Design of Reinforced Concrete Structures
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Lecture - 19
Design of Columns Part - I

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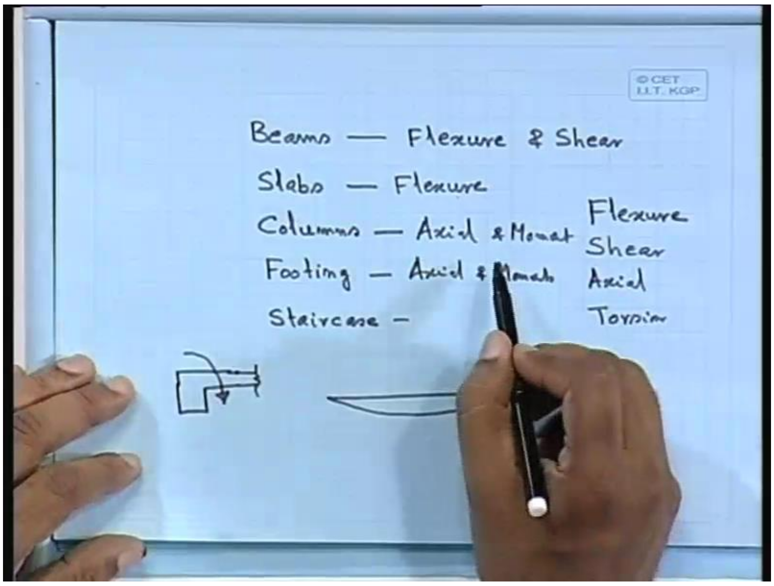

So, let us start again the designed of reinforced concrete structures so, far we have done the beams design of beams then, we have done slabs. Now, we shall come to the columns those compression members next, we shall go for footing in addition to that, we shall also design staircase. So, if we can design all those 5 components we shall be able to design a building that is our primary concern, at least for this particular course.

We can have advanced 1 say seilo, then bunker, then you say water tank so many other components. But anyway finally, you come back to these components while these beams means flexure and shear these are the dominant 1 we can have say axial 1 also, we can have torsion also that we shall consider. So, what are the basic 4 components: 1 is that flexure then, we have shear, axial and then, we have torsion.

So, if I find out all 4 will not act in any particular element. Elements means, here we are talking say beams, slabs, columns, footing, staircase. These are all calling as module or elements of a particular building of a particular structure. It may be bridge also, there also you will find out few of them like that beams, slabs, columns like that you will get it as well as footing also, but footing will be different.

So, for building whatever the type of footing for bridges the footing will be different. Generally, we call it say pillars are supported over the piles. So, we have to design your say piles over that you are having pile cap then, over that you are having pillars. Finally, you are having that pile cap then, you are having bearing and over bearing that your super structure will be that set. So, this is the different components for bridges.

So, for buildings here whatever you shall do we shall start from the top say slab then, your beam, then you say what is called columns finally, the load is transferred to footing. So, we have to design footing in addition to that for accessible access to different floors we have to design staircase. But all those things we have to find out here, flexure and shear in beams we shall I shall show, at least 1 problem where that torsion also may act. So, if torsion is there then how to tackle the type of beam problem.

So, where it may work like this say for example: this is the 1 case of beam now, due to this load what will happen these beams subjected to the torsion, not only a beam which is bending u like this as well as, it can if it bends the other way that means, along this 1. So, that also we have to consider and how to design that when torsion is applied. So, that we shall find out later let, our consider for the time being say little bit say advanced stage, but anyway we shall find out.

So, slabs mains we are found it is nothing, but flexur so, in few books you may find that they have started with slabs. Because the flexure 1 then, flexure and shear, here we shall come the columns axial force and also it may occur that it may happen that moments, also applied bending moments also applied. So, we can have this type of problem then, footing is nothing, but extension of column.

So, here also we can have axial and moments. Staircase when we are considering here, most of the cases common staircases we generally, consider here with as dominant 1, pre-dominant 1 that flexure. So, we have to design staircase that we shall take it separately, what I mean to say here all the components that means, if you take it say 1 component wise and if you consider this super position valid because, independently we are working.

So, flexure shear, flexure axial, bending moment, all those things are working and torsion can also work. So, that is why we are considering this 1 as I say element wise different elements. So, whenever you are considering 1 particular structure then, you have to find out what are the different elements and what are the forces acting which 1 is dominated like that bending movement.

Then, you have to take care in a certain way because, that you know whether, it is say shear that you have to take care in that direction. So, like that you have to go. So, here today we shall in next few classes we shall consider you say columns, if I consider that columns.

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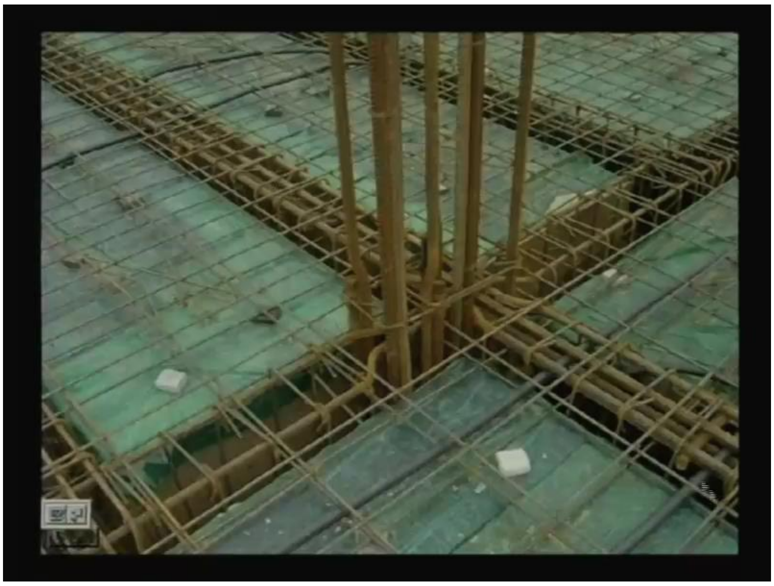

So, let us see first already I have shown, but let us come here specifically that this is your beamed reinforcement. You see, this is the top of the this is slab this 1 is your slab, the reinforcement and you are providing this 1 you please note these all those things provided here to give clear cover otherwise, it will just simply lie on the that you say floor itself roll of that say these form work.

So, you will not get the clear cover so, you have to provide the clear cover here, here like that in different places you have to give that clear cover. Now, you also see these bar if you just reduce the subtract the clear cover from the top of the slab or from the floor, you will get this 1 that is at the top level. So that means, here you can consider that is T beam the design as a T beam.

