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NPTEL ONLINE CERTIFICATION COURSE

Course
on
Reinforced Concrete Road Bridges

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Lecture 08: Limit State Method of Design
as per IRC 112:2011

Hello everybody, so we have discussed so far that working states method as per IRC 21 and also which is applicable for IS456 2000 also. Next we have discussed on IS456 the limit state method because I thought that you are introduced first with that IS456 2000 those who are old may be if you are using that IS978, first time actually the limit state method was introduced in 1978 IS456 later on IS456 2000 that is actually modified certain crosses. Now we shall go for it the next one that is our lecture 8.

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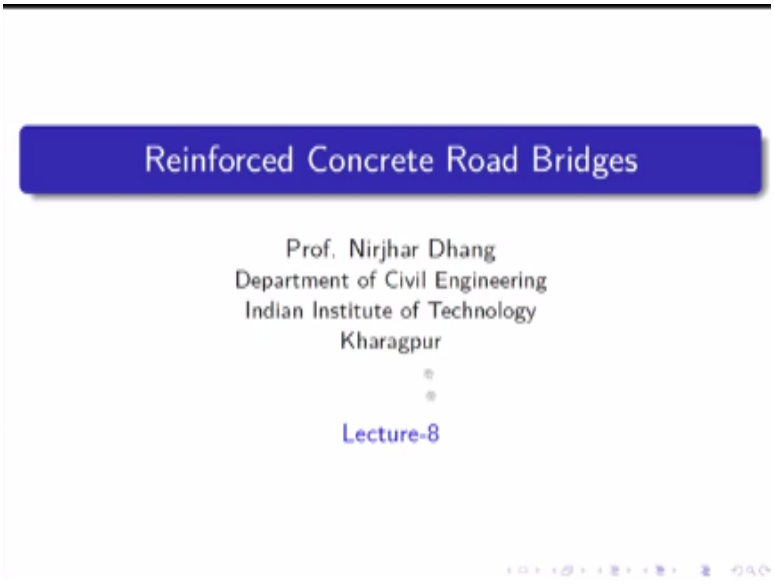

That reinforced concrete road bridges lecture 8 that we shall consider.

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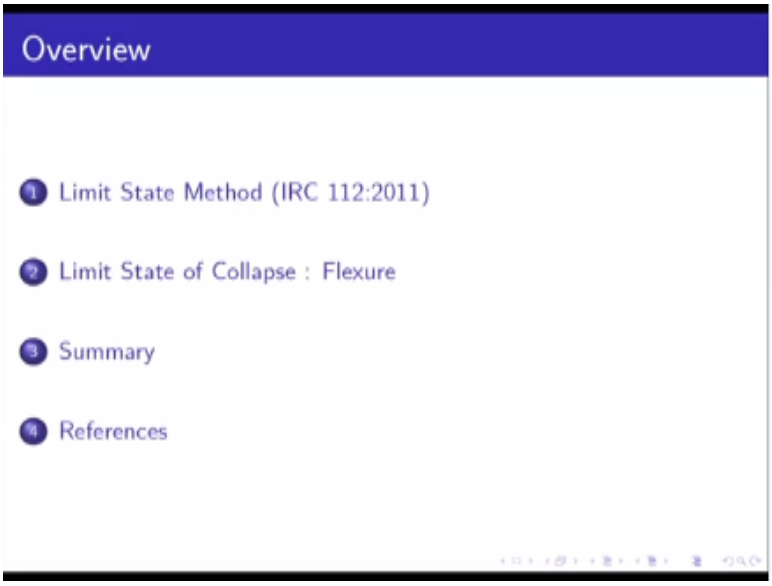

And now we shall go for limit state method that what is the general one IRC 112:2011 and then we shall consider the flexure and later on we shall go for your CR, whenever which solve the problem that time we shall go procedure, because I thought that certain orientation is required regarding that you are say concrete then it will be easier to know that how we are going to apply that.

And also very interesting that when you are having work state method as well as limit state method then it will be very interesting to know the difference or other you will find out there is no such difference only few parameters are being changed and then the whole thing is working fine that is my idea that is the one my understanding. So coming to this one here, limit state method IRC 112:2011 whatever that code says let us see. Limit state of collapse that finally we shall discuss then summary and references.

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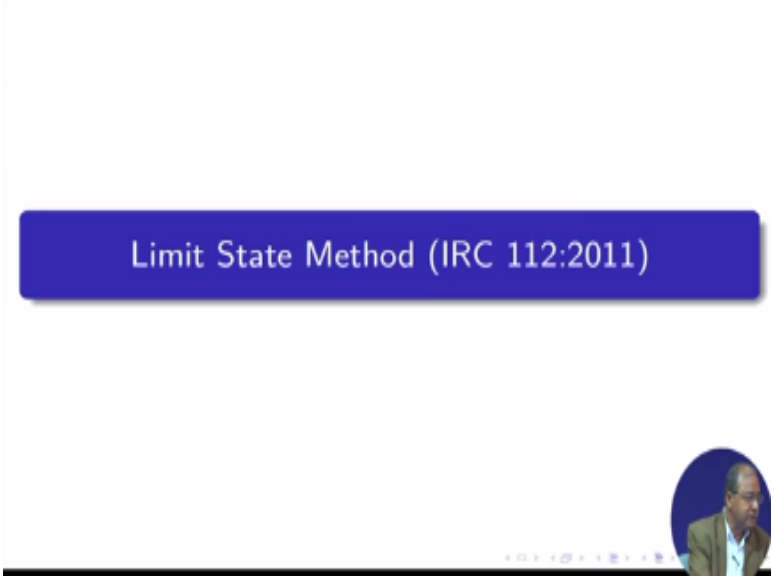

So limit state method IRC 112:2011.

