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

Lecture - 04
Working Stress Method

So, this lecture we shall start the Working Stress Method; we shall start this lecture with the Working Stress Method. Before going to the difference in your actual method, let me give you that one the different steps of construction - just one schematic one. I do not know whether you can see; can you see this one? Just a floor.

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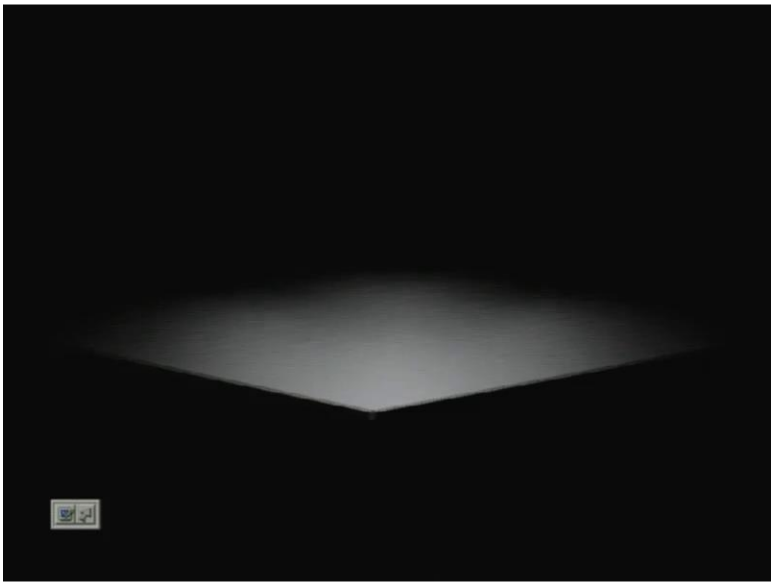

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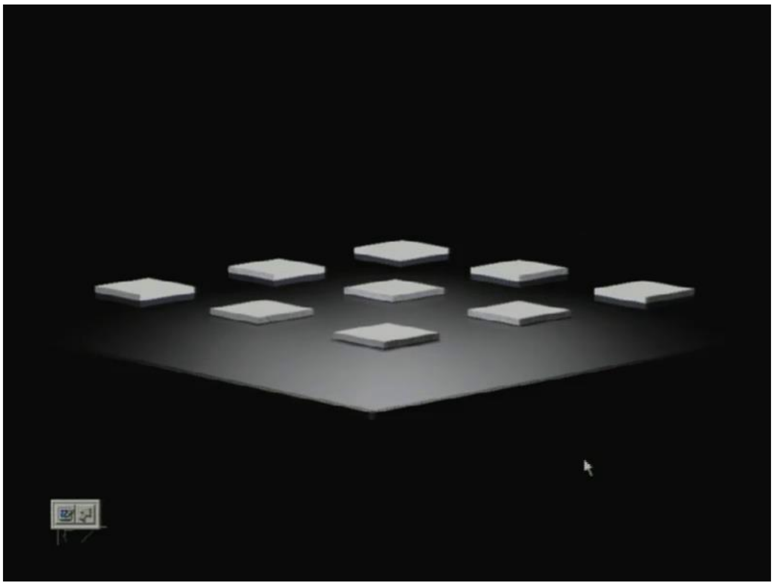

So there are… these are all three different say footing, because I have told you the construction showed three different footing, the other three, and the other three; so there are say nine column footings.

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And we are having, say columns, the second level, and third level, so that we can have. And this is your that tie, these are all tie beams. So, we generally do not provide the… for wall, we do not provide the wall footing; we start from this tie beam, which will take the wall load.

Also, we can take it for the frame also that connection; that also we consider, but we generally use it for say walls. And we have that beams, though we construct these beams and slab all together, whenever we cast the beams and slabs, that all together, but just to show you, that otherwise I cannot show you, because if I keep that one, then we cannot see the beam; that is why I have made this.

So this is the one, actually the construction how we do it. We have started from the bottom, but when we shall design, we do it other way, we start from the top. So slab, then beam, then column, then tie, and then footing. So this the one during the your design will be there. Even if you have staircase, the staircase has to be designed first, to be designed first. So this is the just only one just schematic one.

So I should acknowledge here, because that particular program, that is the your POV-Ray - the program name is POV-Ray - so I have use that POV-Ray that one for this one. I thought ok , I shall use it. This is a very free software, and I have found so far, say so many software - redundant softwares - available, but I have found this one is the so far the best one; of course, what ever my best thing always changes; that is another part. Anyaway, so this one, just to show you one example,, you can also try; you can download, and you can also try, that differrent thing you can try.

