Design of Reinforced Concrete Structures
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Lecture – 27
Design for Torison

So far we have done the design for beams, to resist bending moment and shear forces which is also applicable for footing as well as slab and the other one we have done that axial, axial loaded column. Now, we shall learn how to design for torsion where it is applicable. So, for that this lecture concerned this is our lecture number 27, design for torsion.

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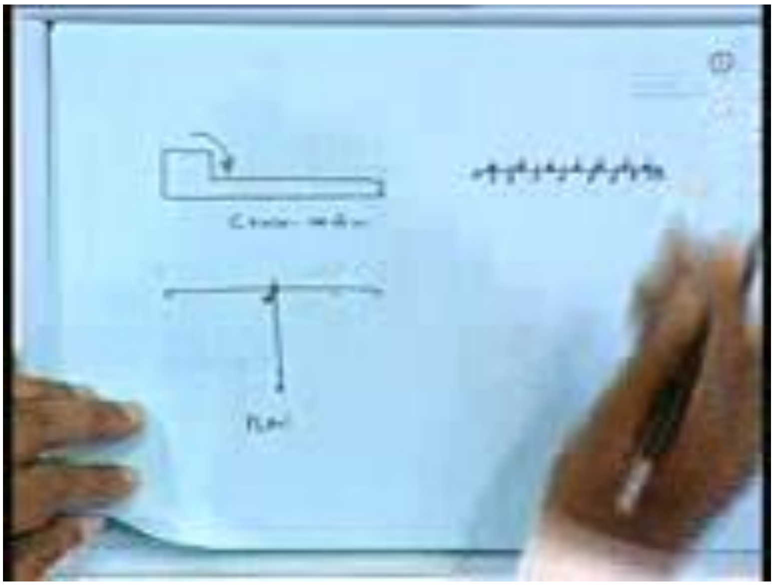

And now let us come, that where the torsion is really applicable, there were x if you take a cantilever slab say we would like to say cantilever slab supported by a beam. A cross section I am drawing it could be other way also beam so, this is your beam that this beam is supporting this cantilever slab. So obviously, you will find out that if you take 1 beam say like this may be simply supported also possible.

In that case, what will happen then you will find out not only the bending moment or forces acting here; you will have that torsion due to this moment. So that means here, you have to design it for torsion also and this beam you have to design for bending moment for shear forces, as well as for torsion developed due to this slab.

Similarly, it is possible if you draw it in plan this is a cross section if we might draw say beam plan, we are drawing the plan here. So, if we draw this is plan please note it is not the elevation. So, what will happen? Due to this beam, torsion will be developed at this point.

Because, this beam will develop that apply certain kind of torsion like this and for that also it will design. But that torsion only applicable at this point or may be you can say what the width of this beam whereas, in this case this torsion is applicable over the like this over the whole beam from one end to other end. So, this is the so you can find out that there are so many other cases, where it is possible that where torsion will be developed. So, how shall you design that?

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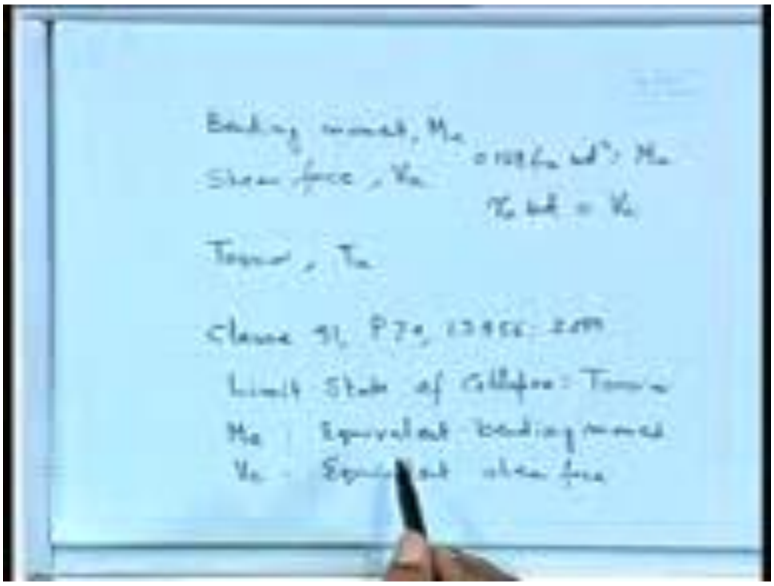

What we generally do, there there we can say that direct that means when you are talking say bending moment and the other 1 shear force. So, we can directly we can compute the effective depth that 0 138 fck b d square equal to say Mu as per the limit state design. So you can find out the depth directly, then Mu is the ultimate moment developed due to this bending moment that you are whatever load applied. And shear force also we have that shear force, that is your say b or b u.

So, from that also you can find out the shear stress developed say tau v and we can find out so tau v times say bd equal to say Vu. So, you can find out the shear stress and critical stress also you can find out, so tau v minus tau c from there we can provide the shear reinforcement.

But regarding torsion, we do not go directly what we do; we find out the equivalent bending moment developed due to torsion say Tu. Tu the torsion applied after say factored 1 that means, after we multiply with 1 5 or whatever the appropriate factor. And then we can find out the Tu and this Tu that there is no such scheme or no such formula from where we shall directly get the d.

Because, here we are having that you can say 3 parameters or 3 things are being applied: one is bending moment, another one is shear force and another 1 is torsion. So, what we shall do it here? We shall find out the Tu that how it is actually applicable? what is the equivalent 1 that for bending moment as well as for shear force. And this one we shall find out in clause for your reference clause 4, page 74 , IS 456: 2000.

So, this is your that clause for limit state of collapse and that is torsion. So, we shall do this particular one here; so, what is our objective then ? If say this is your Mu, this is your Vu. Then we shall find out, which is a function of Tu and Mu also that we shall find out Me that equivalent bending moment and Ve that equivalent shear force.

So, which is a function of that your say Tu as well as Mu, Vu like that. And what we have to do? What we have to provide? We have to provide the reinforcement so obviously, the reinforcement will be here; for bending moment the reinforcement will be here. The longitudinal reinforcement and for this Ve that you have to provide the shear or web reinforcement or the stirrups. So, these two things we have to provide.