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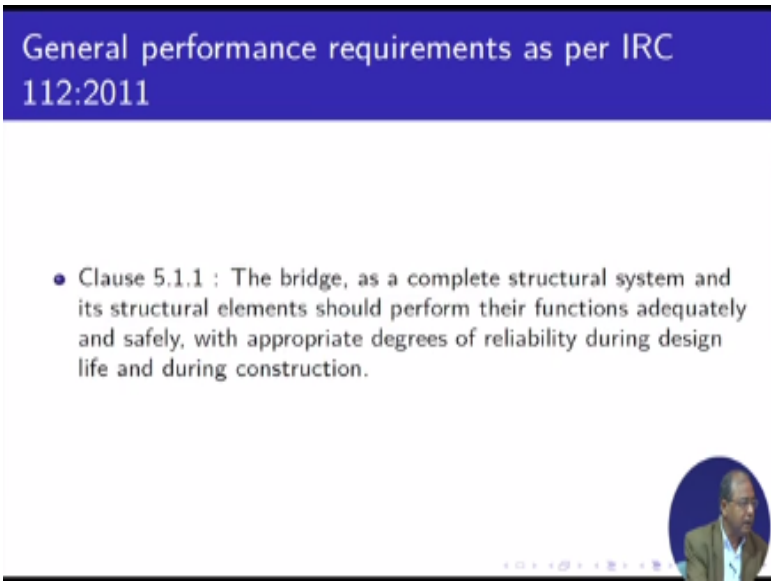

So this is one clause I have taken this particular one here, that I have taken there are 11 clauses are there only, so the bridge as a complete structural system and its structural element should perform their functions adequately and safely with appropriate degrees of reliability during design life and during construction. So this is the one which is defined in that clause 5.1.1 that it is given here so what it says again.

Let us repeat one more, as a complete structural system and its structural elements should perform their functions adequately and safely it appropriate degrees of reliability during design life and during construction so not only during design life or as well as during construction also that we should care that.

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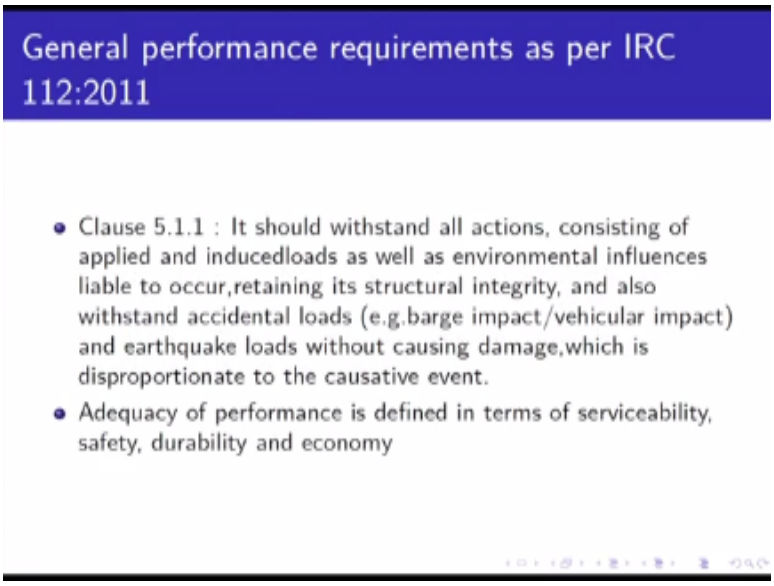

It should withstand all actions, consisting of applied and induced loads there should be a gap here induced loads as well as environmental influences liable to occur, retaining its structural integrity and also withstand accidental loads as for example, barge impact, vehicular impact it happens and earthquake loads without causing damage which is disproportionate to the causative event, so this is your another one that part of that.

Adequacy of performance is defined in terms of serviceability, safety, durability and economy so you have consider many aspect that whether the performance is adequate or no, whether it is defiance in some other aspect or not that you have to find out from all aspects serviceability, safety, durability and economy also.

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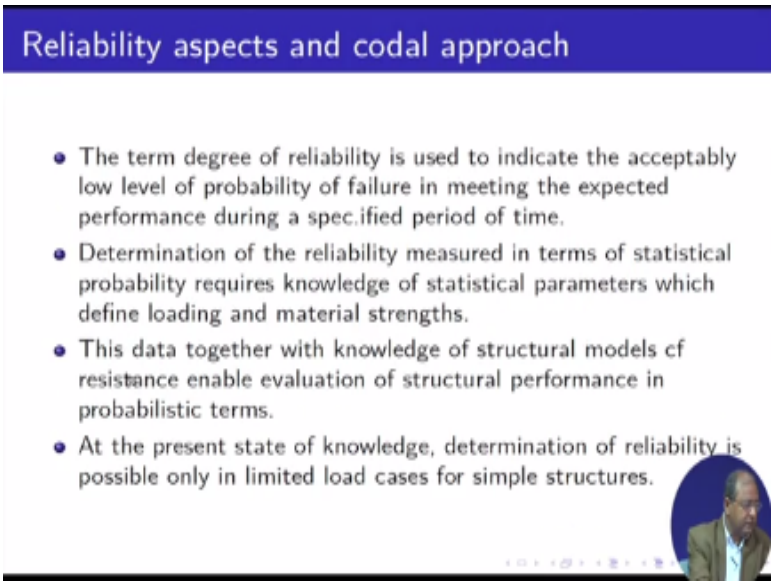

There are certain things I have told you actually the reliability other things that is coming into picture always so and then I thought it is worth to repeat that one whatever available in that particular code, that let us see this particular one whatever its states. The term degree of reliability is used to indicate the acceptably low level of probability of failure in meeting the expected performance during a specified period time this dot will not be there, during a specified period of time.

Determination of the reliability measured in terms of statistical probability requires knowledge of statistical parameters which define loading and material strengths, as I have told you in the fifth one lecture that we have shown you that your say reliability the certain kind of thing that we are telling.