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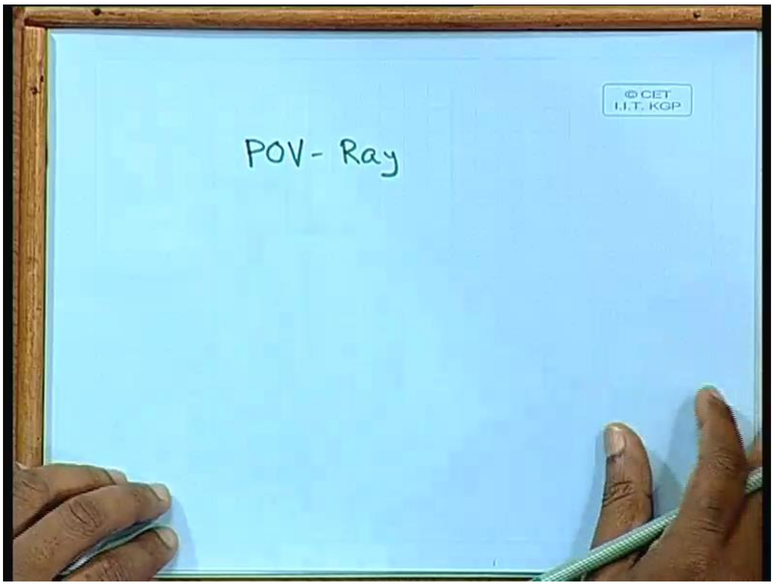

Yes, so just to name it, I think I should write down POV-Ray.

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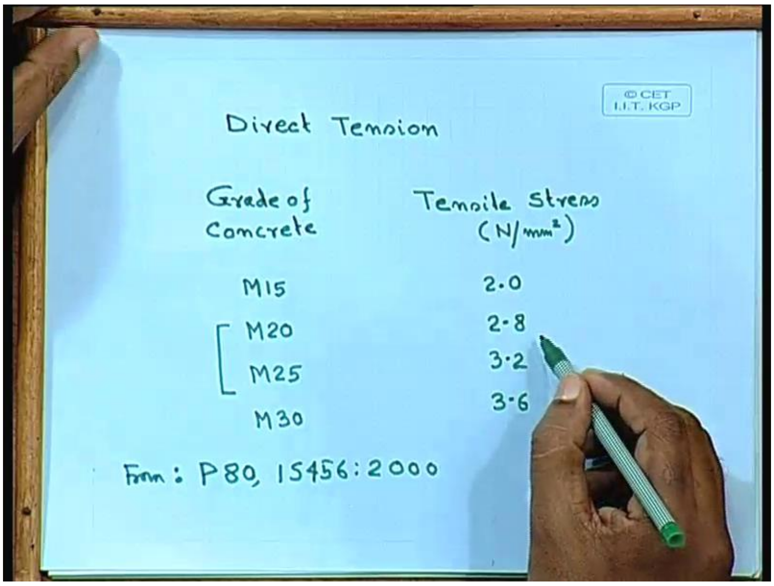

So, working stress method, we are talking, and it should have the limits. Direct tension, I could write down in power point, but then I find that it will be difficult; so that is why let us write down in paper, so that you also can copy. So grade of concrete, because these are the limits we should know. And tensile stress, we have M 15, though we do not use it, but M 15, and the permisable space is 2.0 Newton per square millimeter.

M 20, 2.8; M 25, 3.2; M 30, 3.6. There are so many others, but we shall consider M 15, M 20, M 25, M 30. Generally, we consider RCC is that M 20 and M 25; so our tensile stress is 2, 2.8, 3.2, 3.6, and this from page 80 IS 456:2000. Let me write down.

So, this your the limiting values for concrete when it is under direct tension. When it is under direct tension, so these are the limiting values, and we shall mainly consider these two. So you could remember it also, 2.8 and 3.2; otherwise, of course, it will be specified in the that examination, that your question paper.

