Design of Reinforced Concrete Structures
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Lecture – 28
Design for Torison
Part – II

Well, in the last class we have started the design for torsion. So, in continuation with that we have started one problem that which we could not finish it. So. let us just start where, upto which portion we have arrived the problem. We have started that is your simply supported beam of 5 meter span.

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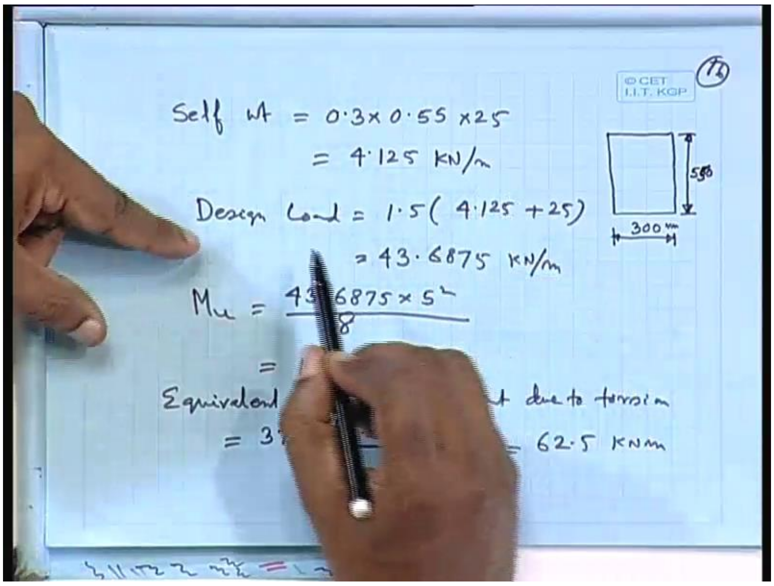

So, after few iteration few trials we have come to the section that is having that width of the beam that is 300 millimeter and overall depth that is 500 millimeter. So, I think not 550 so 300 by 550 that is the over all depth. So, the self rate that we have got it as 4 125 kilo newton per meter design load with that factor 1 5 4 125 plus 25 which comes to 43 6875 kilo newton per meter. That ultimate moment parallel due to the simply supported beam we are getting 136 52 kilo newton meter.

The factored torsion that is 37 5 55 times 1 5 that we have got it and due to torsion what is the equivalent bending moment that we are getting, by using the total provision we are getting 62 5 kilo newton meter.

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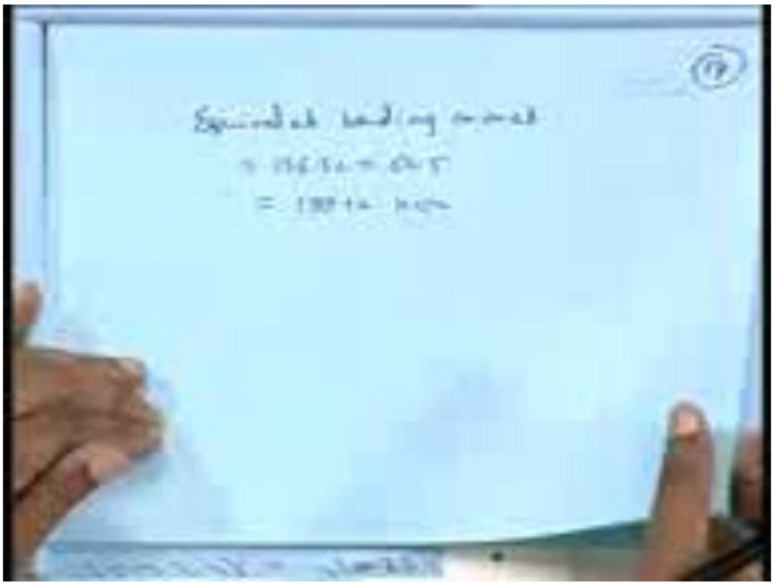

And finally, we have got the equivalent bending moment the sum of that for the applied load plus due to torsion so you can get 199 02 kilo newton meter. So, this is the final moment we are getting it here bending momen, for that we can find out the area of steel. So, we shall get the area of steel taking this 199 02 kilo newton meter.

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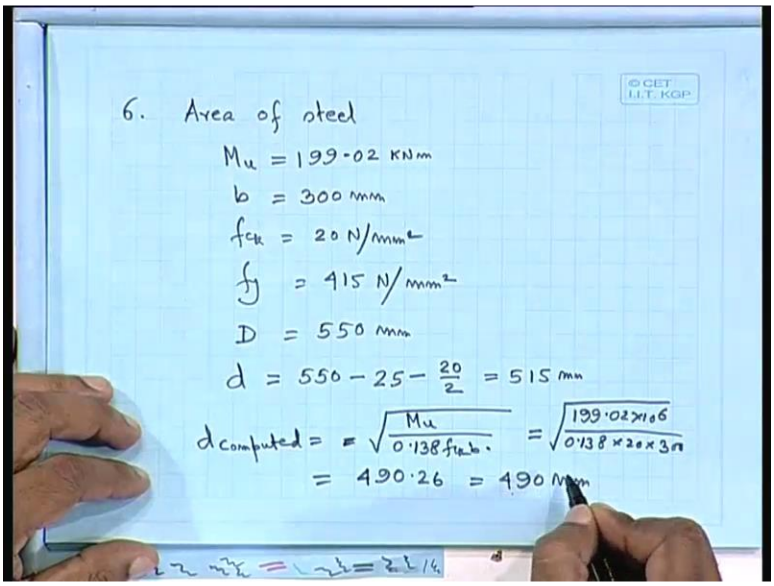

So, next step is your area of steel Mu let us write down all of them mu equal to 199 02 kilo newton meter, b 300 millimeter, fck 20 newton per square millimeter, fy 415 newton per square millimeter, overall depth D 550 millimeter so, d we can find out here effective depth that is we have provided here 550 minus 25 that is the clear cover minus we cannot we take it or 20 also.

Let us, take try with 20 where I have mean to say that we shall provide 20 millimeter dia bar. So, we can get it as say 550 minus 25 minus 20 by 2 that is the effective depth, which we are getting it here 515 millimeter earlier case we took it as 25 millimeter that dia bar. But here I am assuming that we may accomodate that 1 within say your 20 millimeter diabar may be 4 or 5 whatever will come.

So, we can find out we know Mu, b, fck, fy, D, d all of them we know let us find out that d computed effective depth that 1 should be equal to Mu by 0 138 fck b. So, that we can get it here root over 199 02 into 10 to the power 6 divided by 0 138 into 20 into 300 that is your width. So, we shall get it 199 02 10 to the power 6 divided by 0 138 divided by 20 divided by 300 square root of that which is coming as 490 26 equal to say just simple 490 millimeter.

So, what I am trying to say here, that we have provided 515 millimeter obivously, it is greater than we computed it is greater than say 490 millimeter that is required. What we can do? One way we can do it here, that we can take it say 490 plus say 25 plus say 10. So that means, we can make it say 525 also. We could provide 500 25 atleast at this stage that means, if we do it now again we have to again recalculate whole thing.

