Offshore structures under special loads including Fire resistance
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Module – 2
Advanced Structural Analyses
Lecture – 29
Shear Centre IV

Friends we will continue with the discussion on topic Shear Centre, this is lecture 29 in module 2 where we are discussing some topics on Advance Structural Analyses under the NPTEL course title offshore structures and the special loads including fire resistance design.

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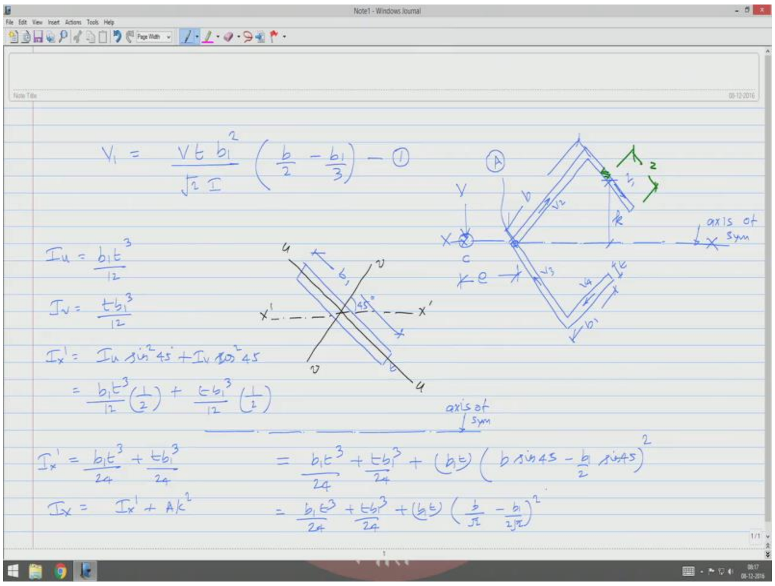

Let us continue with the example what we discuss in the last lecture. So, thin walled section of uniform thickness t and this dimension was indicated as b 1, and this dimension is indicated as beam and this becomes my axis of symmetry, we already know that when a section has at least one axis of symmetry, the shear centre will lie on this, let say this is my shear centre c where the vertical force will be applied to avoid testing movement in the given cross section.

From this point we take the offset of the shear centre as e and let us call this point as point A; if you look at the shear flow within the cross section, we know that this is V 1, V 2, V 3 and V 4. To find V 1 we took a section, which is z from here from here and you derive that V 1 is V t b 1 square by root 2 I, b by 2 minus b 1 by 3 equation number 1; let us try to find the I value which is moment of inertia of the entire cross section about the axis symmetry. So, let us take this object separately and we know the dimensions of this yes b 1 and thickness is t, it is got 2 axes, let us say this is my u u axis and this is my v v axis and let say this x dash x dash axis.

So, 1 can easily say that I u is b 1 t cube by 12, and I v is t b 1 cube by 12, and we know that this angle is 45 degrees therefore, I x dash can be calculated as I u sin square 45 plus I v cos square 45, which will be b 1 t cube by 12 sin square 45 is 1 by 2, plus I v t b 1 cube by 12 and 1 by 2 which tells me is b 1 t cube by 24, plus t b 1 cube by 24 dash, but I want to find about this axis the moment of inertia. So, I x using parallel axis theorem will be I x dash plus A k square, which I say b 1 t cube by 24, plus t b 1 cube by 24, plus b 1 into t is the area and k is actually the censorial distance of this from here that is may k.

Which will be b sin 45, minus b 1 by 2 sin 45 that is the distance for whole square, which can be b 1 t cube by 24, plus t b cube 1 24, plus b 1 t b by root 2, minus b 1 by 2 root 2 the whole square.