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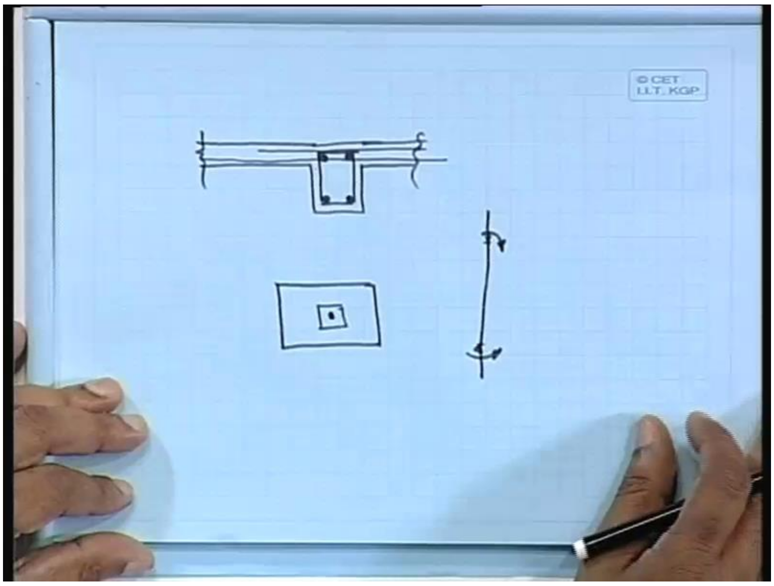

So, if it what I mean to say this is your beam say slab, this is your beam let us say. So, your reinforcement is going up to this for beams and here whatever, your reinforcement for the slab that is also there, if not that we are not concreting here. Because, it will be cost materially with the slab also so, and you can see few places there is a lapping big 1, small 1 all those things.

So, whatever do whenever you are talking say reinforced concrete you have to consider also what gap should also be provided here. These gaps that also you have to because, whenever you are giving the digital reinforcement detailing that time also, you have to consider they have to take care that whether you have sufficient gap for providing you say core segregates.

Because, it is dependent on the core segregates otherwise, what will happen at the time of casting if proper valuation is not done. Then, it may happen there is a gap there we say the material that 1 there is a void in the concrete and which will weaken the concrete though you have designed for say M 20 grade of concrete. But even then, you will not be able to achieve that particular 1 because of these voids.

So, that is why it is very important also that you have to check whether you are having sufficient gap and how much will be gap because, if you consider say maximum size of the aggregate say 20 millimeter. If it is 20 millimeter so, at least you have to provide the 20 millimeter so that 1 portion aggregate can be promoted at within that place so, like that but our quotes says in detail that we shall come afterwards when, we shall come in detailing 1 anyway.

So, another 1 here any important though we are providing say 4 bars. Let us, say we are providing 4 bars in the column in 4 corners of the rectangular column. Similarly, how many bars we have to provide for if it is a circular 1. Quote says that, you have to provide 6 numbers for rectangular 1 4 numbers minimum. And for circular numbers 6 numbers that you have to provide.

Now, what is the bar diameter? What is the minimum bar diameter? Because, these all those things we have to give detailing that 1 you have to provide. Now, when you are talking this 1 that how many bars that means, what is the minimum percentage of the steel of the cross section area. If b and d is the that is the always you have to take care that portion. That what allows you have to take care and our quote says for example, for the slab it is 0.12 percent for each ISD bar or deformed bar whereas, 0.15 percent for the that you say just mild steel.

So, that is first slab similarly, for columns also we have certain kind of minimum reinforcement that you have to provide. Even if do not have say sufficient strength that load applied even then, you have to provide the minimum. Similarly, what shall be the minimum dimension there is a restriction also that means, you cannot go less than that value generally you provide say 200 millimeter.

So, this all these things you have to provide so, first of all the load is applied in our case it is just simple say axially loaded 1 it is axially loaded for the time being say consider. But even then, even it is not axially loaded say For example, if this is a column cross section I am talking the plan.

So, how far shall we have allow it is the ideal case; that means, the load is applied here that actually loaded, but that is not possible. Even if you go from the first floor ground floor to the top floor say be say second floor or third floor level then, even then due to construction also it will damaged little bit. So, how far shall we allow this eccentricity?

Then, how far shall I allow so that, we can say it is though it is theoretically not, but practically it is an axially loaded column. Otherwise, what we have to consider otherwise, we have to consider this 1 here that movement also in addition to the load that movement also you have to consider. So, if we let us consider before going to detail when, you are talking say your column what we have? What are the different components we have to provide?

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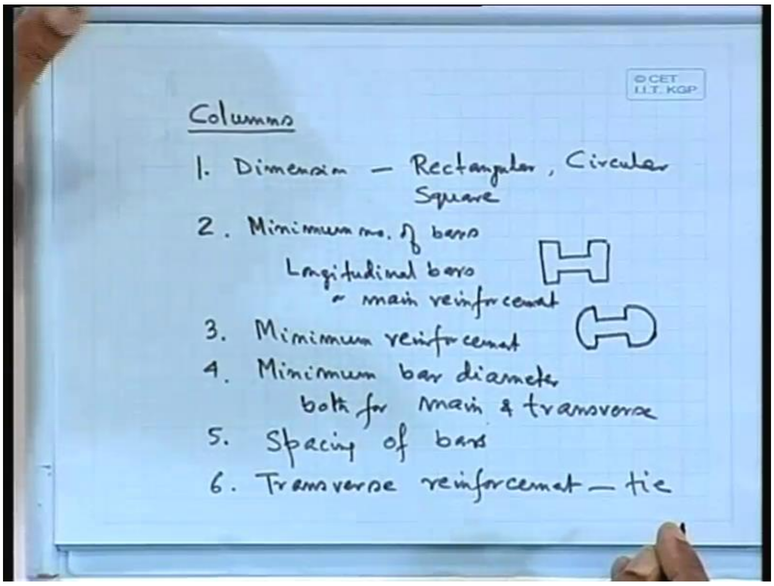

So, we have to provide so let us, first draw down columns. We can have the dimension, the rectangular square also 1 special case circular. Let us keep that 1 say square, it can be hexagonal also or it may be any other shape from the other point of view may be architectural point of view or from practical point of view that also we have to consider. It may happen that the shape could be like this also.

So, like that or the shape because, we do not know that well there could be many other shapes. So that means, I can provide the shape like this also so, in this way the different shapes are also possible, but what you have to do that you have to design this 1. Number 2: that you have to provide that minimum reinforcement, minimum number of bars we have 2 1 is longitudinal this has called also main reinforcement.

So, this main reinforcement that is longitudinal main reinforcement here this 1 we call this 1 called longitudinal. So, we talk this 1 that means, this 1 will share the load along with the concrete; concrete and steel both together will share the load and that 1 will be shared by this longitudinal 1.

Then, we are having say minimum reinforcement, minimum bar diameter both for main and transfers, spacing of bars and spacing of bars there is 1 more you call it that is that main and transverse reinforcement. So, let us give that 1 say transverse reinforcement here. So, transverse reinforcement we call it tie; tie verse the compare to that you say stirrups here we call it tie. So, tie means this is the lateral reinforcement.