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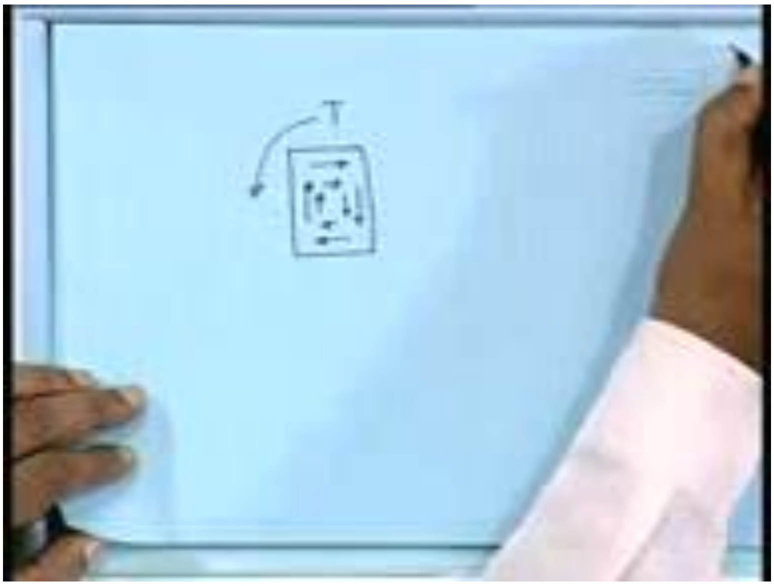

So, what is the idea behind that ? If we take it say any section say this is your say torsion then shear stresses developed like this, about the surface which is true for circular one also, for the noncircular one also. So that means, shear force you will find out the shear stresses at different fibre that is developed.

So, if we can now if the shear stress developed here; so, if we can resist the shear stress providing say reinforcement longitudinal which is coming equivalent to your say bending moment from where you are getting. And the web reinforcement or stirrups you are providing so, which is your say shear reinforcement. And that we shall do it here; that is the thing that is the philosophy here; how we are taking care of the torsion.

So, due to this torsion what how the shear stresses developed here on the surface and accordingly you have to provide the sufficient reinforcement. So that, we can resist shear that cracking can be avoided and so, that longitudinal reinforcement and your web reinforcement.

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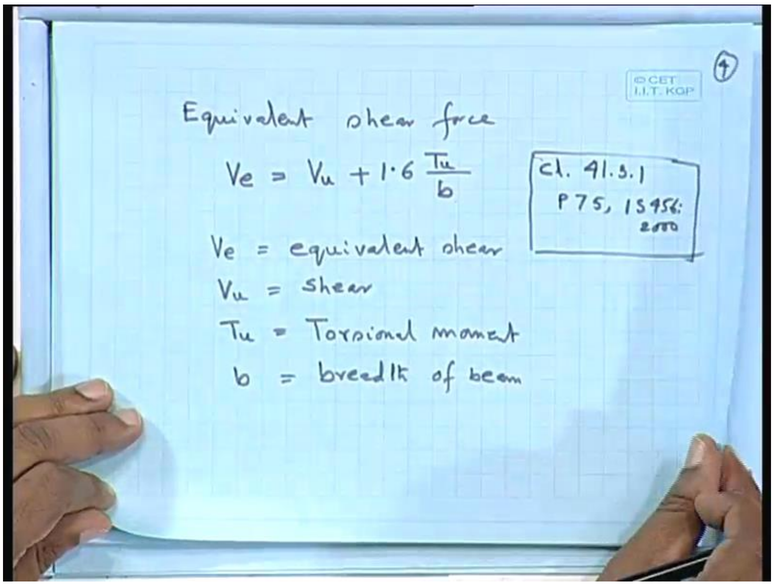

So, what is the that what our code says this is very simple one we can say for equivalent shear force. So, we can say in a particular section we can say Ve, where that torsion is acting. So, Vu the shear force from the usual whatever way you have got it plus 1 6 Tu by b. This one available, in clause just for your reference clause 41 3 1, page 75, IS 456: 2000.

So, Ve equivalent shear, Vu that shear that developed due to your say applied load whatever is coming in the usual way. It will come from the analysis also, that we shall do it in the next few classes for a total frame we shall do it, Tu torsional moment and b breadth of beam.

So, here one parameter is in your hand rather in our hand that is b Vu and Tu that is coming from the analysis, due to applied load say. Now, the equivalent shear that we can reduce it taking say proper width of the beam that means, since it is at the bottom denominator. So, what we can do it here, denominator so, we can take that b say may be that generally we take it say 250 which is governed by the wall thickness, we can change it to 300 also.

So that means, in unusual cases that where we are getting the shear force is quite high, then we can at least we can do some kind of say your changes reduce it by taking proper b though it is in linear parameter. But even then, we can change it. So, b that means there is no such big thing only thing we have that, we have to change the using this equation let us, find out the corresponding equivalent shear force. Then, we shall go as per the standard procedure of design of shear.

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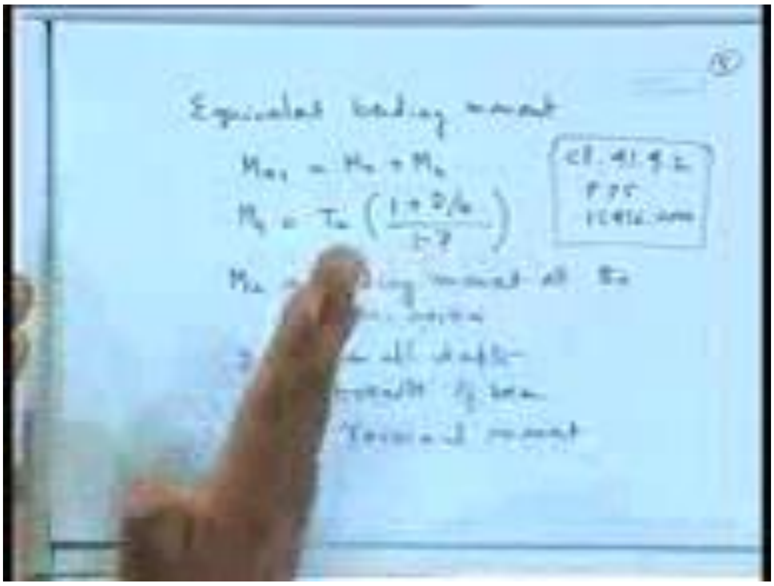

The other 1 that is for the equivalent bending moment. So, I can write down so let us write down here Me 1 equal to Mu plus say Mt this is for the applied load and this is for the torsion. So, Mt equal to Tu divided by 1 plus d by b by 1 7. So here, Mu bending moment at the cross-section and Mt that equivalent that moment bending moment due to torsion we are getting. D is the overall depth, b breadth, Tu torsional moment.

