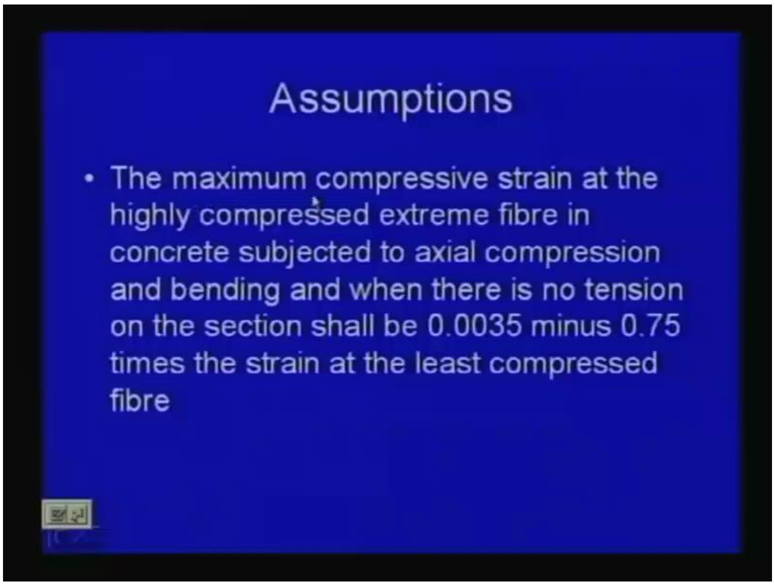
Design of Reinforced Concrete Structures
Prof. N. Dhang
Department of Civil Engineering
Indian Institute of Technology, Kharagpur
Lecture - 20

Design of Columns Part – II

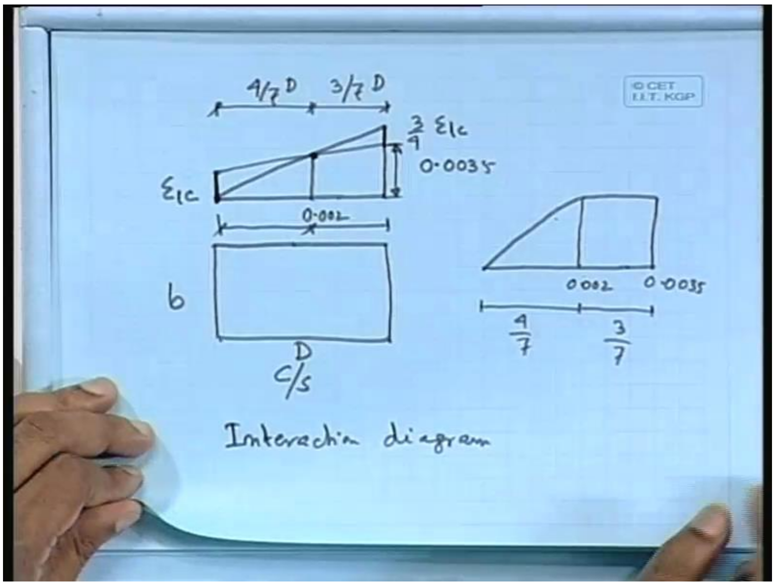
So, let us start that part 2 **o**f design of columns in the last class we have stopped we are discussing that second assumption specifically for compression members.

(Refer Slide Time: 01:07)



It says the maximum compressive strain at the highly compressed extreme fibre, in concrete subjected to axial compression and bending and when, there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed fibre. So, let us draw the cross section, I think let us make it; so, we can have this is the cross section of a column.

(Refer Slide Time: 01:45)



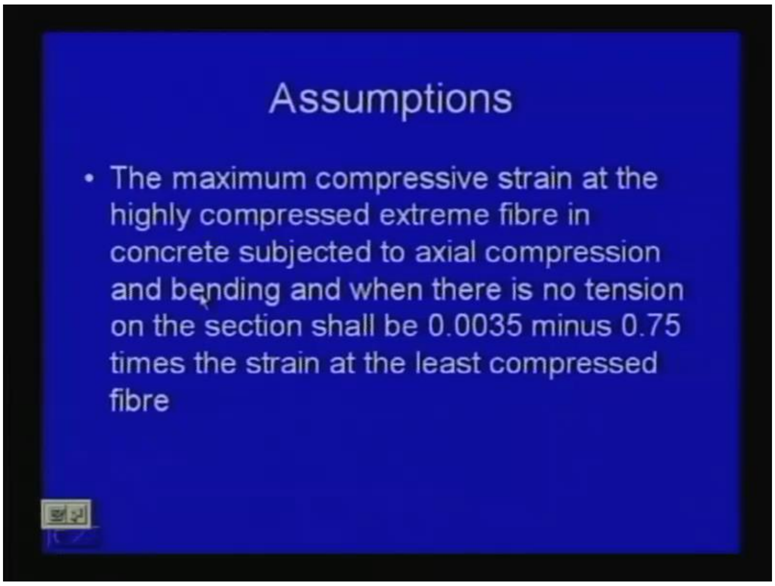
It says, that if, let us assume this is your maximum compressed site, why it is possible it is possible when there is that bending acting on the column. In addition to the axial low the bending also there; so, how is an do what is the case then the case here we can say there is no tension here, if there is no tension, how for shall we go. Let us assume, this is strain diagram, this is the cross section b and D; I am telling that maximum allows a 0.0035. This is the 1 maximum strength; in any case we cannot go because concrete cannot take more than 0.00 35. So, we can go up to 0.0035 and also I am telling that this site there is no tension; that means, this is the 1 we can have, because if we have somewhere we can have so that means that tension may occurs.

So, I can have this limiting value; so, from these end to these end I can have here will be then your 0.002, it will be somewhere say here. So, 0.002 from there we are getting that and 0.0035; what we can do it here. We can gets somewhere here 0.002 the strength; so, how much is these portion we have 2 parts 1 part is 0.002 means; it will be 4 by 7 and these portion 3 by 7,4 by 7 and 3 by 7. Because 0.002 and 0.0035. So, these portion is nothing but, out of 4 by 7 this 1 and this 1 3 by 7; in other way I can say, this is 4 by 7 D and this is 3 by 7 D. The three-seventh of D and this is four-seventh of D. So, we can have this 1; now, what we say that these line will move rotate with the respect to these point because if you rotate about these or you can rotate about these, then what will happen then our strength may be increase it will go beyond 0.00 35.