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So, this is the lateral reinforcement that you have to provide or I can say this 1. So, this is your that ties we are providing here I personally I don’t like this type of say stay 1. Generally, we provide whatever the gap we shall providing here I prefer say 1 along this the other 1 little gap here, that I shall tell you in due course. That will be easier to make it anyway this is the, but it is also correct, but it depend on that how fast you can say make the workmanship that work that is why I put it other way.

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So, detailing also it is not the unique solution you can have number of solutions also. And this is you say 1 circular column and with spiral that not only we can provide ties, but also you can provide that 1 say spiral binding like this we can go . So, when you come to this 1 these are the different components that we have to provide, in addition to that we have when you consider these all of them.

So, these columns say dimension you say minimum number of bars, minimum reinforcement, all those things that transverse reinforcement all those we have. In addition to that, we have to take care that what is the effective length, effective length of the column.

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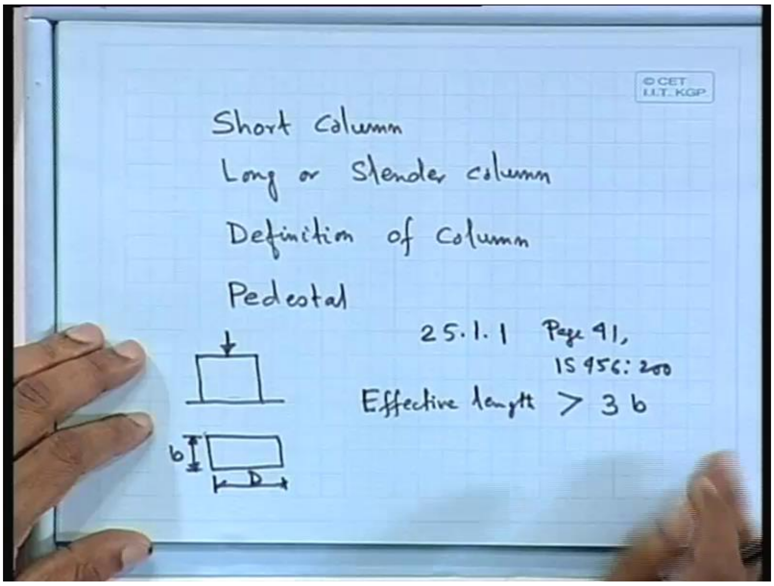

So, from there also you have to find out what is that how whether, it is a short column or long or slender column. Let us, come to the 1 that definition of column that is 1 more item we called it Pedestal. Pedestal that is just a simple 1, a short 1 and it is having say certain kind of say dimension if you take the pedestal we are using for some purpose may be for say formation foundation or very different purpose we are using certain rate of pedestal we used to make it.

Now, shall we are calling this 1 as a pedestal; shall we call it say your why not columns also. Because, it is having also axially loaded or even if it can have say bending also,the quote says and that we shall find out here the quote says let us, come to the clause; specific clause. Because, that is very important I should say anyway, I think 25.1.1yes so, we can get this 1 in clause 25.1 1.

The page 41 IS 456: 2000 our code says, the column or start is a compression member the effective length of which exceeds 3 times the least lateral dimension. Effective length greater than 3 times of least lateral dimension that means, if it is a rectangular 1 originally we provide this 1 say your b and the other 1 say your d depth, this is width.

Generally, it happens that this is the width always say smaller compare to the depth. So, effective length should be greater than 3 times of the least lateral dimension. If that be the case then, only we shall consider this 1 as a column otherwise, it is a say here in this case the pedestal. So, it is dependent on this 1 if it is less than equal to the less than 3 times say your least lateral dimension then, we shall consider it as a pedestal otherwise, it is a column.

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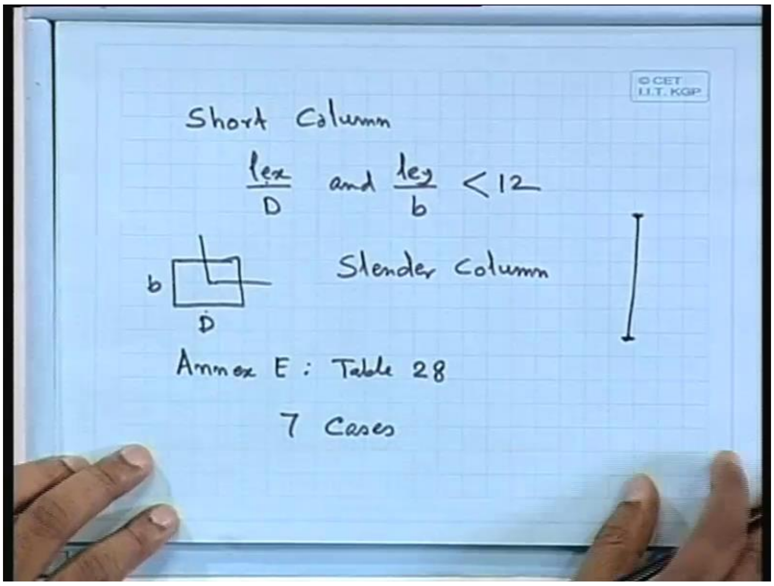

So, what is short column? Short column here lex by D and the other axis ley by b say we are talking a section b and D. So, if we take care of this so, lx by D and ley by b less than 12 then, we shall take the we shall call that 1 as a short column otherwise, it is a slender column. If it is greater than lx by D ley by b greater than so, we then have to take care that 1 as a slender column. For that what you have to do yes lx and ly is the effective length x axis is about the x axis and effective length about y axis.

So, why you are having 2? Because, we do not know the effective length of the column is dependent on the support condition that is why your effective length could be different about 2 different axis about x and about y it could be different. What is the support condition? The support condition could be we are talking say at the bottom at that top support condition, it could fixed here we can get this 1 in IS 456 and xe.

So, we shall just take care this 1 so, annex E: Table 28 that we have and we have how many different cases it says, it says 1 2 3 4 5 6 7 there are 7 cases. So, let us first since we are talking this 1 let us, summarize the whole thing.

