Offshore structures under special loads including Fire resistance
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Module – 02
Advanced Structural Analyses
Lecture – 26
Shear Centre I

Friends, in this lecture today we are going to discuss about an important segment in advanced structural analyses, which is Shear Centre. In the last lectures we discussed about importance of unsymmetrical bending, in case of even accidental inclination of loads because of constructional irregularities, the stress in the cross section can enhance by about 20-25 percent, which is a very serious concern for the designers.

Similarly, we need not always use sections for design which has both axis of symmetry. It is always common that we may choose sections with no axis of symmetry or at least with one axis of symmetry and try to load the section maybe inclined to the vertical axis not along the principal axis of inertia, which can result in un symmetric bending, in addition to this there is a very peculiar problem which can also arise is sections, which can cause twisting of the cross section or torsion in the cross section at various segments along the length of the member.

So, the point of application or the plane of loading with respect to the plane of bending, makes a very important decision in construction aspects as well as in design aspects generally these are not intentional; for example, you have a proving ring, the proving ring is connected to 2 points and you stretch the proving ring depending upon the point of application and the point of contact of the load at the proving ring, it may cause a load which may not lie or intersect with the plane of bending.

Alternatively in the case of a crane hook, which is used in construction process very commonly, the lifted load may not always lie or pass through the plane of bending. So, there are special issues where the applied load may have a disagreement with the plane of bending or the plane of applied load will have a disagreement with the plane of bending. In addition to that we may also have sections which do not possess even 1 single axis of symmetry, in such cases shear centre identification becomes a very important scenario in advanced structural analyses, which we now discuss in series of lectures from now.

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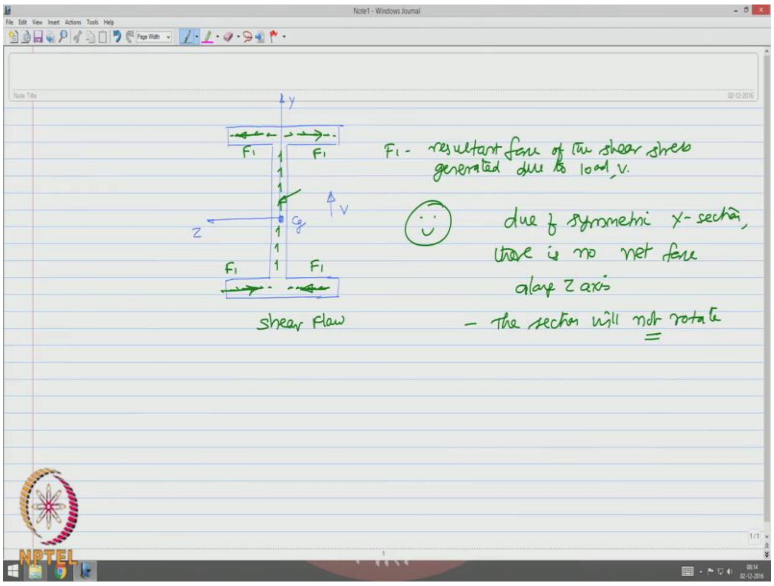

To start with let us try to ask a question if I have a section, which is commonly used in structural applications and also in offshore structures for supporting the deck etcetera which are of very large span, we use let us say I sections or built up sections which has a cross section of I in shape. It is very evident to all of us that this section has 2 axis of symmetry; the point of intersection of this becomes the cg of the section. If the section is subjected to some vertical shear V and this being my z axis and this being my y axis, if you look at the shear flow you will see that the shear will be maximum here and closely becoming zero here. Similarly maximum here and becoming zero and the shear varies parabolically here and again maximum here and practically goes to zero and maximum here and practically go to zero, which we assume is a linear variation.

So, if you look at this as a shear flow, if F 1 is resultant shear, due to symmetry you will see that this will also be F 1, this will also be F 1 and this is also F 1. F 1 is the resultant force of the shear stress in the flanges generated due to the vertical load V; you can observe that the advantage is due to symmetric cross section, there is no net force along Z axis and all forces will be taken away by this resultant as a result of which the section will not rotate.