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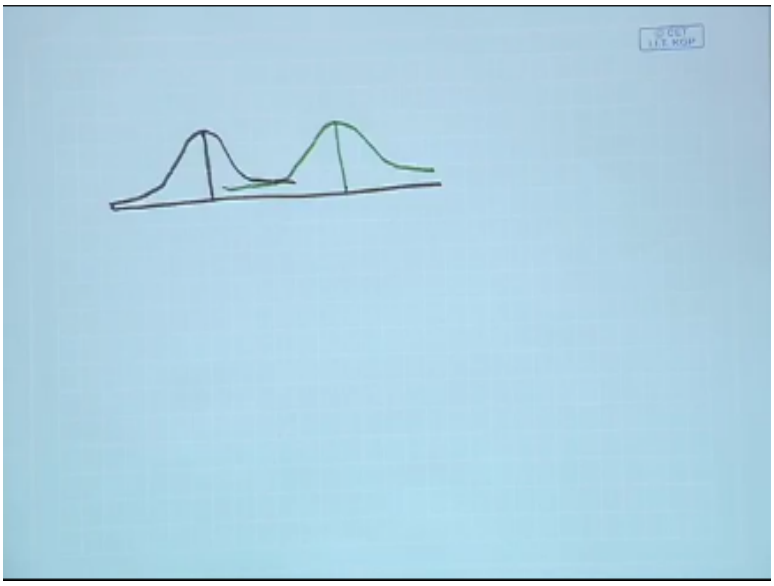

Just to tell you that something like that we are getting let us use another color so that it will be clear, generally we use Gaussian distribution on normal distribution, these case we are having certain value here, these case we are having certain value here so these particular one now whatever we are doing this particular one here statistically whatever distribution because it will not happen that only one single value itself get it every time, we shall get different values but that value will follow certain pattern, certain actually distribution the distribution most of the cases it happens normal distribution.

So that particular one you have to consider here, so that is why you have taken the knowledge of statistical parameters how it is actually viewing statistically that also we have to know, that is for the loading also for the material strength also. The data together with knowledge of structural models of resistance enable evaluation of structural performance in probabilistic term. At the present state of knowledge, determination of reliability is possible only in limited load cases for simple structures that is true of course.

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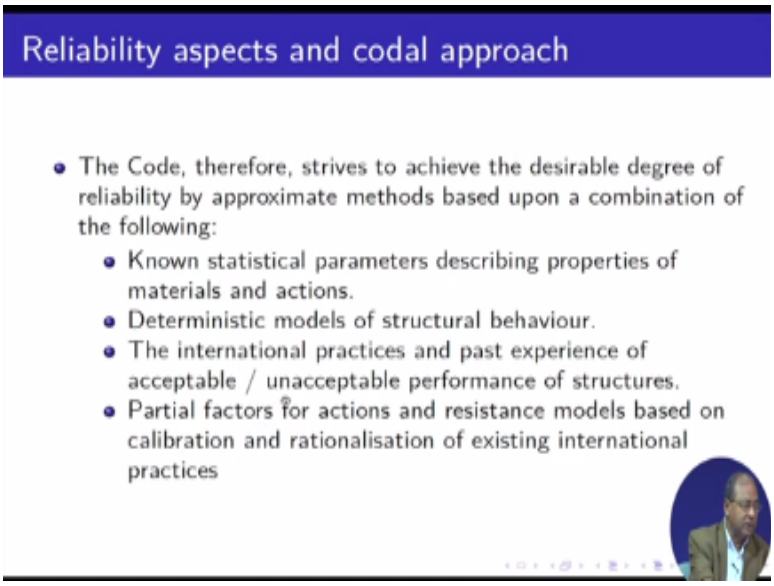

The code therefore strives to achieve the desirable degree of reliability by approximate methods based upon a combination of the following, what are those combination? Known statistical parameters describing properties of materials and actions. Deterministic models of structural behavior. The international practices and past experience of acceptable unacceptable performance of structures.

Partial factors for actions, resistance models based on calibration and rationlisation of existing international practices, so this is one I have taken from IRC 112 this particular one that you can see this particular one there itself.

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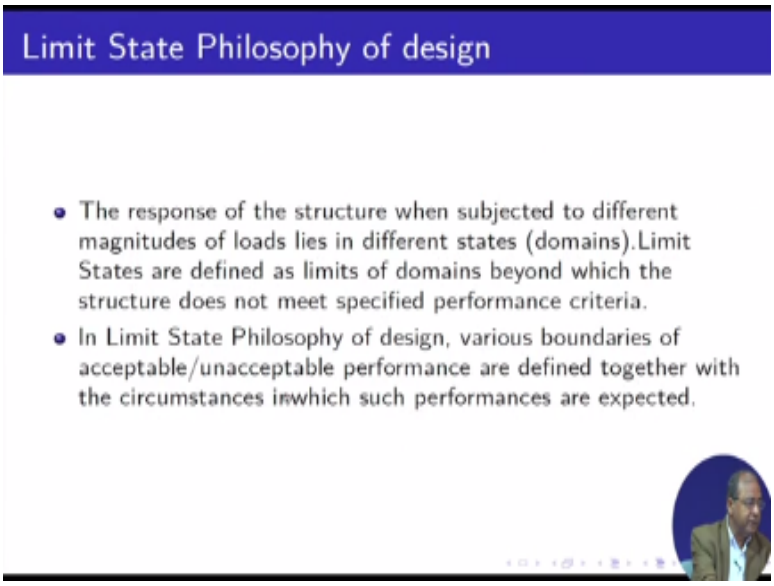

The response of the structure when subjected to different magnitudes of loads lies in different states. Limit states are defined as limits of domains beyond which the structure does not meet specified performance criteria; this is the one we can say. In limit state philosophy of design various boundaries of acceptable, unacceptable performance are defined together with the circumstances in which such performance are expected, so this is the one that we as a limit state of philosophy the various boundaries.

So we shall give the different boundaries that is one that is why it tells a partial limited, we are giving different boundaries and we are working with that particular one domain, so that we can consider we are giving boundary for say your steel or concrete for loading, for deflection like that we shall give different boundary that we shall give it, it is not the one only unique criteria that only it will be stresses.

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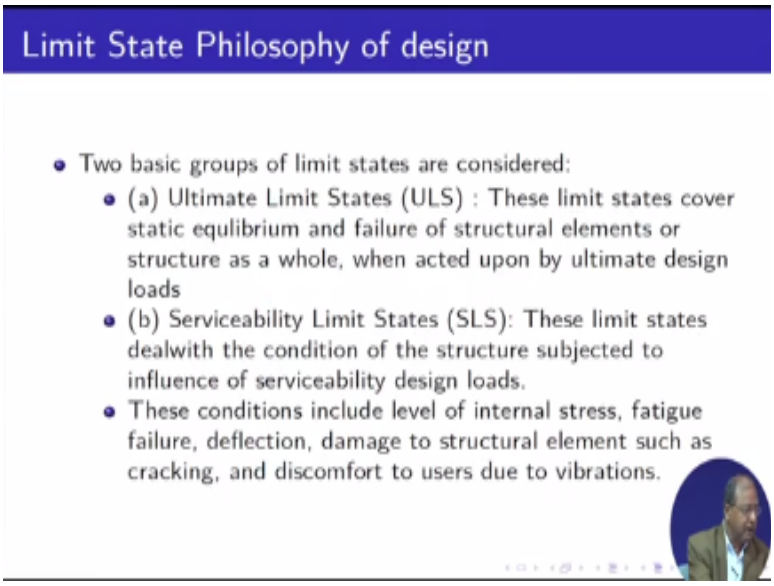

Now coming to this one here two basic groups of limit states are considered ultimate limit states or ULS, these limit states cover static equilibrium and failure of structural elements or structures as a whole, when acted upon by ultimate design loads. And the second one we are having serviceability limit state SLS, these limit states deal with the condition of the structure subjected to influence of serviceability design loads.