Now, we have one more thing Me1 equal to Mu plus Mt and this is available that clause for your reference clause 41 4 to be more specific I can say 41 1 2, page 75, IS 456: 2000. The parameter 1 7 or the parameter 1 6 that obviously, because we generally come to this 1 finally, we come to say optimum one so that it is safe. But in actual case, if one is interested one can go for the whole analysis, one can find out little different.

But finally, we come to thus 1 6 1 7 for design purpose so that, we can it is applicable for the wide range of say your rectangular sections or for beams. That is the objective here, that how we generally come to the that your say all the clauses, wherever you are having the different parameters; one can say say sometimes we find out something say modulus of stress say e that is say 5700 root over fck.

So, if one is interested for design say you are so from the analysis or from the experiment one can find out the value, may be it is coming say 5200 or 5300 like that. But finally, we are coming to that particular value so, that it is applicable to wide range that is the basic concept in any design code and for any country.

So, even if you find out that in say American code they may vary little bit say UK European code it may vary little bit. But almost you can say it is coming towards certain value, which is closer to that. And there is a committee for each and every country also that for a particular code say IS 456 that is a committee similarly, for say IS 800 for steel.

Similarly, say IS 875 for each and every code there is a committee who are looking after that things and coming to a poin, that this value may be quite sufficient for wide range and applicable to our say Indian standard or Indian condition rather.

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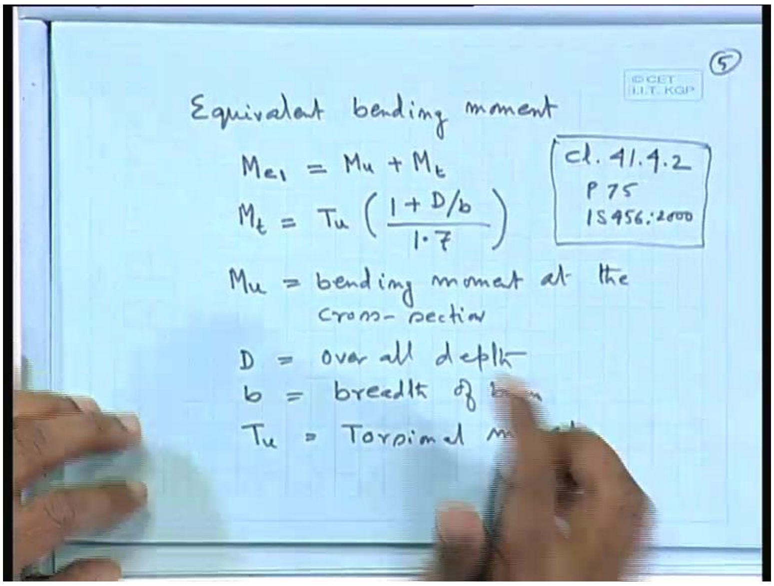

So, now I would also like to tell something more that here also you can find out that Mt that 1 that d by b that means, the earlier case only we have the parameter that b with by which we can manipulate or rather we can reduce the value. Similarly, here also choosing say d by b and then we can find out t hat Mt we can reduce, that Mt that also we can here.

And one more thing I shall tell you that, if we take say span by depth ratio say here say for simply supported case say 20 then, we shall find out that it will not be with that. If we start then it may happen that we are really going that that value that one only very very less. Anyway so let us, find out what more thing we can do it let us find out.

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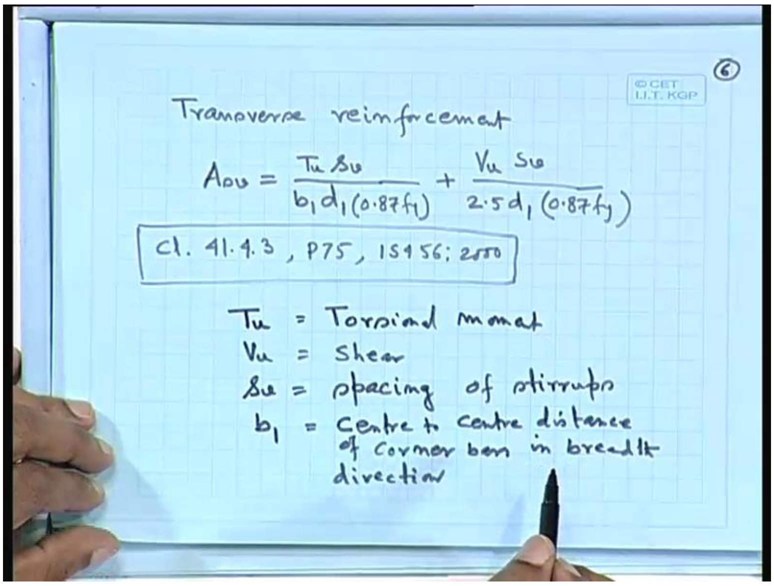

There is one more thing that is your say for transverse reinforcement, that is your say shear reinforcement. We find out here say Asv that your say stirrup that area of stirrup or reinforcement it says Tu by Asv; Asv the spacing of stirrups or web reinforcement b1 d1 times 0 87 fy plus Vu Sv divided by 2 5 d1 times 0 87 fy. We can find out the area of steel using this formula in clause 41 4.3, page 75, IS 456: 2000.