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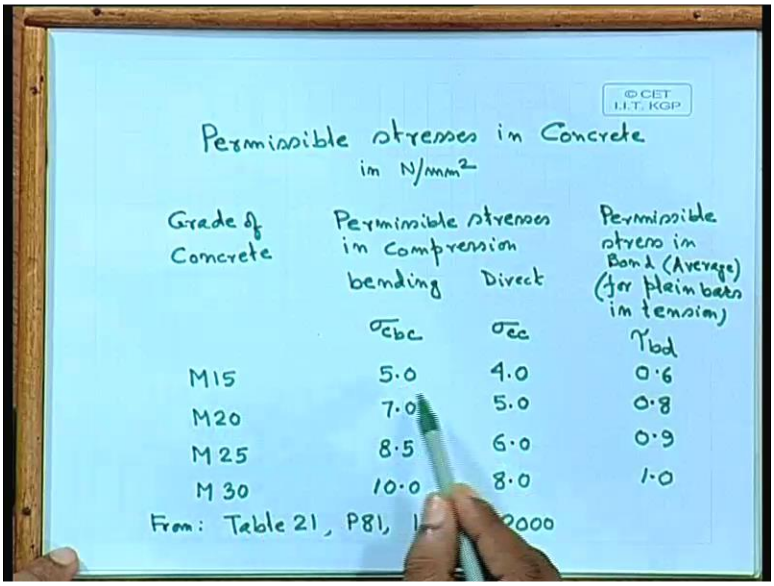

So I can go the next one, I shall tell you, because we should know the permisbile stresses; otherwise, we cannot design. Permissible stresses in concrete, and this one will be in Newton per square millimeter. And we shall specify again that four gates of concrete only, and permisible stresses - permisible stresses in compression. Permisible stress in compression has two parts: one is bending; another one, direct; one is called bending and the other one is called direct. The beam when it is bent, that is called bending compression, the compressive stress whatever developed, that is called bending compression. A column whenever you press the coulmn, say like this, you are pressing the column like this, then that is called direct compression. So you have the bending compression and you have direct compression - two different that compression.

And permissible stress in bond, and this one average; also you can write down to be more specific for plain bars and those will be in tension. So permissible stress in bond average value, for plain bars in tension.

So you shall write down the tension, and we have, see we have we give it say sigma cbc, that is your concrete bending compression; sigma cc, concrete direct compression; and tau bd; for M 15 it is 5.0, direct compression, it is less 0.6; M 20 - 7.0, 5.0, 0.8; M 25 - 8.5, 6.0, 0.9; M 30 - 10.0, 8.0, 1.0. This is we have taken it from table 21, page 81, IS 456:2000.

You can see, I have told that factor of safety about approximately 3; so you can see 15 by 3, 20 by 3, which is coming approximately, which is coming the factor of 53; that means the cube strength here, 15, 20, 25, 30. And you can get the correponding bending compression in concrete almost one-third. So that means we are considering the factor of safety 3, that which I have told in the very beginning, that we are considering it here.

Now, what about steel then? We have to consider for steel also. Let us give the premissible stresses in steel.

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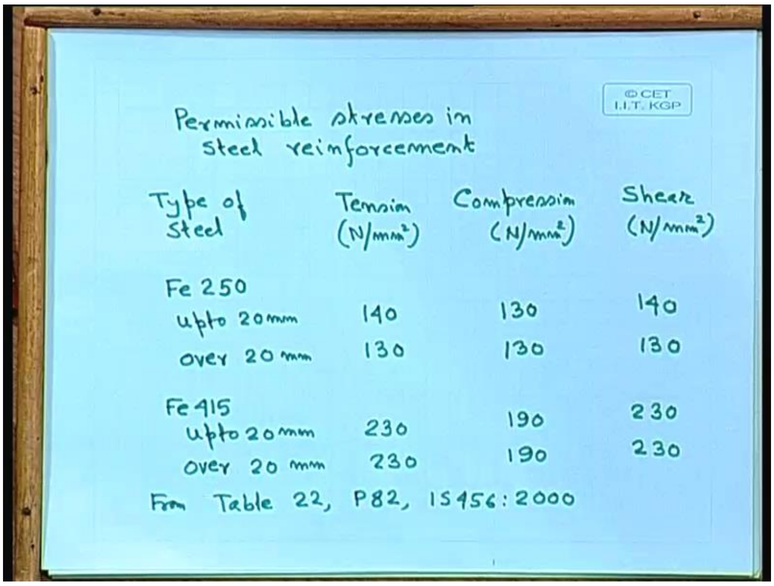

So permissible stresses in steel reinforcement; type of steel; tension; compression; and we should have shear, because these are the different cases where you have to consider the permissible limits, or in other way that your freedom, that how far you can go. Fe 250, that is mild steel; Fe 250 is the mild steel; for that we have up to 20 millimeter dia, we have 140 in tension, 130 in compression, and 140 in shear. Over 20 millimeter diameter, 130, 130 in compression, and again, 130 in shear; that is 130 for all of them, 130. Only in tension and shear it differs if the bar diameter is less than equal to 20 millimeter.

Fe 415, high yield strength deformed bar; high yield strength deformed bar - HYSD - high yield strength deformed bar - HYSD. Up to 220 millimeter it is 230, 190, 230 ; over 20 millimeter 230,190, 230; then, this one we have taken from table 22, page 82, IS 456:2000.