Let us, do not make that exercise now but, if we could do that one then we could provide the balanced reinforcement that means, depth within say 2 or within say plus minus say 5 millimeter plus say 5 millimeter, whatever that effective depth required and whatever effective depth you have provided effective just simply say within say 5 millimeter. Then, what we can say almost we can say that is a balanced section.

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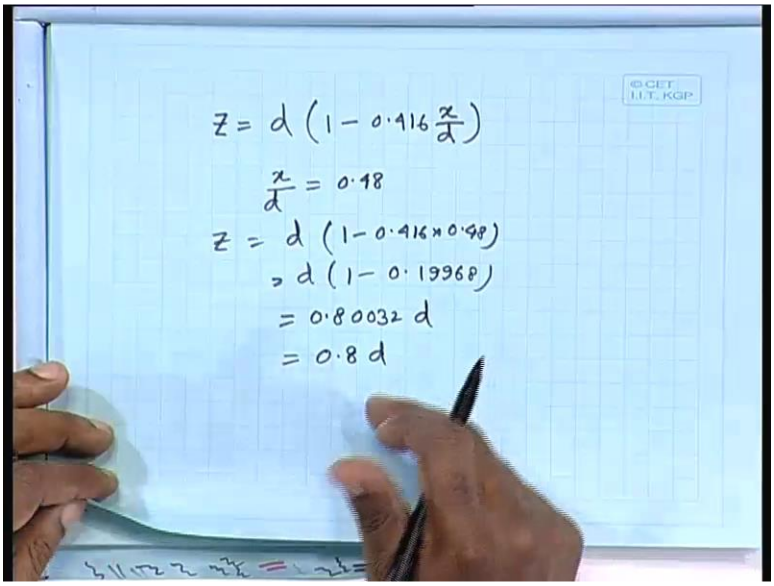

If it is a balanced section, then what we can do immediately we can provide that means, z we can calculate z equal to d into 1 minus 0 416 x by d. So, what we can do immediately we need not calculate that your say from that equation quardic equation what we can do? x by d that is your say 0 48 for the balanced section.

So, z will be equal to 1 minus 0 416 times 0 48 so, we can get it 0 9968 and which comes as 0 80032 d that means, simply 0 8 d. So that means, if we could provide the section within very close to the balanced section then, immediately what we can do the z we need not calculate using that equation what we can do? We can simple take it that point 0 8d and then we can do our calculation for the area of steel to be provided.

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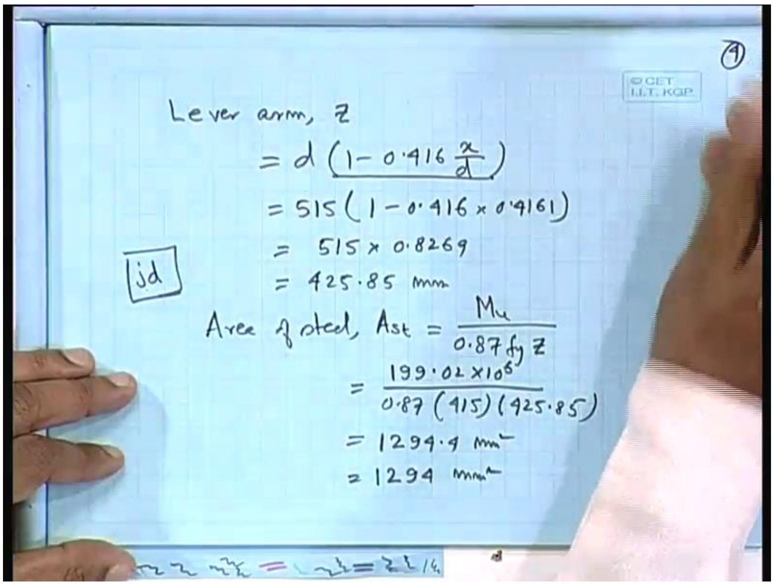

But here, it is significantly where 515 and 490 so, what we have to do; we have to calculate that x by d. In few books we will find out that they are using simply 0 8. So, there in that case what they have done they have provided that effective depth almost very close to the 1 required and that is why there immediately they are using as 0 8d z equal to 0 8d.

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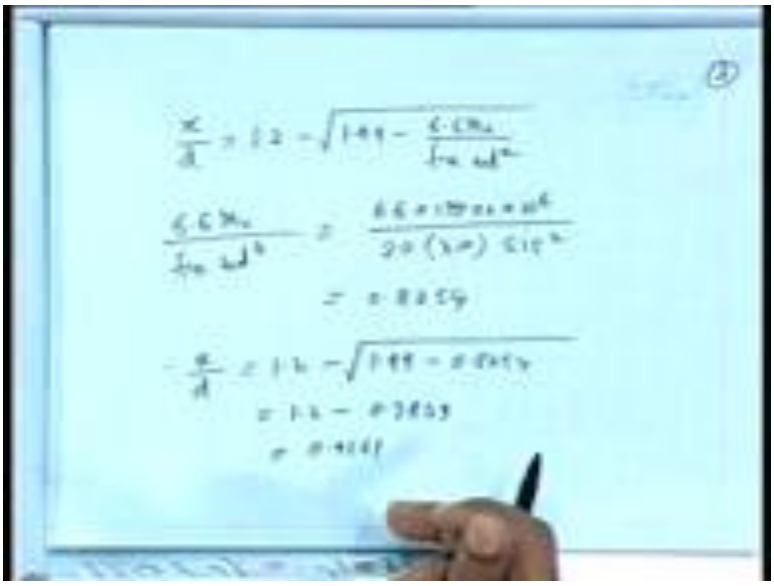

But in our case we have to calculate that x by d so, x by d equal to 1 2 minus root over 1 44 minus 6 6 Mu by fck bd square what about let us calculate this 1 separately 6 6 times

199 02 into 10 to the power 6 divided by 20 times 300 times 515 square which come to 0 8254. So, x by d equal to 1 2 minus root over 1 44 minus 0 8254 equal to 1 2 minus 0 7839 equals 0 416 1. So, x by d we have computed as 0 4161.

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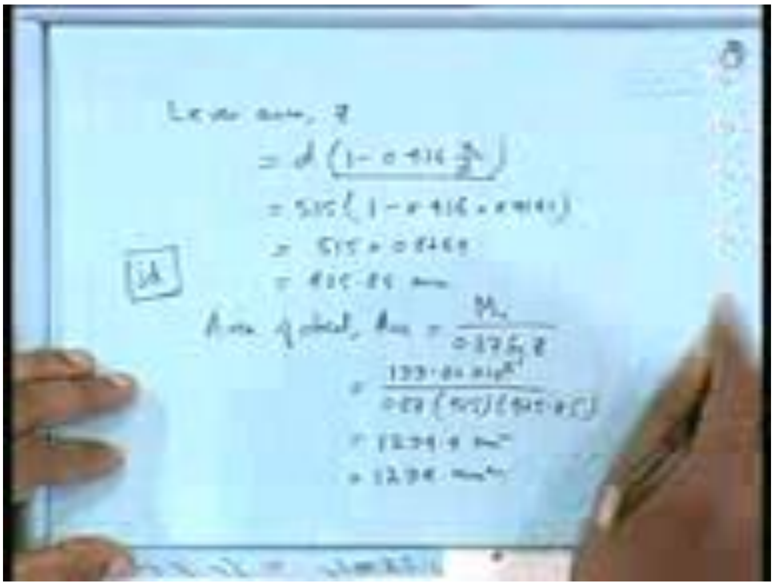

So, what about the lever arm then? So, lever arm z equal to d1 minus 0 41 so x by d equal to 515 1 minus 0 416 times 0 416 1 equal to 515 times 0 8269 equal to 425 85 millimeter. In no case that you would if I consider that if you remember that working stress method, there we use some parameters say jd; d is the effective depth and j is the 1 your say that from the lever arm from there we are talking. Another 1 is k, so k another 1 j.