So, this is our what point if we take what point it means, because I am not telling that the we are detecting that 1 from the assumption. So, assumption it is says that, if we can rotate about these point like this; then we shall get once strain here which will be less than 0.0035 and the other strain is depend of this is the least site that compression site and these the maximum stressed of compression site. So, you can find out and that 1 will be equal to that means, if I know this 1, if I know this value, then I can find out this 1 which is nothing but, let us say epsilon least compression and this 1 will be equal to three-forth of epsilon LC.

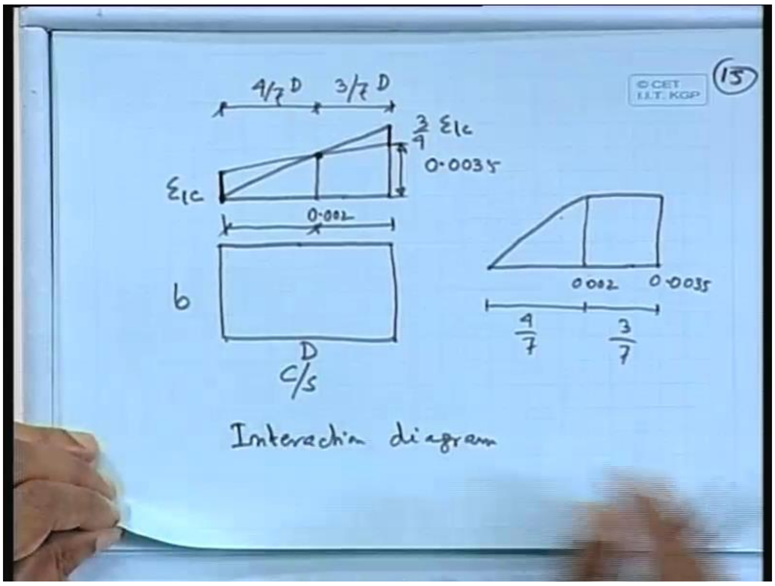
So, 0.0035 minus this 1 will give me the strain here, this is the strain which I am interested to find out. So, I can get 0.0035 minus these 1. So, that means it is pivoted about this point, what is the pivot point? Pivot point is from the maximum compression site at a distance of three-seventh of D. At a distance of three- seventh of D, there we are getting 0.002 with respect to that our stress strain diagram that 1 rotates. So, I shall get a certain compression strength here; so, corresponding on I shall get it 3 4 nothing but, 0.75 that's show I our code says the assumption.

(Refer Slide Time: 06:45)



The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending that means, axially loaded. As well as bending also there and when there is no tension on the section shall be 0.0035 minus 0.75 times; the strain at the least compressed fibre.

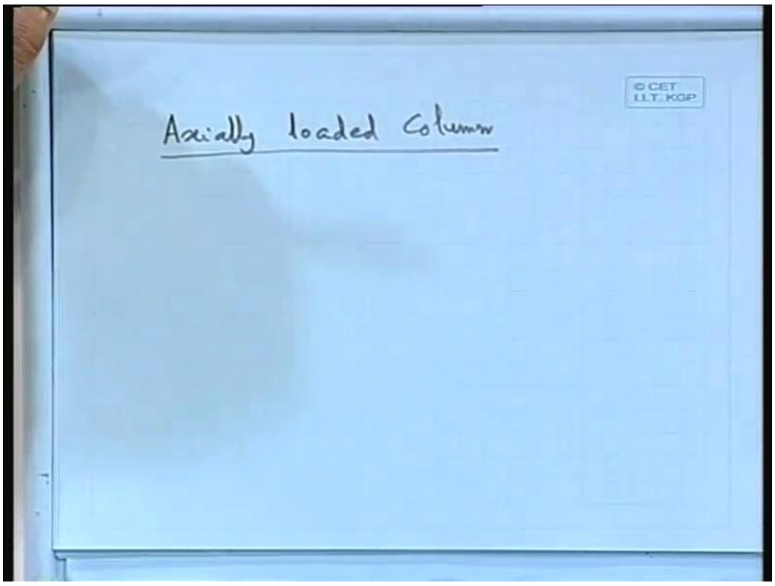
(Refer Slide Time: 07:09)



So, this is your least compressed fibre and this is the maximum stress so that 1 shall we get it considering 0.0035 minus three-fourth of these one, that we you can find out. Now, how I shall we get this value, this value you can obviously; these value we shall find out depending on the situation where the neutral axis is. Because I know this point; so, we can find out that where is neutral axis that we can find out and accordingly we can find out this strength. Why it is so important; it is important because what we do it for uniaxial bending; if uniaxial bending that means the only moment is acting about these axis that is calling uniaxial bending and also axially loaded. What we can do, we can find out from this print diagram as well as from the stress we can find out what is the capacity of that particular see your column; that we can find out capacity of that column.

So, that that is called actually your introduction diagram; so, we can find out that introduction diagram on the basis of these say your strain diagram you can find out and introduction diagram we can find out. And which will useful for design of columns for uniaxial bending cases similarly we can go for biaxial cases also. Now, let us come that what will the permissible stresses and accordingly let us find out how much load it can take, that means, at the section your providing. The section you're providing; so, how much you're that maximum load that accept PU it can take.

(Refer Slide Time: 09:13)



(Refer Slide Time: 09:29)

