dash is basically the concentrated load at the center or we can write that P dash into L that means uniformly distributed load into L total load so P dash is the total load which we can also tell as P dash L.

Similarly H dash is the total load which can be also written in terms of P sin theta means into L if P is the uniformly distributed load. Therefore we can also write Mu as H plus P P is the uniformly distributed load P cos theta into l square by 10 and Mv is equal to P sin theta into l square by 10, right so or I can write H plus means if it is concentrated load then I can write total load into l by 10, so in this way we can find out the moment carrying moment acting on the member along u-u and v-v direction.

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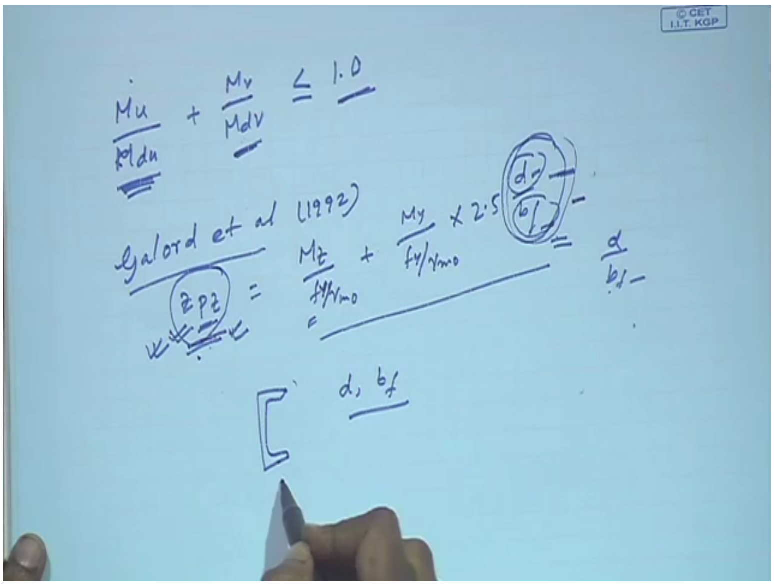

And for biaxial moment we need to check this interaction formula that is Mu by Mdu plus Mv by Mdv should be less than equal to 1, where Mdu is the design bending moment about y-y axis and Mdv is the design bending moment about v-v axis. So once we calculate the design bending moment about u-u axis and v-v axis then I can find out the interaction formula and which needs to be less than 1.

Now question is how to find out the initial section size of a purlin member because purlin is going to be act due to means purlin is going to withstand the load horizontally and vertically and because of that the bending moment will come into picture in both the direction u-u axis and v-v axis, right. So now we we have to find out certain section size to start the design and we do not know what should be the basis of the section size selection.

So here Galord et al Galord in 1992 has made a formula where we can find out the plastic section modulus Zpz as Mz by fy by gamma m0 plus My by fy by gamma m0 into 2.5 into d by bf. So approximate section modulus required for the section can be calculated from this formula which is suggested by the Galord et al in 1992. So here Mz is basically the factored bending moment about z-z axis and My is the factored bending moment about y-y axis and fy is the yield stress of the material and d is the depth of the section and bf is the width of the section. So considering this I can find out Zpz.

Now again here you see if we do not know the section size then we do not know also d and bf, okay again if we have to know the d and bf that means we have to know the section size. So here it is a tricky that how do I find out Zpz unless I know the section size I cannot know the value of d and bf and if I do not know d and bf then I cannot find out the Zpz to find out the approximate section size.

So what we can do we can assume certain d and bf at the initial, right and we know for built up section, sorry for rolled section what is the approximate bf and d and bf ratio either we can consider certain ratio to start with and we can find out Zpz value or we can assume certain d and bf value and then on the basis of that we can find out Zpz value and once we find out Zpz value we can find out a particular section say channel section, or I section, or angle section, or whatever we need and its size. So once we know the size of the section we can find out what is the d and what is the bf.

So after knowing this (df) d and bf we can find out what is the actual requirement Zpz okay and whether it is satisfying that or not, right so in this way we can start the things and it will be clear if we go through the steps what we need for design of the section.

