Design of Steel Structures
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Module - 7
Gantry Girders and Plate Girders
Lecture - 4
Introduction to Plate Girders –Part 2

Hello, today our lecture will be the continuation of the previous lecture. Previous lecture I was discussing about the plate girders. In fact, as I was telling the plate girders has several components. So, it is very difficult to discuss all the things in a short period. So, today I will give the remaining part of the plate girder things right. So, last day up to the design of flange of the plate girder has been discussed. Again plate girder means 2 type of plate girders are there 1 is riveted plate girder riveted joint plate girder and another is welded welded plate girder.

So, I was discussing about riveted plate girder. So, here some components I will exclude from the riveted plate girder and I will discuss in case of welded joint plate girder. Some components means I have showed yesterday means last lecture that what are the components are required to design a complete plate girder. What are the components let us just have a look.

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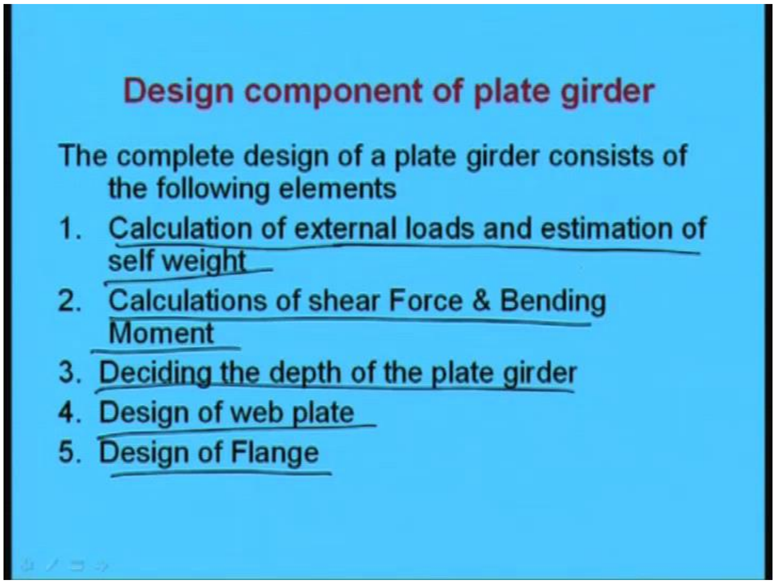

That is say one is calculation of external load and estimation of self weight this we have discussed right, then calculation of shear force and bending moment; then deciding the depth of plate girder. Then design of web plate and then design of flange. These are things which we have discussed. Now, we will discuss remaining part.

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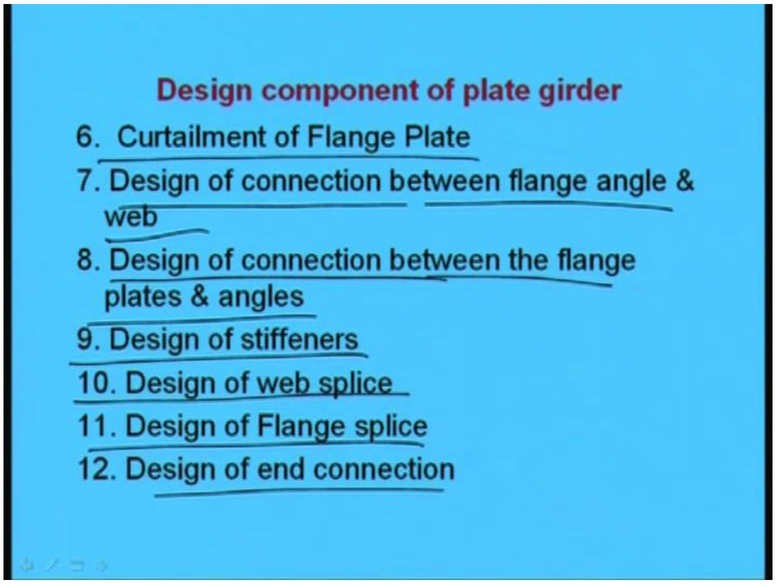

Like curtailment of flange plate. And then design of connection between flange plates and web. And design of connection between the flange plates and angles design of stiffeners. Design of web splices, flange splice and end connections. So, some of these part we will discuss with reference to riveted plate girder and some of them we will discuss later in case of welded plate girder which are similar almost right.

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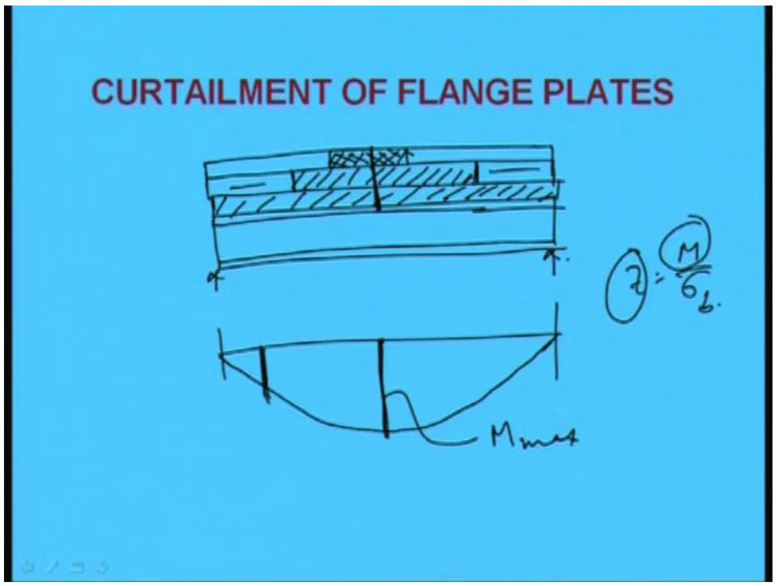

So, first we will discuss about the curtailment of flange plate why curtailment is required. In fact, in case of discussion of beam design there I have shown how the curtailment has been derived means curtailment length has been derived and how it is affected to get economic design right. Just let me give an small overview. Say this is a beam if you seen what would happen now why curtailment is required. Because if we have a huge load then say suppose we have a UDL load then how the bending moment will develop. Bending moment will develop sorry bending moment will develop like this parabolically right.

So, the maximum moment is developing here maximum right. Now, when we are going to design the plate girder we generally design with the maximum moment. So, on this basis we are going to design. And on this basis we are going to provide the additional plate right additional plate we maybe going to provide right. But this much additional plate is required in this section, but is it required here. Because the moment is less as it is parabolically varying. So, moment is going to less. So, is it really required here?

So, it is not required because moment is less. So, the section modulus is nothing but, M by sigma b right. Now, section modulus will be less if M is becoming less. So, what we can do we can make some curtailment may be after some distance we will provide up to this only. So, your first rate will provide throughout in generally plate girder we will provide 1 plate we provide throughout then say we can curtail here. That means here this portions we are not going to take this portion we are not going to take right.

Then may be here maximum is there. So, we are that plate we have curtailed here right. So, this will be another plate. So, in this way we can make a plate girder with heavier section at the middle and lighter section at the side. And we can reduce the depth of the plate girder towards the support if it is simply supported beam right. So, in this way we can make.

