Offshore structures under special loads including Fire resistance
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Module – 02
Advanced Structural Analyses
Lecture – 27
Shear Centre II

Friends, we will continue with the discussion on shear centre, this is lecture 27 on module 2 where we are discussing Advanced Structural Analyses, Shear Centre II.

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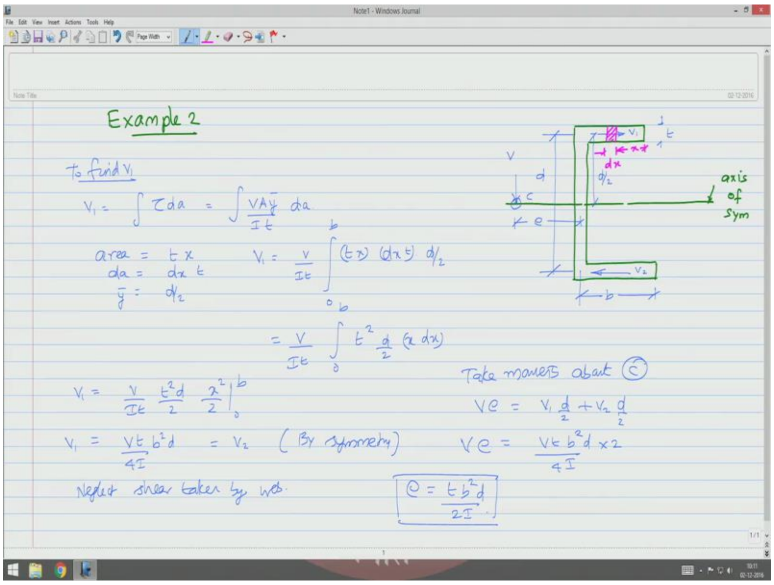

Now, we will take out the second example problem, where the section now is a channel which has 1 axis symmetry as marked now; one can say this is axis of symmetry, let us see the dimensions of this is b, thickness t and depth of the section d. Let us say this is my resultant shear force V 1, this is resultant shear force V 2, for the applied load V at the shear centre C which is distance e on this axis.

Now to find V 1; V 1 is tau d a, which is VA y bar by I t of d a, let us consider a strip which is x from here and whose thickness is d x. So, area under consideration is going to be t into x and d a is going to be d x into t and y bar the strip distance is going to be d by 2 that is this distance. So, therefore, now V 1 is v by I t, integral t x d x t into d by 2 a y bar so which is then, integrating this from the limits 0 to b. So, v by I t integrating 0 to b, t square d by 2 x d x. V 1 now can be computed as V by I t, t square d by 2 x square by 2 0 to b which is V t by 4 I, b square d that is V 1.

We also know by symmetry is also equal to V 2, let us neglect shear taken by the web. So, let us take moments about C. So, V into e which is anti clockwise will be now equal to V 1 into d by 2, plus V 2 into d by 2. So, V into e is V t b square d by 4 I into 2, which gives me e as t b square d by 2 I.

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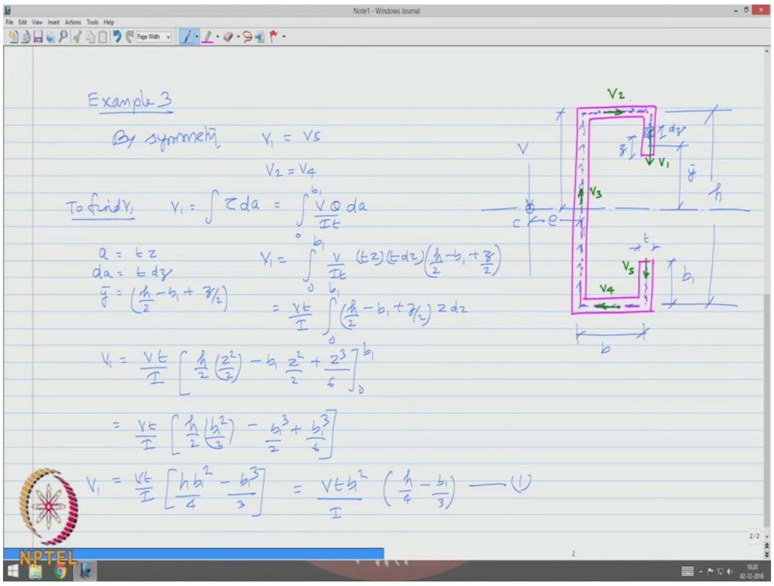