You can get it, in this code you can get this values; you can get these values in this code, but you should keep it in your exercise book also, because we require that one for our calculation. So these are the limiting values for concrete and for steel.

So how shall we calculate the tensile stress? How shall we calculate the tensile stress, that again, we can find out.

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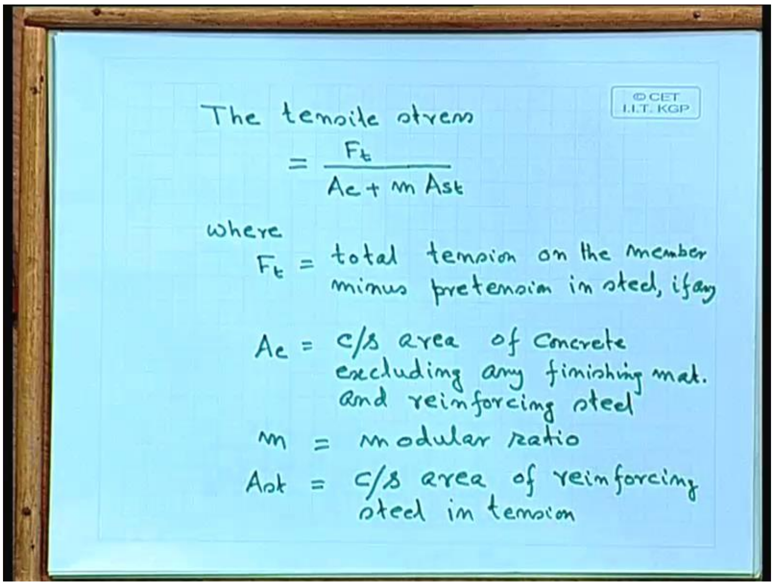

The tensile stress equal to Ft divided by Ac plus m Ast, where Ft equal to total tension on the member minus pretension - this one we are talking, that pretension, that I am coming to explain, if any. Pretension means actually that if you have any pretension, and then you are applying the load, then you are getting the tensile stress will be increased. So, that means, that you will have the initial value of tension - that way we can say. So that, obliviously, we have to deduct it. And Ac cross-sectional area of concrete excluding any finishing material, excluding any finishing material and reinforcing steel. Only we are considering concrete.

m that modular ratio; m equal to that modular ratio. And, Ast cross-sectional area of reinforcing steel, to be more specific in tension. So, the tension stress, you can find out that ft, you have to get it, and you can find out ft the total tension on the member minus pretension in steel if any. If the initial stress is there, tensile stress, that you have to deduct it. Area of Ac means that concrete area, and obviously, you should forget the finishing; finishing means, that you should not take the plastering, the concrete cover whenever you consider the concrete cover, say even if you keep that, say your reinforcement bar, if you can see the reinforcement bar from the bottom after cast the beam or slab, if you provide the… if you provide the plastering, it does not mean you are giving cover; that cover is that is your say finishing material, not the one, it is not the part of concrete. So, that is why we are very specific, that we are not considering any finishing material, whatever you are using.

m is the modular ratio, s by ec, that you can say, that our code does not take in that ratio, it takes in a different formula; that we are coming next. And Ast, the question area of reinforcing steel in tension. So…

[Conversation between student and Professor – Not Audible]

Yes, yes, all the bars; we are considering that always you consider that way, even if you provide the reinforcement, that bars, so Ast actually means, that how many bars you are providing, the total area that your considering, and we assume that one, we can say, we assume that, as you say in the total one, I can say I am coming next, actually, let me continue, and then, I am coming next to your point.

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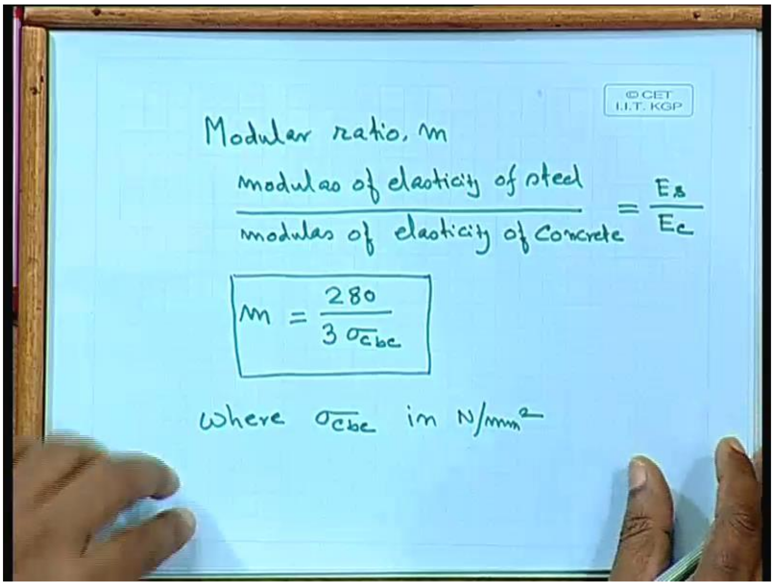