So, here you will find out the j could be say minimum that is 0 8 for balanced section because, it cannot go beyond that. And now, point so 0 8 that means here 0 8285, 0 9, 0 92 something like that in that case it comes that values. So, this is the 1 that parameter the j so j times d in the limit state method you can find out.

So which is nothing but, this parameter is nothing but, that is your j in other way. So, I have got this lever arm j. So, what about the area of steel? Equal to mu by 0 87 fy times z which comes 199 02 into 10 to the power 6 divided by 0 87415 times 425 85 equals 1294 4 let us say simply 1294 square millimeter. So, this is your area of steel that you have to provide.

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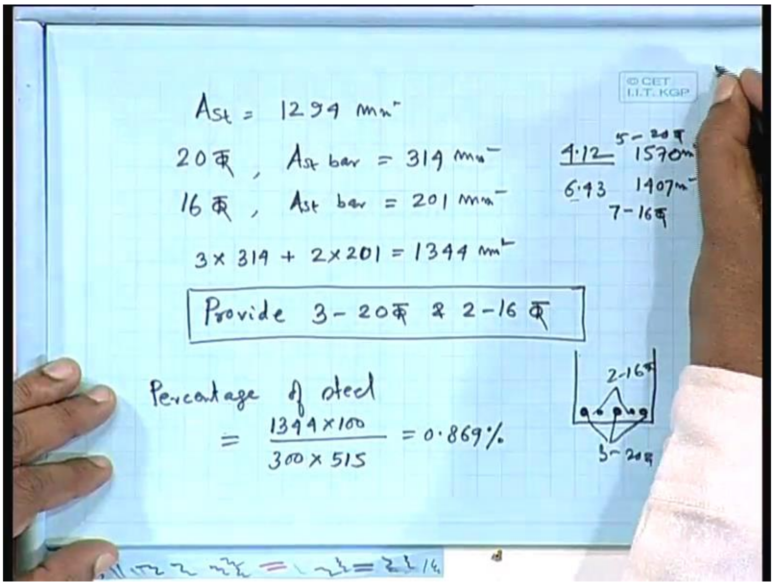

So, 1294 that is your area of steel square millimeter 20 torque bar for that ast bar there for single bar that is your say 314 square millimeter, for 16 torque ast bar equal to say 201 aquare millimeter. So, what we can do? Generally we do it, either we use say single bar that means say 1 type of bar diameter or maximum 2, 3 or 4 all those thing we generally do not provide.

So that means here, if we provide say 20 torque so 314 so, 1294 by 314 so that means, it is coming 4 12 the number. If we provide that say 1294 divided by 201, which is coming as 6 43 the number of bars. And other 1 we can take it say that means , here you have we have to provide here; so 314 into 5 1570 that if there is 5 numbers 1 is possible say 5 20 torque that s possible this 1 we have to provide say 7, which is coming as 1407 square millimeter if we provide say 716 torque.

Alternatively what we can do? We shall provide let us say 3 into 314 that means, 3 numbers of 20 torque plus 2 numbers of 16 torque which comes as 134. That means, which is coming closer to this 1 and less than the say for least of these 3. So, we can provide 320 torque and 216 torque.

So, we shall provide like this how shall we provide? That we shall provide 120 here, another middle here, another here; and in between we shall provide the 16 then. Bacause, we are having 5 so, these 3 will be 20 and these 2 will be 16. What about the percentage of steel? Let us calculate, because we need this one to calculate that to find out that say your critical stress; the shear stress.

So, let us calculate here percentage of steel that is equal to 1344 into 100 divided by 300 that is the width of the beam times 515 which is coming as 0 869 percentage. So, the percentage of steel we are providing that is 0 869 percentage. What is the limit? That also you should check that is your say 0 85 by fy that is the limit that percentage of steel that you have to provide.

So, that is almost you can say 0 205 percent or something like that in that case it will come. But any way it is higher than the value so, limiting value always you have to check that whether we are getting that less than or not that always you have to check.

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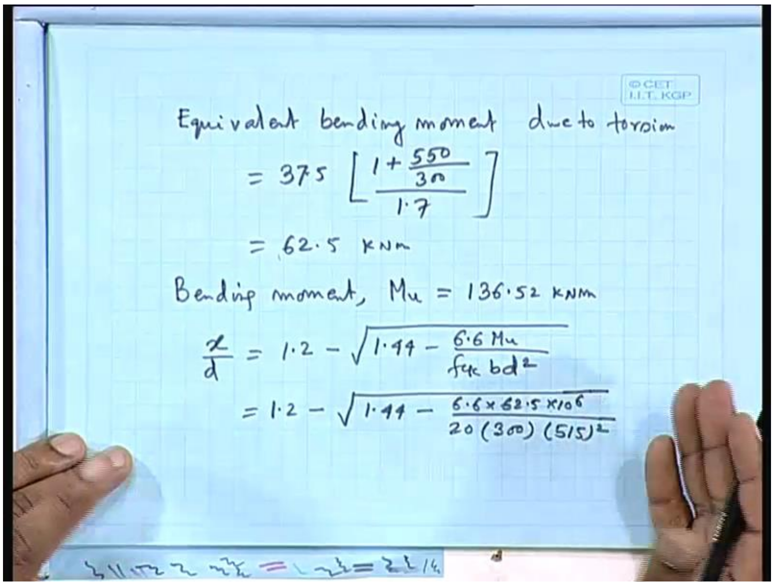

Now, let us now come to the other one here that means here, we are providing that 3 numbers of 20 torque and 2 numbers of 16 torque we are providing. Now, we generally check it that equivalent that bending moment due to torsion, that we have got it how much? So, this is overall depth by width divided by 1 7 as per the coded provision 62 5 and bending moment due to the applied load that is your Mu that is 136 52 kilo newton meter.

Generally, that code says, if these value is greater than this one then you have to provide the reinforcement topped reinforcement of that one say your difference of that. But few designer they prefer that we provide this one according to this value, that also that few designers that they do it. So, what we can do? We can atleast we can try that value let us see that how much it is coming.

So, in this case let us take that one independently for the singly reinfoced section we can again consider independently. But in actual practice that strictly speaking what you have to do, already you have the reinforcement as if that that one already say balanced. So, whatever you are adding so, that one you are giving due to this moment.