So, friends if you can choose a section which has both axis of symmetry, then the section rotation will not occur, alternatively let us take up another section which has only one axis symmetry.

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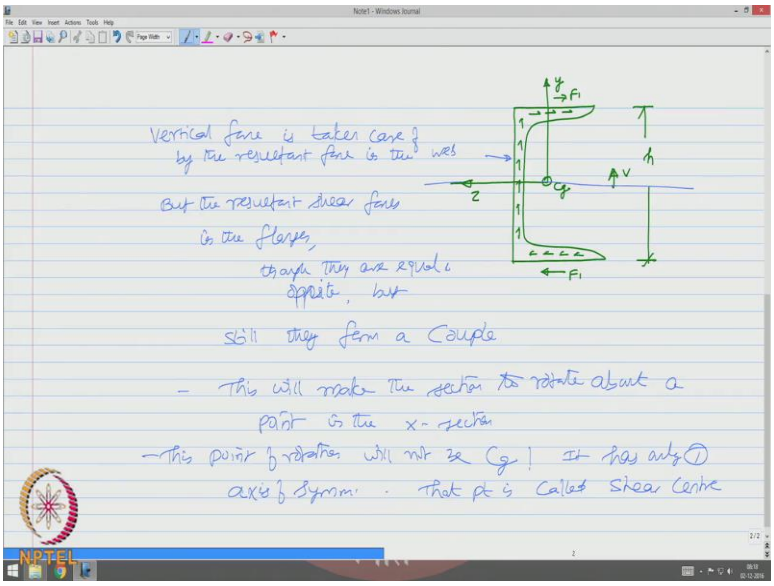

Let us take a channel section, we all do agree the channel section has one axis of symmetry which is along the z axis and of course, the cg will pass through this point which can be located from the first principles.

If you look at the shear flow in this case, this is going to the net force F 1, this is also F 1 due to symmetry of the section, for an apply load V you will see that about cg if this is h the vertical force is taken care of by the resultant force in the web, but the resultant shear forces in the flanges though they are equal and opposite, but still they form a couple, this will make the section to rotate about a point in the cross section and this point of rotation will not be cg why? Because it has only 1 axis of symmetry therefore, it will lie on that axis somewhere about which the cross section will rotate and that point is called shear centre.

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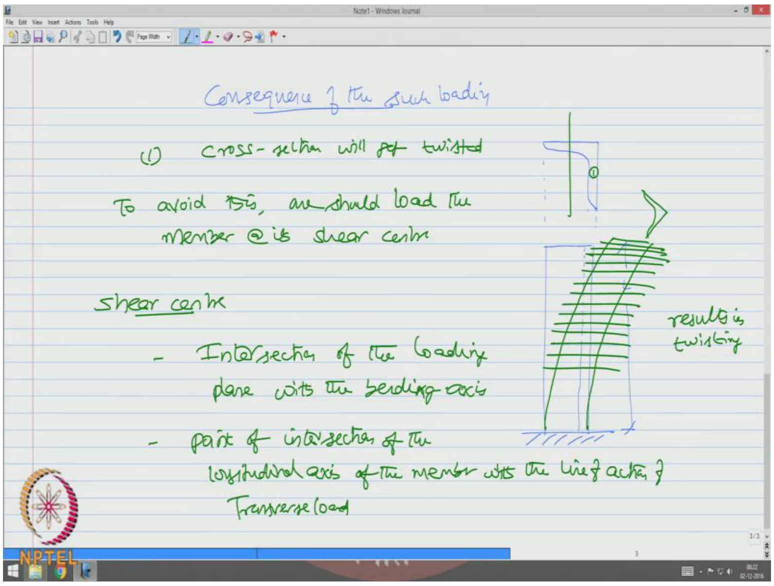

To understand this, let us try to ask a question what will be the consequence of such load? So, let us take an angle section, let us say this is a column member subjected to some loading, let us say the length of the column is L, due to lateral loading the column will have a tendency to deflect, but depending upon the point of application of load even if it is a channel section or an angle section, depending upon the point of application of load let us say this way or this flange apply a load parallel to the flange somewhere here on this section, if will try to make the section rotate and this rotation at every fiber will be different and this differences in the cross section rotation at every fiber results in twisting.