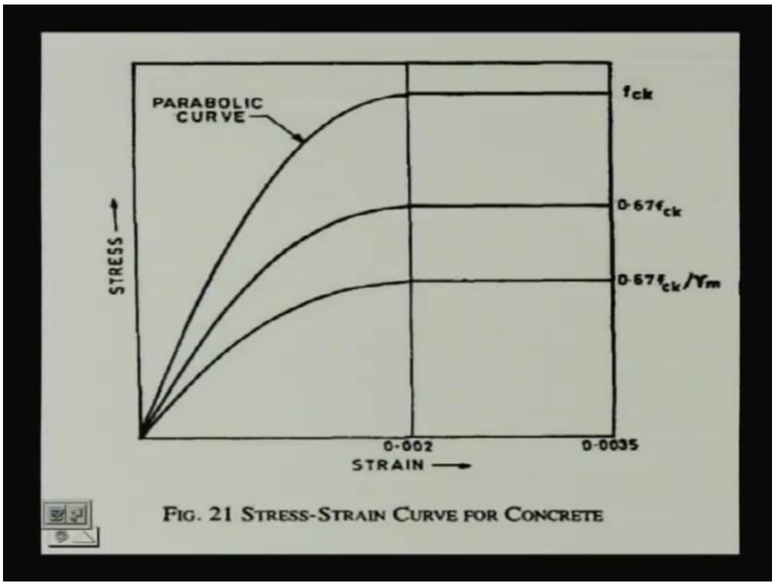
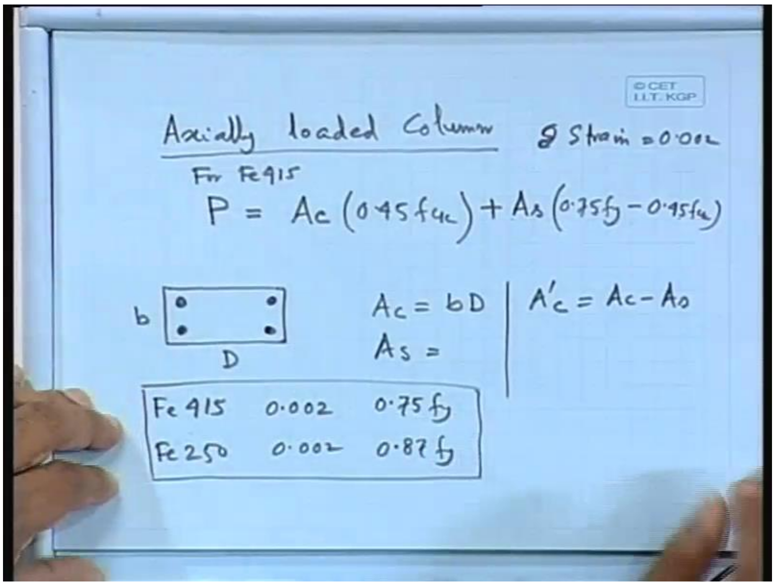


FIG. 21 STRESS-STRAIN CURVE FOR CONCRETE

(Refer Slide Time: 09:47)

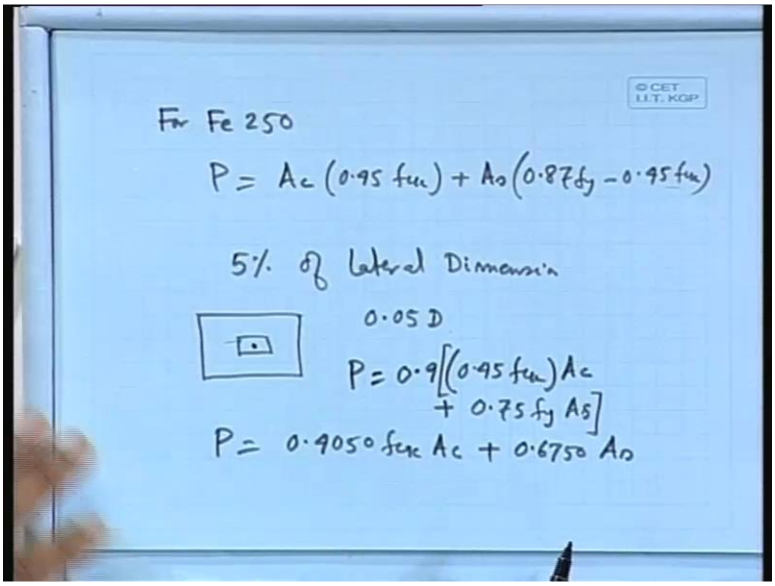


So, axially loaded column so if we take say your 0.002; so, we are getting that 1 which is nothing but, we can take 0.45 fck you can take it as 0.45fck; so, what is the value of P then; P will be equal to area of concrete Ac area of concrete times 0.45 FCK if we take a section if we take a section here, let us say we are having this steel. So, we are having is a b and D Ac area of concrete let us say b times D area of steel will be equal to that; if you have 4 numbers of 6 numbers or whatever numbers that from there you can find out area of steel, that you can find out. So, P will be equal to Ac times 0.45 FCK, because we are talking strain 0.002; this is the 1 hour, but actually loaded column that your direct compression it is 0.002.

What we have to find out then there means at 0.002 strains; what is the corresponding stress in concrete as well as in steel. So, in our case it says we shall already you have achieve that maximum alluvial and that is 0.45 fck. So, area of steel so area of concrete times 0.45 fck that is the 1 that load it can carry, that concrete can carry plus what about your that area of steel; area of steel times at 0.002 for Fe 4 and5 here. It may be different for steel grade for different steel you will get different type of different your stress at 0.002; the stress will be different. If it is say your Fe 415 for 0.002 corresponding stress 0.75 Fy for Fe 250 0.002. That’s already we have achieved that is 0.87 Fy.

So, we shall get the 2 different formula for 415 we shall get 1 for 250; we shall get another one so, if we take now for Fe 415. So, let us right down here for Fe 415; we are talking this 1 the area of steel will be equal to maximum load it can carry this 1 for concrete plus As times 0.75 Fy, but already we have taking that concrete portion. So, let us remove that concrete that area which is nothing but, that we can make it say 0.45 fck; area of steel 0.75 Fy minus 0.45 fck. Because we have already taken that 1 for concrete certain one. So, that's your either you can do it like this A dash c, I can say A dash C equal to Ac minus As that we also you can do it in that case I need not what is called that one subtracted here. But in other way you can do it here, that Ac times 0.45 fck plus As times 0.75 Fy minus 0.45 fck for Fe 415.

(Refer Slide Time: 13:54)



Now, what about you're Fe 250 for Fe 250 that same P will be equal to Ac 0.45 fck plus As times already I have told 0.87 Fy minus 0.85 fck. So, P equal to Ac times0. 45 fck plus As times 0.87, 0.85 minus 0.45 fck here that is the different will get it here. Now, what we do; we assumed that it is within the isolated will be within 5 percent of lateral dimension that means, these P is acted is being acted here, within 5 percent of lateral dimension. That means, let us say 0.05 D I can say that means it will act then we shall consider these 1 axially loaded column; that means, we shall not take that eccentricity. If we goes beyond that in that case up to the load applied P multiplied by the eccentricity will give me the corresponding movement, but here, what we are doing since your talking say axially loaded column. So, we can go up to

0.0 that means, we had not necessarily at this meet point; it can go how far we can go that 5 percent of the lateral dimension.