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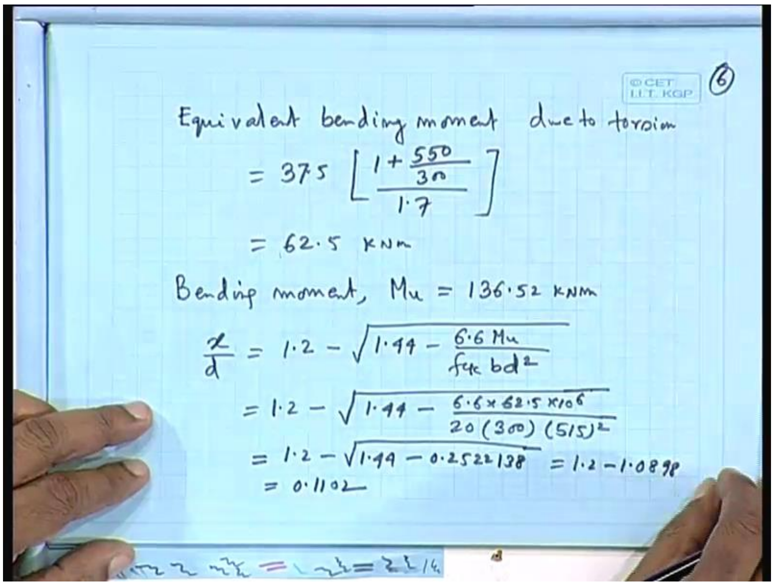

So, you can find out that x by d which equal to again 1 2 minus the same formula; so equals 1 2 minus root over 1 44 6 6 times 62 5 into 10 to the power 6 divided by 20 times 300 times. Let us take, that 515 we may reduce that one because, that effective depth may be incase because not necessarily that we have to provide 20 millimeter dia bar at the top; may be 16 millimeter is also possible we do not know right now. Anyway, we can use the same value here 515. And which comes as 22138 equals 1 2 minus 1 0898 equals 0 1102. So, this is the value we are getting here x by d.

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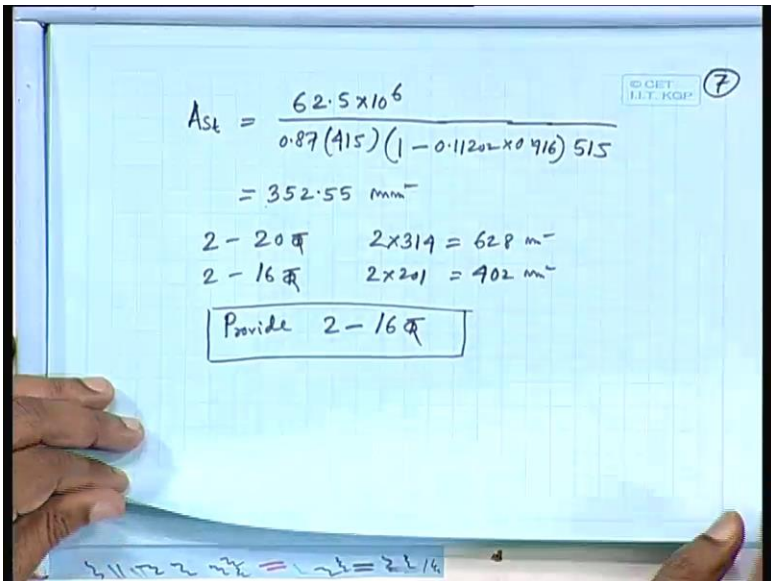

So, we are getting this one due to this mu means here; please note this mu means due to torsion not this one. This mu due to applied load which is acting say, if you consider that one that is acting say below, but where as our code says that we need not provide since some design few designers prefer.

So, let us take that one, let us see that one because after all we are providing the topped reinforcement as hanging bars. So let us, provide that one on the basis of this, that we can always provide so due to torsion we are getting that Mu which is coming as 62 5 into 10 to the power 6.

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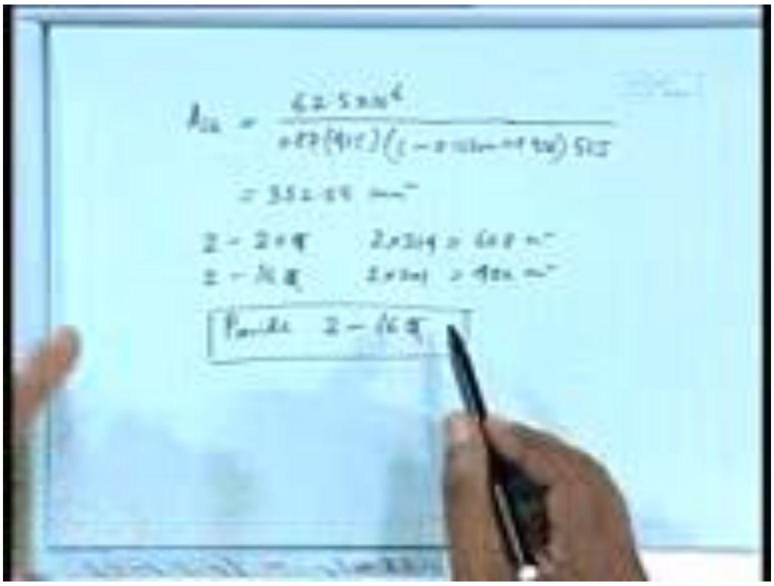

So, area of steel equal to 62 5 into 10 to the power 6 divided by 0 87 fy that 415 and that lever arm which is equal to 1 minus 0 11202 into 0 416 I thing we should write down the other way 0 416 x by d times 515 and it comes as 352 5 square millimeter. So, if we provide the 20 torque 2 numbers 20 torque that means, 2 into 314 628 but, 2 numbers 16 torque because, atleast we have to provide always we have to provide 2 numbers.

So, 2 into 201 which is coming as 402 closer to this value 352. So let us, provide 2 numbers 16 torque so, at in the bottom we have provided 3 number 20 torque and 2 number 16 torque and at the top we are providing 2 number 16 torque. Generally, we provide say 2 number 12 torque for say hanging torque, instead of that we are deciding on the basis of this value.

Alternatively what you have to do? If these value greater than this one then we have to make the difference on the basis of that we have to calculate which is as per code. But in this case we need not provide, but we have to provide that torque reinforcement so we can provide in this manner.

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So, what about now the stirrups? So, design for shear that we have to provide the web reinforcement. So, we have got the w equal to 43 6875 kilo newton per meter am I correct? The value let us go, go back and that is why. Because, whatever we have calculated I think it is here.

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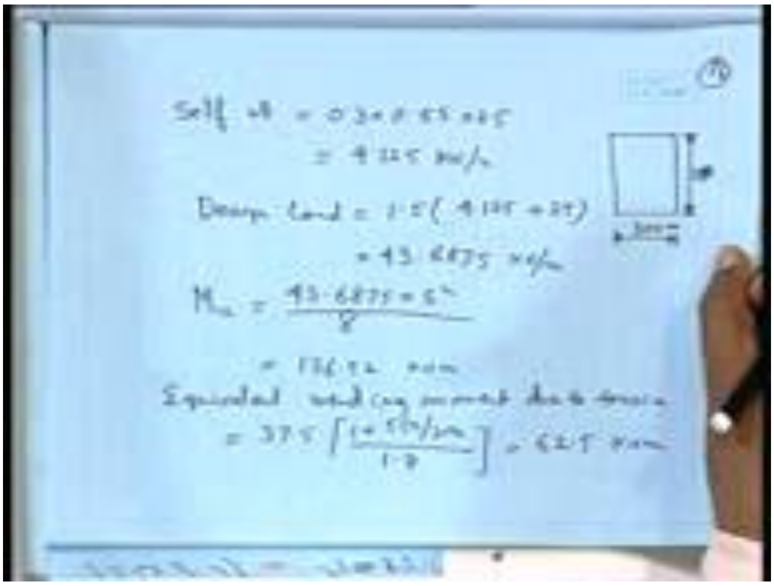

So, that these value because after taking the 300 or 550 we have got 43 6875 kilo newton per meter that is the one. So, that one we shall take it here as the for calculation of the shear force.