Let us take up another example, let us say this is the central line dimensions, this dimension is b, let us say this is b 1 and this is pitch section as uniform thickness t, we agree that this section has 1 axis of symmetry and the shear centre need to lie on this axis, this is the plane of application of V and this becomes by shear centre C, let us say that this is placed at a distance e from here and the shear flow will be like this way. So, let us call this as V 5 let us call this as V 1, V 2, V 3, V 4 and. So, by symmetry we know that V 1 is V 5 and V 2 is V 4.

Now, I want to find V 1. So, let us take a strip which is at a distance z, thickness d z, we know V 1 is integral tau d a, which is integral V Q I t da for the distance 0 to b 1 because that is the strip value 0 to b 1. Area is actually t into z and d a is actually t into d z, y bar that is the distance of this from here that is y bar, let us say y bar is h by 2 minus b 1, plus z by 2 because we know this distance is h by 2, if you say minus b 1 you are here plus z by 2 will give you the distance of this point from here.

So, now let us substitute b 1 integral 0 to b 1, v by I t, t z, t d z, h by 2 minus b 1 plus z by 2; this says V t by I because there are 2 t's here in the numerator, integral b 1, h by 2 minus b 1 plus z by 2 into z d z. So, V 1 will be V t by I, h by 2, z square by 2, minus b 1 z square by 2, plus z cube 6 limits 0 to b 1, which is V t by I, h by 2, b 1 square by 2, minus b 1 cube by 2, plus b 1 cube by 6, which will be V t by I, h b 1 square by 4, minus b 1 cube by which can be then simplified as V t b 1 square by I, h by 4, minus b 1 by 3 that is b 1 let us say equation 1.

Now, let us compute V 2 for this flange.

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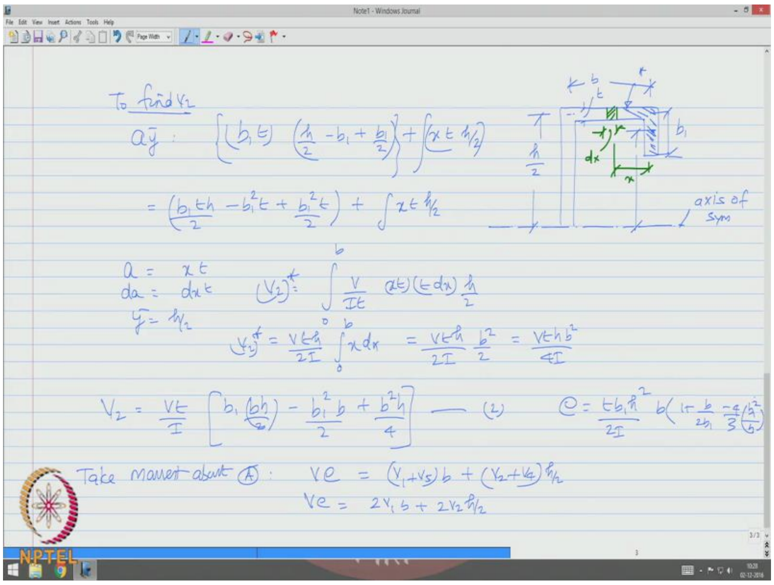

Let us draw this case separately; this is axis of symmetry which is at resistance h by 2 from here, let us consider a strip which is at a distance x from here and thickness d x and we know that this thickness is t and we also know that this dimension is b 1. So, now, there are 2 areas here let us do for both to find V 2.

Let us say first let us compute a y bar. So, b 1 into t, into h by 2, minus b 1, plus b 1 by 2 that will be the distance of this centre from here, because h by 2 minus b 1 will be here, plus b 1 by 2 will give you this, plus that is for the hatched portion here and for this remaining portion it should be x into t into h by 2. So, which can be expanded as b 1 t h by 2, minus b 1 square t, plus b 1 square t by 2, plus integral of this x t h by 2 for the length 0 to b, let us compute the area is x t, d a is d x t and y bar for this piece is s h by 2 therefore, V 2 is going to be V 2 let us say star, that is this part horizontal flange this part is star going to be integral V by I t, x t t d x, h by 2, 0 to b because that is dimension of this 0 to b.