These conditions include level of internal stress, fatigue, failure, deflection, damage to structural element such as cracking and discomfort to users due to vibrations, so these are called serviceability. So one is ultimate limit state and other one serviceability the limit state of collapse which is known as in IS456 and limit state of serviceability here we are say ULS and SLS.

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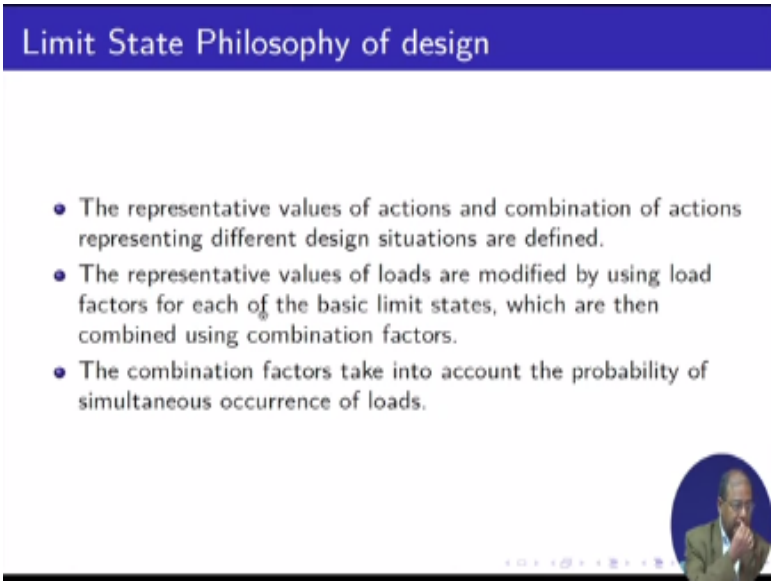

The representative values of actions and combination of actions representing different design situations are defined. The representative value of loads are modified by using load factors for each of the basic limit states, which are then combined using combination factors. The combination factors take into account the probability of simultaneous occurrence of loads, so that is why that wind and earthquake we generally do not take together so that is why the combination we have to consider that, that occurrence of the load on the wishes of that actually you have to decide.

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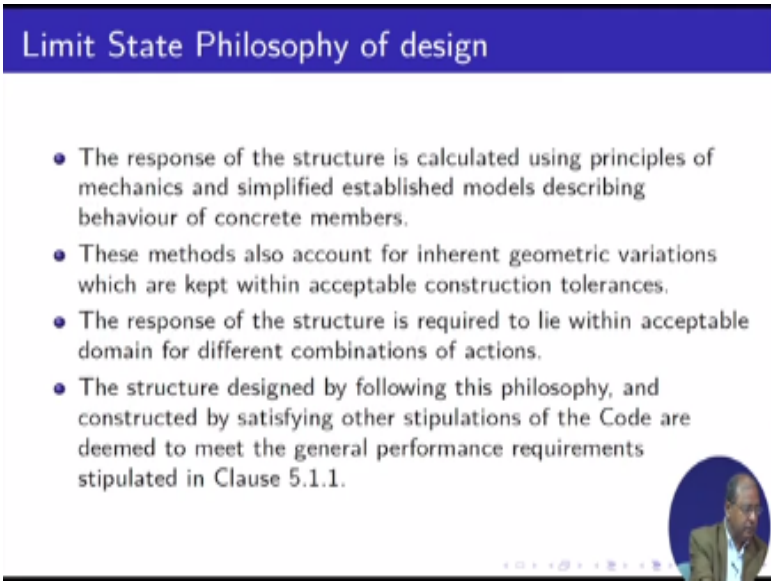

The response of the structure is calculated using principles of mechanics and simplified established models describing behavior of concrete members. These methods also account for inherent geometric variations which are kept within acceptable construction tolerances. The response of the structure is required to lie within acceptable domain for different combinations of actions.

The structure design by following this philosophy and constructed by satisfying other stipulations of the code are deemed to meet the general performance requirements which already we have discussed in the very beginning of this lecture that is clause 5.1.1 which we have told you earlier and that is the one just to repeat once more, this is the one already we have given that particular one I am not reading again, but this is the one already we have given just for continuity I am showing it here.

So I have just simply rate this particular one here but the basic idea that particular one what I would like to say that we are having different parameters and for each parameter we are having different partial safety factors, not only that the load combination that will be dependent on the simultaneous occurrence of that load, that if it does not occur that same time that then we shall not take that particular combination with some other load. As I have pointed out that earthquake load and wind load that we are assume that it will not work together we can take it that particular one there, but for an important structures but then it will be very, very rare situation and in that case we can ignore, omit that particular combination, that taking together earthquake and wind.