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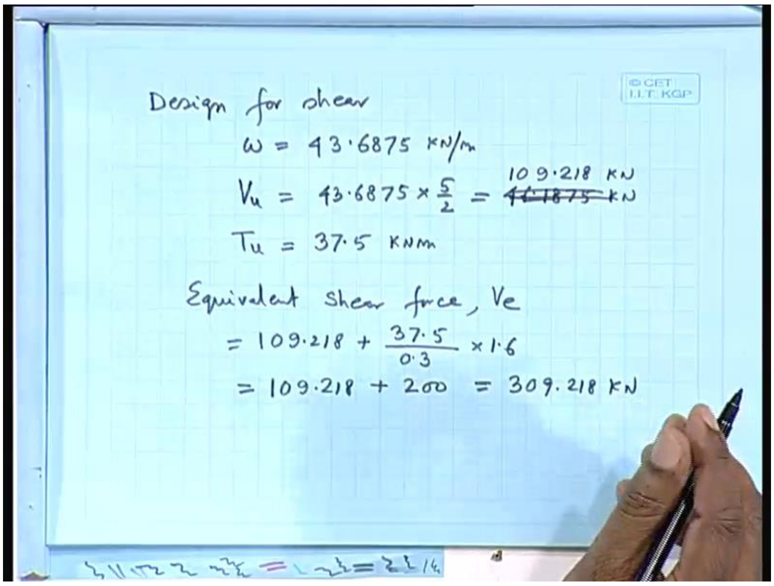

So, Ve or say here simply say your Vu say let us say that is 43 6875 into 5 by 2 which is coming as 46 1875 kilo newton I hope so 109 218. So, the value is coming here it should be 109 218 kilo newton and Tu equal to the same one after multiplication of 1 5 that is 37 5 kilo newton meter.

And equivalent shear force that 1 will be Ve equal to 109 218 plus 37 5 by 0 3 times 1 6, that is the 1 that as per the coded provision that you will get it. And which is coming as 37 5 by 0 3 into 1 6 so 109 218 plus 200. So, this 1 comes as 309 218 kilo newton. So, equivalent shear we are getting it here 309 218 kilo newton.

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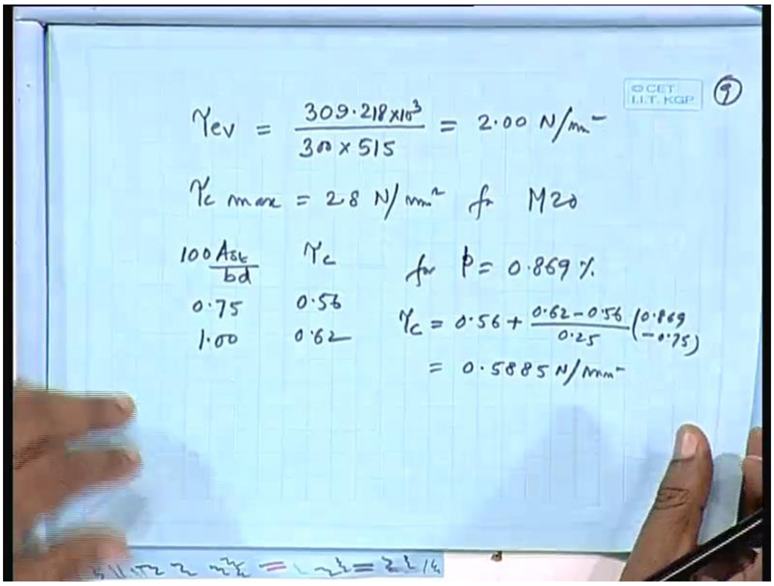

So, we have to calculate first thing we have to calculate that what is the shear stress shear stress we shall get it. So, tow ev equal to 309 218 that is the that ve which we have computed divided by b, b is 300 times d which is here 515. So, we shall get it into 10 to the power 3 in newton per square millimeter 309 218 divided by 300 into 515 which comes as 2 tow c max that is 2 8 for M20

So, less than 2 8 that means we can take this section if it is more than that, we have to change the section; we have to change the depth we have to change. But here 2 that 2 newton per square millimeter which is less than 2 8 newton per square millimeter that is the maximum permissible shear stress.

Now, as per the code that 100 ast by bd so we are getting here for 0 75 that is in say table 19 and tow c that is 0 56. And for 1 it is 0 62 for P equal to 0 869 percentage that which we have computed, P the percentage of steel which we already computed that is coming 0 869 percentage that is the longitudinal steel we have provided.

So, for that we are getting 0 869 percentage so tau c that is permissible 0 56 plus 0 62 minus 0 56 divided by 0 25 times just let us make that 1 869 minus 0 75 comes as 0 5885 newton per square millimeter. So, tow c that is permitted that is 0 5885 critical that is 0 8585 newton per square millimeter.

And what about tow Ev? Due to that equivalent one yes we have already completed that is 2 newton per square millimeter and 0 5885 newton per square millimeter.

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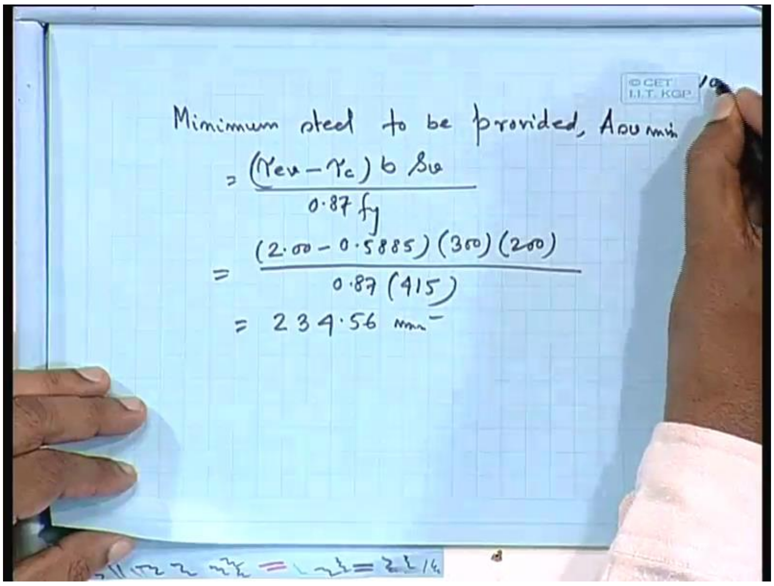

Our code says, that minimum steel to be provided let us check the minimum steel, let us say Asv minimum that web reinforcement equal to tow Ev minus tow c times b times sv divided by 0 87 fy, sv is the spacing what we can do it here. So, tow Ev we have got it say 2 tow c 0 5885, b is 300 spacing let us take 2 hundred if it is say 200.