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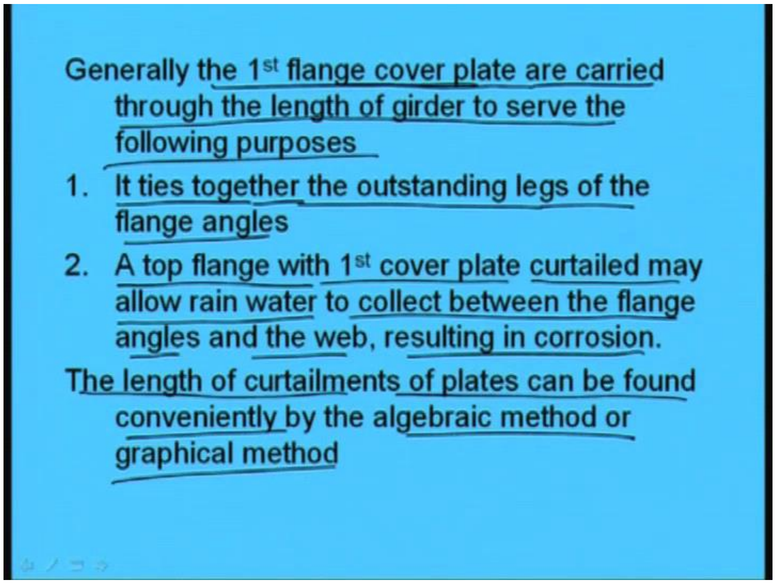

Now, generally the first flange as I was telling first flange cover plate are carried through the length of girder to serve the following purpose what are those purpose. 1 is it ties together the outstanding legs of the flange angles it ties together the outstanding legs of the flange angles. And second is a top flange with first cover plate curtailed may allow rain water to collect between the flange angles and the web resulting is corrosion. So, for this 2 reason generally first flange cover plate are used throughout the span.

The length of curtailments of plates can be found conveniently by algebraic method or graphical method. There are 2 methods; we have one is algebraic method, and another is graphical method through which we can find out the length of curtailment right.

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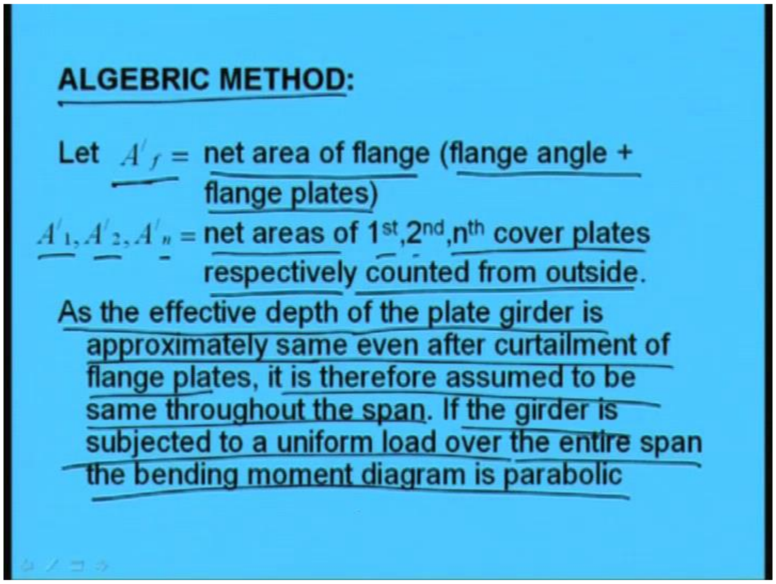

Now, let us first discuss about the algebraic method. In case of algebraic method say let us consider say A dash f is the net area of the flange; that means, net area of flange means flange angle plus flange plates. Net area means the area minus rivet hole right. And let us consider A 1 dash A 2 dash like this An dash are the net areas of the first second and nth cover plates respectively counted from outside.

So, A 1 A 2 A 3 A 4 the number of plates how much we are going to provide we are giving them name as A 1 dash A 2 An dash like this means plate area, we are considering like that. So, as the effective depth of the plate girder is approximately same even after curtailment of flange plates it is therefore, assumed to be same throughout the span. If the girder is subjected to a uniform load over the entire span the bending moment diagram is parabolic as I was telling. In that case what will happen?

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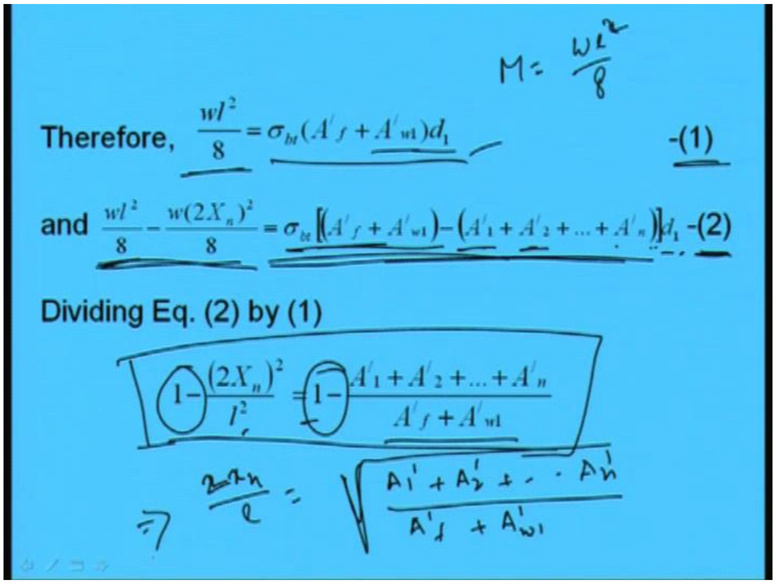

We know bending moment will become. So, wl square by 8 maximum bending moment will become wl square by 8. And that has to this is the external moment which is coming has to be carried by the plate. So, moment of resistance will become sigma bt into A dash f plus A dash w 1 into d 1 right. The terms which already we have used in last lecture similarly we will use here right. Now, we can write also wl square by 8 minus w into 2 Xn whole square by 8 is equal to this sigma bt into A dash f plus A dash w 1 minus A 1 dash plus A 2 dash plus up to n. Where A 1 dash A 2 dash I have told already net areas of respective cover plates.

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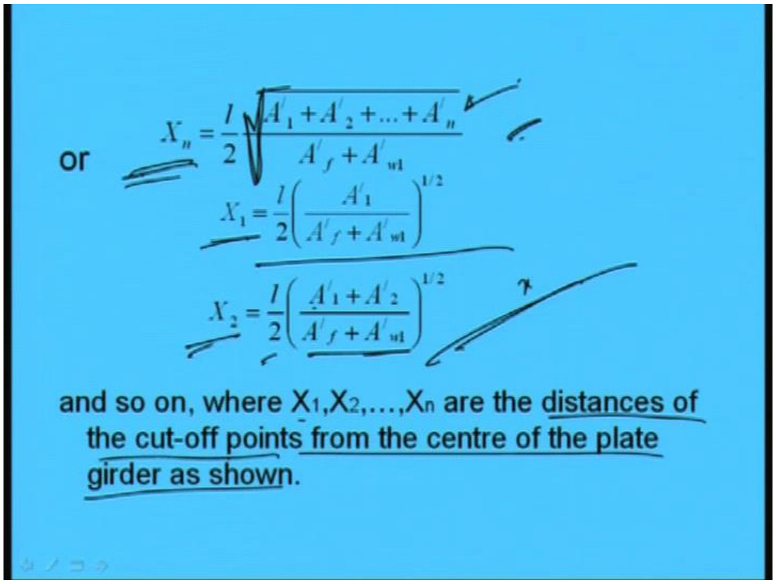

And X 1 X 2 Xn are the distance of the cut-off points from the centre of the plate girder. I will show the figure right. So, Xn for the nth plate the distance from centre to the cut-off points show this we can write in this way right. Sigma bt into A dash f plus A dash w 1 this is the total minus A 1 dash plus A 2 dash like this into d 1 right. Now, if we divide equation 2 by equation 1 then what will happen. We will get this type of equation; that means, 1 minus 2 Xn whole square by l square is equal to 1 minus A 1 dash plus A 2 dash plus up to An dash by A dash f plus A dash w 1 right.