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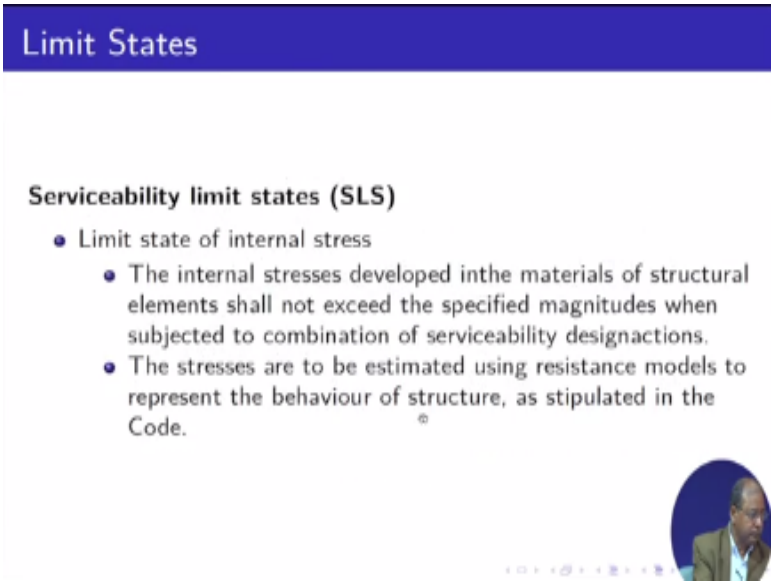

Now ultimate limit state ULS, the limit state of equilibrium when subjected to various design combinations of ultimate loads the bridge or any of its components considered as a rigid body shall not become unstable, so this is the one equilibrium as a whole it should be equilibrium position. And limit state of strength the bridge or any of its components shall not lose its capacity to sustain the various ultimate load combinations by excessive deformation, transformation into mechanism, rupture, crushing or buckling.

So that is the one we can consider that as a part of limit state of strength. The next one this is called under ultimate limit states, so limit state of equilibrium that is we are not going to internal stresses that from externally whether it is in stable condition or not equilibrium condition then limit state of strength we are considering that one the stresses on the basis that.

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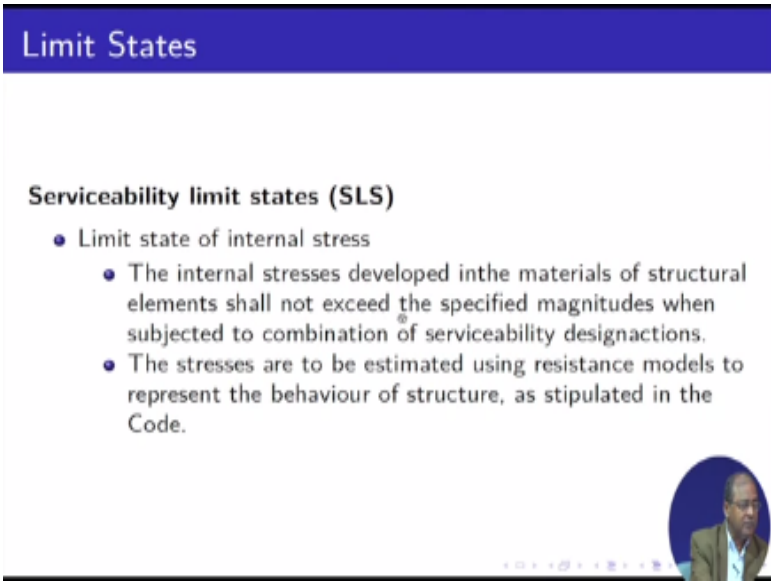

Serviceability limit states SLS, limit state of internal stress; the internal stresses developed in the materials of structural elements shall not exceed the specified magnitudes when subjected to combination of serviceability designations. The stresses are to be estimated using resistance models to represent the behavior of structure as stipulated in the code, so this is the one we shall consider that for internal stress.

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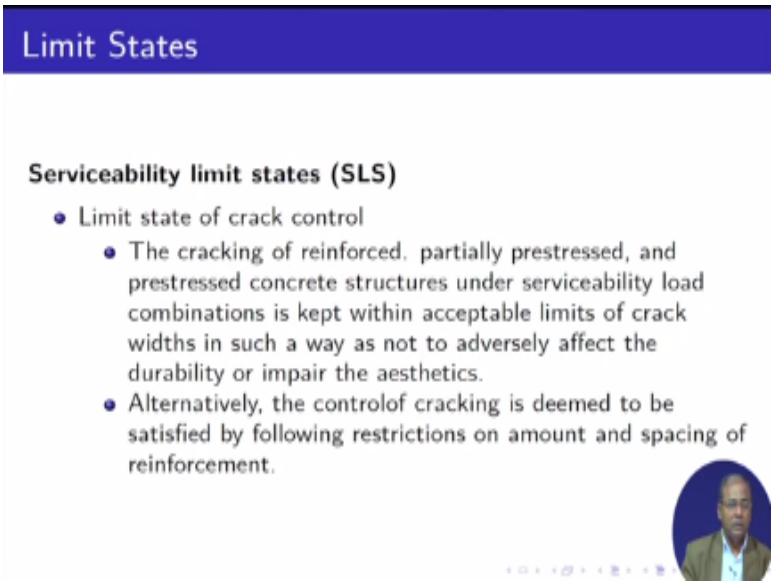

Limit state of crack control, the cracking of reinforcement partially prestressed and prestressed concrete structures under serviceability load combinations is kept within acceptable limits of crack widths in such way as not to adversely affect the durability or impair the aesthetics, so this is the one we can consider here that not only durability but as well as the aesthetics also that you to consider.

Alternatively the control of cracking is deemed to be satisfied by following restrictions on amount and spacing of reinforcement. So that means we can leave restrictions on amount and spacing of reinforcement that also we need.

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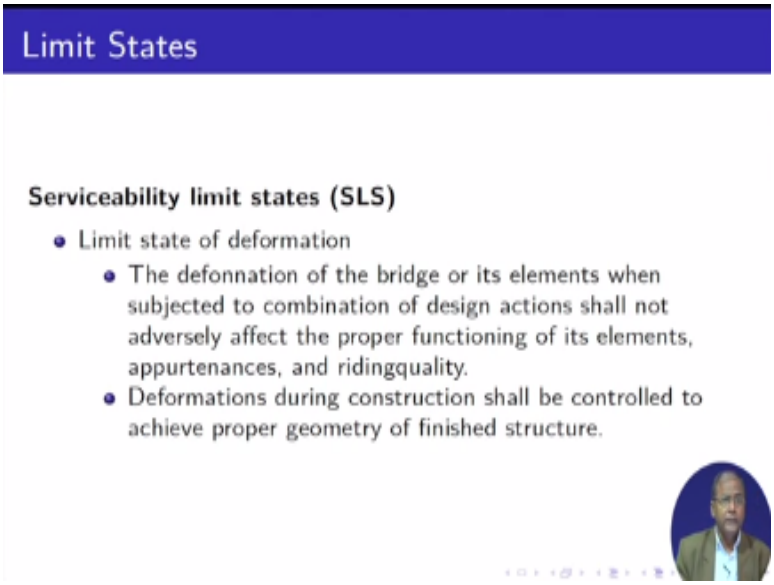

Next one is SLS we are having actually limit state of deformation, deformation of the bridge or its elements when subjected to combination of design actions shall not adversely affect the proper functioning of its elements, appurtenances and then riding quality. Deformations during construction shall be controlled to achieve proper geometry of finished structure, so this one it comes under deformation.