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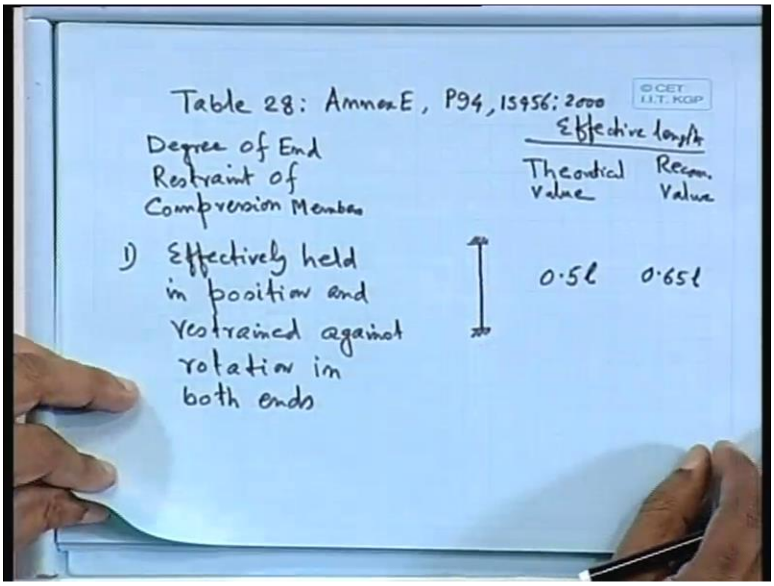

So, Table 28 it says degree of end restraint of compression members and we can have case 1: effectively held in position and restrained against rotation in both ends. Effectively held in position and restrained against rotation in both ends what does it mean? It means, it is fixed at top as well as at the bottom effectively held in position. So, there is no lateral movement and restrained against rotation.

So, there is no rotation if that be the case our quote, we can find out the theoretical value and recommended quote what our quote says. These are all for effective length where shall you get it Table 28 and Annex E, page number 94 IS 456: 2000 this is specific reference where from I talking. So, effective lengths then we are having theoretical value. What is the theoretical value? That, we can get it as 0.5 I hope that you have done that column buckling in your third semester in solid mechanics those of you have done. At least say civil engineering students you have done it.

So, 0.5l you can consult Srinath also those who have not done it so, you can consult Srinath also what I meant to say it here because, it is not in the scope it will be difficult for me to continue in to go to that level. So, 0.5l is the effective length the theoretical value, but our quote says that you take 0.65l, we have this is your say fixed 1, fixed case.

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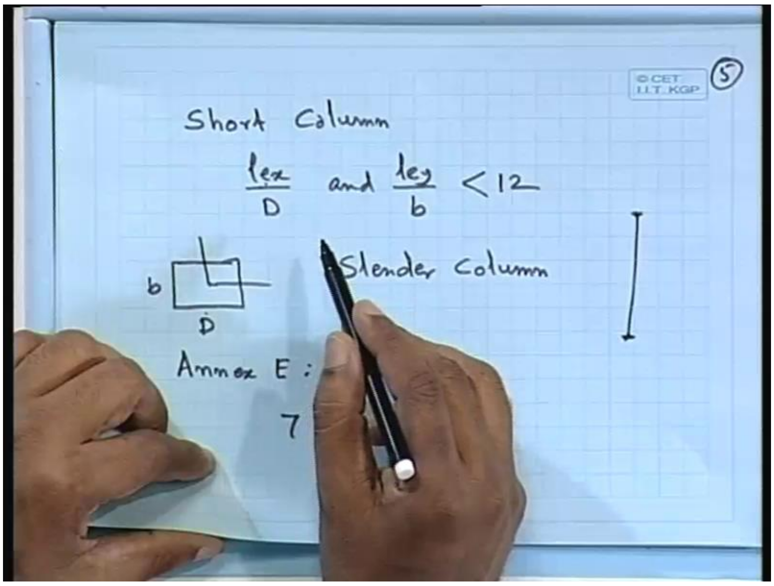

So, it means here if I go back to the previous 1 it means, the effective length should be if it is fixed then we have to find out suitably that lex and ley from the length whatever given. We can find out lex and ley then, we can divide by the D; that means, in the other way it will govern us to find out the D also. Because, if I know the le effective length then, we can find out what should be the dimension?

The minimum dimension we have to provide 200 now, we can find out if you would like to design it as say short column. Then we know 12 so, on the basis of that we can find out what is the depth of the depth and width of the say your column. But if you have a design for say long column sometimes, we do it in few cases you can find out say possibly in our institute those found that column 6 columns.

So, those are your say if you get the dimension those, you will find out as I say your long column. So, similarly that you see the other cases say if you need that big head away possibly for your say for truck or any other loading or unloading. So, there are we have to make it say long column because there is no other way. So, that is why we do it it is not always possible to make it say short column, but mainly for buildings say others always provide say short columns.

Sometimes it happens; that your 1 column that is extended up to say your up to second floor level, not after the first floor level there is a gap so, there it becomes say your say long column. So, now you know that what is the effective length. So, let us compute this 1 then and what are the different other cases.

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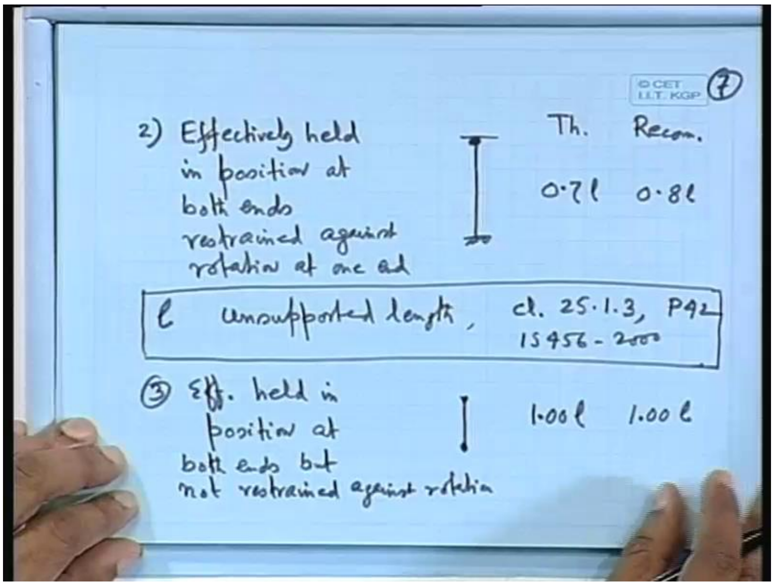

So, case number 2 effectively held in positions, at both ends restrained against rotation at 1 end. Effectively held in position, at both ends there is no lateral movement, but only in 1 end it is restrained against rotation that is 1 end fixed and another end hinged, that is the case what specifically it is telling. So, I can say this is you say fixed case and this is you say hinge 1.

So, if that be the case we should have theoretical value and recommended value. So, theoretical value 0.7 l and recommended value 0.8l what is this l? This l is the unsupported length. But even then, our quote says specifically at what does it mean that what do you mean by unsupported length that is also available. So, that also you can get it specifically and clause.

Let me, tell you here then because, all things should be clear that what we are talking. So, unsupported length let me write down here unsupported length l, l unsupported length and you will get it in clause 25.1.3, IS 456 please give the page number also page 42 IS 456-2000 You will get this 1 specifically, that 1 say unsupported length in this clause.