So, the equation can be made in this way. Now, if we further simplify this can be reduced from both the sides, so what will happen? Xn 2 Xn by l will become root over this A 1 dash plus A 2 dash plus up to An dash by Af dash plus w 1 dash. So, this will become like this. So, 2 Xn by l. So, from this I can find out Xn. So, what will be the Xn value? Xn will become l by 2 square root of this whole square root of A 1 dash plus A 2 dash plus up to An dash by Af dash plus A dash w 1.

Now, these are the area of plates summation of area of the plates. So, from this equation if number of plates are n then the length of X 1 that is the distance of the cut-off point from that from the centre to that plate girder that, Xn can be find out from this equation. So, similarly if we consider about X 1 then we can find out the equation like this that will be l by 2 into A 1 dash by A 1 Af dash plus Aw 1 dash of square root. Similarly, X 2 what it will be? X 2 will be l by 2 into square root of A 1 dash plus A 2 dash by Af dash plus Aw 1 dash right. So, in this way X 1 X 2 X 3 whatever number of plates are there we can find out their length right. So, by algebraically we can find out easily right.

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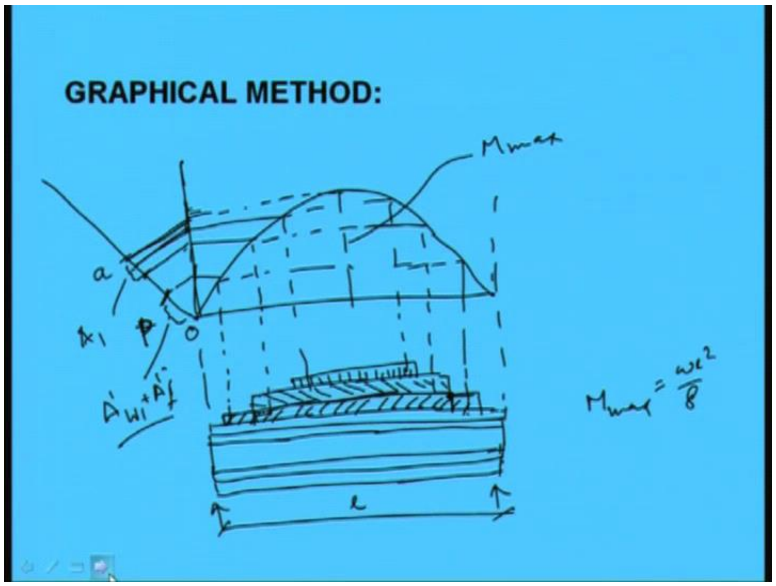

Now, the similar way we can find out from graphical method also. In graphical method what we will do say there is a suppose there is a beam right I mean a UDL load. And this is the first plate which is given means flange this is the flange right. So, what will happen now? Now, we can provide a as we told that first plate will be provided throughout the span this generally we use to make right. Next we will provide some other plates how do we provide let us see.

So, for that what we have to do. We have to take some graph paper from which we can find out. Means, first we will find out because of this simply supported beam which having L length what is the maximum moment right. That is wl square by 8 if w is the UDL load acting on the beam. So, the moment will develop like this right. So, this is the maximum moment which is developing I can write M max right.

Now, what we will do in graphical paper we can means we can make it scale a suitable scale. We can use to scale down the or scale up the results means the moment we are making here right. Now, again what we can do we can write down the area say a line we can keep and area of each flange can be written. First is the original area which is say suppose it is here right this is the o say say let us consider say say x not x say P right.

So, this is the original area means that is given now. Af dash plus A means area of flange right. Area of this is the area A A dash f plus A dash w 1 right A dash w 1 plus A dash f right. Now, other area A 1 A 2 means of the plate we can scale like this say other area is like this right. So, we can give them name say there outsider 1 means the last 1 here let us put say A right. Now, let us join with this the maximum 1 with this the outermost one. So, this is not like this. Next what we will do?

Next for another plate this is say another plate area say A 1. So, this is parallelly we will make parallelly we will go then again horizontally we will give here right. Then if we make like this and if you go down so this should be the plate which we have to provide right. And with some outstanding length because whatever require is there little higher to accommodate the rivet etcetera right for connections right. Again for this it will be parallelly we can take this and like this right. First I did a small mistake first let me take this one. So, this will be like this right.

So, the first plate will be up to this right. So, this is the first plate. And second 1 is here. So, second 1 I am considering this 1 right. So, second 1 is like this. Then in-between if we want to provide some plate say suppose some other plate is there then their cut-off point also can be find out from similar way. Say this should be the cut-off point right. So, in this way another plate we can provide. So, this is how by graphical method also we can find out the cut-off length.

However better way is to do from the algebraic formula because formula is there from formula we can get X 1 X 2 X 3 very quickly right. And the actual length whatever we will be providing will be little higher side from the theoretical 1 right. So, this is the way how to find out the curtailment of the flange. Next we will discuss about welded plate girder the remaining component we will be discussing in welded plate girder. As I told earlier that plate girder is of 2 type 1 is riveted plate girder another is bolted plate girder sorry welded plate girder. Bolted plate girder also is available which is similar to riveted plate girder right.

So, in case of welded plate girder the difference is that here because of absence of hole because the rivet is not there. So, there will be no deduction of area. So, net effective area is not going to reduce from the gross therefore, the efficiency of the riveted welded plate girder will be more right. The strength of the welded plate girder will be more. So, this is the difference. And now, we will see how to find out the effective depth means economic depth and economic size how to find out. In case of riveted plate girder we have seen here we will see which little different means is in a different way we have to do.

Then other things like connections etcetera as we know how to make that for riveted connections. Say like we have to see what is the hum rivet value and what is the forces is coming, then we have to find out number of rivet then we have to find out pitch etcetera. Huh. So, those come means usual things I have not discussing here right. In case of plate little mean in case of weld little more I will discuss about those things those connections etcetera right.

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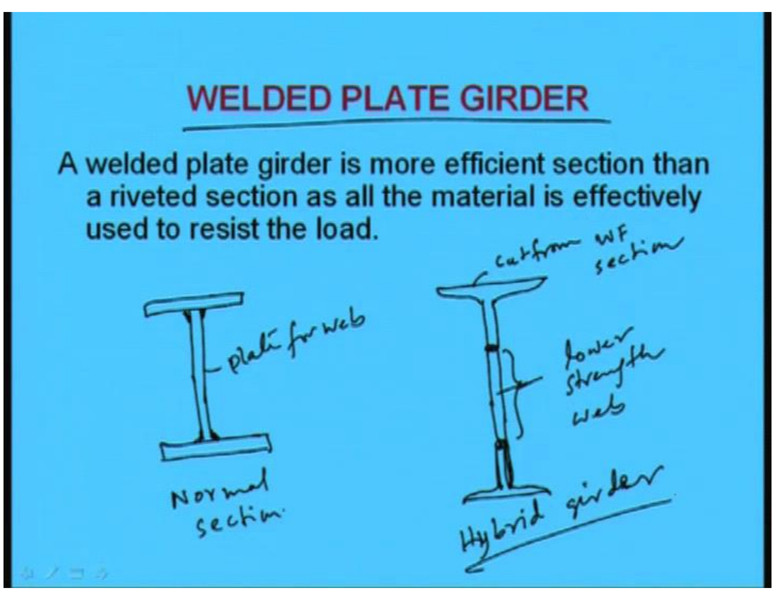

So, first let us how does it look the normal section is generally just simple section what I have shown last day that is simply the girder is made with the plate solid plate. This is the plate the web plate; plate for web right. Now, here it is welded here it is welded right these are in general normal section we can say. Another section also I have shown that is called hybrid girder; that means, we can take it from some rolled section right. Maybe, from t section right and then by the use of butt weld we can go then again some another t section or some other section right. This is basically cut from white flange section right. And this portion is generally this portion is generally lower strength right these are lower strength. And this is called hybrid girder this is called hybrid girder.