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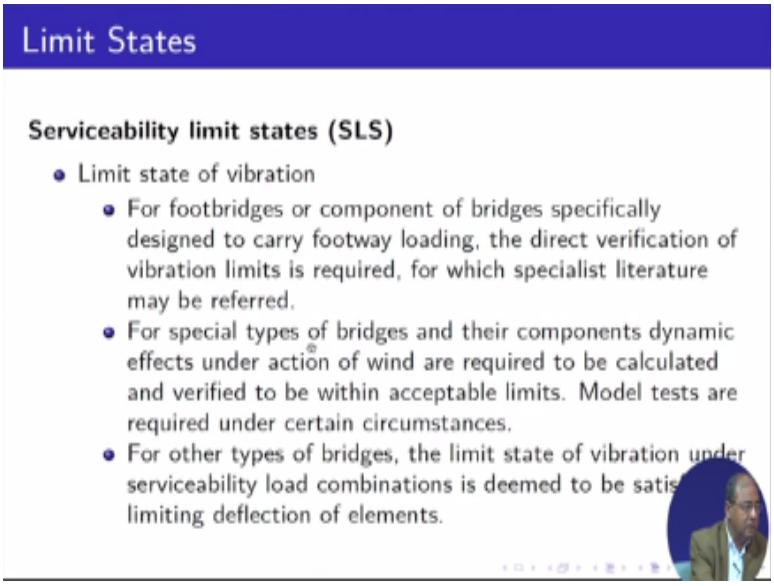

Then the very, very important one limit state of vibration, for footbridges or component of bridges specifically designed to carry footway loading, the direct verification of vibration limits is required for which specialist literature may be referred. For special type of bridges and their components dynamic effects under action of wind are required to be calculated and verified to be within acceptable limits.

Model tests are required under certain circumstances. For other types of bridges the limit state of vibration under serviceability load combination is deemed to satisfied by limiting deflection of elements, so this is the one that whatever available in that IRC and it will from there I have taken it so that you can find out there also, because whatever the sticking wavelength.

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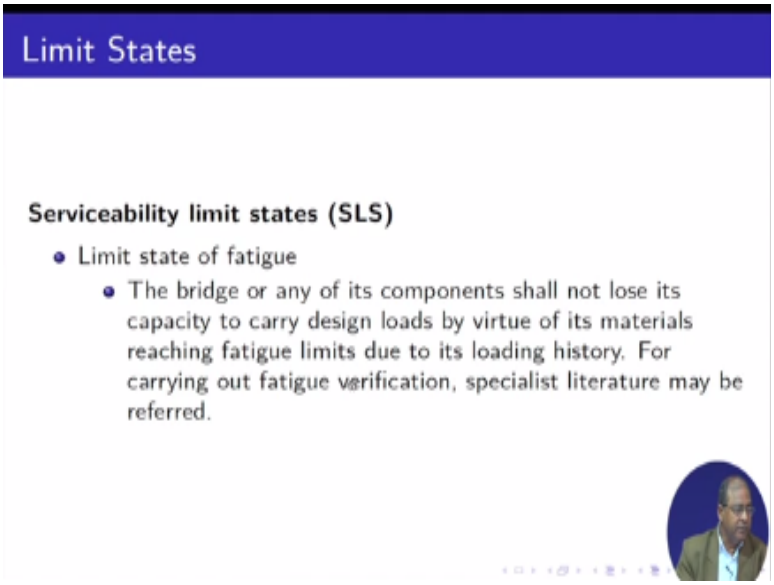

This is another important factor limit state of fatigue, the bridge or any its component shall not lose its capacity to carry design loads by virtue of its material reaching fatigue limits due to its loading history. For carrying out fatigue verification, specialist literature may be referred, so this is the one we have that one here say limit state of fatigue so we can just simply I can once more repeat so ultimate limit states there are two equilibrium and strength.

The serviceability limit state that internal stress, crack control, deformation, vibration and fatigue, so these are the things available we have to check all those things that we have to find out.

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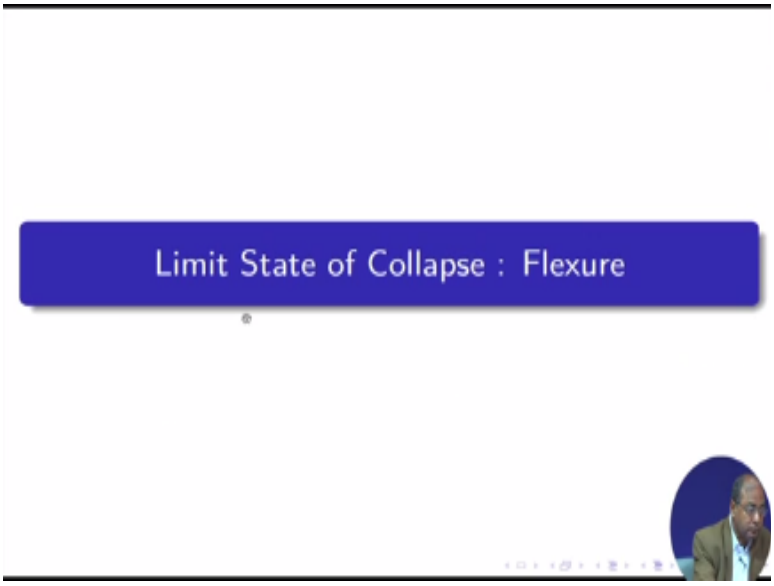

So coming to this one here, the limit state of collapse that flexure or let us see what is available there.