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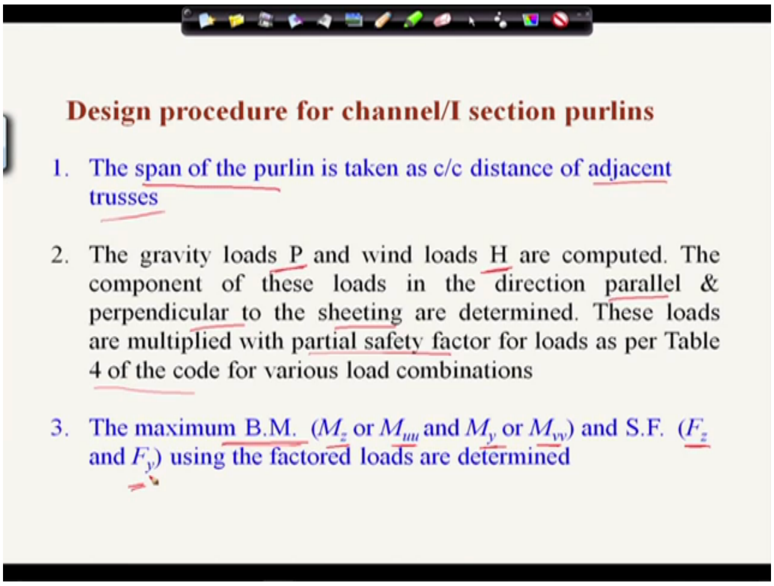

Say for example to design a channel section or I section is different the design procedure for angle section, so first we will discuss about the design procedure of channel section or I section and in case of channel or I section what we can start that first we will find out what is the span length of the purlin, right. So once we know the span length from the center to center distance of the adjacent trusses then I can find out the gravity load the total gravity load acting on the purlin P and wind load H that we can compute, right.

And the components of this loads in the direction parallel and perpendicular to the sheeting are determined so that means along u-u and along v-v axis we can determine the load and these loads are basically service loads, these are multiplied with partial safety factor to find out the factor load which the factor load to find out the factor load we can find out the load factor in table 4 of the code for various load combination.

So after finding the factor load along u-u and v-v direction that means parallel to the roof and perpendicular to the roof once we find out the factor load I can find out the maximum bending moment that will be that can be find out that is P dash L by 10 or P dash L square by 10, right. So maximum bending moment Mz or here we will say Muu and similarly we can find out My or Mvv we say here Mvv and similarly maximum shear force Fz and Fy, right so maximum bending moment, shear force in different directions we can find out.

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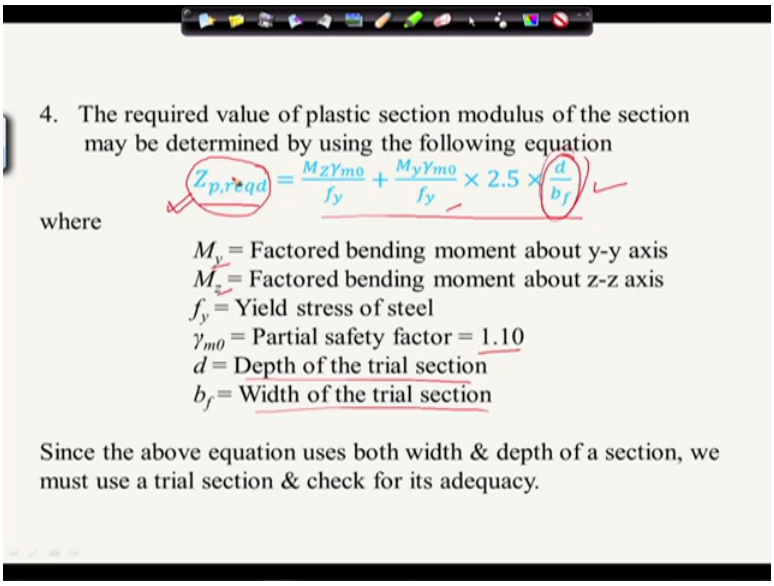

After that we can find out the approximate section modulus required that is Zp required that will be calculated from this formula which was suggested by Galord in 1992 that is Mz gamma m0 by fy plus My gamma m0 by fy into 2.5 into d by bf, where My we know the factored bending moment about y-y axis, similarly Mz is the factored bending moment about z-z axis, fy is the yield stress, gamma m0 is partial safety factor for the material which we generally take 1.1 and d is the depth of the trial section and bf is the width of the trial section.