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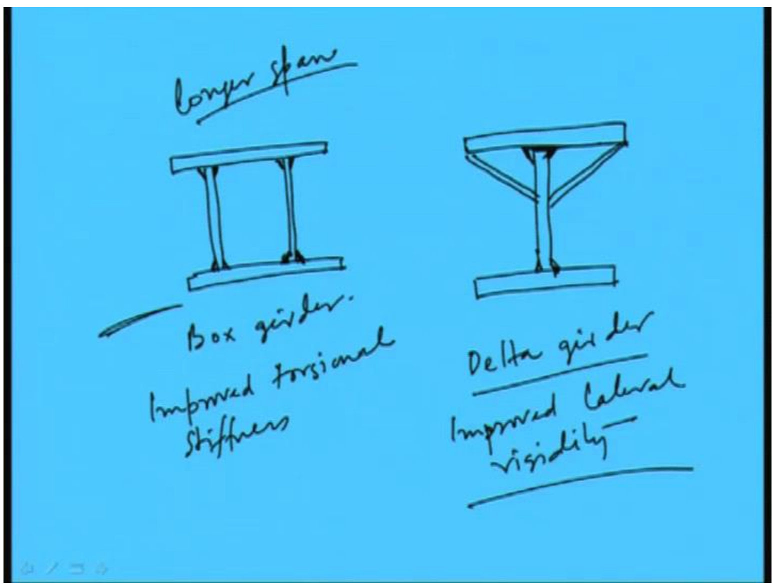

2 other sections I will show which is used in bridge mainly this section is very commonly used in bridge that is box girder right box girder. So, how does it look this is like this; that means, there is a plate solid plates which is forming like a box and welding here at the joint to make this box this is called right box girder. And this improves torsional stiffeners this section improves torsional stiffeners and these are useful in case of longer span. If span length is very high then generally we use to provide box girder longer span right.

Another type of girder welded girder we use that is called delta girder this will be looking like this right this is called delta girder. That is this will be stiffen by like this means it will be joined like this and this will be joined like this right. So, this is called delta girder right. And this improves the lateral rigidity improves lateral rigidity. The advantage of this is to improve the lateral rigidity. So, these are some typical welded connected plate girder right.

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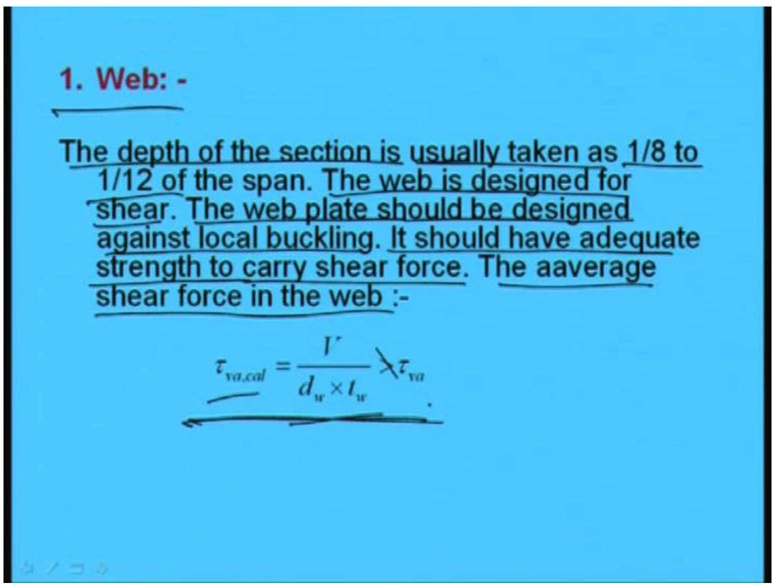

Now, first let us see about the web how do we design means how do we decide the web right. The depth of the section of the web is usually taken as 1 8 to 1 twelve 1 8 to 1 twelfth of the span right the depth of the section. Generally we choose at the beginning 1 8 to 1 twelfth of the span length. The web is designed is for shear as we know flange are taking care of moment and web are generally taking shear. So, web has to be designed for shear.

The web plate should be designed against local buckling it should have adequate strength to carry shear force. And the average shear force in the web as we know is tau v cal that can be find out as V by dw into tw. We know this formula already we have used and it should be less than tau va tau va is the permissible shear stress right that also given in the code.

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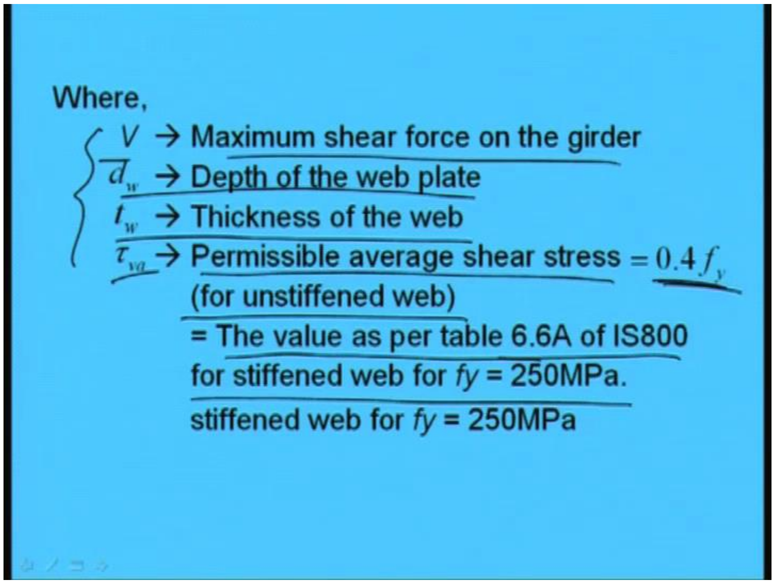

Tau va the permissible shear stress that should be 0.4 fy this is for unstiffened web. And for stiffened web the value is given at table 6.6 A of IS 800 1984 right for fy 250 right. And others are as usual like tw is the thickness of the web dw is the depth of the web plate and V is the maximum shear force on the girder V is the maximum shear force on the girder. So, from the shear force point of view we have to check the depth whatever we have considered we have assumed that is 1 8 to 1 12 whether, that is sufficient or not from shears point of view. Then how do we check that permissible stress either it will be 0.4 fy for unstiffened web. And for stiffened web the value is given in the code in IS 800 1984 in table 6.6 A.

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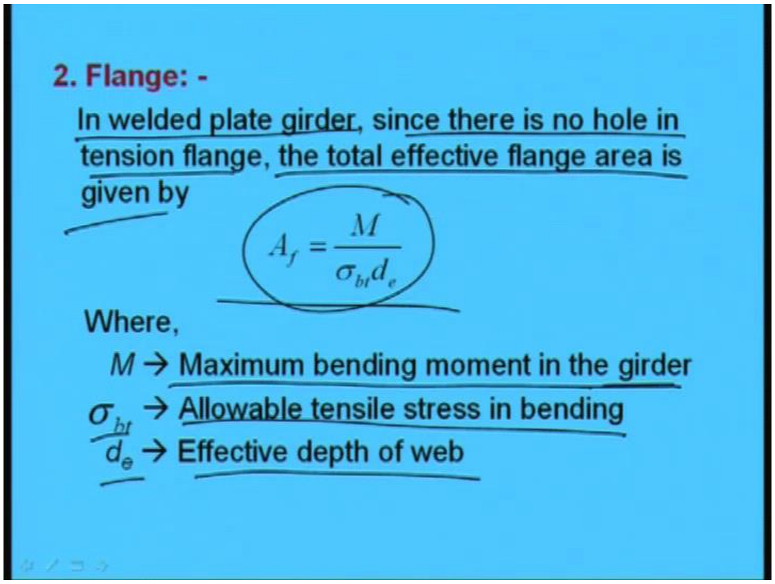

Now, we will go for the flange. In welded plate girder since there is no hole in tension flange the total effective flange area will be given by this. Af is equal to M by sigma bt into de. Where, M is equal to maximum bending moment in the girder M is maximum bending moment in the girder. And sigma bt is the allowable tensile stress in bending. And de is the effective depth of web. So, effective area of flange if we say f that can be find out from this right. So, effective area can be find out then we can find out the depth and thickness this thickness and width you can find out.