So, we are telling that, we shall provide that 200 spacing and then on the basis of that we can find out that area of steel divided by 0 87 times 415. So, we shall get it as into 200 divided by 0 87 divided by 415. So, we are getting here 234 that is the minimum that we have to provide. We can check what is the minimum required as per the loading, this one required actually that we need it. Now, let us find out where from the tu and your vu how much we need.

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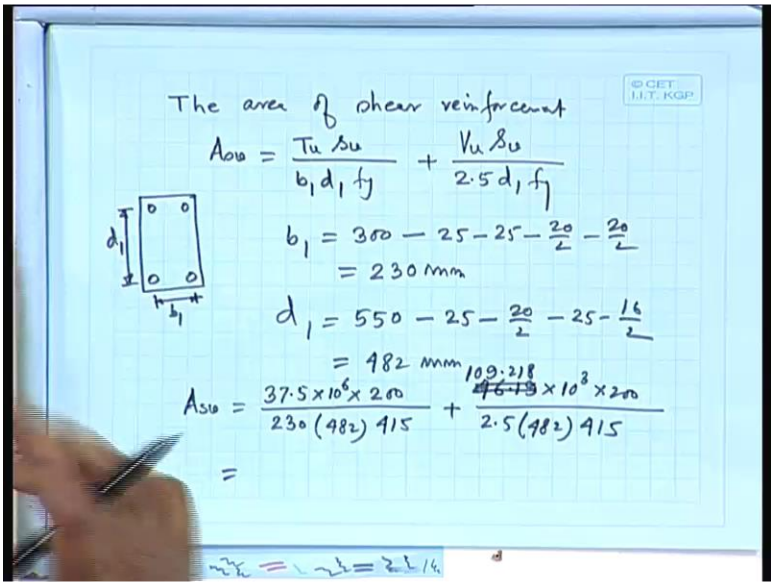

The area of shear reinforcement asv equal to Tu by su tu is the torsion b1 d1, b1. So, please note b1 this b1 center to center distance between 2 longitudinal bars in the breadth direction this is b1 and this is your d1, in the depth direction. So, b1 d1 fy plus shear force vu due to applied load sv times 2 5 d1 fy, b1 will be equal to 300 millimeter is the breadth minus 25 clear cover from one side, minus 25 the clear cover in the other side minus 20 by 2 minus 20 by 2 and that one we are getting it as 230 millimeter.

What about d1? d1 will be equal to overall depth 550 millimeter minus 25 minus 20 by 2 1 side. What about the other side? Other side it will be since already you have provided 60 millimeter dia bar now we can say 25 minus 16 by 2. So, we shall get it here 500 minus 10 minus 8 so 482.

So, Asv equal to 37 5 into 10 to the power 6 into let us say we have selected 200 millimeter spacing divided by 230 times 482 times 415 plus Vu that is 109 218 into 10 to the power 3 I think vu that is different right. 109 218 into 10 to the power 3 so into 200 divided by 2 5 times 482 times 415.

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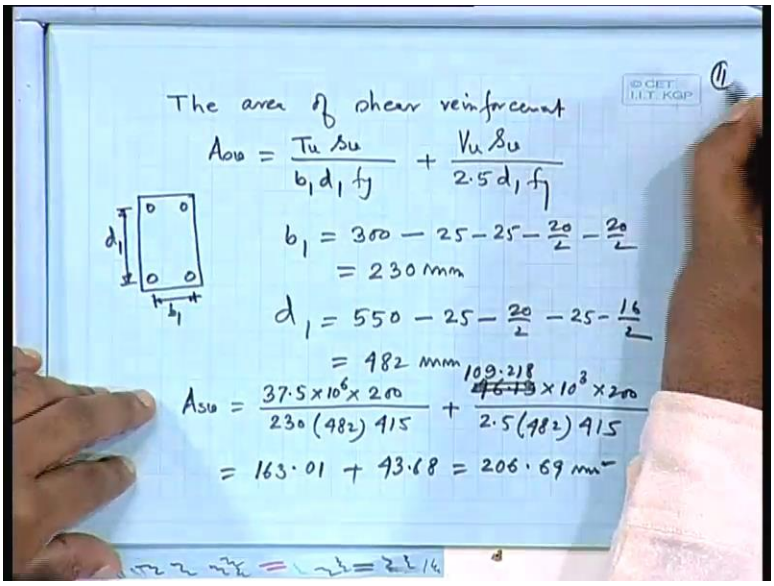

So, let us do 1 by 1 then so 37 5 10 to the power 6 into 200 divided by 230 divided by 482 divided by 415, which comes as 163 01 say plus 109 218 10 to the power 3 into 200 divided by 2 5 divided by 482 divided by 415 which comes as 43 68. So, this 1 equals 163 01 plus 43 68 206 69 square millimeter.

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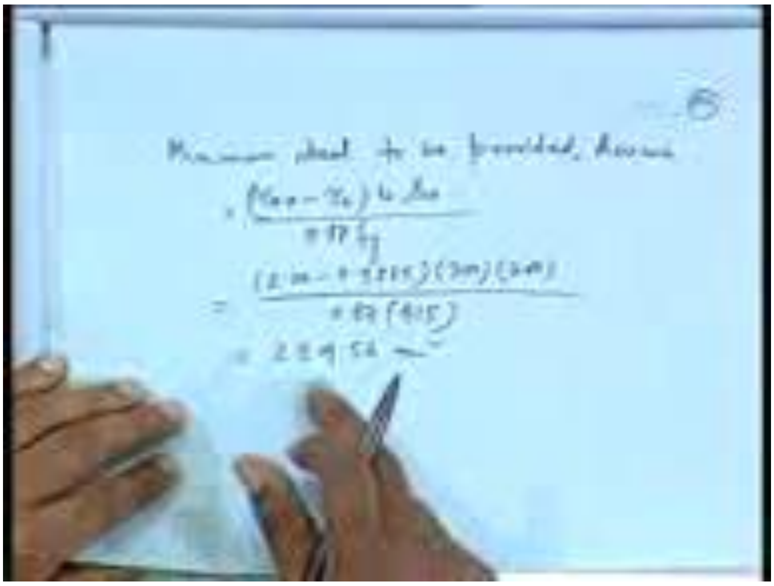

We require 234 that is the minimum here, it is governed by the minimum 1 and so 206 69.