So, 0.05 D if you due to construction error whatever it is it will happen and then we can go up to 0.05 D that show I what we do with consider the P equal to, I can now, come back to your say your class 39.3. So,

[Conversation between student and Professor]

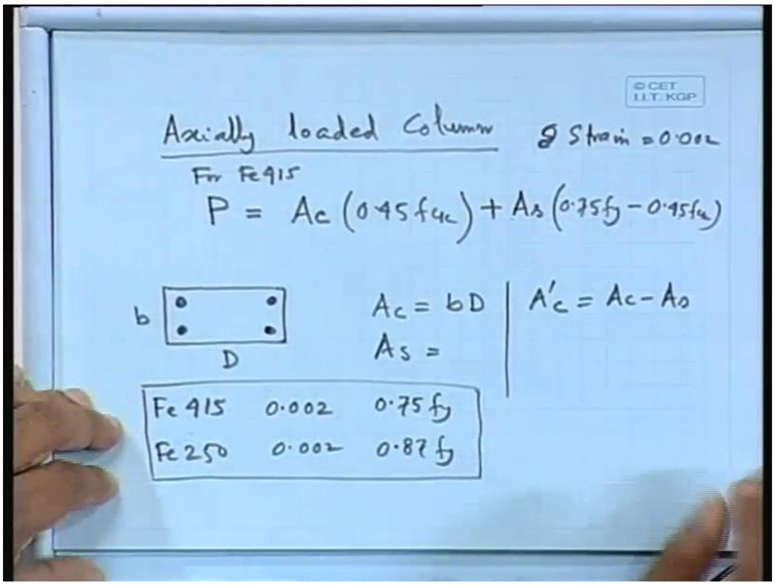
yes we can go a maximum 5 percent that our could say; so, 5 percent you can go.

[Conversation between student and Professor- Not audible ((00:16:16 min))]

yes both sides the other side also you can takes a 5 percent. That we us so P equal to here we can take; we can take that value as 0.9 times point we are taking 90 percent. Because of these we are taking 90 percent of the value. So, 0.45 fck times Ac plus; if we ignore the other value 0.75 Fy. As I mean to say, if we ignore these portion, then I can get 90 percent of the these value you shall take it as the alluvial 1. Because since you know that we shall not be able to construct it we shall not be able to construct within that your say there without any eccentricity. If even if we know that go a maximum 5 percent.

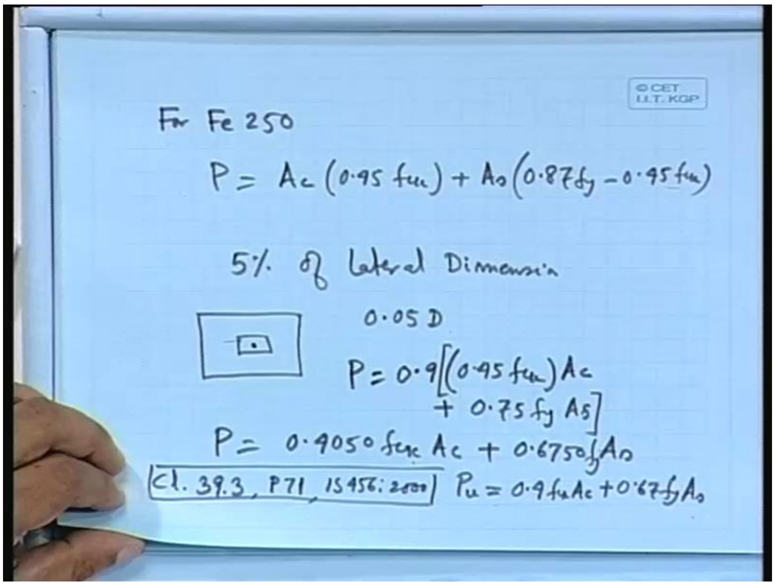
In that case, we are reducing this value that means; if you provide a section which some reinforcement on the what is the maximum alluvial note that we can compute that means whatever value of computed you take 90 percent of that. If we take that 90 percent of that, then what will get it here. P will be equal to so, 0.9 to 0.45, 0.40 fck times Ac plus 0.9 times 0.75 0.6750, As.

(Refer Slide Time: 18:15)



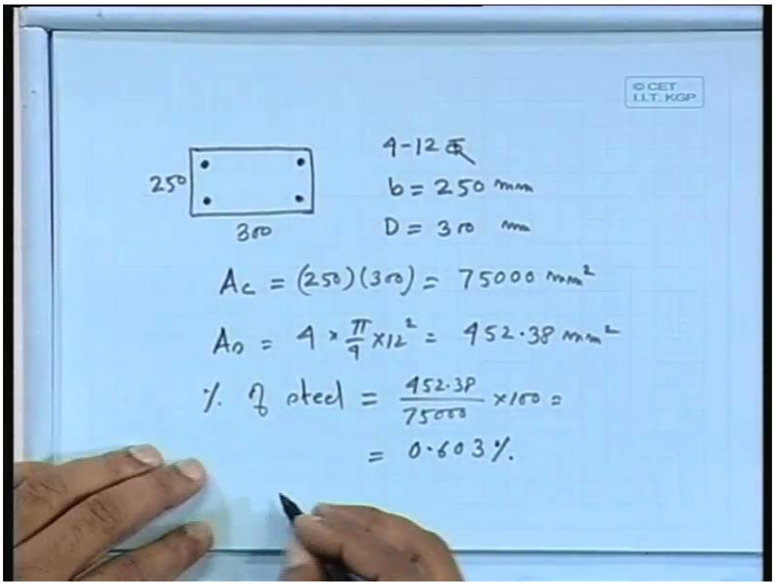
So, whatever we have done it here for say these value axially loaded column for Fe 415; we can get these one; if you ignore this portion then we can get say 0.45 fck Ac plus 0.75 Fy is now, since we shall not be able to constructed without any eccentricity.

(Refer Slide Time: 18:32)