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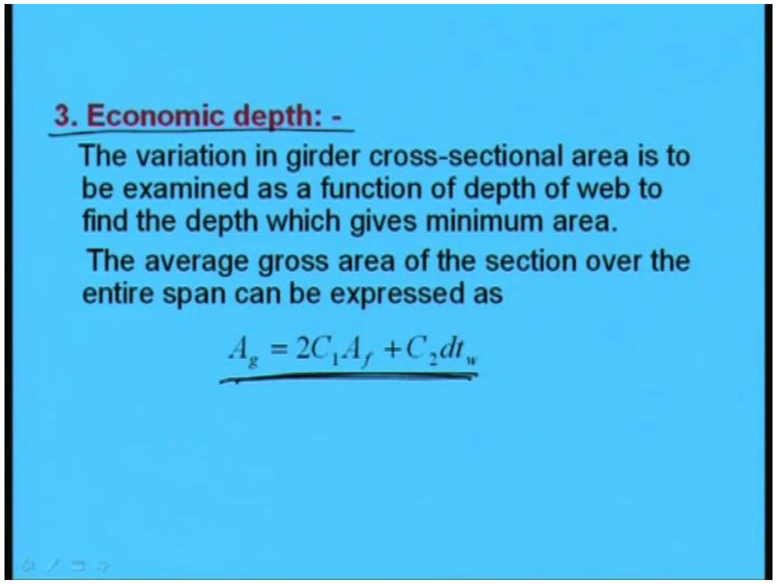

Now, economic depth in case of riveted jointed plate girder we have seen how to find out an economic depth. Here, also we will find out that is the gross area first we will calculate that is Ag which is equal to 2 into C 1 into Af plus C 2 into d into tw right. Now, the variation in girder cross sectional area is to be examined as a function of depth right of the web to find the depth which gives minimum area. That means we will express the equation for writing the area of the total plate girder in terms of depth then we can minimize it right. So, to find out the minimum area we have to find out the gross area then we what we will do. We will partial derivative against the depth right that I am coming.

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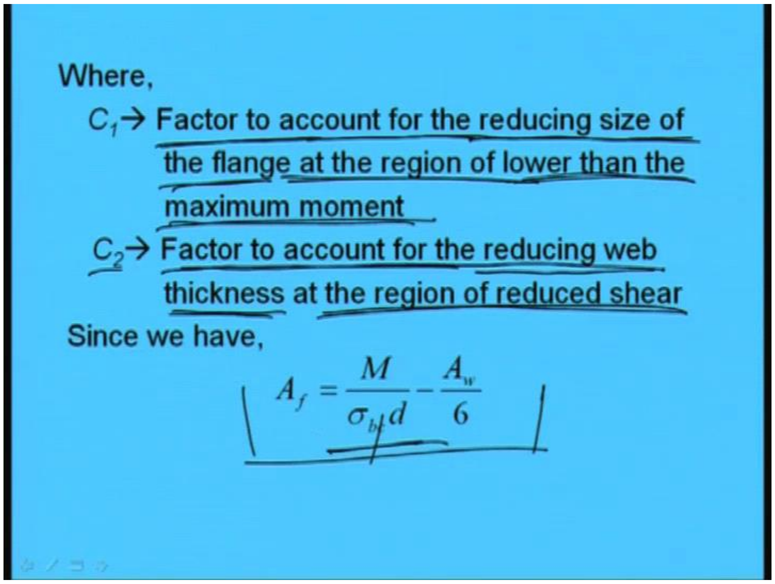

So, here whatever we are using C 1 and C 2 because other things we know Af de tw we know. C 1 is factor to account for the reducing size of the flange at the region of lower than the maximum moment right. And C 2 is the factor to account for the reducing web thickness at the region of reduced shear right. Let me repeat again what is C 1 and C 2. C 1 is factor to account for the reducing size of the flange at the region of lower than the maximum moment.

Then C 2 is the factor to account for the reducing web thickness at the region of reduced shear. And as we know Af is M by sigma bc or bt or be for hum laterally resistant beam we can write. Af is equal to M by sigma bc sigma bcd minus Aw by 6.

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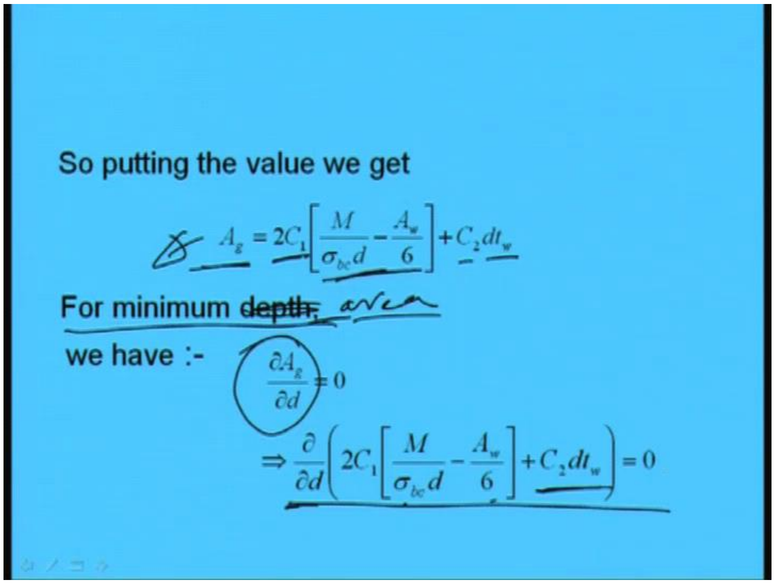

So, from this we can find out Ag the value of Ag will become this 2 C 1 into this f plus C 2 into d into tw right. So, Ag we can find out. Now, for minimum depth for minimum area what we have to do for minimum area we have to make del AG del d equal to 0 right del Ag del d is equal to 0. So, if we this Ag if we make partial derivative in terms of d then we can get this value as like this. Del del d into 2 C 1 into M by sigma bc into d minus Aw by 6 plus C 2 into d into tw right. So, in this way find out the value.

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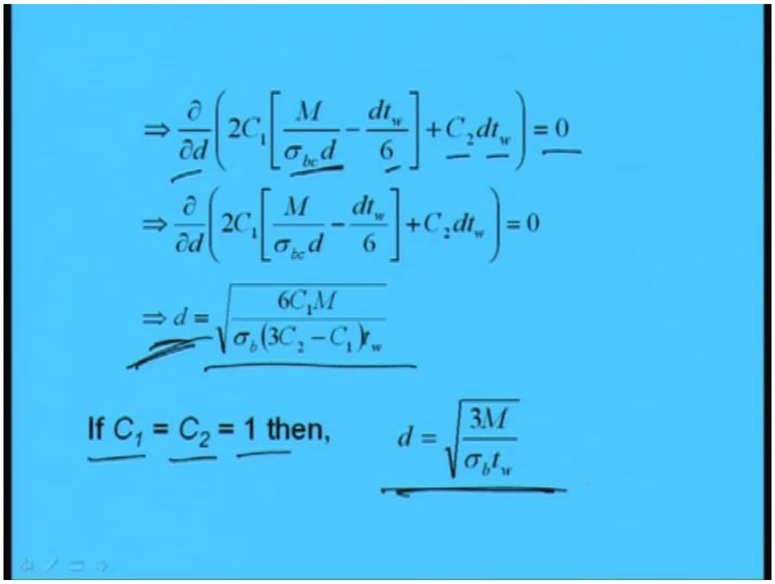

So, if we further derive we will get that del, del d into 2 C 1 into M by sigma bc into d minus d into tw by 6 plus C 2 into dtw is equal to 0 right. So, from this I can find out the value of d right. So, value of d will become this that is square root of 6 C 1 M by sigma b into 3 C 2 minus C 1 into tw right. So, d I can find out from this expression right. Now, if we assume C 1 and C 2 as unity then I can simplify to this d is equal to 3 M by sigma b into tw d is equal to 3 M by sigma bt sigma b into tw. Here, sigma b is either sigma bt or sigma bc right.