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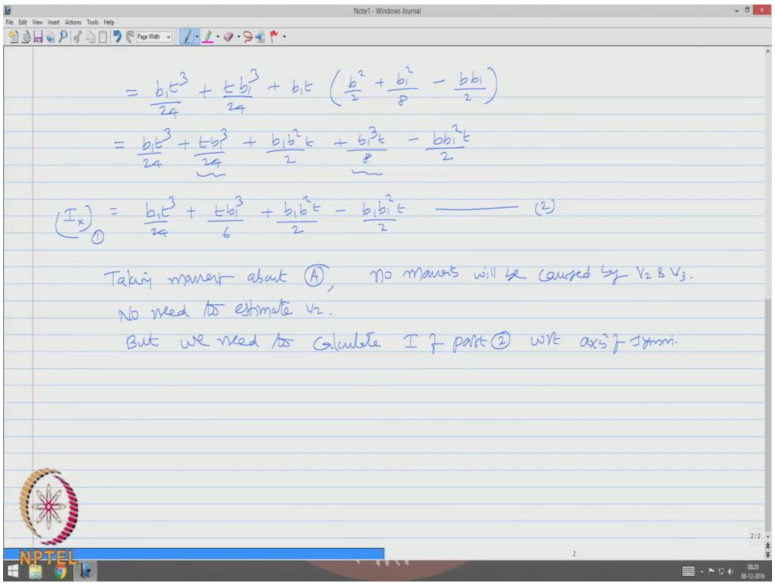

Which can be b 1 t cube by 24, plus t b 1 cube by 24, plus b 1 t, b square by 2, plus b 1 square by 8 minus bb 1 by 2. So, expanding further b 1 t cube by 24, plus t b 1 cube by 24, plus b 1 b square t by 2, plus b 1 cube by 8, minus bb 1 square t by 2 which can be further simplify because I have a term b 1 cube here and b 1 cube here.

So, let us say b 1 t cube by 24, plus t b 1 cube by 6, plus b 1 b square t by 2, minus bb 1 square t by 2; let say this is I x only of the component and let say first component equation 2. Now let us look back this figure, if you take moment about the point a since V 2 and V 3 pass through this point they will create no moment, only V 1 and V 4 you will create moment. The distance of V 1 from this point will be equal to b therefore, we can take moment about the point A, no moments will be caused by V 2 and V 3 therefore, no need to estimate V 2.

But we need to calculate the moment of inertia of the part 2 with respect to axis of symmetry that is required.

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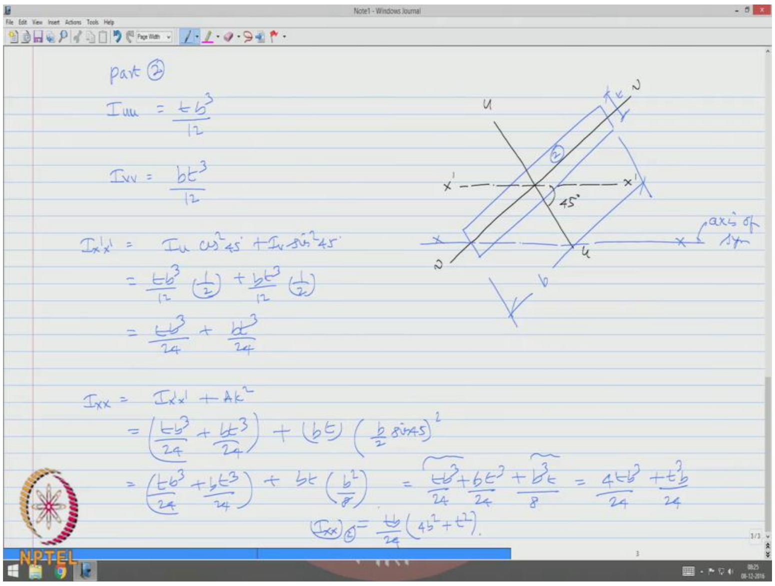

So, let us take part 2 which is like this, u u axis, in this is my v v axis say this is my x dash x dash axis, this is angle is 45 degrees. So, we know now that and the dimensions are this dimension is b and this thickness and this t therefore, I u u of part 2, this is part 2, I u u is t b cube by 12 and I V v is b t cube by 12, I x dash x dash will be I u cos square 45, plus I v sin square 45 which will be t cube by 12, 1 by 2 plus b t cube by 12, 1 by 2 which gives me t b cube by 24, plus b t cube by 24.