What we shall do it here? That Asv we can find out that means, I know Tu, I know Vu b1 what is b1? fy we know, say Fe 415 so, 450 newton per square millimeter. So, Tu Tu is the torsional moment, Vu shear the is not the 1 other than that say Tu not we have not taken equivalent please note that Vu the shear whatever it is coming due to applied load, Sv spacing of stirrups.

Let us say because finally, you have to provide that 1 as stirrups we call it web reinforcement. So, we have to provide the stirrups Asv and this b1 and d1; b1 centre to centre distance of corner bars in breadth direction. What is that? So, we have b1 and we have d1.

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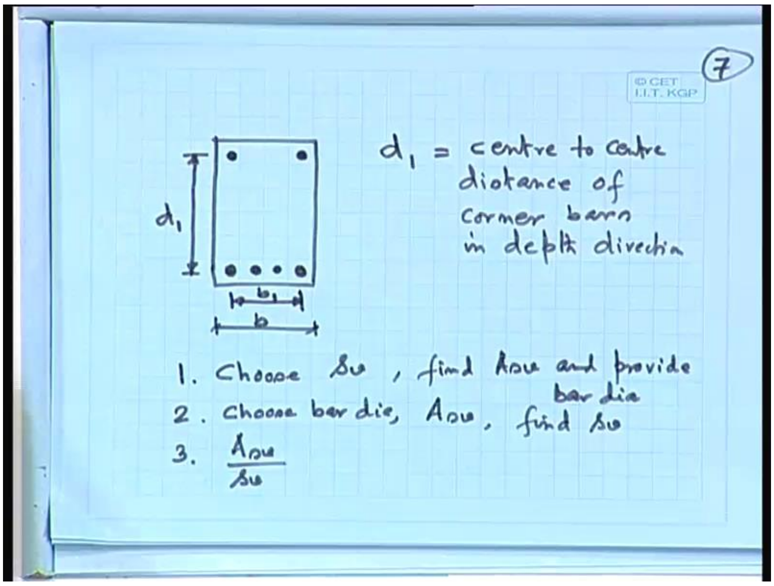

If this is your beam so, we are having reinforcement so b1 means there are many so many bars b1 means this is your b1, along breadth direction b1. So, what about d1? Along the depth direction. So, b1 will be equal to b if this is your b so b minus that clear cover this side 25 millimeter, clear cover this side 25 millimeter minus that half of the diameter here; half of the diameter so that means, 1 diameter.

So, centre to centre distance of corner bars in breadth direction so let us, write down for d1 also d1 will be equal to similar fashion centre to centre distance of corner bars in depth direction. So, overall depth D minus that clear cover for beam 25, 25 for usual cases minus that half of the top bar half of the bottom bar and we can find out d1. So, what we can do it then? Asv that means we know Tu, we know b1 d1 fy everything we know, only thing we do not know Sv.

Now, what we in usual cases what we do in general cases Sv we generally take it say may may be that say we have stirrup spacing say 200 millimeter say. So, if we assume that we shall provide 200 millimeter as per our that coded provision which should not be more than certain value, on the basis of that we can choose say 200 millimeter 250 millimeter.

So, like that if we choose it then we can find out Asv and now if we know Asv. So let us, choose the the diameter of bar and if it is whether it is 2 legged or 3 legged or 4 legged depending on the situation we shall provide. So that means, for each and every design there is a standard there is a specific procedure.

Here what we shall do? That we shall do it that we provide Sv and then we can find. In other way also we can do it, that means from this equation we can take Sv out and we can Asv we can take it say 2 legged or 3 legged on the basis of that also you can find out. Or in other way also we can do it say Asv by Sv also we can make it, that means no the thing is that whether we shall make it say you… I am telling, number 1 choose Sv as per the code that which should not be more than certain value all those things.

Find Asv and provide that bar dia this this may be one case, second case could be choose bar diameter in other way, that Asv find Sv and provide as per the code. So that, way there it is coming within the less than that value within the limiting one. The third could be the standard one that we have done it, for the beam in the very in the beginning. That means, I can take it as Asv by Sv also, Asv by Sv also we can find out and accordingly from this because it is not so difficult.

So, Asv by Sv we can take it we can find out Asv by Sv and then from there we can find out that, what should be corresponding value either selecting Asv or selecting Sv we can find out that. So, these are the three procedures that whatever way we we shall do it. Now, let us start 1 example but, before that I shall tell you one more thing that is I have told you in the very beginning that Me1 equal to Mu plus Mt that is there. And Method we have calculated here.

Now, that could be another possibility that Mt that we have got it that is greater than Mu. The case first of all that is the we are adding up that Mu plus Mt and where we shall provide that one say in the longitudinal reinforcement that Mu in most of the cases Mu which is actually in the bottom the reinforcement we have to provide that means, Mu plus Mt.

Now, in another case it may be it is possible that Mt is greater than Mu, when Mt is greater than Mu then we have to provide the reinforcement at the top for and what is that value, how what is the moment, that will be Mt minus Mu that we have to take it. So that means, it is possible Me 2 also that is another case which is equal to Mt minus Mu.

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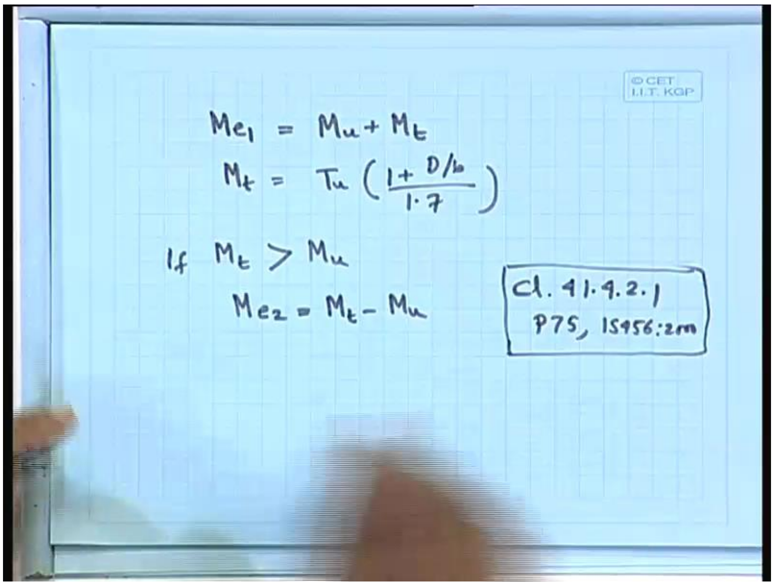

So Mt minus Mu that means, say let us say I have told Me1 equal to Mu plus Mt, where Mt equal to Tu 1 plus d by b divided by 1 7 and this is one case. The other case is that, if Mt is greater than Mu then I shall take Me2 will be equal to Mt minus Mu. So, this is other case and for that we have to provide the reinforcement at the top, we shall provide the reinforcement taking Me2 equal to Mt minus Mu.