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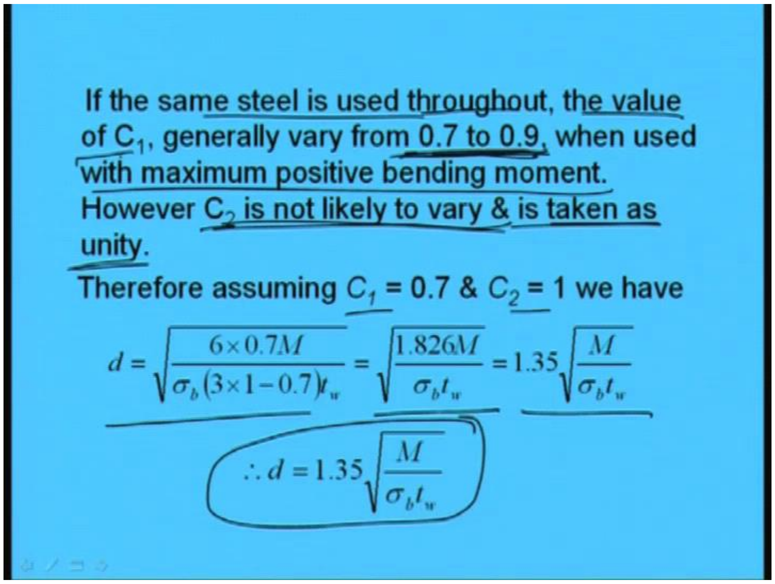

So, in general if you see if the same steel is used throughout the value of C 1 generally varies from point 7 to 0.9. And C 2 varies C 2 does not vary and generally it is taken as 1 right. So, C 1 varies from point 7 to 0.9 when used with maximum positive bending moment. And C 2 is not likely to vary and is taken as unity. So, if we put the value C 1 and C 2 in the previous equation then what we will get we will get the value of d as like this. That is 6 into 0.7 say C 1 I am putting point seven. So, 6 into 0.7 M by sigma b into 3 into 1 as C 2 is 1 minus 0.7 into tw.

So, now if we calculate we will get d is equal to 1.826 M by sigma b into tw is equal to 1.35 square root of M by sigma b tw. So, d we can find out as 1.35 into square root of M by sigma b tw. Here, we got root 3 into M by sigma tw root 3 means 1.73 into M by sigma b tw if we consider C 1 and C 2 as unity right. And if we consider from practical point of view this will become 1.351 in place of 1.73, right.

So, this is how we can find out an economic depth where the area will be maximum minimum right. If d the depth of the web we chosen in this way then we can find out the area of the total cross section minimum. So, d is equal to 1 point 3 5 into M by square root of M by sigma b tw. So, in this way you can start right.

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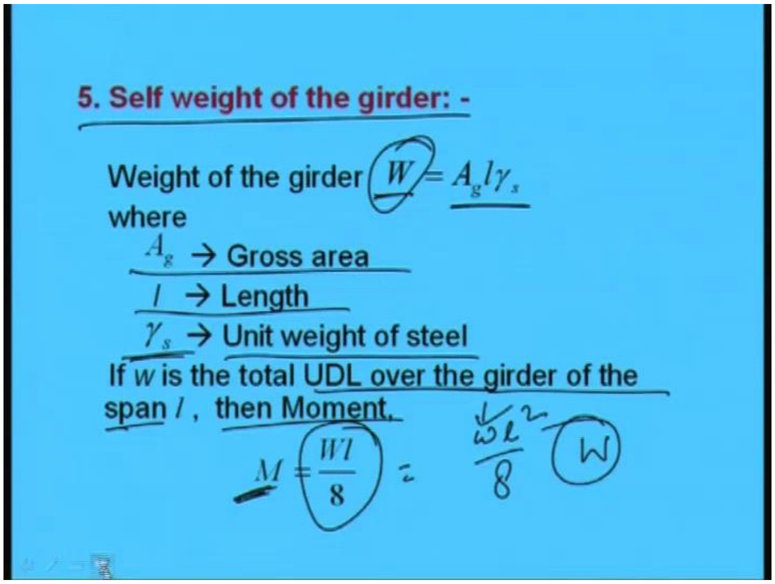

Now, other point is self weight self weight of girder. Now, let the weight of girder let us consider say W as area of of the girder into l into gamma s. Where, Ag is gross area of the cross section. L is length. And gamma s is unit weight of steel. So, weight of the girder we can find out W as Ag into l into gamma s right. Now, if W is the total UDL over the girder of the span then the moment can be find out Wl by 8 right. If W is the total UDL then M will be Wl by 8 or Wl square by 8 it will be if if we take meter per meter run means UDL load right. And if W is the total load on the girder then Wl by 8 will be the moment.

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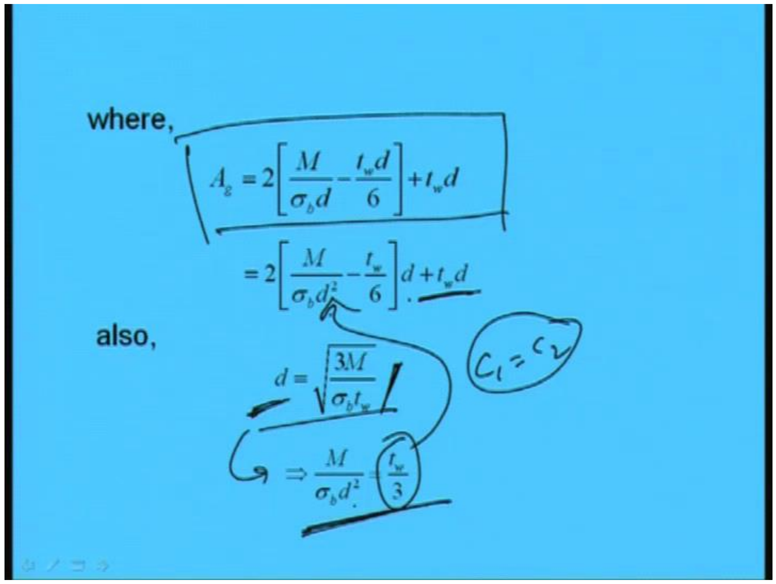

So, from that point of view you have to check now. Now, Ag we know area of means gross area of the section that is 2 into M by sigma b into d minus tw d by 6 plus tw into d which we got from earlier equations if you remember right. So, if we further subdivide mean simplify then this will become 2 into M by sigma bd square minus tw by 6 into d I am taking d common plus tw d. And again d as we got earlier that square root of 3 M by sigma bt w if we put that value.

So, from this we can find out M by sigma d square is equal to tw by 3. So, this tw by 3 I can put here right to get Ag right is it clear. So, here considering C 1 is equal to C 2 we can find out d value and from there from that relation we can find out M by sigma b into d square is equal to tw by 3. Now, if I put this M by sigma bd square here then Ag value will become like this.