So, which will be V t h by 2 I, x d x 0 to b, which gill me V t h by 2 I, b square by 2 this says V t h b square by 4 I that is b 2 star, that is this part. So, let us find the total V 2 which will be V t by I, b 1 b h by 2, minus b 1 square b by 2, plus b square h by 4. So, now, equation numbers 2. So, taking moments about C not doing more over C, taking movement about A; where A is this point, we can write V into e which is anticlockwise which will be equal to V 1 plus V 5 into b, plus V 2 plus V 4 into h by 2, which simply says that it is 2 V 1 b plus 2 V 2 h by 2. So, substituting for V 1 and V 2 in terms of V, we can straight away say e will be given by t b 1, h square by 2 I, b 1 plus b by 2 b 1 minus 4 by 3, b 1 square by h.

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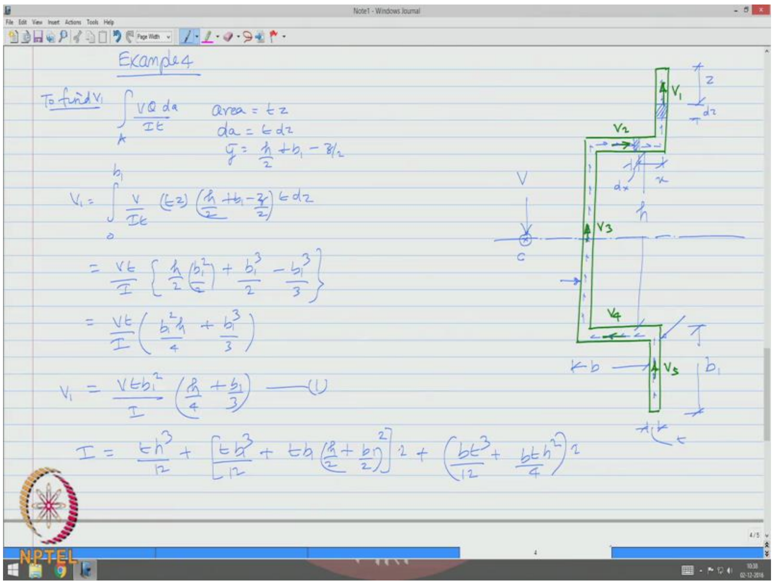

Let us do one more example, the section is again a special section used for housing electrical cables or cable tree, which is called as a channel bracket section. Let us say the dimensions are marked as b 1, this is b which is as same as centre to centre, the section has uniform thickness t throughout and (Refer Time: 21:41) dimension is h, as we now agree section as 1 axis of symmetry therefore, the shear centre will lie at this point, let us subject the vertical load here, the shear flow will be this way to oppose the shear, let us call this net resultant as V 1, this net resultant as V 2, V 3 V 4 and V 5.

Now, to find V 1 we will cut a strip at a distance z from here, let this be d z and for finding V 2 let us cut a strip at a distance x from here let the strip be d x. Now to find V 1, which is integral for the entire area V Q d a by I t; now area is t z, d area is t d z and y bar is h by 2, plus b 1, minus z by 2. So, therefore, V 1 will be integral 0 to b 1, V by I t, z, h by 2, plus b 1 minus z by 2 of t d z, which is v t by I, h by 2 b 1 square by 2, plus b 1 cube by 2, minus b 1 cube by 3, which can be said as V t by I, b 1 square h by 4, plus b 1 cube by 3, which is V t b 1 square by I, h by 4, plus b 1 by 3, that is V 1.

Now, to compute V 2 take this strip into consideration.