So, one of the main consequence of load not applied under shear centre is cross section will get twisted; to avoid this one should load the section at its shear centre. So, then what is shear centre? Shear centre is intersection of the loading plane with the bending axis, in simple terms shear centre is also defined as point of intersection of the longitudinal axis of the member with the line of action of transverse load.

Interestingly how this problem can be more serious in offshore structures?

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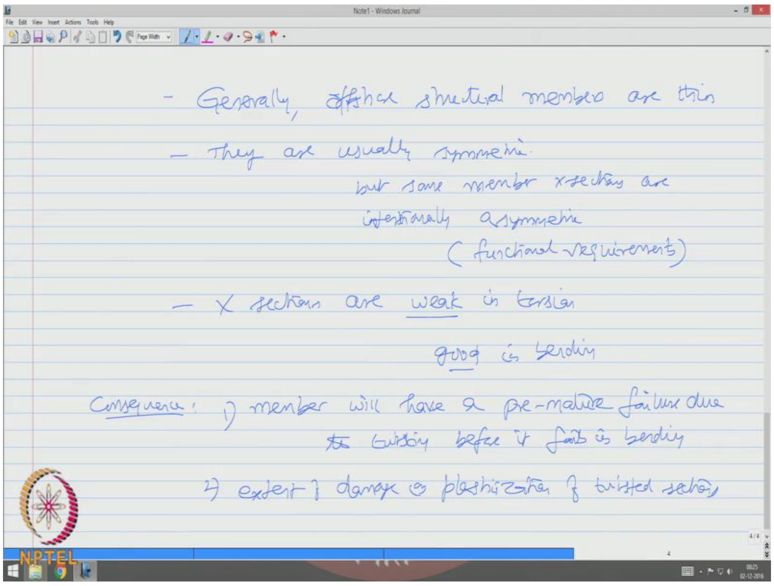

Generally offshore structures or offshore structural members are thin, they are usually symmetric, but some members or some member cross sections are intentionally asymmetric, this is for functional requirements. I will give you some examples later therefore, generally in such cross sections are weak in torsion though they may be good in bending.

So, what is the series consequence here? The series consequence is member will have a premature failure due to twisting before it fails in bending number 1; number 2 it is very difficult to estimate the extent of damage or let me put it like, this extent of plasticization of twisted sections. So, we should avoid torsion in a given cross section deliberately, how you can avoid that very simple, apply the load or ensure that the loading is applied at a point of shear centre. So, when a section has 2 axis of symmetry we have no problem, but when the section has 1 axis of symmetry we must be able to locate the shear centre along that axis somewhere at a point from first principles and ensure that the loading is applied or it passes through this particular point what we call as shear centre.

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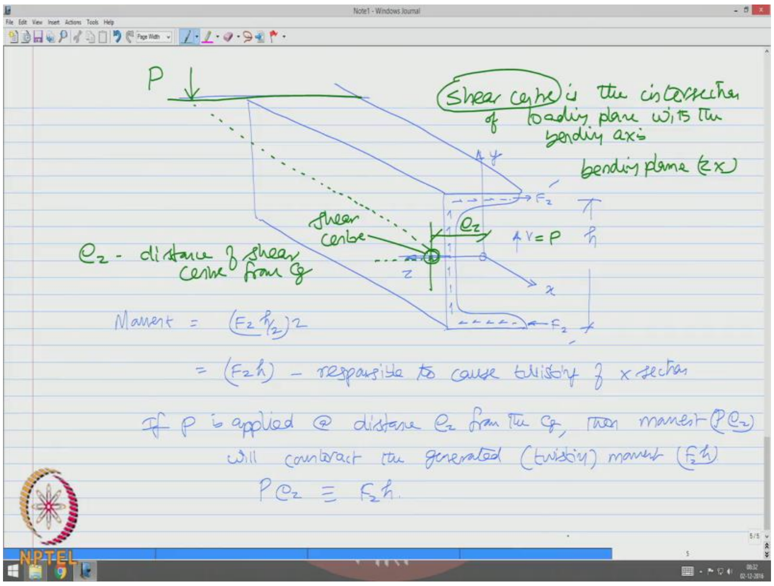