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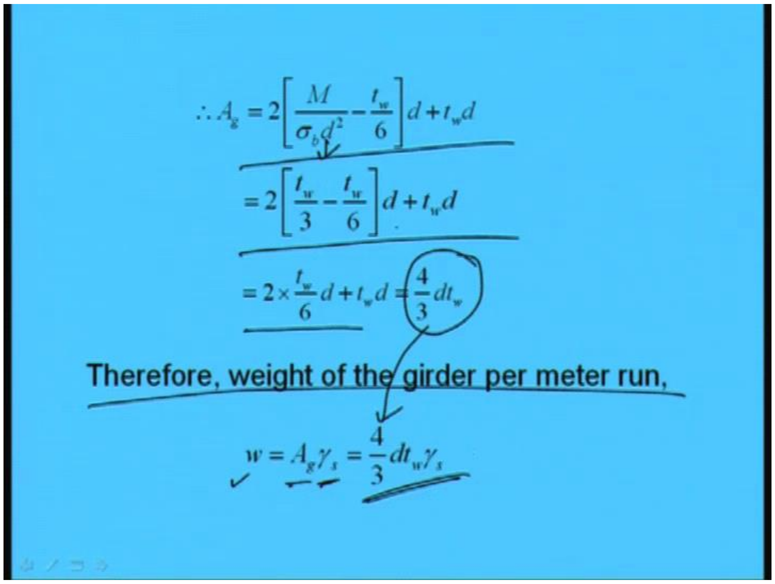

If I put this value then this will become 2 into tw by 3 minus tw by 6 into d plus tw right. Now, if we further simplify finally, we will get 4 third d into tw 4 by 3 into d into tw. Therefore, weight of the girder per meter run can be find out. W is equal to Ag into gamma s where Ag is the area of means gross area of the section and gamma s. So, this Ag we are putting here 4 third into d into tw into gamma s right. So, weight of the girder per meter run can be find out from here.

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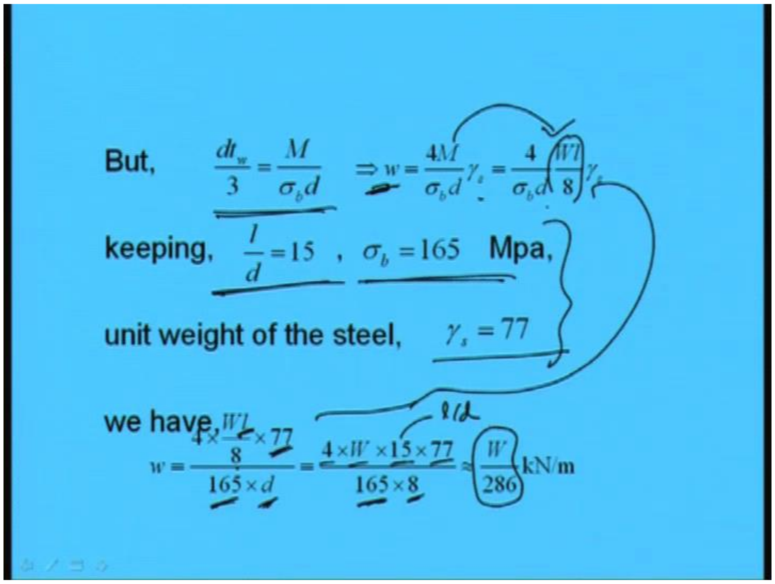

Now, if we put this relation that dt w by 3 is equal to M by sigma bd. Then we can write W this W is equal to say 4 M by sigma bd into gamma s. Which will become 4 by sigma bd into M into gamma s because M I am I am replacing by Wl by 8 right. So, W the unit weight per meter run I am going to get as 4 by sigma bd into Wl by 8 into gamma s. Now, as we know we have some l by d ratio say if we consider l by d ratio as 15 and for fy 250 sigma b as 165 and for steel if we use unit weight as 77. Then we can put the values all these values in this equation right then what we will get.

We will get 4 into Wl by 8 into gamma s is 77 by sigma b into d right. Now, again if you see l by l by d is 15. So, if we put that 1 also we will get 4 into W into 15 that is l by d into gamma s by sigma b and 8 sigma b is 165 and 8 8 was there. So, now if you calculate we will get W by 286. So, in this way we can find out the self weight of the girder means approximate self weight of the girder can be find out in this way which can be assumed from this equation that is W by 286.

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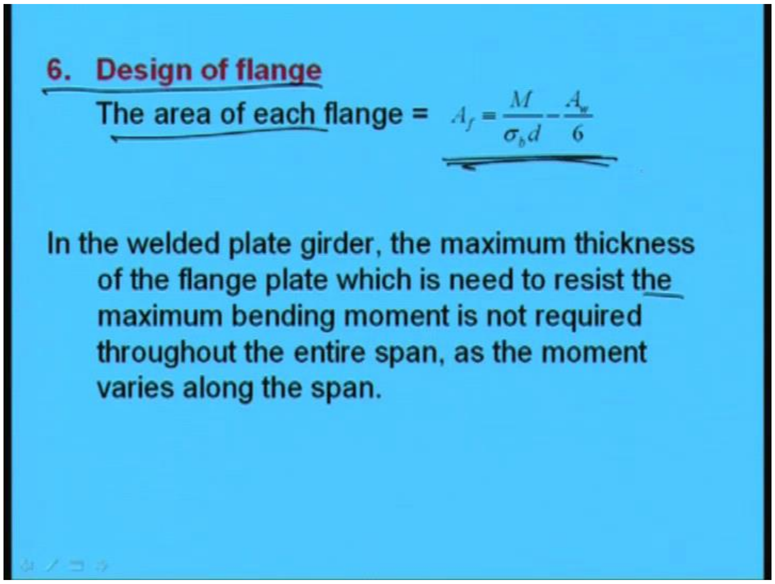

So, now we will see how to flange right. So, the step is the design of flange for welded plate girder. Now, the area of this flange can be find out from this. Now, in case of welded plate also the maximum thickness of the flange will be where the maximum bending moment is coming into picture.

So, here also we can make curtailment of the flanges as per the requirement if the girder is simply supported along with UDL load then accordingly we can find out the moment and accordingly we can cut means make curtailment for the different plates to get an economic section at different places right. So, in the same way we can do what we have done in case of riveted joint plate girder, right.

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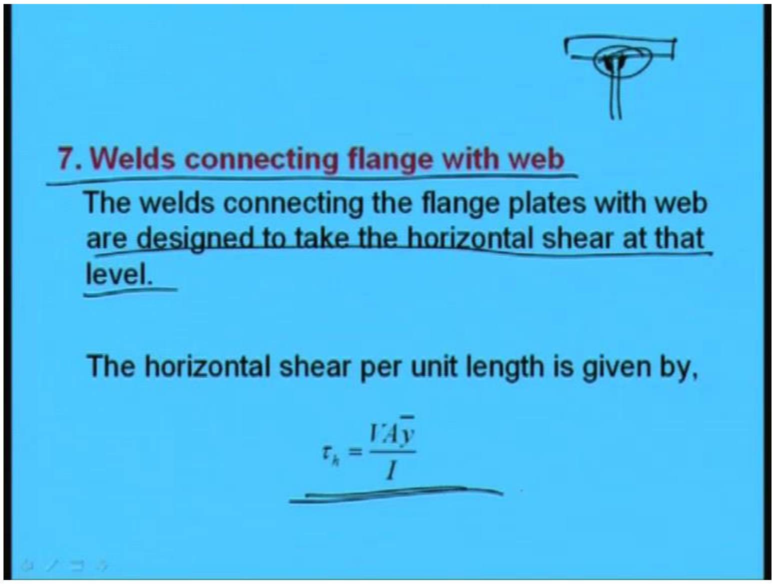

Another thing is welds connecting flange with web flange with web right; if we see weld connecting flange with web. Now, we have to design here right. So, the welds connecting the flange plates with web are designed to take the horizontal shear at that level. So, we have to find out first horizontal shear at that level which can be expressed from this. That is tau h is equal to VAy bar by I right per unit length tau h is the horizontal shear per unit length. So, we can write tau h is equal to VAy bar by I.