Here also I have seen in this one of our code says and that you will find out, that is in clause 41 4 2 1, page 75, IS 456. Now but, I have seen in few other books at least 1 book I have seen and that is where that professor ex professor of IIT Khanpur he is having 1 book of that limited design of reinforced concrete structures, where I have seen papers that even if it is say not less than say Mt and Mu.

Let us not check that one whether it is greater than or less than even if it less than then let us, provide the top reinforcement taking that Mt only Mt. So that, that means say here what I would like to say that in design even that our code says specifically, even then also there is some kind of say practice also. And obviously, that it depends that those thing mainly we are following the Professor Vargheese book but, here also you will find out so, there is a difference of opinion also.

So anyway, it does not matter that way but, what we can do actually after all we are providing that say top reinforcement for the hanging bars. So, that also we can check and we can find out that whether it is sufficient or not considering that Mt value only; that also we can check, if it is sufficient or we can provide at least that value. There is nothing wrong that way at least because, after all we are providing the top reinforcement that 1 say for hanging bars even if we do not require. So, that also we can check but, strictly speaking that as per this clause 41 4.2.1 that we do not need it if Mt is less than Mu.

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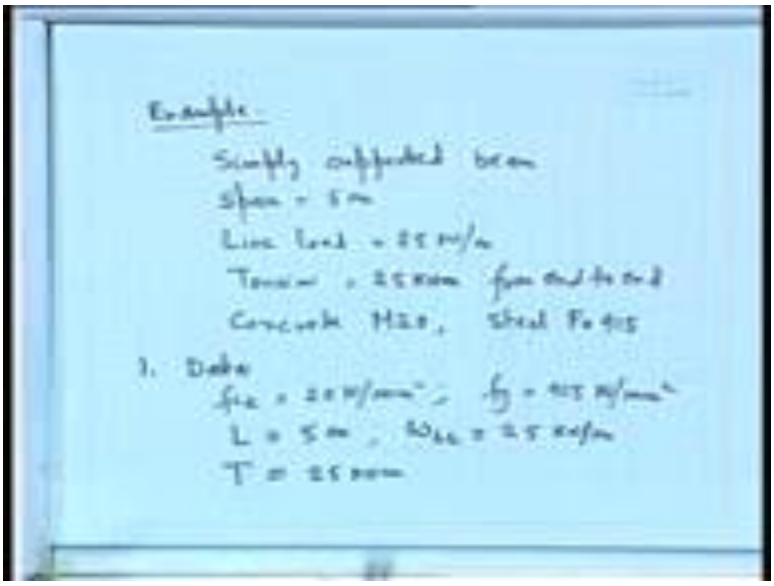

So, let us start one example problem. Let us take, simply supported beam span 5 meter, live load 25 kilonewton per meter, torsion 25 kilo newton meter please note 25 kilonewton meter from end to end. That means, all along the beam this torsional moment is acting; concrete M20, steel Fe 415.

So, data given fck 20 newton per square millimeter, fy 415 newton per square millimeter, l effective span, say here we can take it say 5 meter live load or wll say live load 25 kilonewton per meter, T unfactored that not the design 1, T given as 25 kilonewton meter. Let us, calculate the load.

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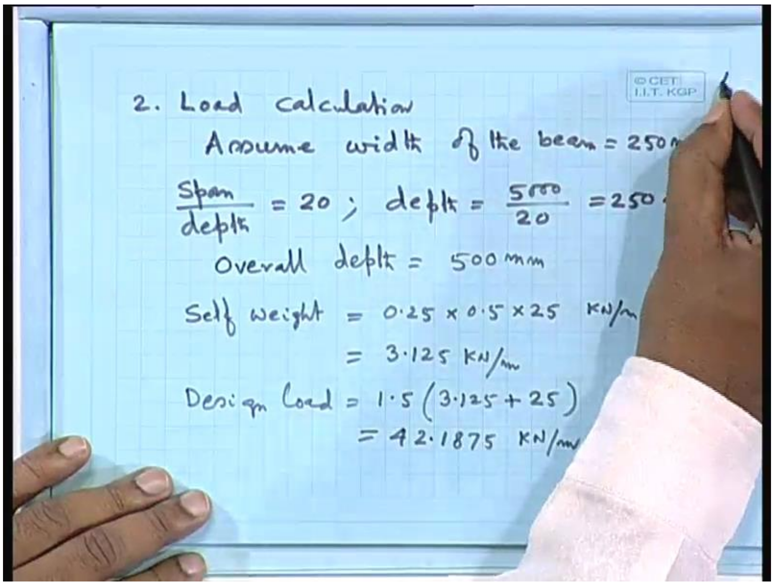

So, step 2 say load calculation we shall try say few trials. Because, instead of directly going to the value it is worth that going say all the calculation because; what are the process, how we repeat the whole calculation. let us start like that. Because, I do not want to make the final value and see that as if it is a magic way we have got it but, it is not like that when we are designing then we do lot of say you are repeating steps.

So, let us say assume width of the beam 250 millimeter. If we take the span by depth let u, take say span by depth say let us take say 20 because for simply supported beam. So what about the depth then? 5000 by 20 which is coming as 250. If we start using this value then you will find out that it will be very very less this value. So, let us start at least say because that is why I do not want to go to that computation. Because, if we start say you have to calculate the self weight of the beam and then your say that live load given.