So what is modular ratio? That already that we know, but still let me make it clear. So modular ration - m - that is called modulus of elasticity of steel divided by modulus of elasticity of concrete, and that one, let us write down Es by Ec. We also write down that our code says, m equal to 280 divided by 3 sigma cbc. So, we do not take it from Es by Ec; instead of that we use this formula. We should remember this, where sigma cbc, that concrete stays in bending compression, in Newton per square millimeter. So we are going to this Es by Ec, instead of that, we shall take this formula that, and on the basis of that we shall calculate m. How much we shall get? So that one which we will take, say 280 by 3 sigma cbc; that we shall consider.

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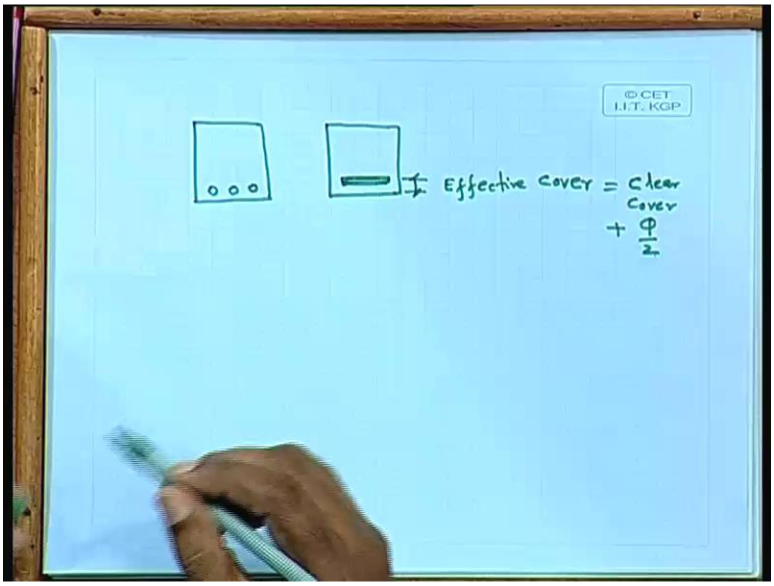

Now, we shall come to your point; though we provide reinforcement, say like this, as many bars, how many bars, we provide say number of bars, but when you are considering say Ast, whenever you are considering that Ast what we do we, can simply say like this, there is nothing wrong; simply, we can say like this; that is the total number of bars; this one.

Assume that we can consider one plate also, because when we are considering that, so but that is at a particular point, and we generally consider that I have already told that effective cover. So effective cover, the thing is that, if you design the beam… when you are going to design the beam, you do not know which bar you are going to provide, but your are calculating the area of steel; but at the time of calculating the area of steel, or say effective depth, you need effective cover; and effective cover is nothing but the clear cover plus phi by 2 the diameter of the bar.

So, here what we do, we assume certain diameter. So based on our experience, say this is the moment, so we know that these bar will come, whether say 12 millimeter, or say 16 millimeter, or 20 millimeter, which type of bar diameter will come, that we can assume that, because if you do not many, even if you do five or six examples, and then, with the difference in movements, immediately you can understand that what type of bars will come, because we do not have finally, you will consider, at the end of the day, you will find out, you do not have, really do not have any choice; much choice.

That means say 250 millimeter is the width of the beam, and you take certain depth; whether that you will provide say 320 millimeter dia, 420 millimeter dia or 225, so like that if you find few combination, you will find out that you do not have many choices, because whatever area of steel you can compute, because finally, you have to provide certain regular number; you cannot provide something say 312.5 millimeter depth of the beam. You have to provide either say 300, 325 - in that fashion only you have to provide as you say, 1 one inch in that way you can say. So, when you have to provide that one, so that means, you do not have much freedom. So one can also do it, that he can keep his, all the beams - all the possible beams - ready, the movement of resistance, also the cr capacity, you can keep ready, and immediately when you will get those once a moment, oaky let us provide this one, let us provide that one.

So from the table itself we can find out, and we have actually one code also, that your is design a that sp 16; that I have already told actually in the first class. So from there also you can find out, from the movement of resistance, calculate and provide the corresponding reinforcement. That area of steel, that also immediately you can compute. That way also your design also will be easier.