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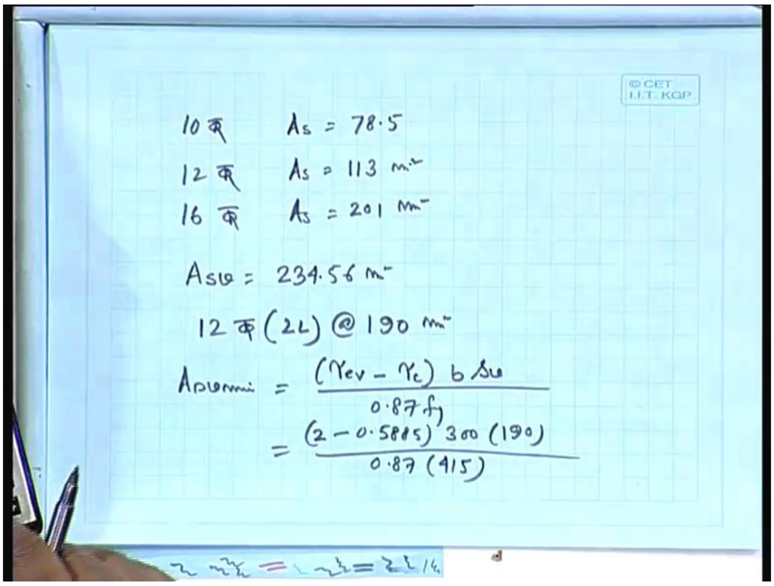

What we can do we can do? It so let us find out say 10 torque so 10 torque we are getting it here 78 5, 12 torque 113, 16 next 1 is little higher 16 torque 201 and we have to provide for 234. Now, what we can do it is coming 200 Asv 234 that means if it is 2 legged, it is 2 legged, because, both sides. So, one side it will be 117 and is really a very very tricky situation because, 78 5 we I dont want to provide say here 78.

So, 234 by seventy if say so 3 legged that is generally very very I do not prefer. So, what I can do 113 it is coming less 226 201 it is quite high 402, what I can do? What alternative I have I have to recalculate I could whether I could make it sv say 190. Let us, make it say sv 190 and if we can make it say 226 I prefer 12 torque 2 legged let us check it at the rate of 190. So, that I can get it say 226 so Asv whether I can get it at 226 so let us find out that 1.

So, I can get it as Asv minimum let us check it once more so which is coming as tow ev minus tow c times b times sv divided by 0 87 fy. Let us, check it 2 so minus 0 5885 times 300 times 190 divided by 0 87 times 415 so 2 minus. We need not check it this way, we can check it directly by the dividing also, which is coming as 222 8 . So that means, we can provide that 12 torque 2 legged at the rate of 199 millimeter so, Asv provided that is equal to 226.

And here we require that 222 8. So, these are what I mean to say that these way we generally change it. The thing is that not necesarrily that blindly you should do it, we should take in this case just if we can make it say 10 millimeter spacing the reduce it. So, that immediately it is coming very closer, why shall we go 16 millimeter diabar and making 16 millimeter dia say your stirrup and is quite heavy. We we do use it but, most of the cases we try to restrict it within say 12 millimeter maximum.

So, 8 millimeter that is very very common practice then 10 millimeter and then 12 millimeter. If you really you need it because, you have to make the link of say 16 millimeter and it is quite heavy that 1 to make it. So, thats why we generally avoid that bar .

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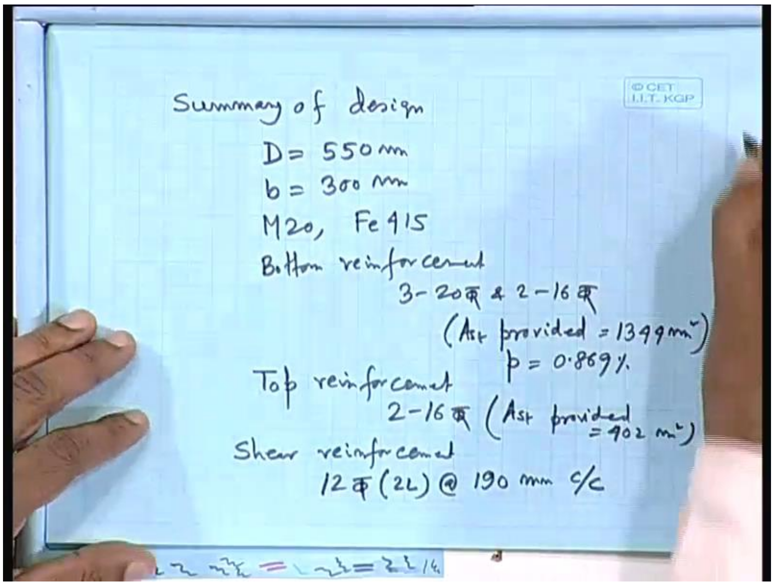

So, let us summarize the thing so d that we have provided 550 millimeter b 300 millimeter, M20, Fe 415 then bottom reinforcement 320 torque and 216 torque. And here what we shall do it, it is preferable that just to make it that yes. So, we are providing here so area of steel provided that is here 1344 square millimeter p 0 869 percentage. So that, just we can check it whether we are fulfilling all the coded provision, the limiting values all those things.

We can stop it here but, it is preferable you should provide that value also what you are providing. Top reinforcement that is 216 torque and area of steel that is provided that is your say 402. Now, stirrup shear reinforcement 12 torque 2 legged at the rate of 190 millimeter center to center.

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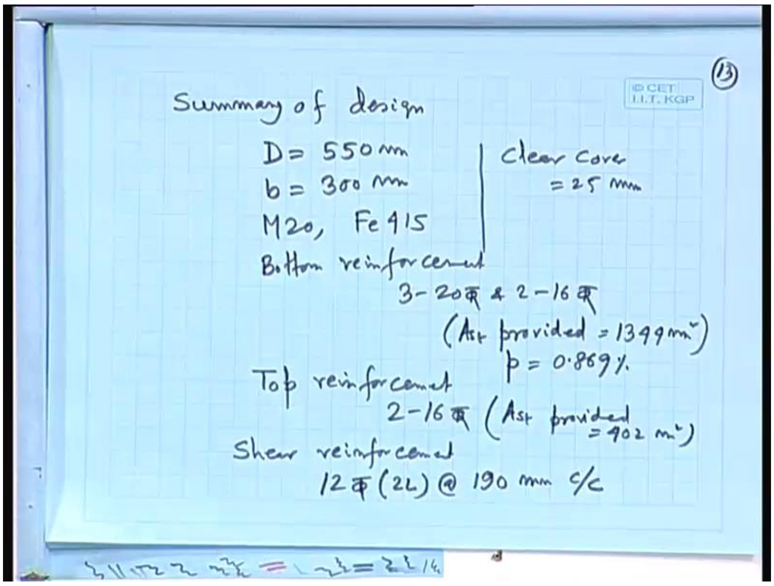

So, we are getting the that summary of design this is the all the information whatever we need. We should mention here upto the clear cover, generally we make this say in the design note that means, when you are doing that your say drawing full drawing. So, in the right hand side we generally provide all the information, which grade of steel, which grade of concrete all those things we provide.

Then, we do the calculation other things we do it, what we generally do say for example, just to tell you I thing I should the common practice in the your say design office I think I whether you can get it or not lets see.