So, I want to find I x x there is see this x x axis passes through this point, this may actually axis of symmetry which a call as x x axis in this case. So, I should say this is I x dash x dash plus a k square parallel axis theorem, which will be t cube b cube by 24, plus b t cube by 24 plus b into t is the area and k will be b by 2 sin 45 the whole square, which gives me t cube b cube 24 plus b t into. So, which will give me; I have 2 b cube terms, let us add this it will be 4 t cube 24 plus t cube b by 24, which means t b by 24, 4 b square plus t square that is I x x of part 2.

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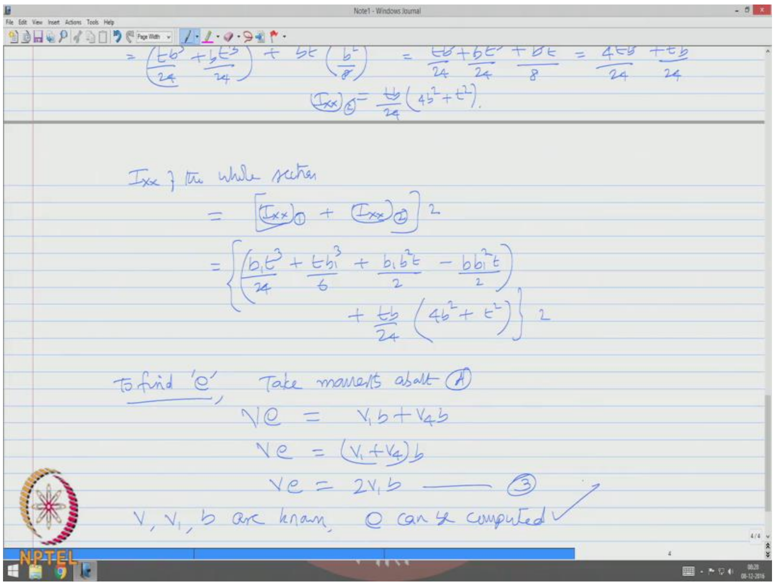

Now, I want to find I x x of the whole section, which will be now equal to I x x of part 1 plus I x x of part 2 into 2 there are 2 such parts.

Which will be b 1 t cube by 24, plus t b 1 cube by 6, plus b 1 b square by 2, minus bb 1 square t by 2 that is path 1, plus t b by 24, 4 b square by t square, now the whole multiplied by 2. Now 1 can to find e; to find e take moments about A, the taking moment about this part; so I should say now b 1 into b, V into e will be equal to V 1 into b, plus V 4 into b which is V 1 plus V 4 into b, which essentially is 2 V 1 into b. So, in this equation V, V 1 and b are known e can be computed or on the other hand V 1 is known in terms of V. So, they for still e can be computed. So, in this example we have seen how one can locate shear centre for sections which has at least one axis of symmetry.

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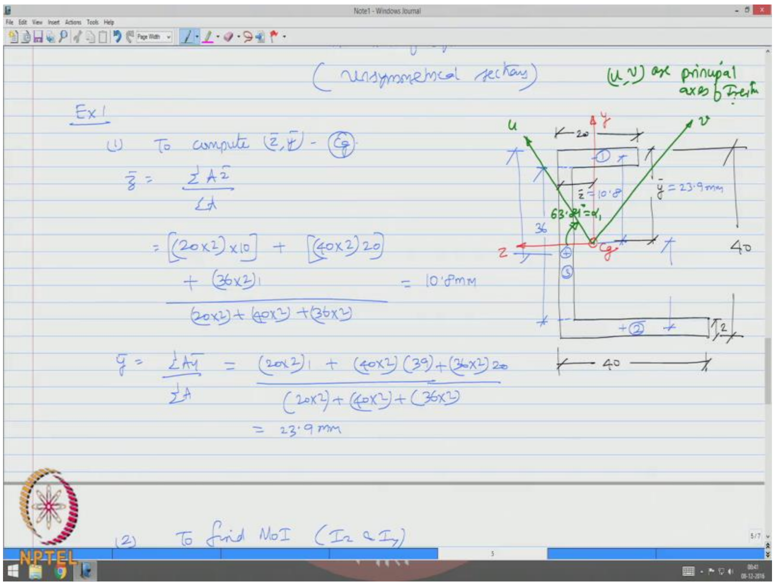