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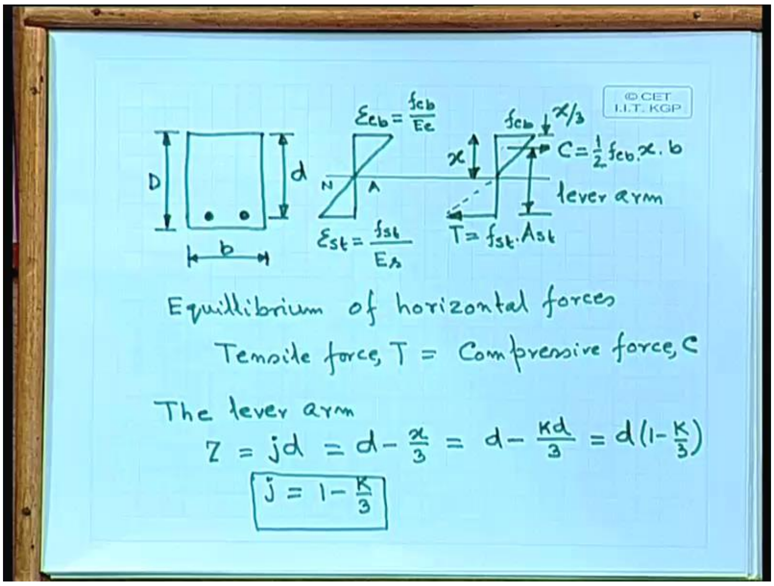

What we shall do now, let us take one example. That we would like to find out a formula. And we are working on the Working Stress Method; Working Stress Method. Let us provide just two bars, that depth - the overall depth; we consider it as overall depth; so overall depth capital D; width b; effective depth, small d; and strain is linear, so epsilon cb. The strain in concrete, in bending, the stress divided by modulus of elasticity. And epsilon st, strain in steel, say fst divided by Es, this is our neutral axis. It should have the corresponding stress, because, since concrete does not take any tension, that is why I am not drawing the stress diagram here, because all the tensions, that forces will be taken care of by the steel only; so this you say t, so fst times Ast. The stress developed in steel, that is fst times the Ast, that we shall get it. And fcb, let us say this one, that depth, neutral axis, so this is x, x is the neutral axis from the top, neutral axis from the top, and this force will be at the center head of this section; so c equal to area of this triangle half fcb times x, and we have definite, say width also, so b. Is it clear to you?

So we are considering the concrete, that compressive stress will be equal to the area of this triangle, and that one, actually we can say, this one, this is OH, triangular OH type; that means, this one having the along the depth also you will get it, so half fcb times x or triangular prism to be more specific. If we consider that one, that your… this is nothing but one right angled, that one prism, and that one we have to consider the volume, and that one will give you the compressive force. So half fcb times x times the width of the beam, that is the total compressive force here.

And the tensile force, this one, here. And this length that is the lever arm. So equilibrium we have two equations: one we can consider here that equilibrium of forces; after all it is a static case, so equilibrium of forces, so tensile force equal to compressive force that one should be there. So equilibrium of horizontal forces; so tensile force T equal to compressive force C.

The lever arm, we can consider this one as say z equal to, we can write down one say fraction of say d, d is the effective depth; so j it is nothing but, so obviously it will be a certain fraction of effective depth, because this the lever arm we are talking, so it will be certain fraction of the effective depth. So z equal to jd equal to d minus x by 3; this one x by 3 - this portion; so d minus x by 3 is your lever arm. So this one will be equal to d effective depth minus x by 3; that one will be your, your lever arm, which again we can write down, x again we can write down as another parameter, say kd; I am assuming x as another fraction of the effective depth. We are considering everything in terms of effective depth; so another fraction say k.

So first one we have considered that j, and the coefficient we are considering that particular one, say k. So jd is the one the lever arm we can consider, and kd, we can consider that one, that how much is, what is the your depth of the neutral axis that we can find out as if it is kd. We do not know k; neither k nor we know j, but we can write down in this way, which we can write down as d times 1 minus k by 3. So we can write down jd; that means j equal to nothing but 1 minus k by 3. So this is one important equation here j equal to 1 minus k by 3.

So effective depth we can calculate, and we can take a fraction, that we have to find out; if we can find out either k or if we can find out j, then obviously, we can find out the other one also. So this is the one that we do it.