Let me, just give you 1 example there are so, many cases in beam and slab construction itself be that unsupported length shall be the clear distance between, the floor and the another side of the slender beam framing into the columns in each direction at the next higher floor level. So, that quote says actually undersigned slender beam that you have to take not that there is it may have, that 2 there are in 2 direction, there have been 2 beams not having the same depth.

So, you have to take the slender 1 that means, the depth less so, that 1 you have to take. So, there are so many other cases also that you can find out in the clause 25 1 3 you can get, but any that you can find out here. So, now if you come to the next 1 that number 3: it says that effectively let us, write down here effectively held in position at both ends, but not restrained against rotation.

So, this is the case of effective held in position at both ends, but not restrained against rotation it is the case of both sides hinged. So, it is it says you take it 1l that means, just simply you take it the unsupported length. So, this is the case 3 so, we have few more cases.

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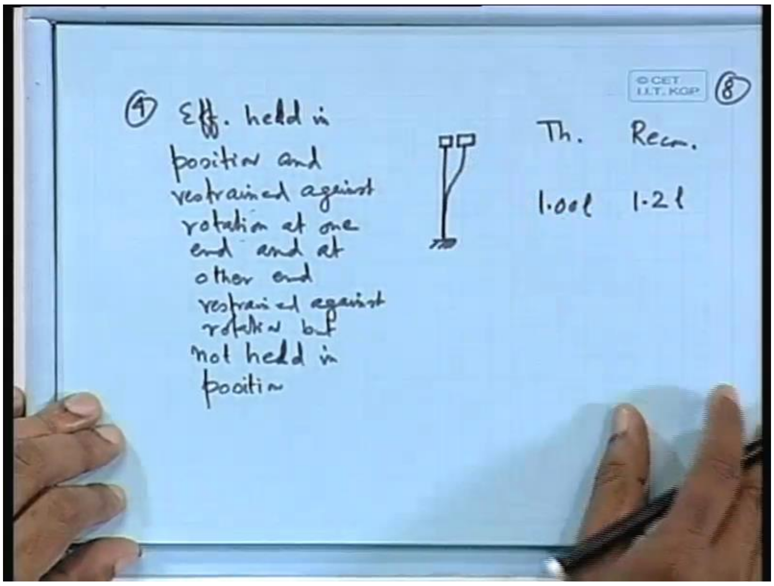

Number 4: Effectively held in position and restrained against, rotation at 1 end and at other end restrained against rotation, but not held in position. It means, as if you are having something like this what happens here, in this case it may moved say like this. It can go, but it is there is no rotation. There is a roller here you can consider here, that

particular 1 it can move like this, but it is there is no rotation here. So, in that case, the theoretical value it comes in 1l and recommended value the quote says, you take it 1.2l. So, you have to take it say recommended value 1.2l that you have to take.

So, this is your another case that you have to consider so, we have 3 more cases let us, finish that 1.

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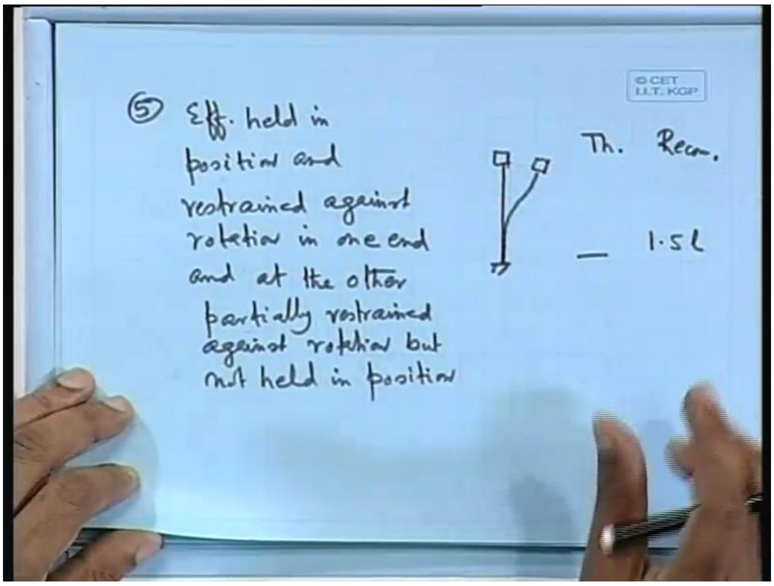

Because, you need for any case effectively held in position and restrained against rotation in 1 end; that means, 1 end again fixed. And at the other partially, restrained against rotation, but not held in position. So, effectively held in position and restrained against rotation in 1 end that means 1 end is again fixed. And at the other end other partially restrained against rotation, but not held in position.

So, it is not fully restrained against rotation so, if that will be the case it is similar type, but we can have some kind of rotation here. If we look this 1 that, it can move only so, there is no that rotation here. But here we are allowing little bit, the rotation if that be the case. Then, your theoretical value there is no such thing that because, you do not know how much the possibly 1, but your recommended 1 it says, that you take it 1.5l.

Basically, what you are doing your moving towards that cantilever column. We have started with the fixed 1, we have started with the fixed both ends then, you have made 1 end hinged, the other end also hinged. Now, you are coming to this 1 that other end you are keeping always fixed, the top 1 slowly you are releasing. So, it is already released from the your movement, but now you are releasing that you say rotation also. So, this is partially so, in that case you have to take 1.5l.

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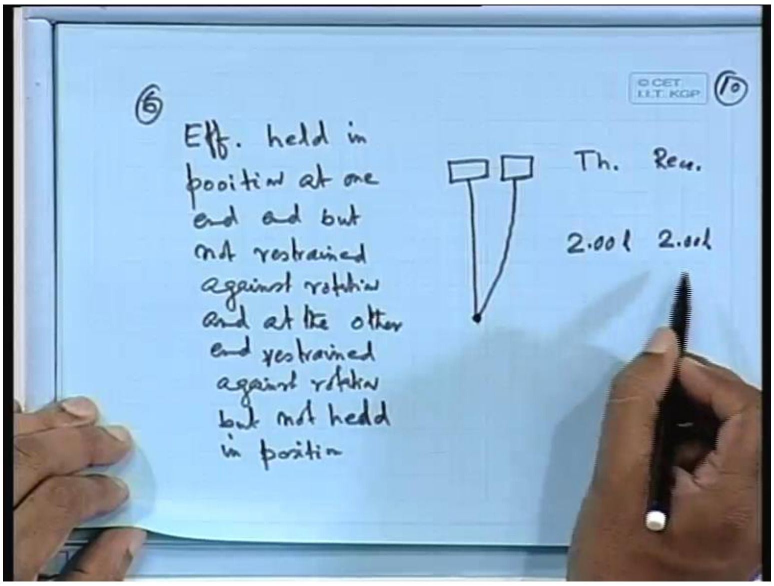

Then, sixth 1: that effectively held in position the same l at 1 end but not restrained that means, it is hinged not restrained against, rotation and at the other end restrained against rotation but not held in position. So, we are talking this way and we can say, it may be something like this it can move and this side is hinged. So, if that be the case the theoretical value, it is 2.2l and recommended value also 2.00l.