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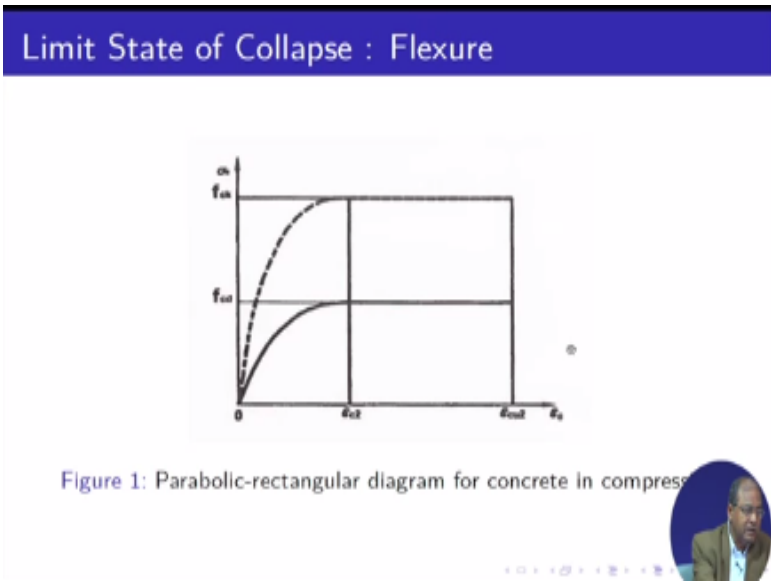

We are using the same curve this particular one we are considering here and these particular one we are considering here the same curve we are considering here.

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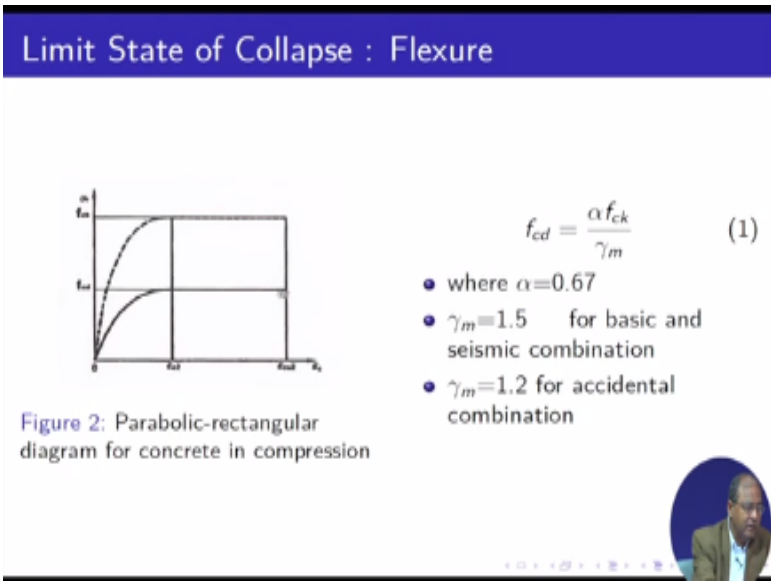

So we can say f_{cd} this is the value of f_{cd}, α_{ck}/γ_m γ=0.67, γ=1.5 for basic and seismic combination, 1.2 for accidental combination, so this is the value that we can consider that one γ_m we can consider here that 0.67 and then 1.5 then 1.2 that particular one is here IRS456 there it is within clearly that you take 1.5, if you take it 1.2 that means we are taking little more value. Otherwise if you take 1.5 so it will come that value these particular value you would come here that 0.45 or 0.4444, 0.45 f_{ck} that will come here.

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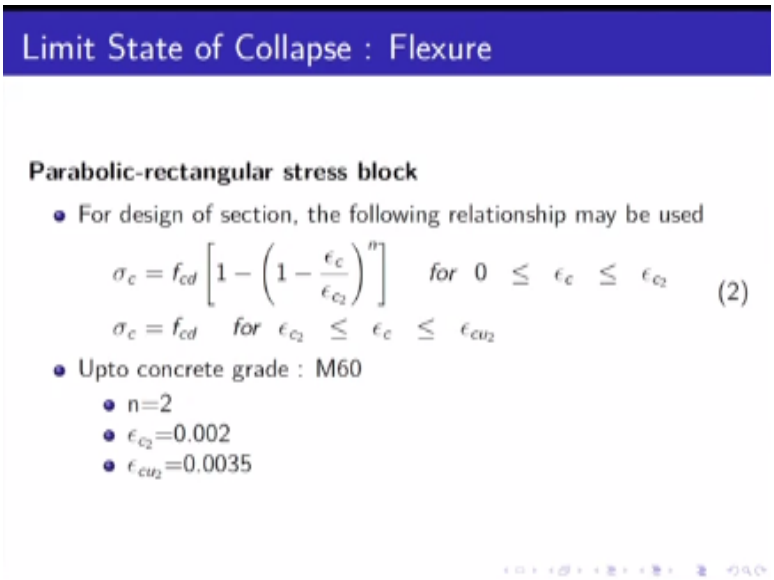

And this is the formula that particular one here because we are having two parts this part and then this part so this is constant and this part parabolic, so f_{cd}[1-(1-εc/ εc2)n] and this is ε_2 to ε_C so that means here we are getting these position constant and these position we are considering parabolic, so one position we are considering constant and one position we are considering here that parabolic that we are considering here and that formula we are getting so that is why n=2, so that code it is given in the code that what is the value of n that is also given in the IRC 112.

Here we have taken for up to concrete grade M60 that n=2, ε_{c2} which I have not mentioned that affect on this is 0.002 that particular one is written and 0.0035 and obviously it is up to M60 according to IRC112.