Now, let us say to find shear sections or shear centre; to find or locate shear centre for sections which have no axes of symmetry, unsymmetrical sections; let us take an example is take this my unsymmetrical section, I am drawing let say is my z axis and this is my y axis and that becomes my Cg, which you need to locate and this section as no axis of symmetry, let us mark the dimensions of the section and say this is 40, this dimension over all is also 40 and this dimension is 20, the section as uniform thickness of 2 mille meters though on by. So, now, let us call this distance my z bar and this distance as y bar. So, the first step is to compute z bar y bar which are coordinates of the C g. So, we will use to find z bar sigma A z bar by sigma A, let us say 20 into 2 area of the first part, is the first part and Cg distance 10 plus 40 into 2.

So, this is the second part and the distance is 20, plus this remaining distance this value will be 40 minus 4 which is 36. So, this is the third part 36 into 2 into the distance of that from here is 1 divided by 20 into 2, plus 40 into 2, plus 36 into 2, which will give me z bar as 10.8 mille meters, this value is 10.8. Similarly y bar is sigma A y bar by sigma A, which is 20 into 2 into 1 that is the distance, 40 into 2 into 39 30 is the distance of the second piece plus 36 into 2 the distance of this Cg from here, we are bother about this distance, which will be 36 by 2 is 18, 18 plus 2 is 20. So, 20 divided by 20 into 2 plus 40 into 2 plus 36 into 2.

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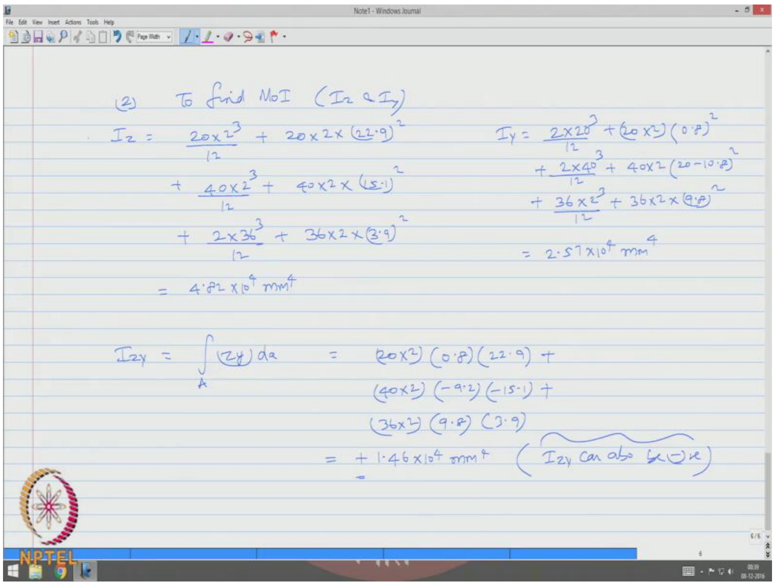

I get y bar as 23.9 mille meters. So, you have look at the Cg, now the next step lies to find moment of inertia which is I z and I y. So, from the first principles we can find Iz as 20 2 cube by 12, plus 20 into 2 into 22.9 square, we look at this we are interested in finding let say this distance. So, 23.9 minus 1; so 22.9 square that is what you're writing here, plus d b cube by 12 a k square. So, this distance will be 15.1, is actually 39 minus 23.9 that is what you get, 15.1 square, plus 2 into 36 cube by 12 that is by the part 3, plus 36 into 2 into 3.9 square because this Cg will be from here.

Eighteen plus 2 20 this 23.9 refer 3.9 square, which amounts to 4.82, 10 power 4 mm 4; let us find I y b d cube by 12, plus a k square, let say I am talking about I y, this is 20. So, this is 10 and 10.8. So, 0.8 square, plus 2 into 40 cube by 12, 40 into 2 into 20, minus 10.8 square plus 36 into 2 cube by 12 plus 36 into 2 into 9.8 square. I get I y as 2.57 10 power 4 mm 4, I can also find I z y. I z y is summation z y d a for the whole area. So, let us do it or part 1 20 into 2 is the area and the z value and the y value, plus part number 2, 40 into 2 and the z value is minus 9.2 and the y value is minus 15.1 plus the third part into 2 is 9.8 positive and 3.9 positive.