So, that is 2 00l is the maximum so, this is another case. Here, this side is hinged and other 1, you have considered this side is fixed here. I consider this side is hinged so, we can have that both theoretical and recommended at 2.00l. So, that you have to take that you say effective length as 2.00l.

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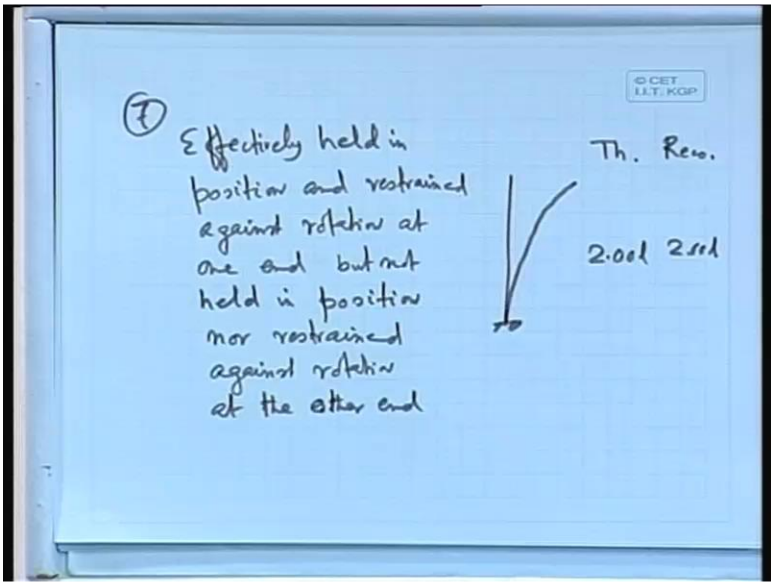

The last 1 it is nothing but the cantilever column, but we specify like this effectively held in position and restrained against rotation at 1 end, but not held in position nor restrained against rotation at the other end. This is the maximum we can have so, we are talking like this as if it goes like this. There is no such limit neither, in your say your movement or in rotation your theoretical value it gives 2 00l, recommended value it gives also 2 00l.

So, this is the maximum we can have 2 00l that means, twice the unsupported length that is the, maximum for the cantilever beam and minimum that is you say 0.5l. So, it is very important that what should be the effective length. So, this is the general case also we can have also we can also find out.

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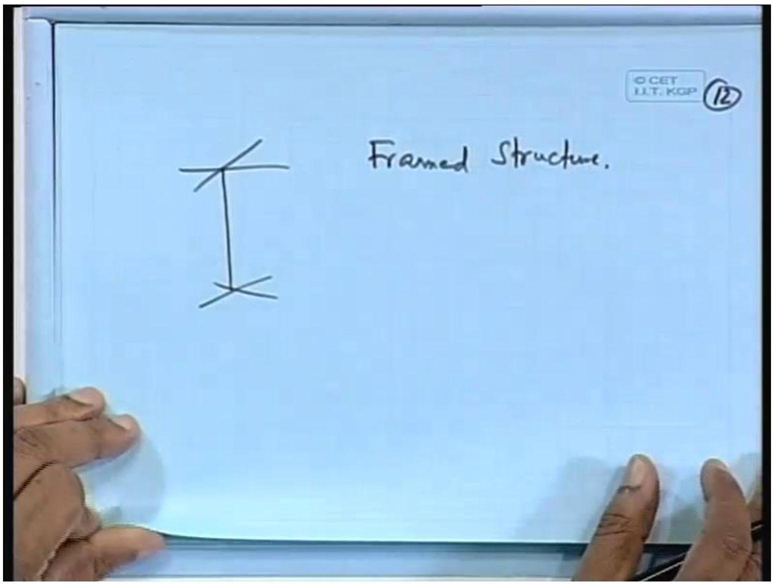

Because, say if it is a frame structure then how shall you find out your say effective length then, if it goes like this. So, in that case also we can find out the stiffness and we are having 2 more figures in that quote I think we shall come in due course. So, we shall solve that multistoried frame design that 1, that time I shall tell you that how to find out that, you say effective length for frame structure that we shall find out.

Because, you have to find out the stiffness and on the basis of that at the top and at the bottom from there, you can find out the fixity level and then, we can find out that effective length. So, that we shall do it separately here that, we shall find out first the frame structures that we shall do it separately we shall not going in detail. Anyway, so know that effective length that what does it mean that is very important.

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Now, let us come these are the few cases already I have seen in the very beginning. (Refer Slide Time: 44:19)

So, now we shall come to that 1 that what is the method. The method is that here, the same 1 we had talking say limit state method. And this is limit state of collapse not, the serviceability we are talking limit state of collapse from the strength point of view. We are talking that, how much maximum load it can take and this 1 we are talking compression so far we have done your say shear and we have done for flexure now, we are talking say your compression.

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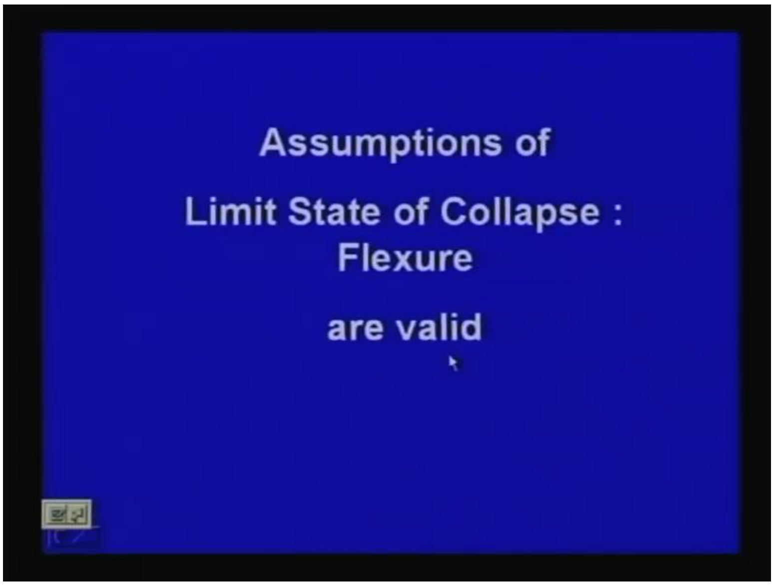

So, what is compression that for 1 what are the assumptions because, it is based on some assumptions, pure assumptions. The assumptions of limit state of collapse flexure are valid here also valid, those clauses are valid.