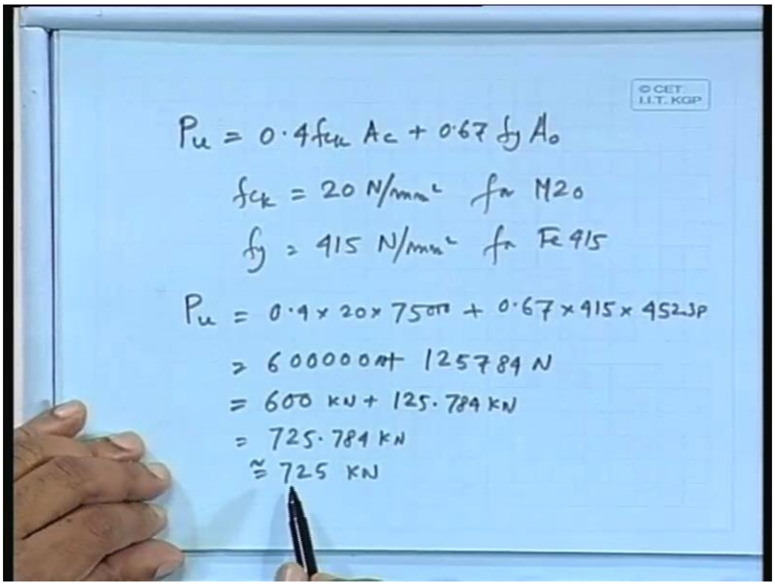
Eccentricity will come on the even for due to construction also; so, that’s way you’re taking that maximum alluvial load. Let us say we shall take 90 percent of that so whatever we have calculated you take 90 percent 0.9. So, we are getting 0.4050 fck Ac plus 0.6750 As; now, our codes is that is in class 39.3 P is 71 IS 4562, 1000 our codes is it is Pu equal to 0.4 fck Ac plus 0.67. Here Fy is missing Fy As; so, our codes is that point 4fck Ac plus we have reduce these 1 see another5 that 1 so we come to that 0.4 fck Ac plus 0.67 Fy As. So, this is the maximum alluvial that means, if we know a section certain dimension b and D and your; you know that a provide a steel. So, you can find out that what is the corresponding maximum alluvial load it can take that is Pu using this formula for axially loaded column. Similarly, you can find out for say your uniaxial other cases that we can do it, but anyway so, this is the case for axially loaded column that we have to do it.

(Refer Slide Time: 20:26)



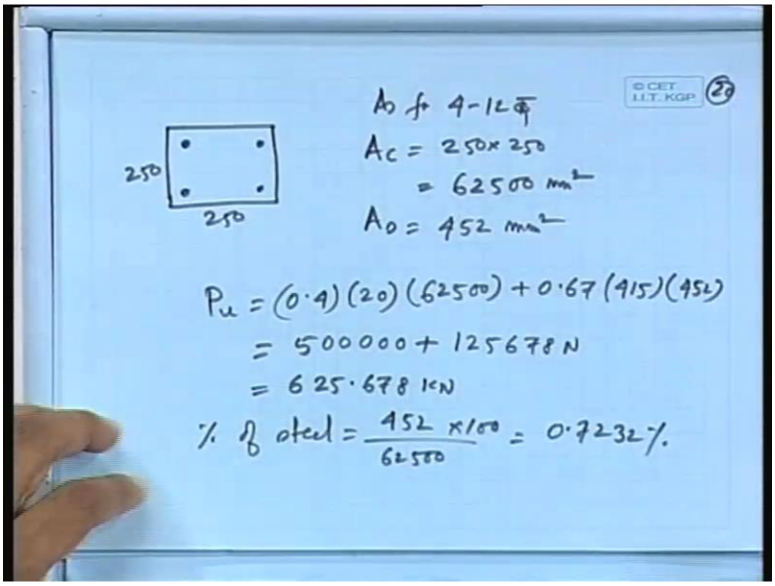
So, the design of column is very simple in that case; so, what you have to do let us take one section say 250 by 300. Let us take section 250 by 300. Let us take, I am giving here say 412 torque b equal to 250 millimeter D equal to 300 millimeter Ac equal to 250 times 300 As equal to 4 times. Let us say, let us find out the percentage of steel, it was going to the calculation. Percent of steel equal to which comes us 0.603 percentages. So, even if say the section can take the load whatever your applied even then we cannot provide this section with these reinforcement because it is less than point 8 percent. First one that whenever even say you we can calculate these one according to this formula that Pu let us find out first.

(Refer Slide Time: 22:51)



Pu equal to 0.4 fck Ac plus 0.67 Fy As; let us take fck equal to 20 M 20 Fy 415 Newton per square millimeter for Fe 415. So, Pu equal to 0.4 times 20 times 75000; that is the one we have got it plus 0.67 times 415 times 452. I think you should be stop there 452 only anyway. So, we are getting here 0.4 times 20 times 75000 plus 4 107 times, 4 15 times, 452, 0.38. We are getting here 1 2 5 7 8 4 say let us make it like this Newton. So, we can find out here let us say 725 kilo Newton; that means, the Pu is maximum alluvial 7 25 kilo Newton. These particular one we can get it 725 kilo Newton. What we shall do here, may be in the case here, that your section it can take that load actually applied less than 725. What we can do, we can reduce this 1 say 250 by 250also; that also you can do and we can find out we are getting that what is the value of Pu. Let us try that one at least.

(Refer Slide Time: 25:17)



So, if we take is square section 250 by 250 the same way; so, Ac equal to 250 into 250 equal 62500 millimeter square and As for 412 torque we are using the same one. Which is coming as say 452 square millimeter; you can go 452.38 all this things, but in a so, 452 we can take it. So, Pu equal to 0.4 times 20 for M 20 grade of concrete times 62500 plus 0.67 times 4 15 times 452 which comes as 1420 into 625. So and the other 1.67 and score 15 times 452 which comes as 1 25678 is a Newton equals 625.678 kilo Newton. So, we can get Pu these one, but whatever the percentage of steel equal to 4 52 divided by 6 to 500 times 100.

So, 452 into 100 by 62500.7232; so, this is the percentage of steel that is even if 250 or 250; generally, what I meant to say here, most of the cases you will find out this is a very standard practice that they lesson all most things in general building. What they do the 250 by 250 and used 412 numbers of bars, but according to highest score even then it is in that case it is very less; the value there is less than 0.8. So, we have to follow those that codes that what exactly will get it here that will get it in because it is very important. And here generally, we check those things the calculation it means that in design of the concrete; I repeat the reinforce concrete the bending moment shear force or axially loaded column axial forces all those things you will find out it is very less.