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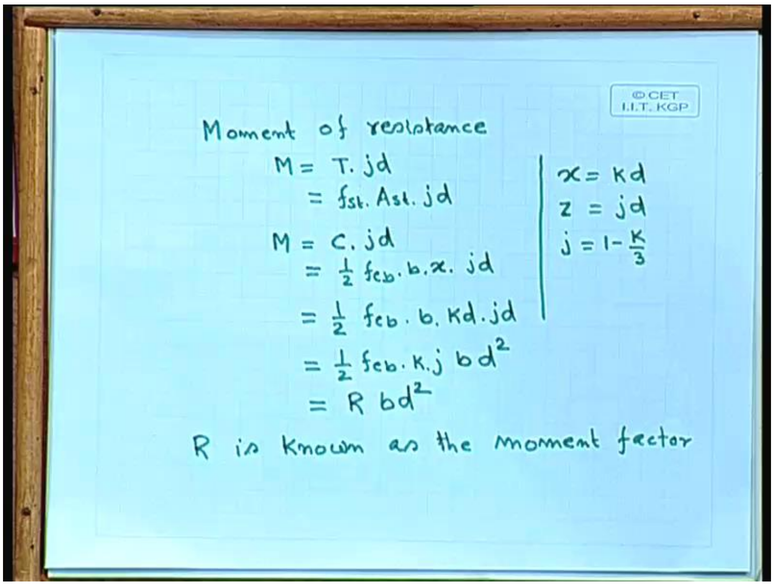

So, now, we come to the next one, that moment of resistance. What we can do, let us make it this way. We can do it; let us keep it like this, so that it will be easier. So, we are keeping this one, and then, let us make it in this particular fashion. I think we can show that, we can get the equation again.

So moment of resistance, that is the one we have to find out - m. m will be equal to t times jd; I can write down T times jd which is nothing but Fst times Sst times jT. So moment of resistance, if we consider from the steel point of view, so T times jd; T times jd will give me the amount of resistance; also we can consider from the other part also, that C times jd. So we can also write down m equal to C times jd which equals, which equals half fcb times b times x times jd.

So, we can write down, now we can take out this one, because this is simply little bit of arithmetic only. So, we can now write down; so m equal to C times jd which equals half fcb b x is nothing but I have already told kd; let me write down here x equal to kd, z equal to jd, and j equal to 1 minus k by 3 - already we have done it - times jd. So you can write down half fcb k j b d square; so you can write down half fcb k j b d square. We can write down this one as R bd square; R is known as the moment factor.

So, if you remember, that in the very beginning of the third lecture, we started with something said m by I equal f by y; from there also, we have got certain equation that point 0.167 f bb square, that we have got it. So similar fashion also, here also you will find out we are getting the same type of relationship; that means 0.167 f that whatever you got, and here we are getting say R; so R bd square; so this R is dependent on fcb and also it will be dependent on k, it is dependent on j. So we can find out that moment of resistance of a section we can find out, if we can find out k and j also, we can find out. And if we can get the moment of resistance and we can check the section whether it can take the load - the load applied - on that particular beam. So that way the moment of resistance is very, very important.

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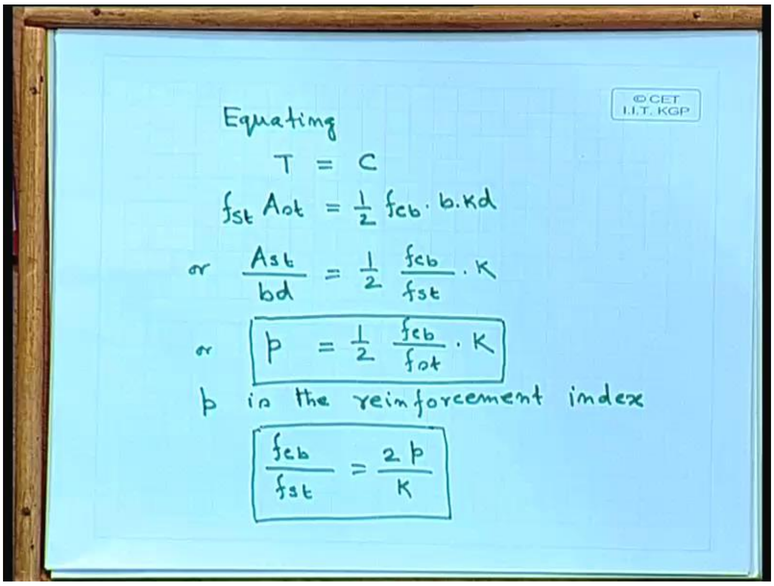

The other one we can consider, that we can equate the tensile force and compression force. So t equal to c. so you can write down fst stress in steel times area of steel, that one equal to half fcb b kd. So this your corresponding that your force, and here, we are getting this one, the corresponding force in the steel or we can write down Ast by bd. We can take this b and d, so Ast by bd, which we will just rearrange that one, half fcb by fst multiplied by k. Or we can write down p Ast by bd is nothing but p equal to half fcb by fst times k. This p is called reinforcement index. So this is reinforcement index. We can get it from the percentage of steel also you can get; from there also you can get the percentage of steel also you can find out.