Then, I have to calculate that Mu that bending moment due to that applied load and then, I have to find out that equivalent bending moment due to torsion. So, let us because if I start with 250 millimeter then it will be very very less. So, let us take for calculation of the self weight the overall depth let us take say 500 millimeter.

Because, from 250 to 500 to going to that level obviously, it is better you can try checking with that value at least you try 250 and check that how it is coming instead of directly going to that 500. So, self weight 0 25 is the width, times 0 5 is the overall depth, times 25 kilonewton per meter cube, which gives us 3 125 kilonewton per meter; design load 1 5 times 3 125 self weight approximately you can say 300 k g per square meter.

So that means, in few cases what we can do instead of going directly we can take say 400 k g per square meter also we can take it or 4 kilometer per square meter. In that case also,sometimes we take it that way also. So, 1.5 3 125 plus 25 that is the live load and which comes as 42 1875 kilonewton per meter.

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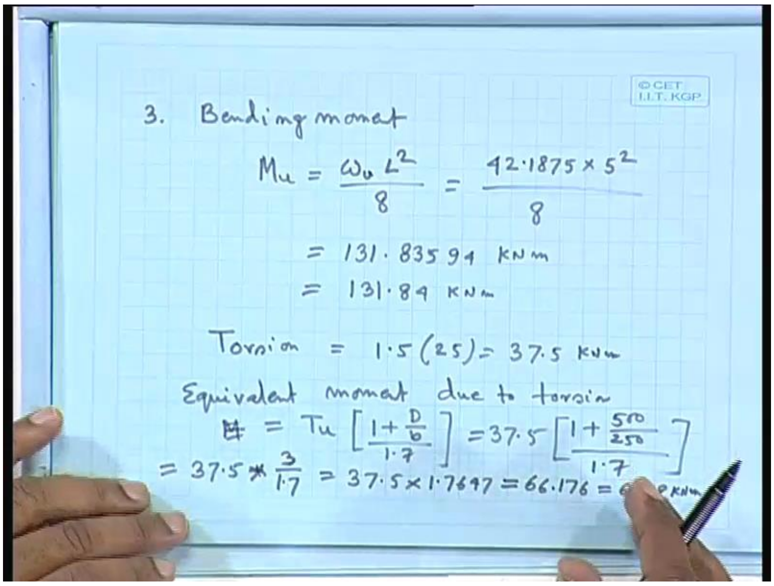

Whatever the bending moment, Mu equal to Wu say ultimate times l square by 8 42 1875 times 5 square divided by 8 equal to 131 83594 kilonewton meter we can take it at say 131 84 kilonewton meter. Few designer paper say, okey we shall go since it is coming in the calculator so as much as possible we can go. The other alternative also we can take it say as a simple say after say up to 2 decimal that also we can do it.

So, what I am trying to say, that when you design it sometimes it happens that you have to submit the design also, design report also, that how we have come not only that our final objective though to make the drawings, which will go to the site. But at the same time sometimes for proof checking or for other purpose for record also, we have to submit the design also.

Now in that case, it happens that we can go to this say as much as possible but, there we can taking the very beginning we can write that what whatever whether we are gone up to say 2 decimal or 3 decimal. Because, after all that after that it will only unnecessary it will take time, but we can round up to that say 2 decimal for when you are talking say kilonewton meter.

So similarly, for meter we can go up to say only say after meter we can go say may be say 2 or 3 decimal because, up to millimeter we can go. If it is say millimeter then we can go only 1 decimal if it is or we can keep it in millimeter only. So, those things we can write down in the very beginning of your say design note that these are the things we are followed.

Now, what about the torsion? That is equal to 1 5 times 25 so 37 5 kilonewton meter. So, we can find out the equivalent moment due to torsion. So, equal to Tu 1 plus d by b divided by 1 7 equal to 37 5 times 1 plus d we have taken 500 b, we have taken 250, you can take it 0 525 also but, after all we are taking this only millimeter millimeter. So, we can here and 1 7 which comes as let us see 37 5 plus 3 by multiplied by 3 by 1 7 what I mean to say that.

Let us see that, how what is the factor I can get it directly I can get the whole value, but that I am not interested I am interested in usual cases it may happen that, sometimes it happens that your checking that what should be the Tu times how much. So that, let us say that that means here we can get get it as say 37 5 into 1 7647 that means, 76 percent extra the 1 76 that is what I am interested to know.

Because, only from this one you will not get that idea you will not consider that what should be the value that means here, even 37 5 in worst case I can take it as say just simply I can multiply with 2 also, the twice of that. So, what I mean to say that in that way those values factors are coming. So I can say that 37 5 into 1 7647 and which is equal to 66 176 equal to say 66 18 kilonewton meter.

So, I can find out 66 18 kilonewton meter. This one thing I would like to make it here comment that generally it happens these values that whether you can for any design purpose if you have to feel it. In a sense that whenever you are getting any numerical value, the numerical value whether it is coming all right or not. So that, you have to check at each and every step whenever you are doing the design that each and every step it would take that whether that value is coming all right or not.

Because, if you do at least few may be say 4 or 5 problems like these then you will have an idea that that value at in each step if you find out any unusual value. Then, immediately you can find out you can understand, okay there is something wrong. So, thats why these few steps that you all each and every step you have to do it and accordingly you can find out. So that means, say it if it whether you are doing any calculation mistake or not.

So, just simply putting all those value in your calculator you can find out this value and that what we do it. But since we are getting this idea the twice or something that it should not be more than twice or something like that what is the range. So, immediately you can find out whether you are getting that value correct or not, that is the standard procedure of design that you have to do.