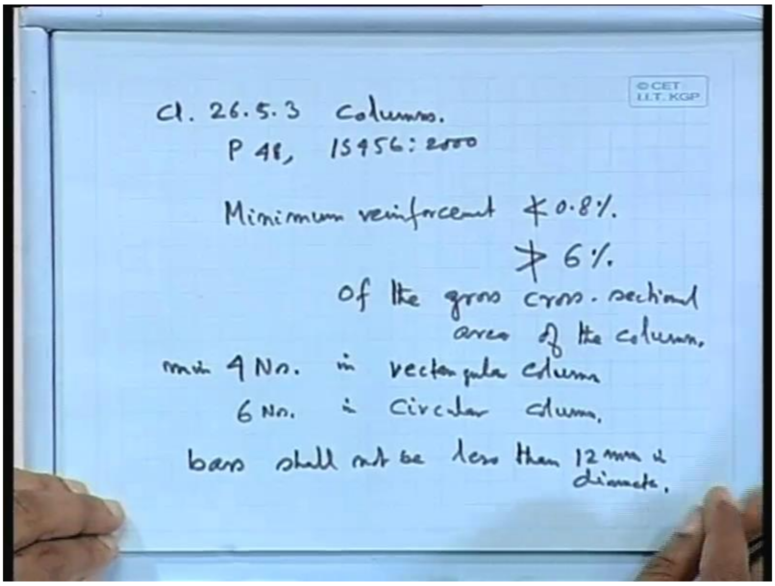
But even then you have to provide certain minimum 1 from there say your cracks thin gage creep and lot of water things also involved stability. So, from their point of view you have to provide the minimum reinforcement; if you have to provide the minimum reinforcement or minimum dimension that we got to provide and for that you have to follow highest 456. If there is any dispute, then obviously; if you follow according to this score then nobody can say that use that much. So, this is the very important is a non necessarily that it is be just simple mathematics that will using formula getting thing and you are providing it. It not that one it is much more than that where you have to provide that 1 that restricted by say the minimum reinforcement that we have to follow.

So, here

[Conversation between student and Professor- Not audible ((00:29:01 min))]

What I am trained to say, I have initially, I have taking say 250 by 300. And I have used 412 numbers of bars just orbitally I have taken then even then I am coming to say 250 by 250; what I mean to say here, in this case in most of the cases you will find out that people are using 250 by 250 section and 4th number 12 bar that is very standard practice you will find out. So, in that case what i have found that it is not as per IS code 0.8. So, let us come now to the your code and that will find out in class.

(Refer Slide Time: 29:44)

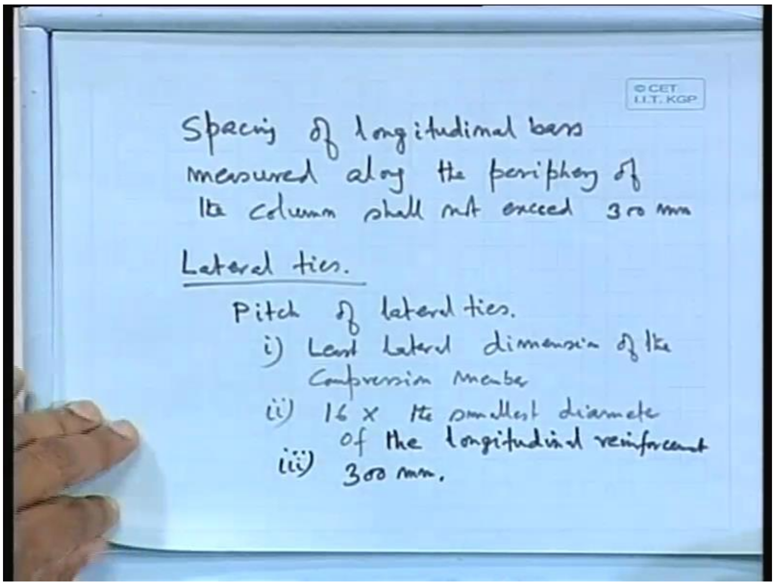


26.5.3 that columns P is 48 IS; I am always referring this one; so, that a you will be familiar with this classes. So, what you says the first class that a the cross sectional cross sectional area of longitudinal reinforcement shall we not less than 0.8 percent minimum reinforcement not less than 0.8 percent. And not more than 6 percent afford of the gross cross sectional area. So, this is your basic thing that 0.8 percent should not be less than that means in our case 250 by that one that will very less. Let us {se} say, 6 times 113 that means, 6 number of bars let us consider divided by 62500; so, it comes say 1 percent. If you use a 6 number of bars into 250 by 250 section. So, it comes 1.08 percent; that it comes.

So, at least you should provide we say 6 number of a12 bars that you can provide. Here because other next higher you are having because next higher ratio say 16 dia bar but if you say, 4 16 number 16 dia bar if you provide which is coming us 1.28 percent. So, in the practical cases a 250 by 250 section we can provide the minimum reinforcement that you can provide say 6 numbers of 12 bars. If you provide than in that cases coming 1.02 percent but even then you can provide though it is go it is little more than 0.8 percent, but that is the one you can provide.

So, this is the 1 that we should always follow, the minimum number of bars minimum number of longitudinal bars provided in columns shall before in rectangular columns and 6 in circular columns. So, 4 numbers minimum 4 numbers in a rectangular column and 6 numbers in circular column the bars shall not be less than 12 millimeter in diameter less than 12 millimeter in diameter.

(Refer Slide Time: 33:31)

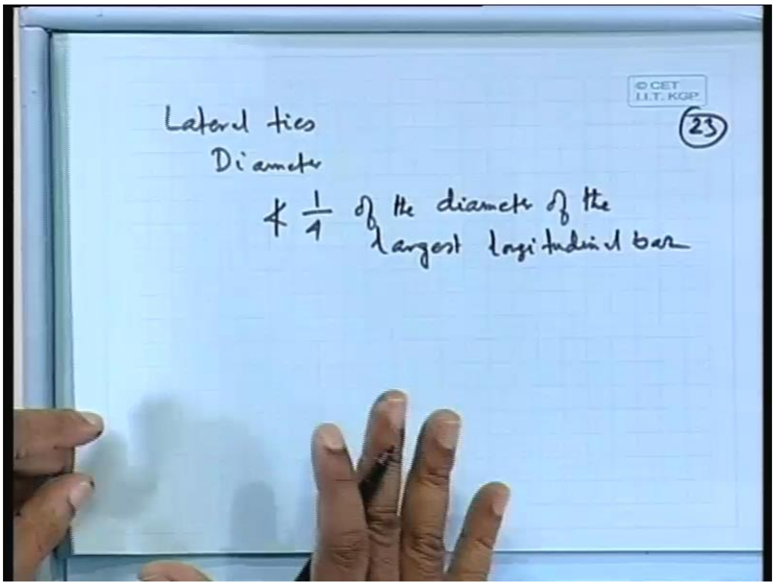


Then we can have spacing of longitudinal bars measured along the periphery of the column shall not exceed and 300 millimeter that means, you can have 3 millimeter that is the 1 that gap between maximum gab between the longitudinal bars. That if it is more then we have provide that 2 number even the if it say the reinforcement are say it is not that means what i meant to say it is not dependent on only the strength point of view the load applied. It is dependent on so many other guidelines also that minimum number of bars then your say bar diameter then you're these restrictions at 300 millimeter all those things say, sometimes. It may happen that whatever the reason the column dimension from practical point of view or whatever the case the dimension is more say may be say 500 to 500; that you will to provide.