To explain this further, let us take a channel of thin wall cross section, let us say the channel is subjected to some loading, the channel has 1 axis of symmetry, this is my x axis, this is my z axis, y axis. We just now saw the shear flow pattern assuming a linear variation in the flanges and the parabolic variation in the web, we know that this force is going to be the net resultant F 2 or let us say F z, this force is also net resultant F z they are same in magnitude, but opposite in direction, which are separated by a distance which is depth of the section which is h; on any applied load V which will be actually equal to some load applied here on this plane somewhere, let us say P and let us say this is the load applied and the load is seen to be applied on the z y plane and I try to extend the point of application of load at this point let us say at this point, at this point and I call that point from the cg as e z

We know that the shear will be actually equal to P, but the moment caused by these unbalanced forces there is going to be a moment about this point which will be actually equal to Fz into h by 2 into 2, which is nothing but Fz into h, which will be responsible to cause twisting of cross section. To avoid this if P is applied at a distance ez from the cg, then the moment P into ez will counteract the generated twisting moment Fz into h. So, P into ez will be actually equal to Fz h. Now, ez is the distance of shear centre from cg and this is the point which is shear centre. So, therefore, shear centre is the intersection of loading plane with the bending axis; the bending plane is zx plane, the loading plane is zy plane and the point of intersection of the loading plane to the bending axis is the shear centre.

So, friends it is very important for us to now estimate the location of shear centre for a section which has 1 axis of symmetry, if the section has luckily 2 axis of symmetry and they also happen to be the principle axis of inertia for a given vertical loading or for a given loading matching with the plane of bending, there will be no un symmetric bending as well as there is no twisting of the cross section. If the section has only 1 axis of symmetry and the loading does not match to the bending plane, then you have a problem of unsymmetric bending as well as twisting of cross section for which we need to locate their shear centre.

To locate the shear centre, let us go back to the basis of structural mechanics and try to understand the equation for estimating the shear stress at the given cross section because shear centre is going to be the nullifying effect of the resultant of shear forces and their moments about any point on a given cross section. So, to estimate the resultant shear force we need to know the shear stress in the given cross section at any given point, let us try to do that first and apply it on some problems and see how we can locate shear centre conveniently mathematically.

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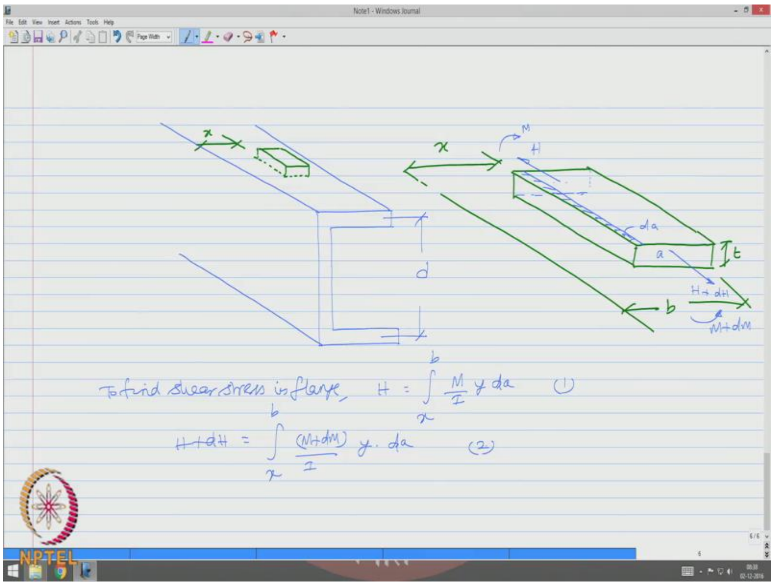