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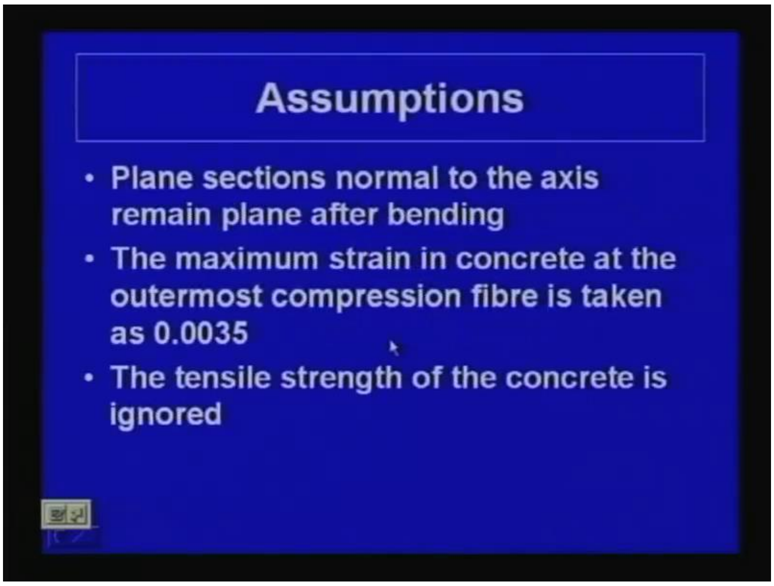

What are those? That plane sections normal to the axis remain plane after bending. The maximum strain in concrete at the outermost compression fibre is taken as 0.0035 so, that is the limiting strain for concrete. The tensile strength of the concrete is ignored just let us recapture it once more.

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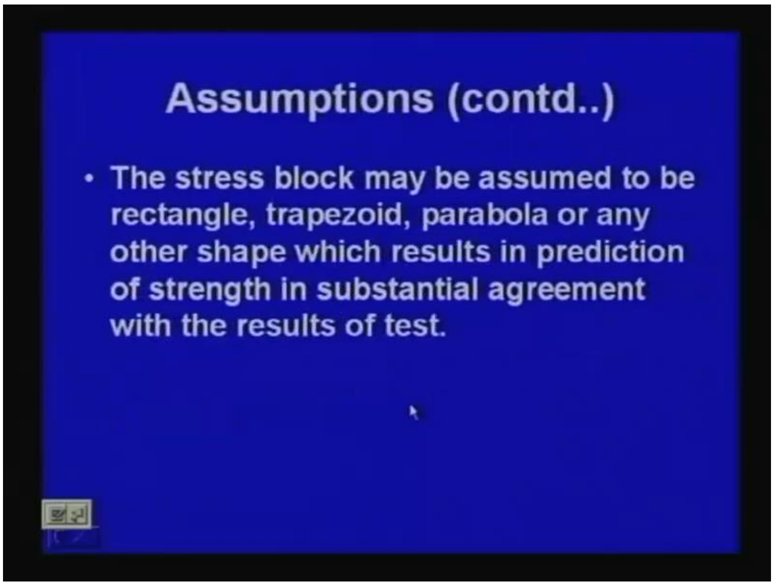

The stress block may be assumed to be rectangle, trapezoid, parabola or any other shape which results in prediction of strength in substantial agreement with the results of test. This is the 1 that already, we have taken care of that which type of say your stress block we have to use.

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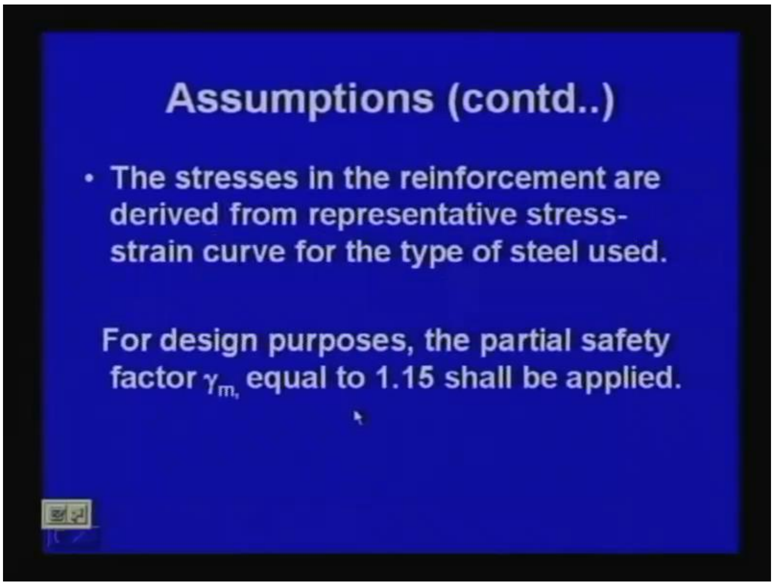

The stresses in the reinforcement are derived from representative stress-strain curve for the type of steel used. For different steel we have to use different your stress-strain curve.

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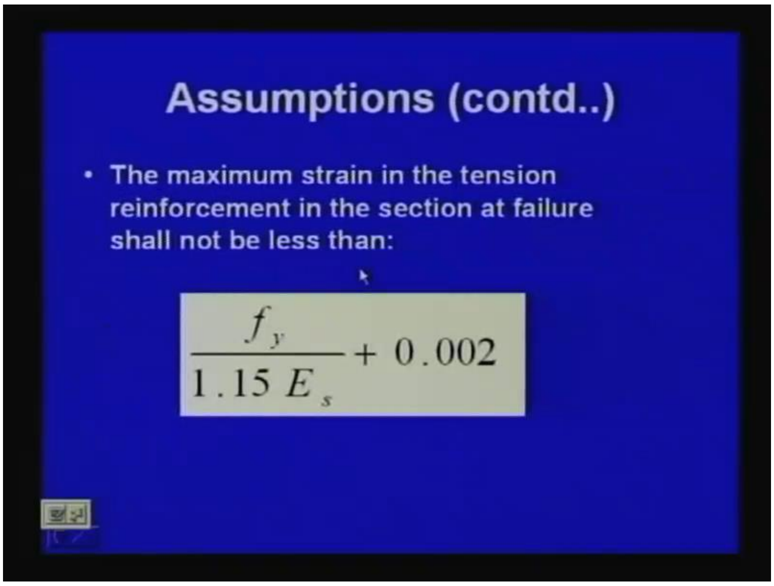

The maximum strain is dependent on the steel used. So, from there we can find out the maximum strength that for say Fe 415 or Fe 250 or Fe 500 we shall get different limiting strength for steel.

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Now, specifically for limit state of collapse: compression in addition to those the maximum compression strain in concrete in axial compression is taken as 0.002. That means, we are talking that 0.0035 8 that 1 that limiting strength that is for from the bending point of view. For beam or slab we are taking 0.003, but here for direct compression we shall take 0.002.