So, if you have to provide that dimension, then you have to provide the reinforcement in that case what we do we know the load is not coming more the load is very less. Which can be accommodating 250 by 250 section, but since it is 500,500. So, you have to provide the reinforcement 0.8 percent of that 500 cross section. So, in that casing you know that it will the steel more coming more but even then {we ca} we can't help it that will to use it. And that we have to do it according to this IS code. Similarly that not only that your that bar diameter also you cannot provide say 8 millimeter you have to provide not 10 millimeter will provide say 12 millimeter. So, this is your case now I shall tell you regarding say lateral ties that means, they way we considering beam that is stirrup here. We call it is tie so the least lateral dimension pitch of per spacing of lateral ties number one least lateral dimension of the compression member number 2: 16 times the smallest diameter 16 times. The smallest diameter of the longitudinal reinforcement if you have say 12 and 16 all those things.

So, it will be depending on the minimum least of that or number 3, 300 millimeter. So, we have least lateral dimension that is one case then another one which kind of what about that longitudinal diameter you have provided. Multiply with the 16 point if you have say 12 millimeter 16 millimeter like that; out of that you take the smallest diameter and mu. And then you find out the 16 times of that or 300 millimeter out of these which one is the minimum that we have to provide. So, this is your lateral ties that your say pitch or spacing that means, what will be the spacing that we have to provide like that.

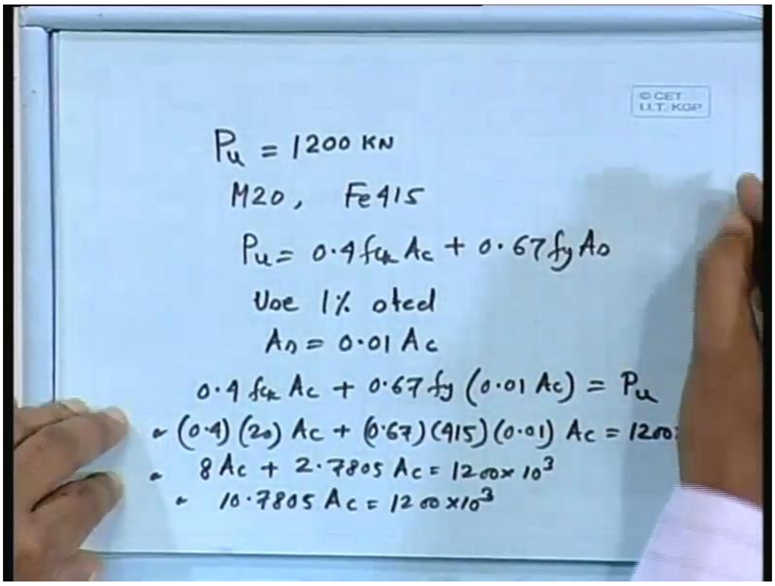
(Refer Slide Time: 38:10)



But whatever the diameter, the diameter the diameter one-fourth not less than one-fourth of the dia of the largest longitudinal bar; Please note here, for spacing we have taking the least and for diameter we are taking the largest if you have12 millimeter 60 millimeter all those things so you have to take the largest 1. So, this is the case we have to consider here, one-fourth of the diameter of the largest longitudinal bar. So, with these what we have to do, with these we have to design our so that means we know now, we know the restriction and with these we have to design you say that your, what is called that compression member. There is 1 another 1 we can had that is called. Your say because how you can find out it is very simple that you can find out you provide that 1 first whatever you do. Number 1 you find out the effective length of the column, they on the basis of that you find out what is the dimension of the column. If you would like to design it as a say soft column; then it will be restricted by say Lx by Ly D there is should be less than 12.

So, you can give that your dimension of the column also and what we can do. If you assumed that it is a 1 percent steel that as assumed the other way also you can do it we can find out that 1 percent steel.

(Refer Slide Time: 40:37)

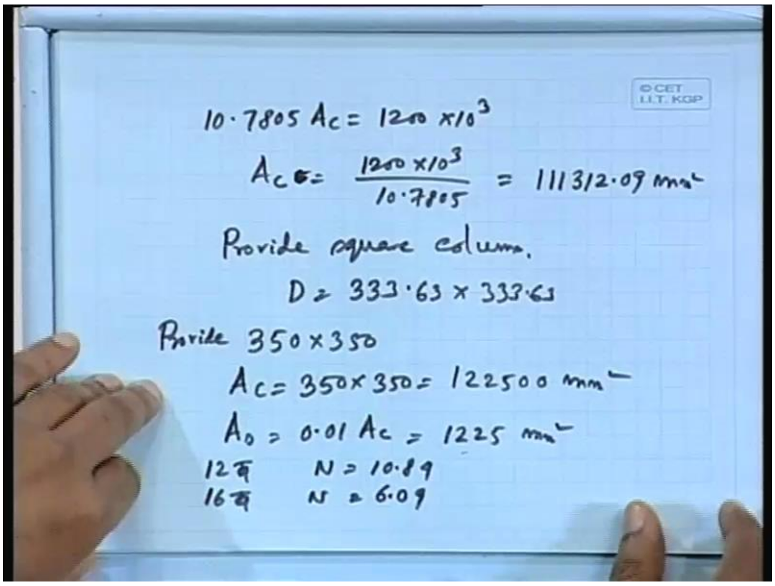


Our design calculation is very simple, that Pu let us say one way, let us say Pu equal to 1200 kilo Newton say that is we have computed from any that is from analysis 1200 kilo Newton M 20 grade of concrete Fe 415 that we have done it. So, this is your case what we can do we shall find out we know Pu equal to point 4 fck times Ac plus 0.67 Fy As. What we shall do it here we can assume that we shall use 1 percent steel; so, you can say As equal to 0.01 Ac.

So, you can right down here point 4fck Ac plus 0.67 Fy times 0.0 1 Ac equal to Pu. Because I can now calculate Ac also or point 4 times 20 times Ac plus 0.67 times 415 times 0.0 1 Ac equal to 1200 into 10 to the power 3. I am making in it all in

Newton r thus find out 0.4 into 20 8 Ac plus 067 times, 4 15 times 0.0 2.7805 Ac equal to 1200 into 10 to the power 3 r 10.7805 Ac equal to 1200 into 10^{th} over 3.