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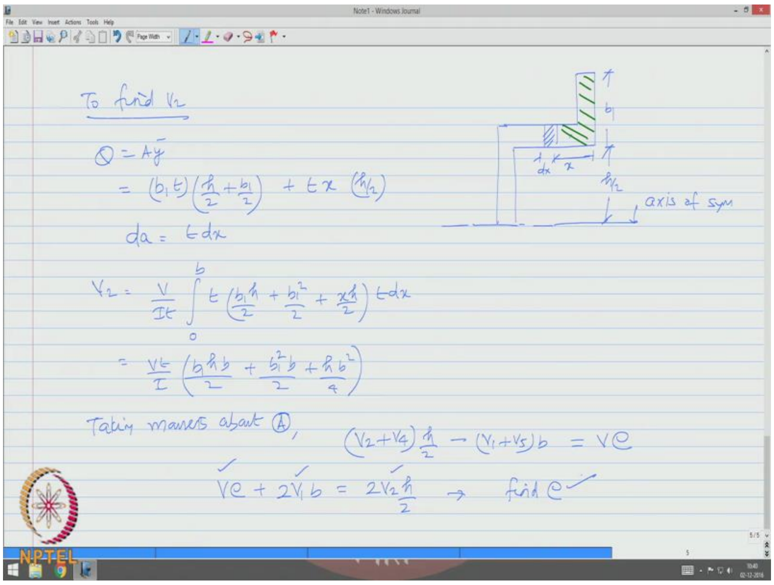

So, to find V 2, now looking for this is an axis of symmetry, I am cutting a strip here, after distance x from here of d x. So, we have to look at this area and AY bar of this separately. So, there are 2 pieces here one is horizontal, one is vertical, let us work out separately. So, Q is actually AY bar, let us say b 1 into t is the vertical strip, this distance we know is h by 2 and this of course, we know it is b 1 therefore, the distance will be h by 2, plus b 1 by 2. Now for the horizontal strip it is simply t x and the distance of this is h by 2, t being very small we can straight away say that this distance is as same as this distance. So, d a is t d x therefore, V 2; V by I t integral 0 to b, t, b 1 h by 2, plus b 1 square by 2, plus x h by 2 of t d x, which can now say it is V t by I, b 1 h b by 2, plus b 1 square b by 2, plus h b square by 4 at substituting the limits.

One can also calculate I for the entire section, we will do it here. So, the moment of inertia for the entire section can be calculated as t h cube by 12, that is for the web t b 1 cube by 12 that is for this portion as well as the above one, then parallel axis theorem t b 1 h by 2, plus b 1 by 2 the whole square; there are 2 elements of this, plus b t cube by 12, plus b t h square by 4 again 2 elements of this. Once I know I now taking moments about point A, we can say V 2 plus V 4 into h by 2, because they will cause a clockwise movement about this point V 2 will cause a clockwise moment, minus now this going to cause a anticlockwise moment V 1 plus V 5 of b will be actually equal to this will cause again a clockwise moment, which will be equal to this moment which is V into e. So, one say V into e, plus 2 V 1 b because V 1 V 5 are identical, it is actually equal to 2 V 2 h by 2. So, we have equations for V 2 we have V 1 and V is a known value, by solving I can find the shear centre distance e which is marked from this point which is calculated. So, e can be updated.

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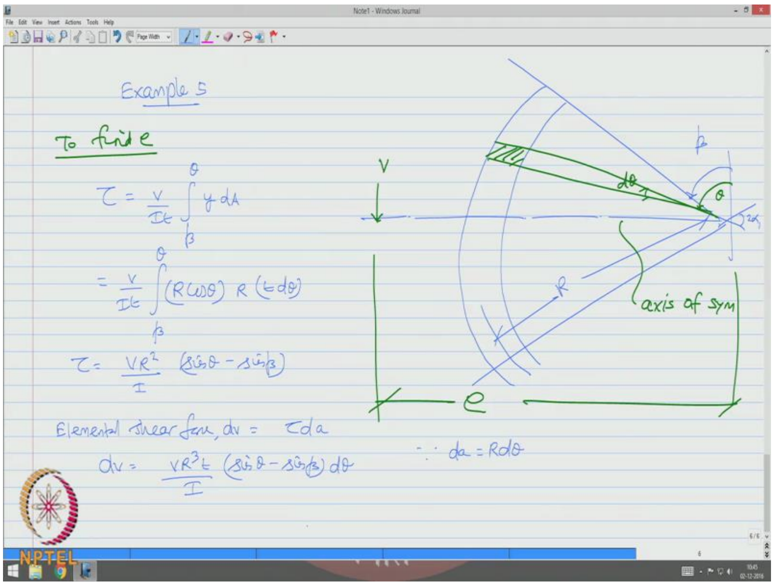

Let us take one more example which we will take a curved section, let us say this section has an angle which is extended to be 2 alphas and let the radius be R, let from the vertical the strip be beta and let us now cut a strip at an angle theta and let this angle be d theta. So, this becomes my axis of symmetry, let us may my load is applied here and let this be the distance e the distance of shear centre.