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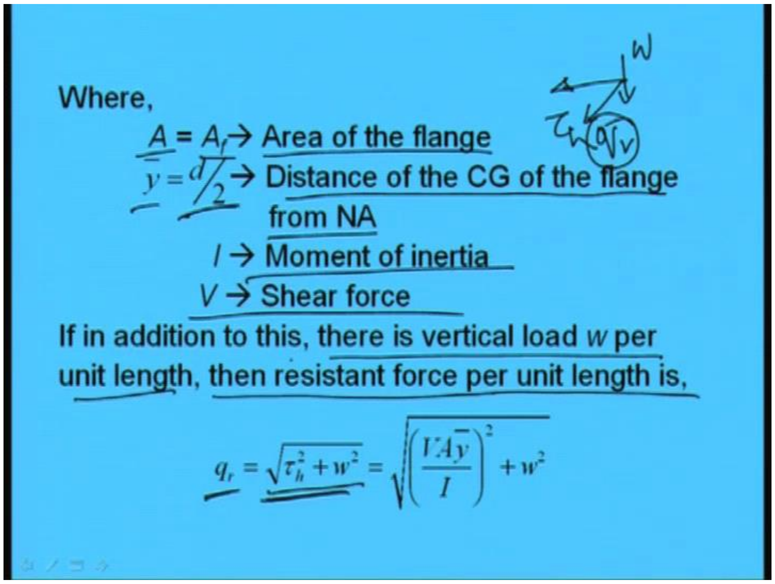

Now, here A means area of flange right Af. And y bar is nothing, but d by 2 that is distance of the CG of the flange from neutral axis. And I is the moment of inertia. And V is the shear force shear force means maximum shear force we have seen right. In addition to this there is vertical load W per unit length if the vertical load is there. Then resistant force per unit length will become qr as tau h square plus w square because horizontal shear is coming in this direction tau h. And again if the vertical load is there at that point then it will be W.

So, the resultant will become which is named as qr that will become square root of tau h square plus w square right tau h square plus w square. And tau h is written here VAy bar by I remember this is shear per unit length not the shear stress shear per unit length right. So, and w is also load per unit length. So, here if we put those values tau h as VAy bar by I then we can find out qr the resistance force per unit length as this right. So, qr we got.

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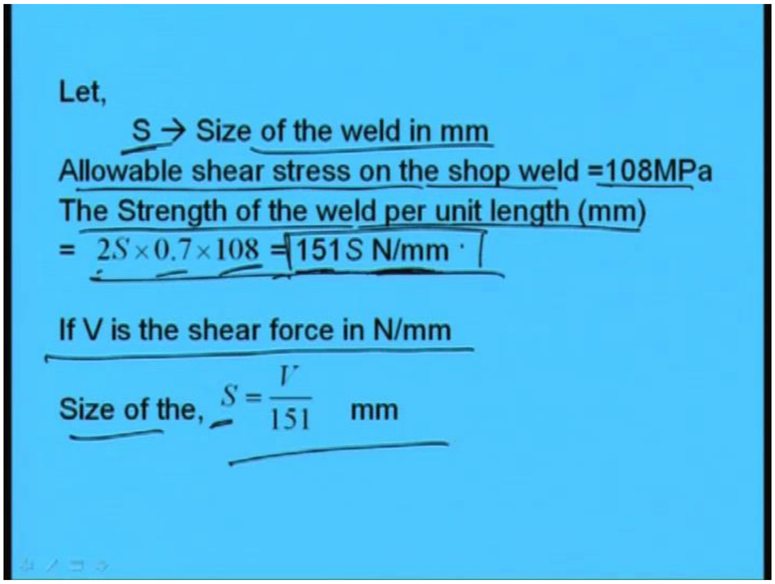

Now, if we consider S as say size of the wield in millimeter and let us consider allowable shear stress on the shop weld as say 1 0 8 MPa. Then the strength of the weld per a plate girder is there with a span of 20 meter. So, let us assume we are going to use I section right at the beginning later means I section type of plate girder we are going to use right. And so, what are the things has been told that riveted plate girder. So, this has to be keep in mind.

So, the economic depth etcetera will be calculated from the formula which we have derived in case of riveted plate girder right. So, this is twenty meter and a UDL of 8 kilo Newton per meter 8 kilo Newton per meter right. What else is given? It is simply supported and then it is excluding the self weight. So, self weight also we have calculated right. And other things let us assume that the steel we are going to use that is say fy is equal to 250 Newton per millimeter square right. And say as riveted plate girder we are going to use let us use say phi is equal to 20 mm power driven shaft rivet.

So, these are the 2 things let us assume. 1 is rivet diameter as twenty mm power driven shaft rivet and the steel whatever we are using its fy value is 250 Newton per millimeter square right. So, these are the details of the examples. So, what are things are given very preliminary things given. 1 is effective span le that is given twenty meter UDL load w has been given say eighty kilo Newton per meter right. And it is simply supported right simply supported means M will become Wl square by A maximum moment will develop from this formula right.

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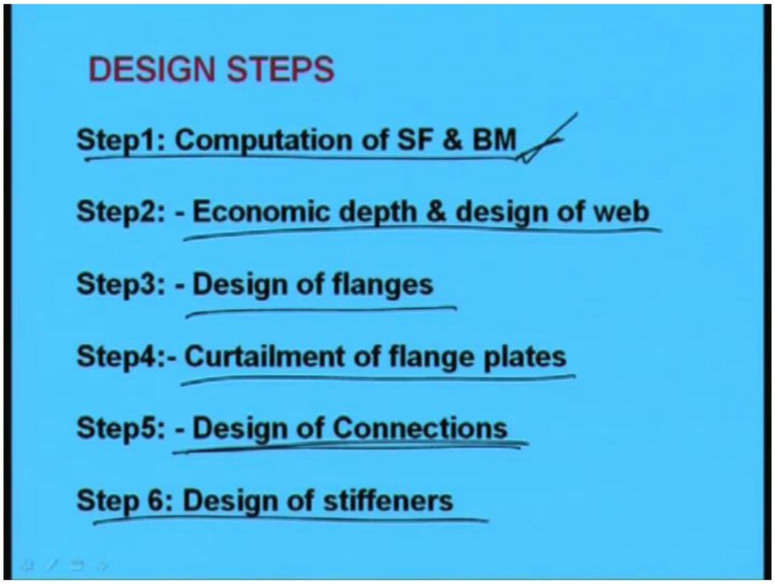

So, what we will do in this problem. Let me go through some steps before starting the example. What are steps will be required to design this plate girder means steps means broadly I have just made 6 steps. One is computation of shear force and bending moment. Say very big step in. In fact, we can say very big means steps are very large.

That means first we have to find out the economic depth economic depth of the section right economic depth of the section. We have to find out then we have to find out the self weight because self weight is not given here, because we do not know the section how do we find out the self weight. So, economic depth is first we have to find out on the basis of formula whatever we have discussed earlier then the self weight also we will find out. Approximate formula is given from which you can find out.

Then we will find out the shear force and bending moment shear force and bending moment. In fact, in case of bridge the plate girder is used for the moving load. So, in that case again we have to see at what position the maximum bending moment will develop at a particular section. And in that way we have to find out the worst condition and then we have to design accordingly right. So, first we will find out the shear force and bending moment.

Then economic depth and design of web economic depth and design of web… Then design of flanges. Then curtailment of flanges flanges plates we can go for curtailment. Then design of connections we will go for design for connections. And then finally, we will go for design of stiffeners if we need to provide stiffeners then we will provide stiffeners also. So, these are the broadly 6 steps we have to follow right. Now, as time is over. So, today I like to conclude this lecture. I will suggest you to work out this example at your home and then in next class when I will be working through this example you can check it then it will be easy to understand properly. So, thank you very much for your patience to listen this lecture.

Thank you.