So, I get this value as plus 1.46 10 power 4. Please note that I said by can also be negative, please understand this and this case it is positive.

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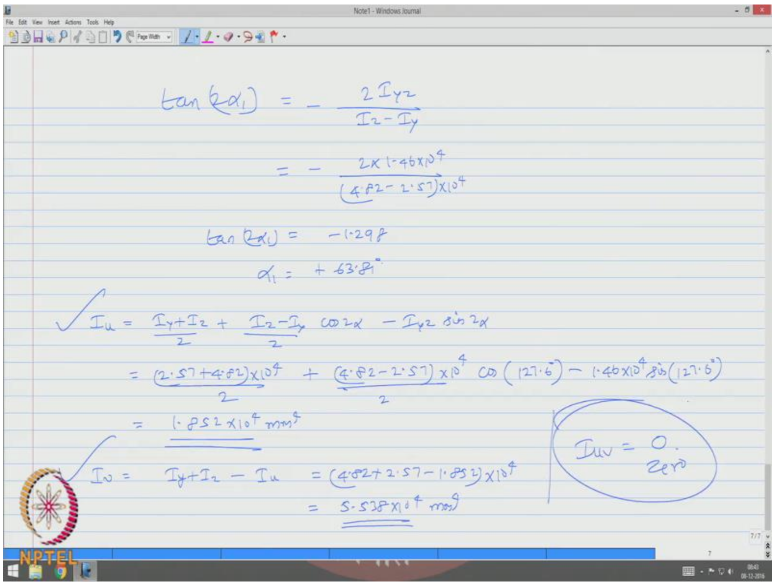

Once I know I z I y and I z y, we can find out the inclination of the principal axes of inertia by this equation, which we already derive tan to alpha 1 is minus 2 I y z by I z minus I y which in my case is minus 2 1.46 10 power 4, by 4.82 minus 2.57 into 10 power 4, we says tan 2 alpha 1 is minus 1.298, which tells me alpha 1 is 63.81 degrees, let us try to plot this. So, this is my u and my v and this angle is 63.81 degrees by just alpha 1 in my positive value.

So, these are u and v are principal axes of inertia, now I can find them I can determine them from the formal equation I u is I y I z by 2, plus z minus y by 2 cos 2 alpha minus y z sin 2 alpha, which can be 2.57 plus 4.82 into 10 power 4 by 2, plus 4.82 minus 2.57, into 10 power 4 by 2 cos of 127.6 degrees, minus 1.46, 10 power 4 sin of 127.6 degrees, which tells me this values 1.852 into 10 power 4, mm to the power 4, I can find I v as I y plus I z minus I u, which will be 4.82 plus 2.57 minus 1.852 of 10 power 4, which tells me is 5.538, 10 power 4, mm to the power 4.

So, I have I u and I v; obviously, u and V b principal axes of inertia, I u v will be 0.

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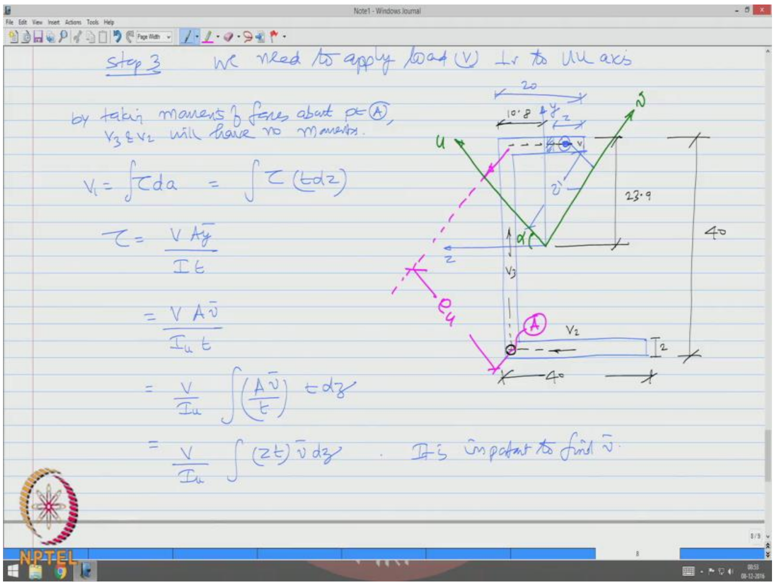