So, now the objective is to find e; locate the shear centre for the section, we know Q is a y bar, which is actually prior to that tau is V by I t varying from beta to theta y d a because that is my area under consideration, which will be V by I t beta to theta, R cos theta, into R into t d theta, therefore tau is V R square by I, sin theta minus sin beta after applying the limits.

Now, the elemental shear force, dv will be tau d a. So, d v will be V R cube t by I sin theta, minus sin beta d theta because that is my da or d theta because da is R d theta.

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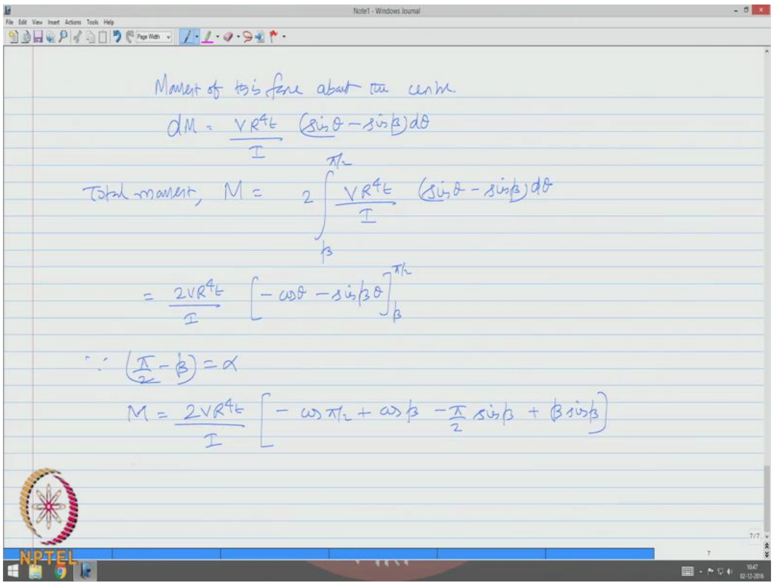

Now, I take moment of this force about the shear centre, let us say dm it is an elementary strip V R 4 t by I sin theta, minus sin beta d theta. So, now, the total moment M will be integral beta to pi by 2, please see the limits here its varying form beta to pi by 2, but twice V R 4 t by I sin theta, minus sin beta d theta which gives me 2 V R 4 t by I, minus cos theta minus sin beta theta applying limits beta to pi by 2, we also know from the figure that pi by 2 minus beta is alpha that is this angle, this angle will be actually alpha because the total angle is appended is 2 i.

So, using this relationship, since pi by 2 minus beta is alpha, let us rewrite M as 2 V R 4 t by I, minus cos pi by 2, plus cos beta, minus pi by 2 sin beta, plus beta sin beta.

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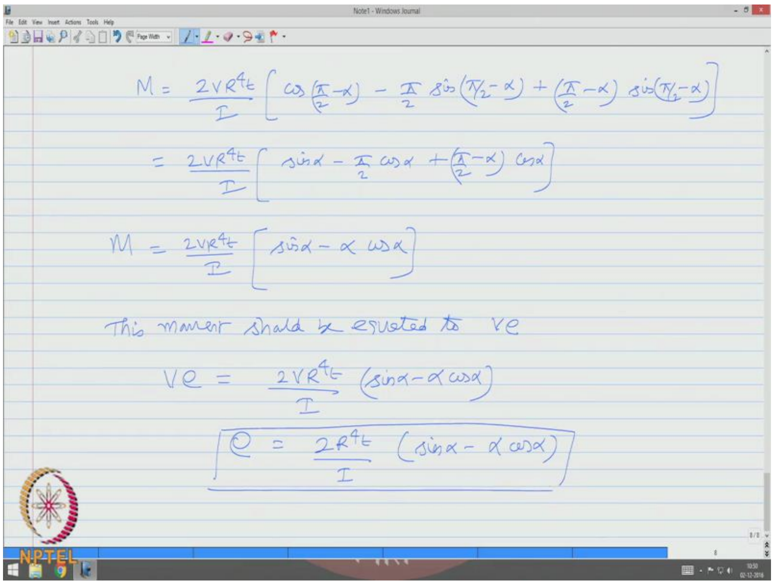