Let us say I have a cross section which is channel; for simplicity sake I am not drawing the angular bending at the web and the flange intersection, let us say this is my depth of the section d. I take a strip here let me draw the strip, this strip is cut at a distance let us say x, then let us draw this strip separately, let us say the strip has a thickness t and the edge is here and the distance of this from the (Refer Time: 28:11) is x and this distance is b. So, at this point if I have H, I will have a difference at this point at the same location which will be H plus d H there is a small increment in the horizontal force, if this is going to be m and this will be m plus dm, let us have a small incremental area da which is this whereas, this has an area A and this is da.

Now, to find the shear stress in flange, H will be actually equal to variation x to b that is the strip variation, M by I into y into da, H plus dH will be now same integral m plus dm by I into y into da.

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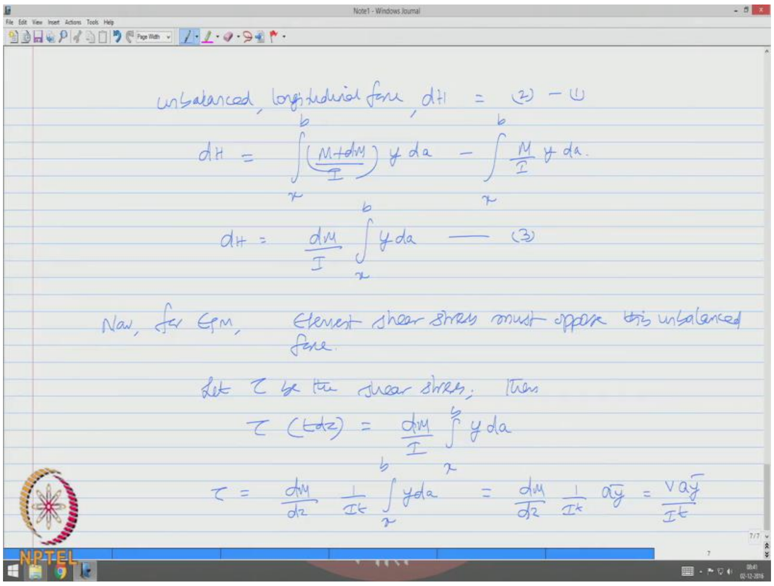

So, I can now find the unbalanced force in the longitudinal force which is dH, by simply saying equation 2 minus 1 which will be x to b, m plus dm by I into y da minus x to b, m by I into y da. So, dH in simple terms can be dm by I y da, x to b, I call equation number 3.

Now, for equilibrium; the element shear stress must oppose this unbalanced force, let tau be the shear stress then tau into tdz that it is the cross section area of the strip should oppose dm by I, x to b, y da from this I can say tau is dm by dz, 1 by I t integral x to b, y da which can be dm by dz, 1 by I t, a y bar and dm by dz is actually V a y bar by I t that is my tau.

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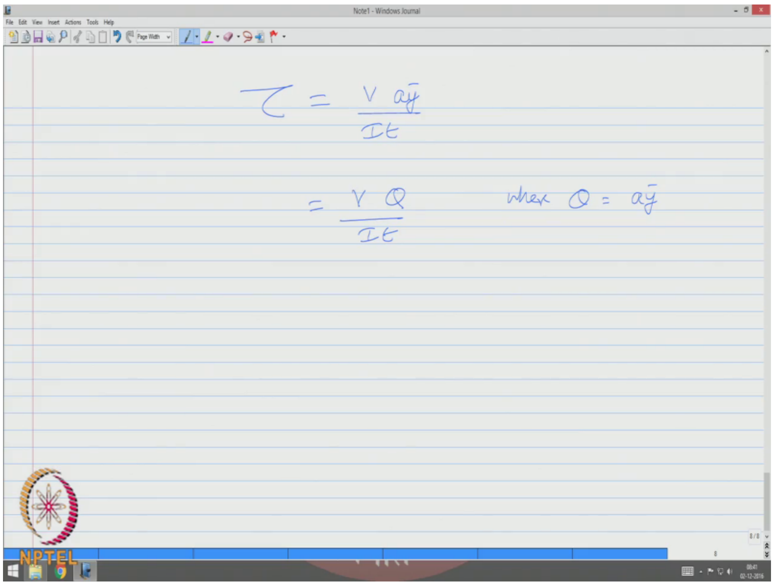