And I have told to find out Zp required we have to assume certain d and bf because here unknown is this as well as this, so unless we assume certain things we cannot find out the Zp required. Therefore we preliminary assume certain d and bf and then we will find out the approximate plastic section modulus required, right.

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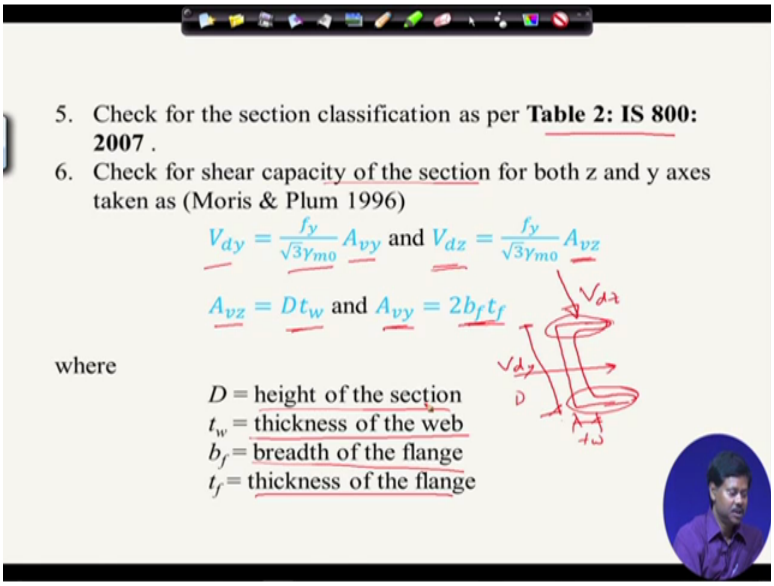

And then next step we will assume certain section size based on the Zpz required and then we classify the section as per table 2 whether it is plastic or compact or semi compact according to that we have to then design, right. So once we find this then what we can do we can find out the shear capacity of the section say Vdy and Vdz, right. So Vdy will be fy by root 3 gamma m0 into Avy and Vdz will be fy by root 3 gamma m0 into Avz because here design shear strength has to be calculated for both the direction that means here we have to calculate and here we have to calculate this is Vdz and this is Vdy in this direction, right.

And for calculating the shear capacity we need to calculate the area web area that is Avz and Avy, Avz will be D into tw that means depth if this is depth and if this is the thickness of the web then D into tw will be Avz cross-sectional area along z-z direction and Avy is the cross-sectional area about y-y direction that is bf into tf into 2, this is the area bf into tf and in 2 sides it is the so Avy will be calculated as Avy as 2 into bf into tf, where bf is width of the flange, tf is the thickness of the flange, tw is the thickness of web and D is the height of the section.

So from these dimensions we can find out the Avz and Avy and then we can find out the shear capacity of the section in Z axis and Y axis.

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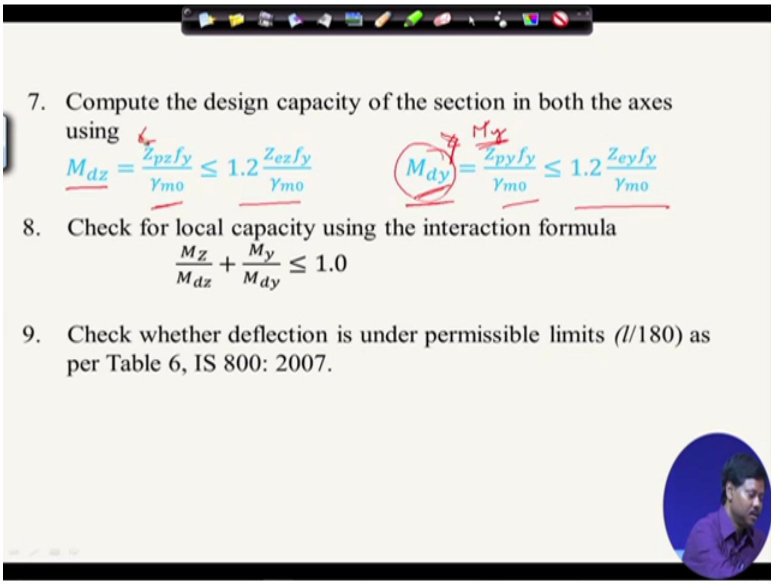