This says M is 2 V R 4 t by I, cos pi by 2 is 0 therefore, cos beta can be said as pi by 2 minus alpha, minus pi by 2 sin beta is again sin pi by 2 minus alpha, plus beta sin beta that is pi by 2 minus alpha multiplied by sin pi by 2 minus alpha, applying trigonometric rules we can say by I this becomes sin alpha, the second term becomes minus pi by 2 cos alpha, plus pi by 2 minus alpha cos alpha, which can be 2 V R 4 t by I sin alpha, minus pi by 2 cos alpha plus pi by 2 alpha goes away, minus alpha cos alpha that is my M. So, now, this M should be equated to V into e because we are talking about at the centre we have taken moment about this point. So, V into e should be equated. So V into e is 2 V R 4 t by I sin alpha minus alpha cos alpha.

So, 1 can now find e as 2 R 4 t by I, sin alpha minus alpha cos alpha, provided we know how to compute moment of inertia for this segmental piece will be able to compute the shear center distance from the centre of curvature as shown below.

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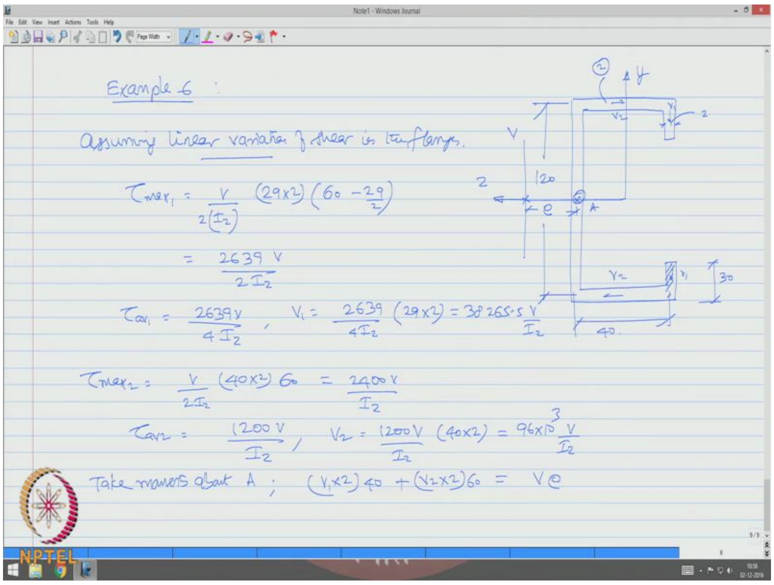

Let us take one more example and see how quickly we can compute the shear centre. Let us do by some other quick technique to find down the shear centre, take a same example of a channel, but we do this problem slightly in a different manner.

Let us say this dimension is 30, this dimension is 40 and this dimension is 120 and the thickness is 2, we know that it has 2 axis if marked like this out of which one is axis of symmetry. So, shear centre need to lie on this let us say this is my plane web the resultant forced need to be applied. So, I take this distance as e. So, the shear flow says that is V 1, this is V 2 and this also V 1 and this is also V 2 by symmetry we already know this assuming linear variation of the shear in the webs.

So, assuming linear variation of shear in the flanges tau max 1 is actually let us say the force V is applied; V by I z thickness is let us say 2 as V I t. So, 29 into 2 is the area of this t is no this one, the distance could be minus 29 by 2 which gives me 2639 V by 2 I z therefore, tau average will be half of this 2639V by 4 I z because we have assumed a linear variation, similarly tau max 2 that is for this piece will be V by 2 I z, the piece area is 40 into 2 and the distance of cg is 60, which gives me 2400V by I z. So, tau average 2 will be 1200 V by I z. Now I can easily find V 1 is 2339 by 4 I z into this area 29 into 2 which is nothing, but 38265.5 V by I z and V 2 is 1200 V by I z into the area this is V 40 into 2 which gives me 96, 10 power 3 V by I z. So, now, I have V 1 and V 2.