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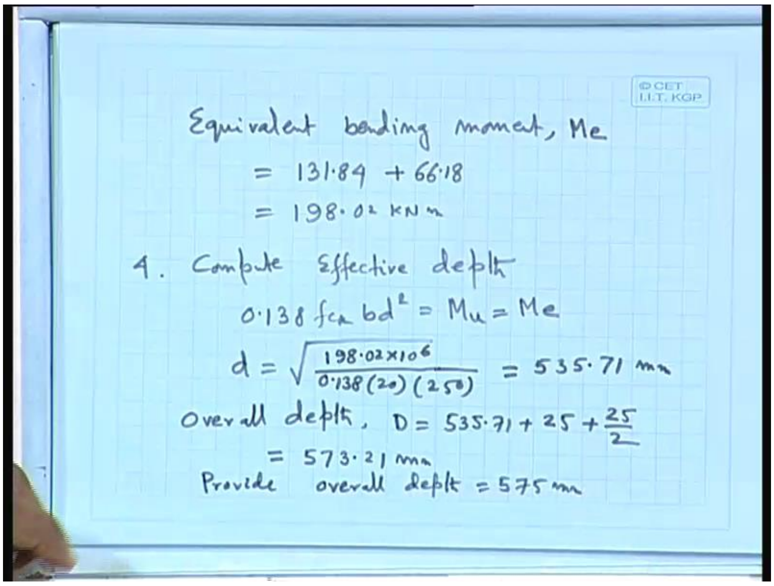

So, what about the equivalent bending moment? equal to 1 31 84 that is the Mu we have got it due to the applied load plus equivalent moment, which is coming as 66 18 and which is coming as 198 02 kilonewton meter. So, what about the effective depth we can compute we can check effective depth let us compute effective depth. So, we have the same formula so 0 138 fck bd square equal to Mu.

Let us, write down here Me this is our Me so Mu means here, as per our that say due to torsion so it should be applied here Me. So, we can find out d equal to 198 02 into 10 to the power 6 divided by 0 138 times 20 times 250 equals 535 71 millimeter overall depth d equal to 535 571 plus 25 is the clear cover plus let us take that bar diameter little higher side 25 by 2 that is 25 millimeter dia bar.

Let us, assume so we are taking little higher side may be 20 millimeter may be sufficient. So, which is coming as 573 21 millimeter so we can provide overall depth say 575 millimeter. We have come to a problem, the problem is that we have selected we have taken the self weight as say 500 millimeter, breadth width of the beam that is 250 millimeter, 573 21 millimeter that is the overall depth to be provided.

So, just we are really in a marginal situation 575 millimeter. So that means, we do not know that due to the self weight, whether that we shall steel will be in the safer side. Because, that 535 71 another 1 we have taken that your say Tu we have taken here Tu that d by b so d is that say your say 575 that means, Tu due to this torsion also that your bending moment will change.

So, if we really provide that 1 say 1 alternative could be that we can go say 600 millimeter and we can check all of them we can do it, instead of that what we can do it we can do it the other way. Let us try this way that we shall change the width. So, let us change the width.

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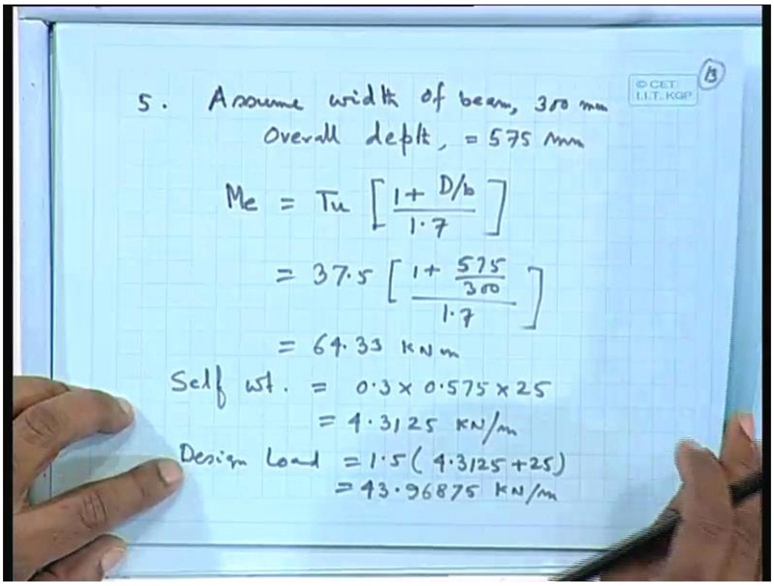

So, assume width of beam say 300 millimeter, overall depth 575 millimeter here since I have changed the 300 I could reduce it or anyway let us, do not change this. Because, it may happen that that value will come less but, anyway let us do not reduce it at this stage. So, Tu 1 plus d by b by 1 7 equal to 37 5 1 plus 575 by 300 divided by 1 7 equal to 64 33 kilonewton meter, self weight equal to 0 3 width of the beam times 0 575 overall overall depth of the beam, times 25 kilonewton per meter cube comes as 4 3125 kilonewton per meter, design load equal to 1 5 times 4 3125 plus 25 equals 43 96875 kilonewton per meter.

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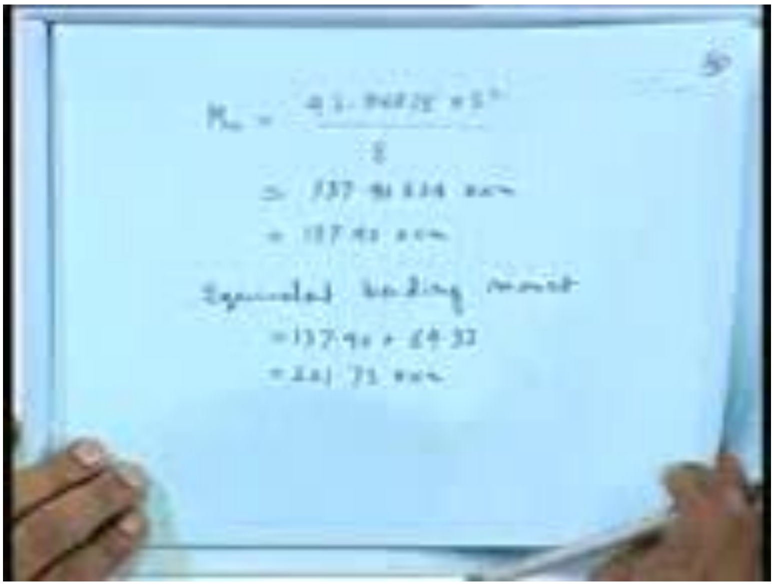

So, we have got the design load we can calculate that Mu equal to 43 96875 times 5 square by 8 equals 137 40234 kilonewton meter. Let us, say 1 hundred thirty 7 point 4 zero kilonewton meter. So, we have got Mu so equivalent bending moment equal to 137 40 plus 64 33 equals 201 73 kilonewton meter.