So, tau is V ay bar by I t, it is also called as V Q by I t where Q is a y bar, first moment of area about any section with respect to the axis under consideration.

So, by multiplying the shear stress with area we will be able to get the net resultant shear force, taking momentum about these forces about any point we will be able to locate the shear centre, we will apply this concept for different cross sections with one axis of symmetry, with no axis of symmetry, with curvy linear sections and see how the shear centre can be located from first principles.

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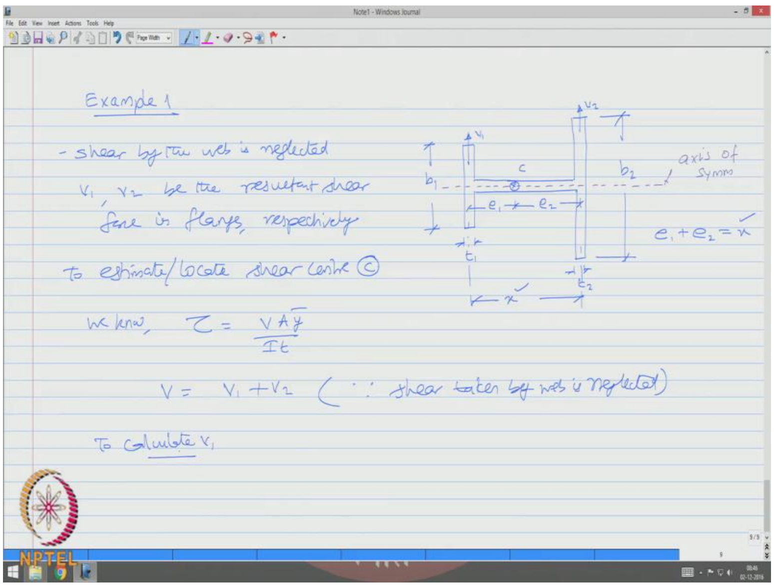

Let us take an example, let us say we have an I section with different flange dimensions, let us say this dimension is b 1 and this is b 2 and we all agree that this is axis of symmetry, let us say this is t 1 and this is t 2 and this distance from the centre to the centre is x which is no and we locate a p point c the shear centre, which is at a distance e 1 from here and e 2 from the centre, that is e 1 plus e 2 is x which is known to us that is a section geometry. Let us say the section is subjected to the force v, so the shear resultants can be V 1 and V 2 and shear by the web is neglected in this case.

So, let V 1 and V 2 be the resultant shear force in flanges respectively; the objective is to estimate or locate shear centre point c, we know the shear intercity is given by V A Y bar by I t. So, total shear V applied to a cross section will be the sum of V1 plus V 2 because shear taken by the web is neglected.