Now, after locating the principle axes of inertia our interest to find the shear centre, we need to apply load V that shear volts, perpendicular to u u axis. So, let us say this is my object or this is my section, this is my z axis, this is my y axis, this is my u axis, v axis, this angle is more and these distances or also known this is 10.8 and this is 23.9 and this value is 40, this value is also 40, this value is 20 and this thickness is 2.

A shear flow is like this, let say this is my V 1, this is my V 3 and this is my V 2, V 3 and V 2 into sector this point. So, let us say I want to apply the force perpend uu axis let say applied here applied here. So, I am interested in finding out actually this distance, interestingly if we call this point as point A, by taking movement about of forces about point A, V 3 and V 2 will have no component. So, let say only V into e will be there, let us cutter suction at distance z and the Cg of the section is let say V 1. So, V 1 is tau d a, which is integral tau t d z, tau is V A y bar by I t, in my case it is going to be V A v bar by I u into t. So, which will be going to equal to V by I u, integral A V bar by t into t d z, which will be V by I u integral z t into V bar d z

Now, interestingly it is important to find v bar of the Cg of the portion, this distance you want to find the V bar.

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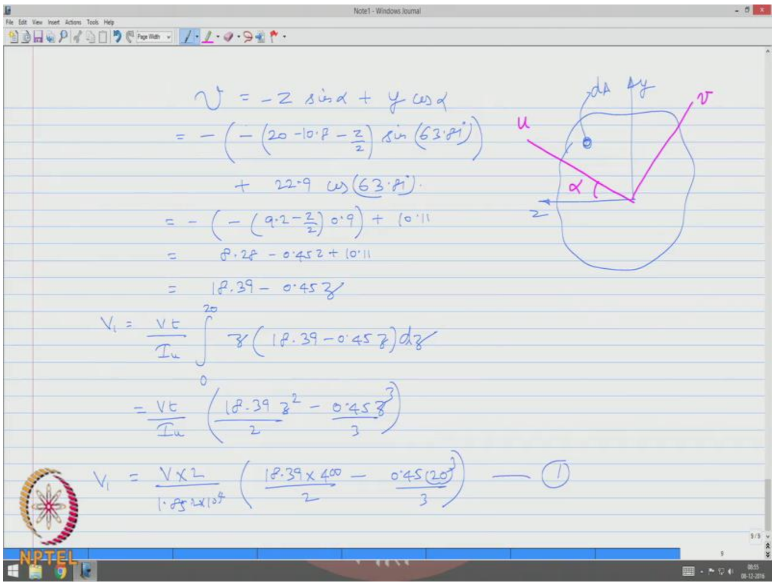

We know V is actually equalled to z sin alpha plus y cos alpha. So, if you look at any cross section? If I say this is my z, this is my y and this is my let say d a and these are my u and v axis, and this is my alpha then I can easily say I resolve this negative side of v therefore, v is minus z sin alpha, plus y cos alpha. Now you will like to know the coordinates of this specific Cg in terms of v bar. So, which will be minus of minus 20 minus 10.8, minus z by 2 of sin 63.81 degrees, plus 22.9 cos 63.81 degrees that is going to be my e value. Now the question is why this is negative? Can see here this is 20, the Cg of this point is on the negative side of z that is why it is minus.