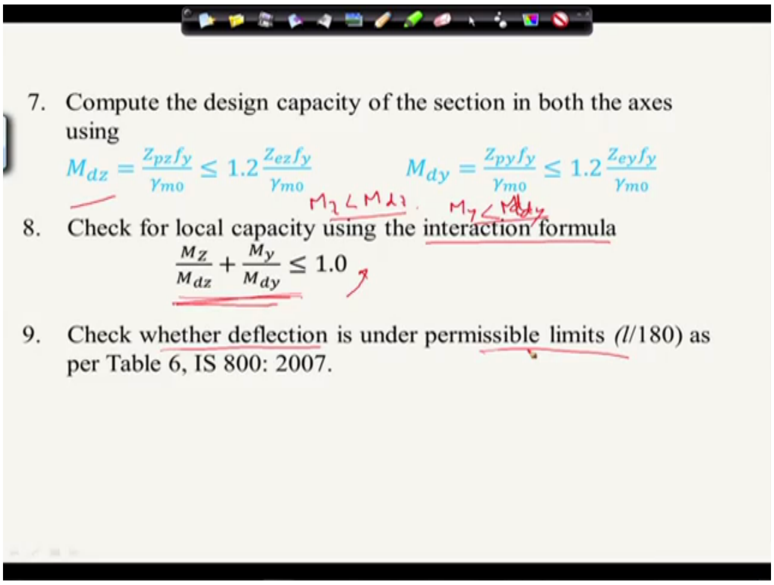

Once this is done we can now find out the design capacity in both the direction design capacity about z-z direction Mdz can be found as Zpzfy by gamma m0 and it has to be less than or equal to 1.2 into Zezfy by gamma m0. Similarly Mdy the design capacity about y-y axis we can find out as Zpyfy by gamma m0 and it has to be less than 1.2 into Zeyfy by gamma m0. So Mdz and Mdy we find and this (())(22:05) to mention that this Mdy should be less than the My value or Mu, right and this should be less than sorry this should be greater than My because this is design capacity and this is the external moment.

Similarly Mdz should be greater than the Mz whatever moment is coming, right so that has be checked that means we have to check that Mz is less than Mdy, Mdz and My should be less than Mdy. Now if it is not satisfying this criteria then we have to increase the section size and after increasing the section size again we have to go through the same exercise that means we have to repeat the same and we have to find out again the design capacity of the section both for shear and moment, right.

So unless this satisfy this criteria we have to go on increasing and if satisfies then we can go for checking local capacity using interaction formula. So interaction formula means that Mz by Mdz plus My by Mdy should be less than or equal to 1 because for biaxial bending moment we have to check the interaction formula and we have to fulfil this criteria. So if this again if we see that Mz is less than Mdz and My is less than Mdy but it is not satisfying then again we have to increase the section size because the biaxial bending moment as biaxial bending moment is coming so we need to check for the interaction formula and we have to satisfy this criteria.

So once this is satisfying then fine otherwise we need to increase the section size and again we have to repeat and once it is satisfied then we will go for step 9 where we have to check for deflection and we have to check whether the deflection is under the permissible limit, okay. So as per table 6 we have to check whether the deflection is under permissible limit or not and if it is okay then the section whatever we have consider is fine otherwise we have to again redesign. So this is how the channel section or I section for purlin member can be designed under biaxial bending moment, okay.

And we will be clear means it will be easier to understand if we go through one example, before going to that example again I will discuss about the angle section how to design a purlin using angle section and in case of angle section we generally use some empirical directions to find out the angles means section size of the angle section.

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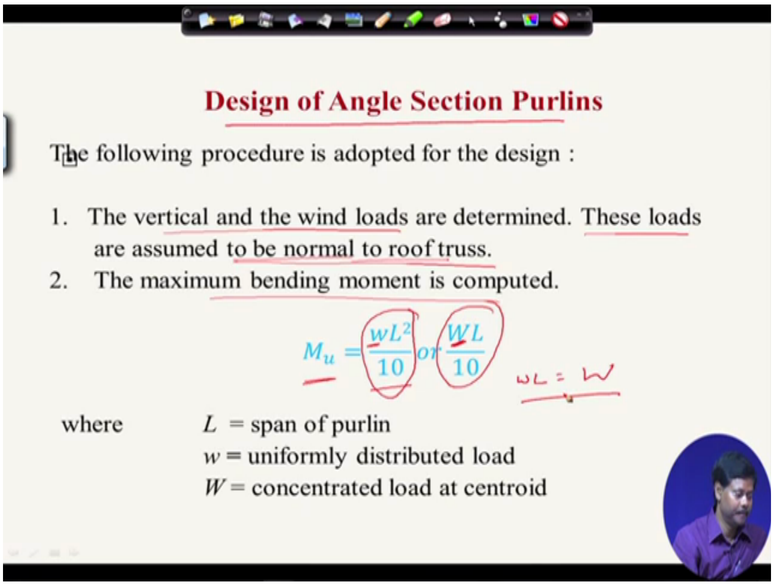