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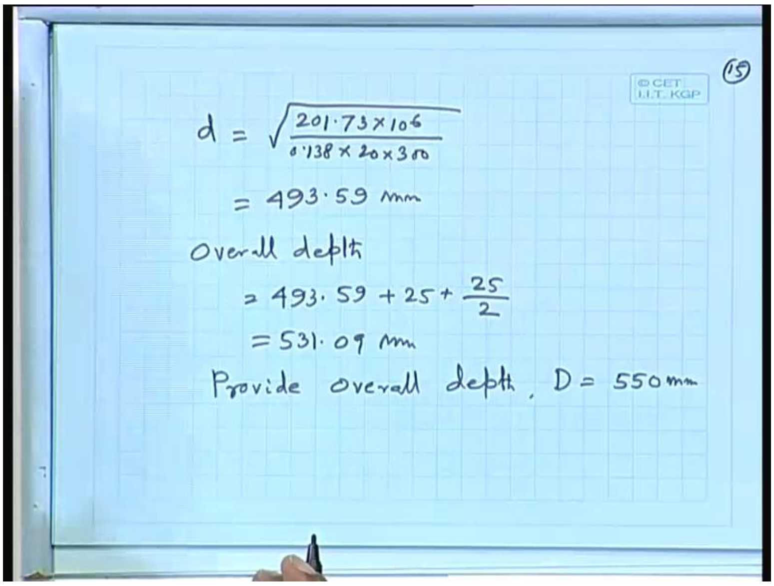

D equal to let us calculate d. So let us you see that 493 millimeter only, overall depth 4930 59 plus 25 let us still take 25 millimeter dia bar we shall provide. So, 531 09 millimeter provide overall depth D equal to say 550 millimeter 540 also we can provide but, anyway let us say 550 millimeter.

So, we can now we can still we can change that value because, self weight also that means if we provide a 550 that means here; so, we can provide that self weight let us check the self weight again.

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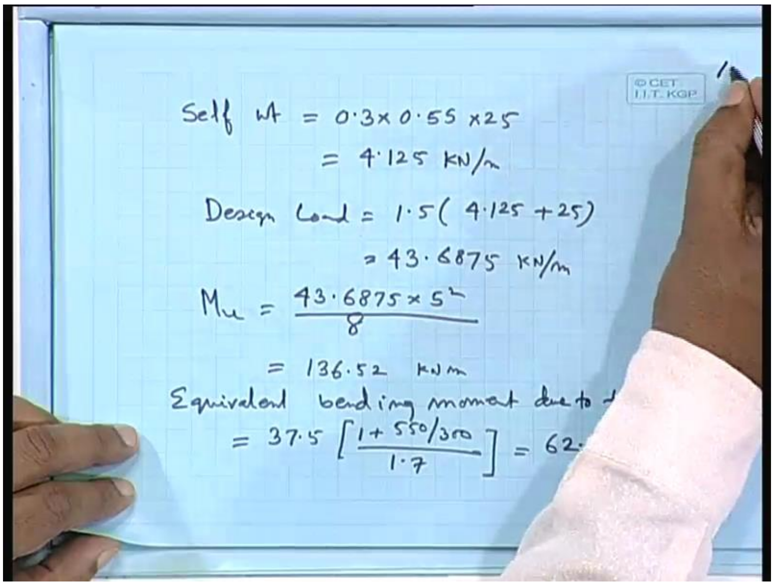

So, 0 3 times 0 55 times 550 times 25 comes as 4 125 kilonewton per meter design load equal to 1 5 times 4 125 plus 25 equals 43 6875 kilonewton per meter Mu equal to 43 6875 times 5 square divided by 8 equals 136 52 kilonewton meter equivalent moment so, 37 5 1 plus 550 by 300 by 1 7 equals 62 5 kilonewton meter. So, this is due to torsion only this is due to torsion only.

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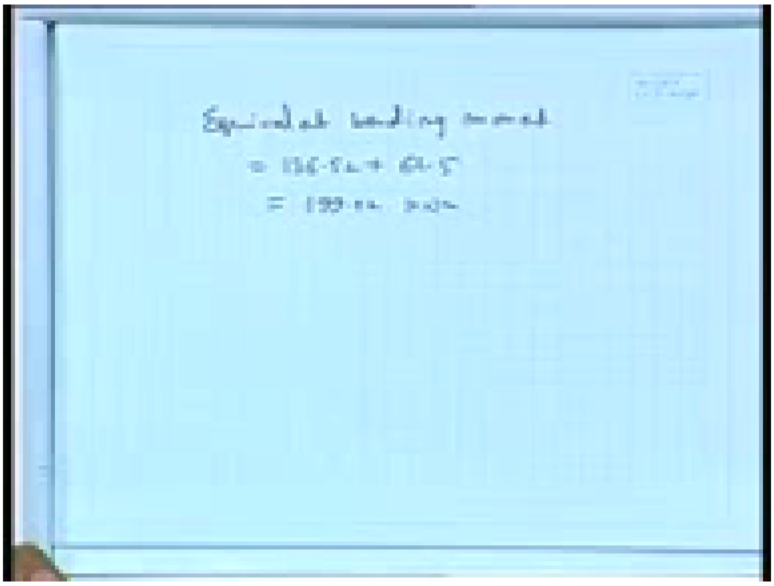

So, equivalent bending moment equal to 136 52 plus 62 5 equals 199 02 kilonewton meter. So that means finally, we can set to this value that 3 by 550 millimeter and then, we can take it 199 02 kilonewton meter for the bending moment and we can provide the reinforcement for this bending moment. I think we shall stop it here, we shall continue in the next class.