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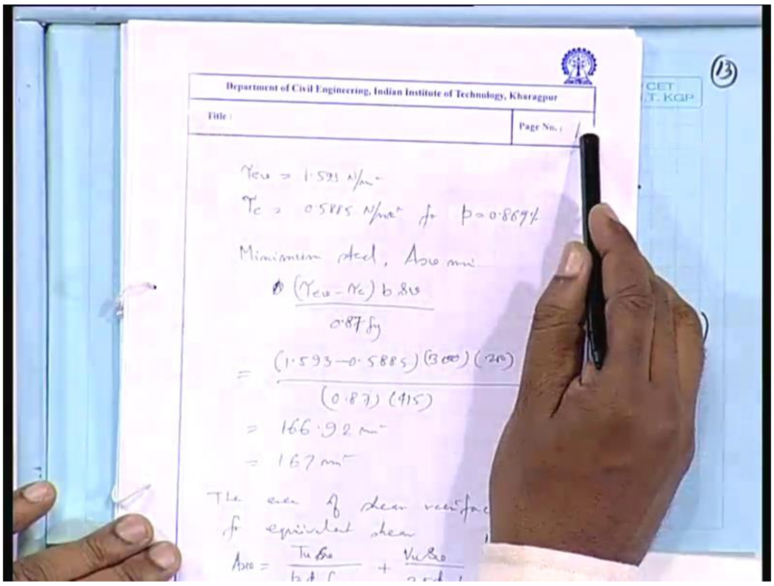

Generally it happens that, your say let us say something could you find out that your say there are some graph type of thing we have written that lines actually. Generally, what happens that, we should have some kind of say that department or so companies name and then title, then page number and then who has designed that one that actually we should have that signature all those things.

So, this is the way actually we make it, for your say for design calculation and other things and that if it is required you have to submit it also. So, I think this is all regarding say design of the design for torsion. Now, I think I have I have not told regarding the reinforcement. Because, we have some time I think now I can tell you regarding the reinforcement detailing of your say stair cases that, which we have not completed.

So, we have done the calculation, which we have not completed. So, let us do that part that how it comes, where we have to provide the reinforcement, how to provide let us do that one.

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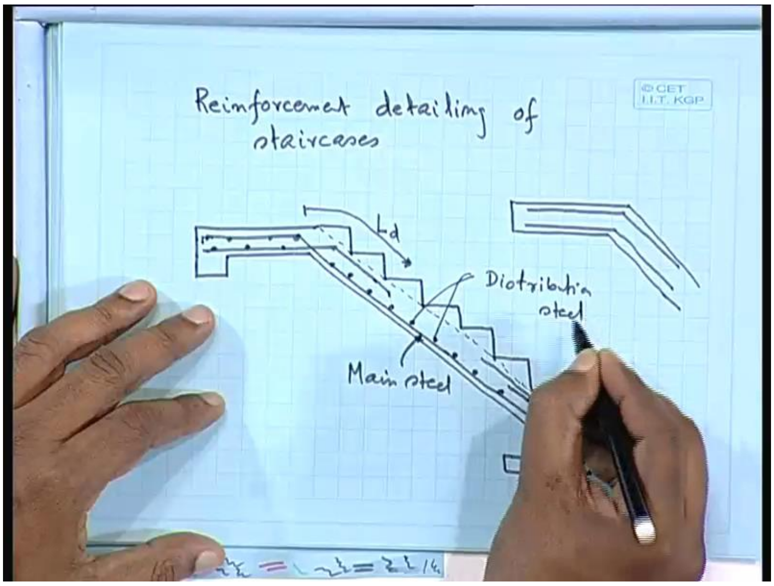

What we do it? So, reinforcement say this is your beam and this is the landing say it is starting like this. And these are the steps, the steps can be made of bricks or say steps can be made of say concrete also. Let us say, this like this we are getting some kind of thing like this. So, we have to provide the reinforcement using wl square by 10 that formula we have got the reinforcement all those things. And the top reinforcement and the bottom reinforcement.

So, this your reinforcement what you need; please not the detailing is not like that we are just simply making here and then we are moving that is going up. The reinforcement which we are providing here please note, that reinforcement we are providing here this is in the bottom portion where the tension will be developed, due to this type of say stair case. It will bend like this so, it provide reinforcement at the bottom surface.

What we are doing? We are not doing like this say that means, if a section like this we do not provide the reinforcement in this way neither these way not so simple what we do? We just simply go up and provide the reinforcement. And the bottom reinforcement also, it will go further and come here. So these reinforcement here this is one, this is another one.

So that, there will be no because if we have only one that is the chance of that cracking the concrete will come out. To avoid that one in this type of junction we provide that reinforcement in this fashion. Similarly here also, we provide the reinforcement like this.

And the distribution steel obviously, you have to provide all the cases we provide the distribution steel so here, as well as here so like that we provide the reinforcement.

And the other reinforcement we also provide for the top one, we provide the reinforcement here; we go like this and. Here, there is no problem because, this concrete will not go out but, here there is a chance of that concrete because of the bending, here the concrete can come out. But here there is no problem so you can simply use the same directly.

What about this length? How far we shall go? This length, these length will be from here we shall start it will go upto ld. So, this your that say ld that developed length that we have to go upto this that extension of this one. And these are called distribution steel, this is called all your main steel.

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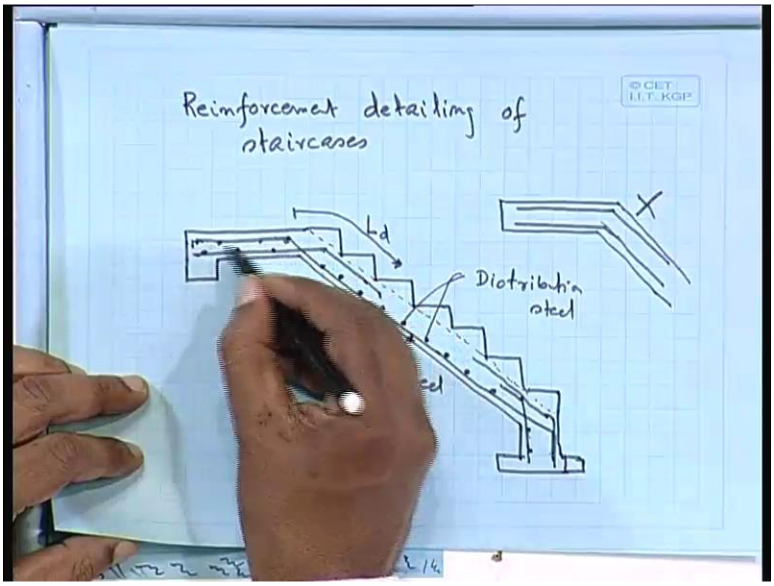

So, distribution steel will be according to that 0 12 percentage of that for the slab, for slab that is 0 12 percent. Here I would like to say, that for slab that is 0 12 percentage for the tor steel, for beam it is 0 85 by fy. Now, where you are providing any stirrups or shear reinforcementwe can treat it as a slab. So, that means there we shall provide say 0 12 percentage, but where we are providing that your say stirrups.

So, there it is preferable that you should provide the reinforcement say your according to beam minimum reinforcement of the beam. So, because the code is silent in this case what should be the case? Code is telling that, you go as per say beam theory. But specifically it does not mention in few cases it does not mention that what should be the specific say minimum reinforcement.

So, you we may find that different company or different say designer using say different kind of say reinforcement some time say 0 12 percent, sometimes may be say your according to the minimum beam reinforcement whatever it is. So, I personally feel that where you are providing that reinforcement for the slabbed reinforcement only there is no shear reinforcement.

So we can take it as you say slab where you are providing say stirrup, then we can consider it as a beam. So, accordingly we shall take our limiting values for reinforcemen. And only thing you please note, that it should not be like this you should always that one this type of say your detailing in that case what you have to do that is this link should be going up and then change the reaction. Similarly, here also you do it so, that in no circumstances concrete will come out. I think we shall stop it here.

Thank you