Let us take moments about A; we know it is going to be V 1 into 2 into 40 because V 1 and V 5 are same, plus clockwise, so plus V 2 into 2 into 60, that should be equal to V into e.

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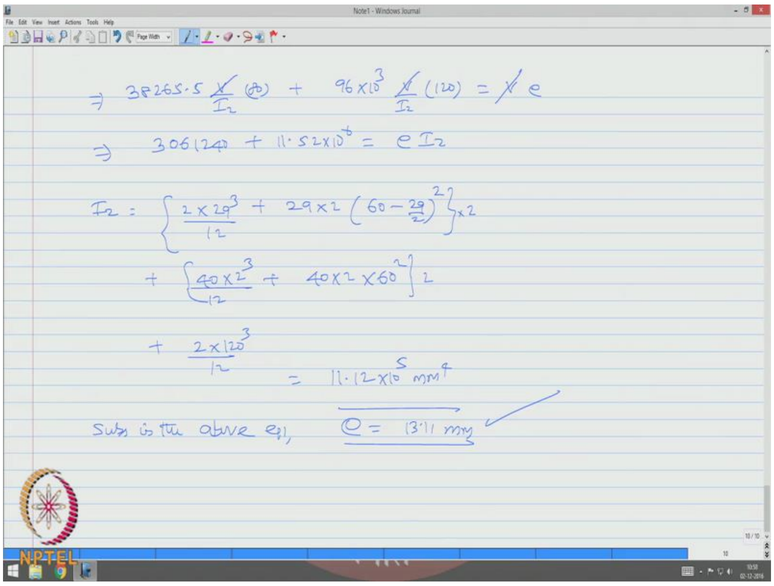

Let us substitute back 38265.5 V by I z into 80, plus 96 10 power 3 V by I z into 120 V into e, V goes away therefore, 3061240, plus 11.52 10 power 6 will be e I z. So, now, let us see how to compute I z quickly from this figure, I z will be 2 into 29 cube by 12, plus parallel axis theorem 60 minus 29 by 2 the whole square 2 such pieces, plus V d q by 12 that is 40 2 cube by 12, plus a k square, 40 into 2 into 60 square again 2 such pieces, plus of course, whether b d cube by 12, which I get I z as 11.12 10 power 5 mm 4 substituting in the above equation e is 13.1 mm.

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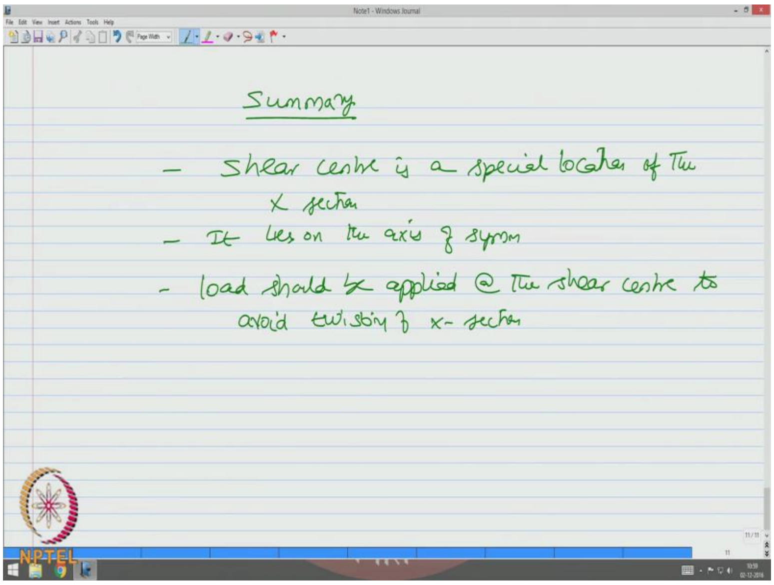

So, friends let us look at the summary, shear centre is a special location of the cross section. It lies on the axis of symmetry preferably load should be applied at the shear centre to avoid twisting of the cross section. We have seen examples to estimate shear centre for sections which has 1 axis of symmetry because shear centre will lie on that axis. We will also take up examples to estimate or locate the shear centre where there are no axes of symmetry how they can be obtained in the next lecture.

Thank you.