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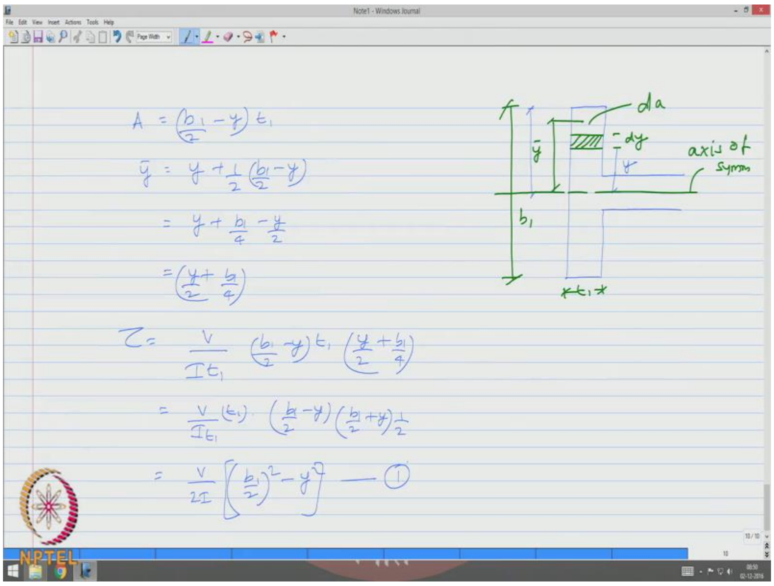

So, let us calculate V 1, let us take an elementary strip the thickness of the strip is dy area da, the cg of the strip from the axis of symmetry y bar, and thickness of the strip t 1 and dimension of the strip. So, area of the strip is going to be or b 1 by 2 minus y into t 1 this is y. So, b 1 by 2 will be this value, y deduction will be this value, t 1 is the thickness of the strip area under consideration, cg of that will be y plus b 1 by 2 minus y half of that, which will be y plus b 1 by 4 minus y by 2; which can be y by 2 plus b 1 by 4 and tau is going to be V by I t 1, b 1 by 2 minus y of t 1, in y by 2 plus b 1 by 4 which is V by I t 1 into t 1, b 1 by 2 minus y into b 1 by 2 plus y half.

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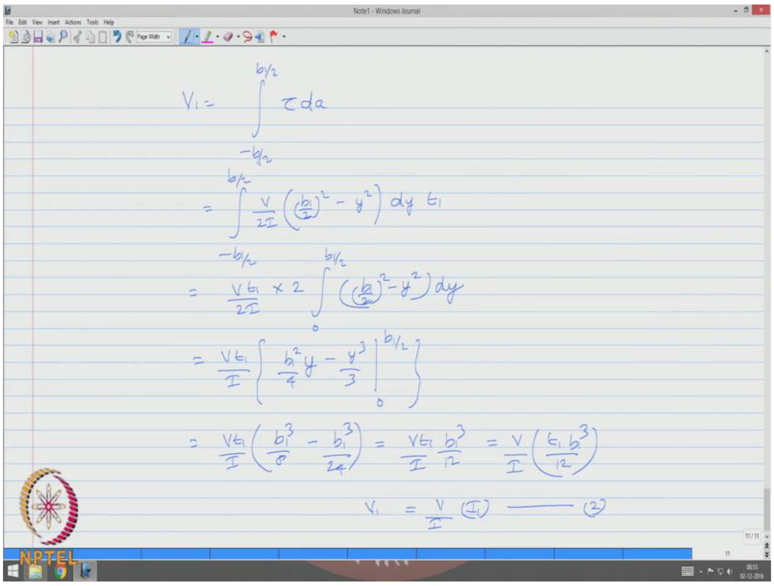

So, that becomes V by 2 I; a minus b a plus b. So, a square minus b square equation number. V 1 is now integrating this for limits minus b 1 by 2 to plus b 1 by 2 which maybe minus b 1 by 2, plus b 1 by 2, V by 2 I, b 1 by 2 the whole square, minus y square of da, if you look at d a this is actually dy into t; So, dy into t. So, that gives me V t 1 by 2 I into twice of integral limits can be changed in this form, which can be V t 1 by I, b 1 square by 4 of y minus y cube by 3, applying the limits 0 to b 1 by 2, which can be V t 1 by I, b 1 cube by 8, minus b 1 cube by 24 which can be V t 1 by I, b 1 cube by 12, which is also written as V by I, t 1 b 1 cube by 12. Looking at the figure, you will realize that I 1 is t 1 b 1 cube by 12. So, I can replace this as V by I into I 1 - equation number 2.