So let us see the step which we use for this the design for design of angle sections for we will follow these steps that is first we will find out the vertical and wind loads which are acting on the truss member on the roof truss then we will find out the value normal to this truss and parallel to this truss, right. Now wind loads are assumed to be normal to roof truss and gravity loads are vertically downward.

Then we can find out the maximum bending moment, okay well before that let me tell you that this vertical load also for design of angle section we are assuming that that is normal to the roof truss, right. So simply we are making approximate calculation so approximately we are assuming that all the loads are to be normal to the roof truss, so if it is so then we can find out Mu value as simply wL square by 10 or WL by 10, right where w is the uniformly distributed load and capital W is the concentrated load at center, right.

So maximum bending moment can be computed for angle section as this small w into L square by 10 or capital W into L by 10 where small w into L is equal to capital W, total load is equal to uniformly distributed load into length of the purlin. So once we find out maximum bending moment then we can find out the required section.

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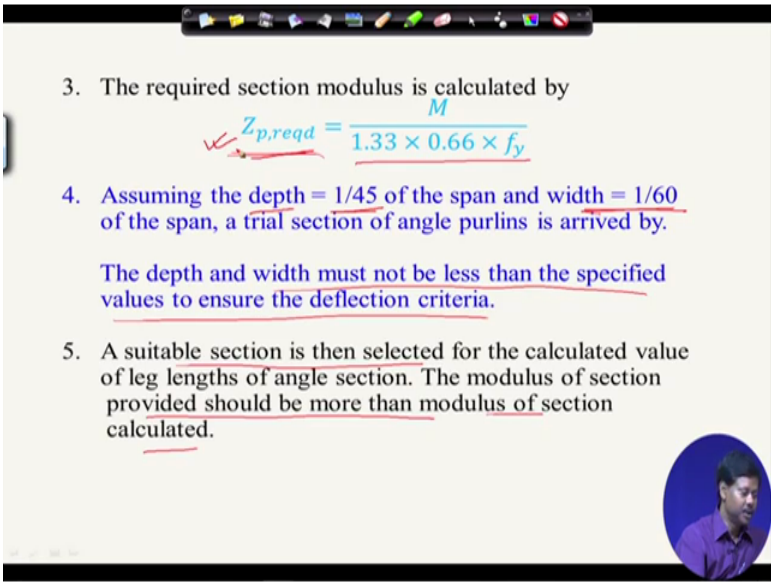

So for finding the required section we can use this formula which is given by the code where Zp required the section plastic modulus plastic section modulus will be M by 1.33 into 0.66 fy. So Zp required we can find out, right. Then we can assume certain relation means the depth of the angle section we can assume 1 by 45 of the span and width as 1 by 60 of the span to start with the trial section of the angle for the purlin, okay.

So the depth and width are assumed on the basis of 1 by 45 of the span and 1 by 60 of the span and then with certain thickness of the angle section we have to arrive this Zp required. And you see the depth and width must not be less than the specified values to ensure the deflection criteria, okay to ensure the deflection criteria we should not make less than this the specified value, okay.

So after that a suitable section now we can select to calculate the value of leg lengths of the angle section and the modulus of section provided should be more than the modulus of section calculated. So we have required section is this and on the basis of assumed section we have calculated the section modulus which should be more than the required one. So in this way one can decide the section size of the angle for purlin, okay. So this is how one can design the angle section.

So for purlin we have seen that generally we use either channel section, I section or angle section and most commonly we use channel or angle. So the design criteria for channel sections are discussed similarly the design criteria approximate design criteria for angle section to use as a purlin member are also discussed. So on this basis the design of the member should be carried out and in next class we will go through one example to understand how to design the purlin section, thank you.