Also you can get it here, from this equation fcb by fst will be equal to 2 p by k. We can also get the same equation by other way also. We can get this equation, then also we can rearrange this one, the other way we can also specify this equation, because we need those things; so you can write down the...

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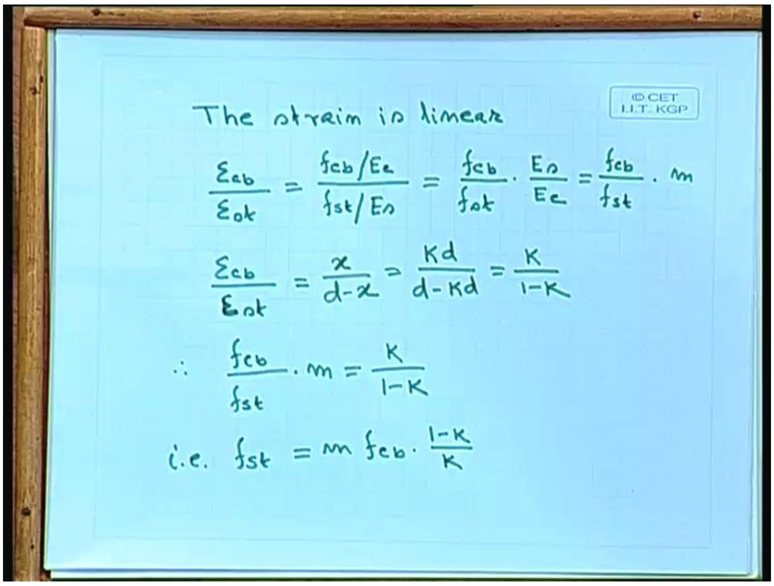

Here we have considered the strain is linear - plane section remains plane before and after vending - that assumption; epsilon cb by epsilon st equal to you can write down fcb by Ec divided by fst by Es; rearranging fcb by fst times Es by Ec equal to fcb by fst times m. Es by Ec is nothing but m, because that is the one modular ratio, and we can consider this working stress method is nothing but modular disc method also.

So Es by Ec, because that is the one - the governing one - in our whole design - that Es by Ec, that modular ratio m. Epsilon cb by epsilon st equal to… epsilon cb by epsilon st that is equal to… just if we go back. Yes, so if I show you here epsilon cb by epsilon st that is equal to this is your x, just if you come back, that is your x, x; and this part is d minus x - that is the total depth d, and this one x, and this is d minus x.

So when we are getting this one, so you can write down epsilon cb by epsilon st is nothing but x by ds; the similar triangle; equal to x is nothing bby Kd, d minus Kd equal to K by 1 minus K. Now epsilon cb by epsilon st is equal to this one fcb by fst times m. So you can write down fcb by fst times m equal to K by 1 minus K.

We can write down in other way fst equal to m fcb times 1 minus K by K; just rearranging the equation, we can write down fst equal to m fcb 1 minus K by K. that also we can write down. So we shall… almost we have finished.

So fcb by fst times m equal to K by 1 minus K; fcb by fst equal to 2 p by K that already we have done it; that already done it, fcb by fst equal to 2 p by K; therefore, 2 p by K multiplied by m equal to K 1 minus K or twice mp 1 minus K equal to K square. Or we can write down K square minus twice mp 1 minus K equal to zero. So you can write down K square minus twice mp 1 minus K equal to zero. We can find out m. So m equal to 280 by 3 sigma cbc, getting from the code, we have to choose one particular grade of concrete; may be M 20 grade of concrete. For that M 20 grade of concrete, we can find out the corresponding sigma cbc - compressive stress in bending; from there we can find out that modular ratio m. If we can get m, but we have to find out that K, but if we know m - modular ratio, and if we know that percentage of steel, that area of steel you have provided, so from there we can find out the corresponding your that K. So K if you can find out, then also find out j, and we can find out, then we can go for you say calculation of moment of resistance.

So we go in this way; so we shall go with some problem in the next class. And then, you will find out, and finally, we shall go to that limit state design. Because I think we should know the working stress method also, at least; you should know all at least one example, because it is still not possible for us within this time frame to go to both, and if you see that your Varghese book, you will find out it is given the appendix - that appendix A possibly, in appendix A you will find out the working stress method.

So we shall conclude today; so we shall meet in the next class.

Thank you.