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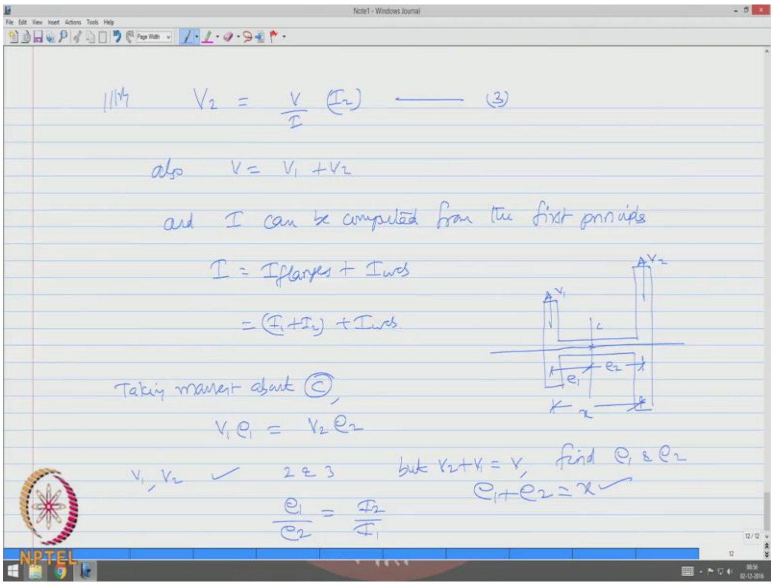

Similarly, 1 can also find V 2 as V by I of I 2, also we know that V is V 1 plus V 2 and I can be computed from the first principles. So, I of the flanges plus I of the web which will be I 1 plus I 2 plus I of the web

Now, draw these figures back again, we know this is V 1 and this is V 2 and there is a point C which is e 1 and e 2. So, taking moment about C; V 1 into e 1 should be clockwise should be V 2 into e 2 to avoid twisting. V 1 and V 2 are available from equations 2 and 3, there are 2 unknowns, but V 2 plus V 1 is also equal to V. So, substituting one can find e 1 and then e 2 because the distance between e 1 and e 2 that is e 1 plus e 2 is x which is known to us. So, by simplifying one can really find that e 1 by e 2 will be actually I 2 by I 1 and 1 can find e 1 and e 2 from this problem.

We will do couple of more examples in the next class to understand how to locate the shear centre for a given problem.

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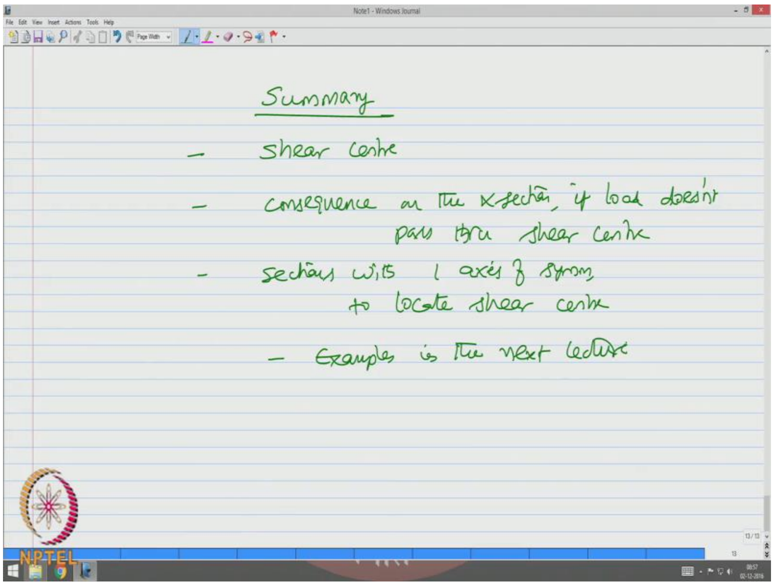

So, friends in this lecture we understood that what is a shear centre, what will be the consequence on the cross section if load does not pass through shear centre, for sections with 1 axis of symmetry, how to locate shear centre? We will do more examples in the next lecture.

Thank you very much.