You are substituting minus, minus 9.2, minus z by 2.9, plus 10.1, which gives me 8.28 minus 0.45 z, plus 10.11 which will tell me 18.39 minus 0.45 z; now, let us get back to be 1 which will be V t by I u, integral 0 to 20 z, into 18.39 minus 0.45 z of d z, which can be v t by I u, 18.39 z square by 2, minus 0.45 z cube by 3, which can be V into 2 by 1.852 into 10 power of 4 of 18.39 into 400 by 2, minus 0.45 20 cube by 3.

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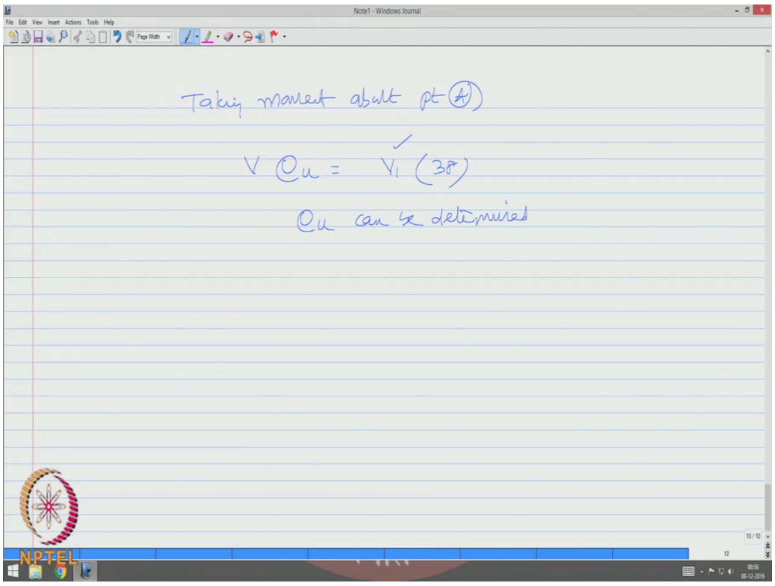

So, 1 can find V 1 by equation 1. Once I know V 1, taking moment about A, I can say V into e u is V 1 into 38, because 38 is the distance of Cg, in this point to this point that is this distance. So, V 1 is known in terms of V therefore, we will cancel and e u can be determined.

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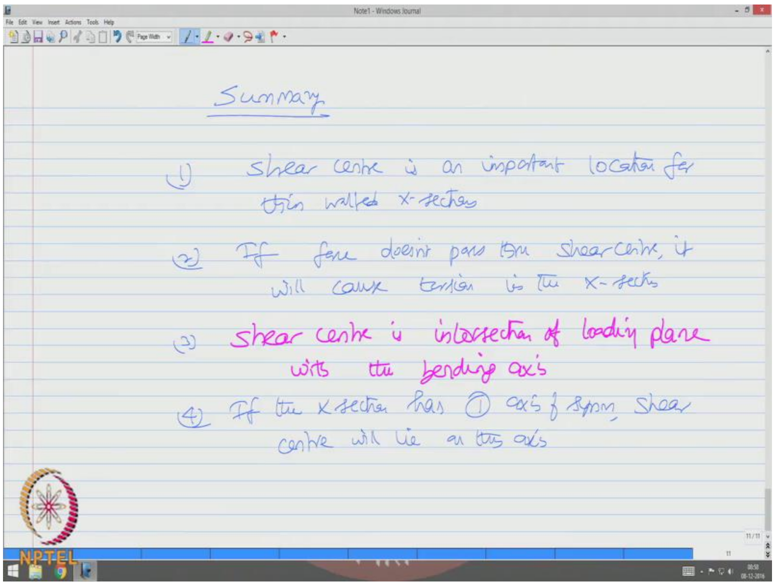

So, friends the summary of all this 4 lectures, shear centre is an important location for thin walled cross sections. If force does not pass through shear centre, it will cause torsion in the cross section and shear centre is intersection of loading plane with the bending axis, if the section has 1 axis of symmetry, shear centre will lie on this axis. We have seen examples to find out shear centre for cross sections having at least 1 axis of symmetry and also for cross section does not have even any one single axis of symmetry.

I hope you have understood these lectures and followed these examples, there are many more examples available in the literature please try to solve them and try to find out how you can estimate shear centre location for the given cross sections.

Thank you very much.