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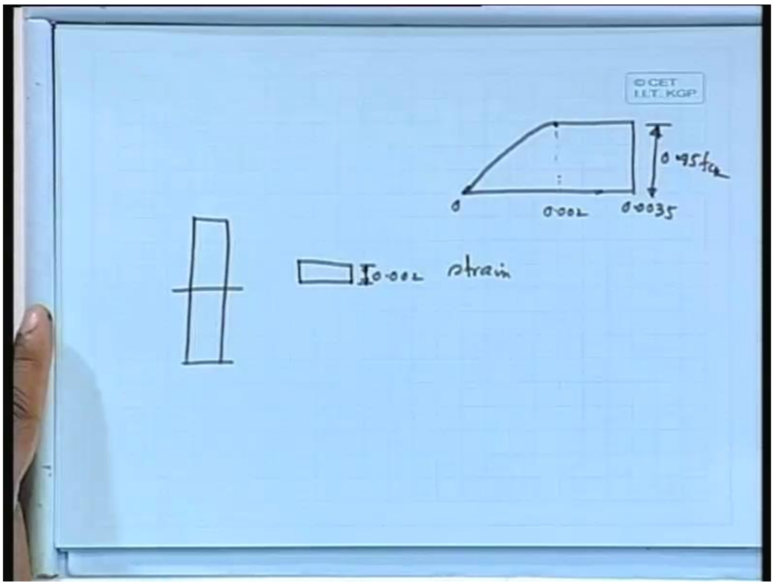

So, we shall take 0.002 that means, if there is a column here if you take a cross section then, we can have the strength 0.002 that is strain. The stress what will be the corresponding stress the corresponding stress here. Because, your stress block it goes like this that means, 0 somewhere here 0.002 0.0035. And what about the designs stress, this 1 0.45 fck is the design stress that we have to accept it after that partial set effect. And lot of other thing that twice we are doing then, you are getting 0.45 fck which is nothing, but four-ninth of fck.

So, if you take since you are allowing say 0.002 that is the limiting strength for direct compression. There means, already you have least up to 0.45 fck. We have already re-stepped to 0.45 fck that means, here you are taking the maximum stress all over here. So, this is your quote says that, the maximum compression strain that 1 you can use it here.

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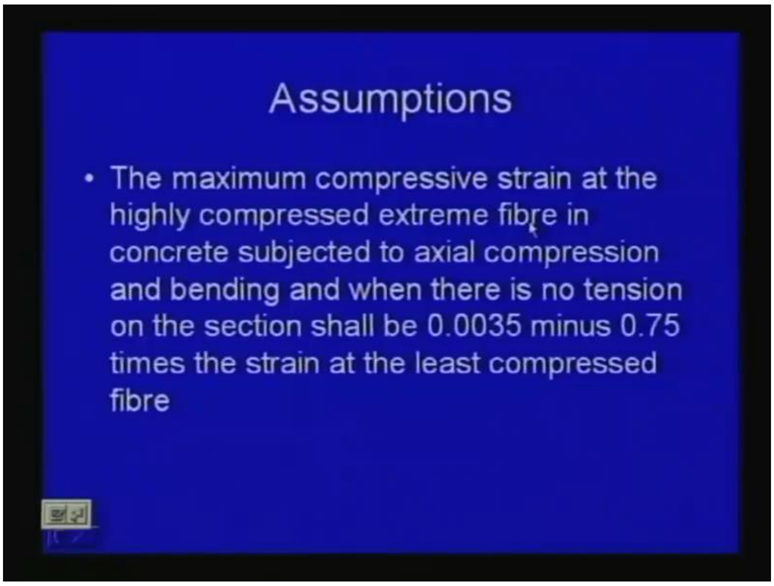

Now, the maximum compressive strain at the highly compressed extreme fibre if it let us, read it. Because, this is very important the maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending subjected to place, not axial compression and bending. The past 1 I have told that is direct compression only fcl load while you are limiting strength 0.002 and the stress will be 0.45 fck.

But here, subjected to axial compression and bending and when there is no tension on the section. That is no tension is developed on the section, in that case shall be 0.0035 0.0035 minus 0.75 times the strain at the least compressed fibre. There is 1 maximum compressed fibre in 1 end, the other end that is least compressed fibre. So, what does it mean let me explain.

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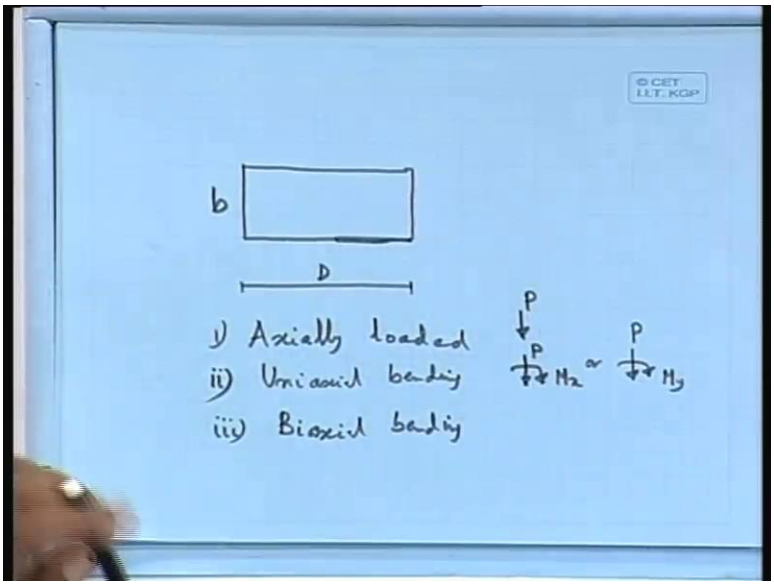

So, we say if this is your say section let us say D what we can do I think I shall let me, I shall tell you in the next class because, it will take some time. Anyway, I shall tell you this particular 1 because, it is very important and it is very important for say calculation of say your when, you are talking say not only you are having axially loaded 1, we have basically we have 1. Case I shall come in detail, this particular clause is very important.

So that, you can generate your own many things while you are talking say computer aided say design. So, this is very important 1 we can do it for different purpose also. So, 1 is that axially loaded number 2: we can have that is called Uniaxial bending there means, we are having axial load we are just simply axial load and say moment in x this is a P and this is you say P and Mx.

The other 1 it can be P Mx or P My, but when you talk this 1 that means, always I can take that 1 as x. So, that is why when you are talking that 1 about x so, it does not mean that always about x about y because, if I take the other y. So, that side is still be taking it as x also and another 1 it is possible say Biaxial. So, axially loaded, Uniaxial bending and we have Biaxial bending.

So, these are the 3 possible cases and you have to design for all of them. So, that is why it is very important because, this 1 the strain this particular clause that assumption will give us that, what is the limiting stress and on the basis of that we have to find out. Let us stop here and we shall continue in detail in next class.