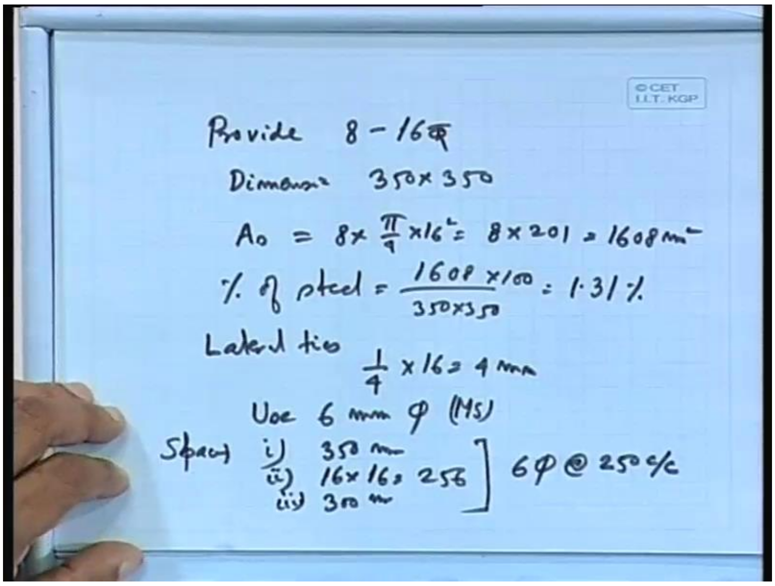
(Refer Slide Time: 42:59)



So, Ac we can find out; therefore, 10.7805 Ac equal to 1200 into 10 to the power 3 Ac equal to 1200 into 10 to the power 3 by 10.7805 equals 11312.09 square millimeter. If you will says square column D comes us 333. So, we can at provide these 1; what we can do it here let us assumed that we are provide 350 by 350 dimension column. So, Ac equal to we are getting here 350 into 350 comes as so 122500 square millimeter. As equal to 0.01 times Ac because we are provided these 1; so, 0. 01 times Ac 1225 square millimeter. So, As equal to 1225 square millimeter if we take which is coming us; if we you say12 torque numbers 10.84; if you use 16 torque number 6.09912 torque 10.8416 torque 6.09. What you have to do it here, if you go for say your12 torque then we have to go at least12 numbers because relevant numbers we cannot provide so you have to provide a12 numbers.

if you go for say 16 torque then we shall go say not say 6 numbers not possible so at least provide say 8. So, in that case you can find out even there also how far we have just 1200 kilometers to accommodate that how far the deviating. So, in that case so if it is not the 1 that tolerance so you have to go restricted we that on also the number of bars so we can provide say 16 torque say let us provide.

(Refer Slide Time: 46:09)



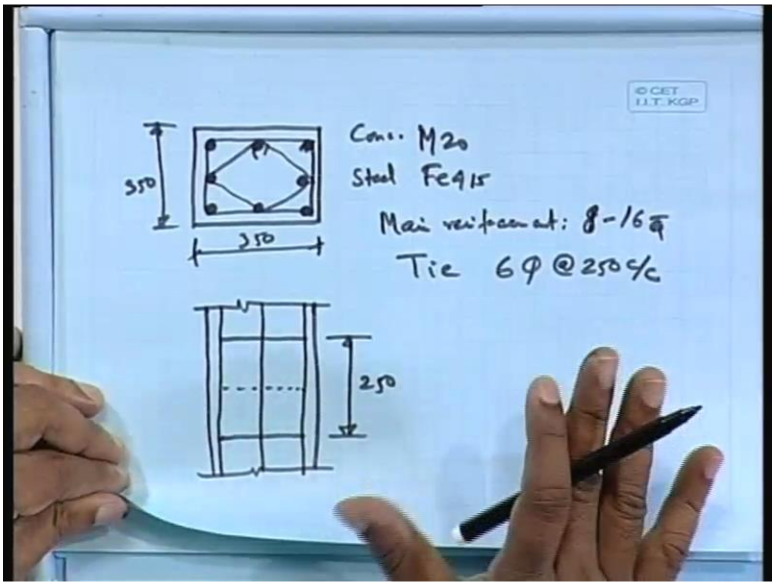
So, let us provide 8 16 torque dimension 350 by 350 then a is equal to 8. So, percentage of steel we are getting here the 1608 by 35 0 by 350. So, that means we are going 21.31 percentage; so, in that case we are going up to 1.3 1 percentage; what about then lateral ties. Lateral ties we can say one-fourth of 16 , but there is no such one-fourth times 16 4 millimeter. There is no such bar of 4 millimeter. So, use 6 millimeter and that 1 will be here 5 that mild steel. Because 6 millimeter torch steel is available torch steel is available only for 8 millimeter. So, you can provide 6 millimeter even then you can provide what about the reinforcement that spacing the spacing we have 3 different cases; we have number 1 that your least lateral dimension which is here, spacing. So, least lateral dimension which is here 350 millimeter number 216 times 16 times the diameter which is coming as 256. And number 3 that 300 millimeters so, out of that we are having 256 is the minimum so let us provide 65 at the rate of 250 center to center.

[Conversation between student and Professor- Not audible ((00:48:57 min))]
We cannot go

[Conversation between student and Professor- Not audible ((00:49:00 min))]

We are giving 250 so you should be it should not be more than 256; so, here it is coming say your 250 so this is the 1 we can do so we can provide finally we can do it we have to provide.

(Refer Slide Time: 49:16)



Once a cross section like this and we have provided 8 bars in 8 corners; first we have to provide and since it is axially loaded. So, we have we can provide in all 4 sites and we can provide here. The tie you can provide here tie and also we shall provide here tie here also for these 1 also not only for the outer 1 for inner 1 also you have to provide. So, these dimension 35350 and let us provide here, these bar so, we can have 1 bar outer side another bar here, other bar here then we can find out that like this. And let us provide here 1; I mean to say these gab is 250 that means; I am not providing the 1 i showed it 1 that i don’t want to provide at the same level.

I would like to provide these 1 say at these level outer 1 and these 1 i would like to provide say 125. So, these gab will 125, but it will go again at 215 interval so that we it is easier to that bind it. So, that way that I preferred that 1, but it but the other 1 also correct it does not mean that there is wrong that is also equally correct. So, we are getting M twenty Fe 415 should right down clearly steel and main reinforcement 8 16 torque tie 65 at the rate of 250 center to center so this is your that design that we have to provide so that the draftsman can make the drawing from here, so this is all that we can say axially loaded column so we shall go in the next class we shall continue with the uniaxial bending okay. Thank you.