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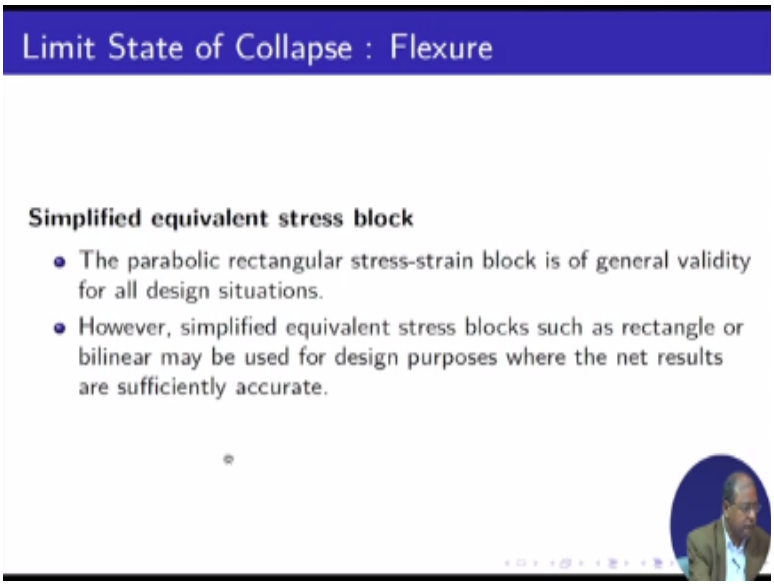

Now the coming that one that we have started actually the discussion on the IRC21 or IRC456 where we have used that your working state method, then we have gone to that limit state method according to IRC456 2000, now we are telling something though we are using the same stress block but here the code says the parabolic rectangular stress strain block is of general validity for all design situations.

That means whatever we have done in IRC456 that is also applicable here is not like that it is not applicable it is also fully applicable. However, simplified equivalent stress blocks such as rectangle or bilinear may be used for design purposes where the net results are sufficiently accurate you are that limit state results sufficiently accurate, they are that all the substantial agreement.

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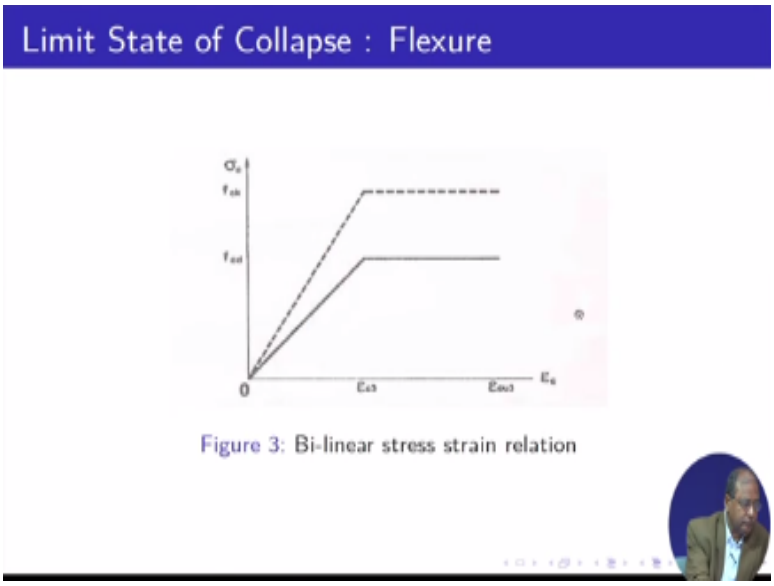

So this is your one case actual one then you are reducing that value that is possible.

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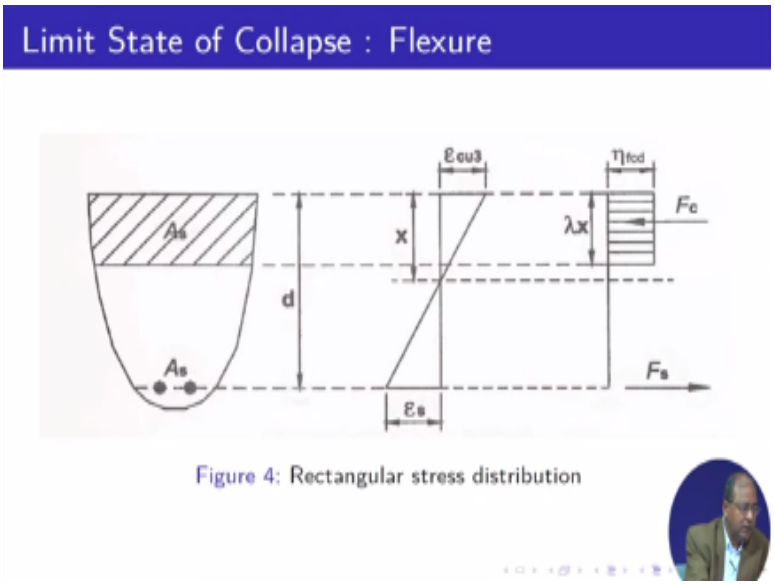

Now coming to this particular one here, what I would like to say that this is the one we are getting here, so if we consider that, that if we consider this particular value that you would say area of concrete and this is area of steel, this is the one that effective depth x is the distance here ε_{cu3}, ε_s that is for the steel and concrete that value we can get it from the table, and these ηf_{cd} λx and f_{cd} so these particular one we can consider.

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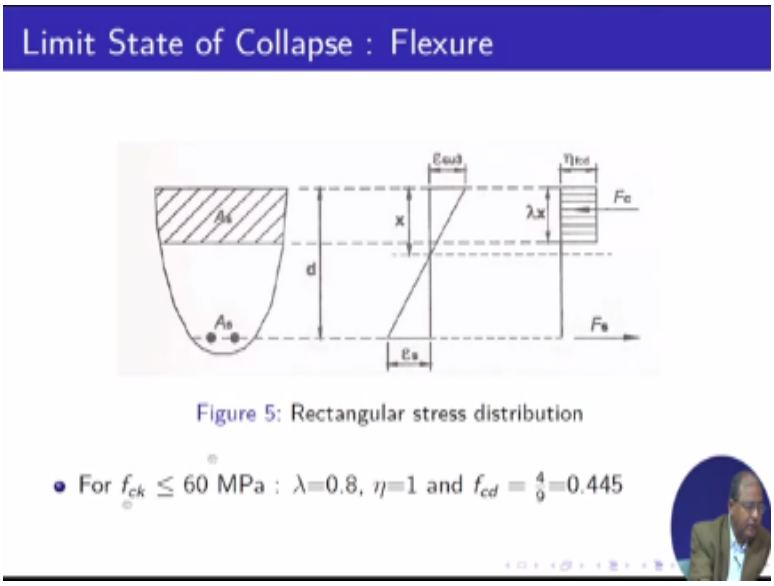

That for f_{ck} less than equal to 60 MPa, λ will be equal to 0.8, η=1 and f_{cd}=4/9 0.445 that is the one, so what we are getting out of it these particular one is very, very important here, what we are getting out of it, so if you really say this particular one here just to give you idea.

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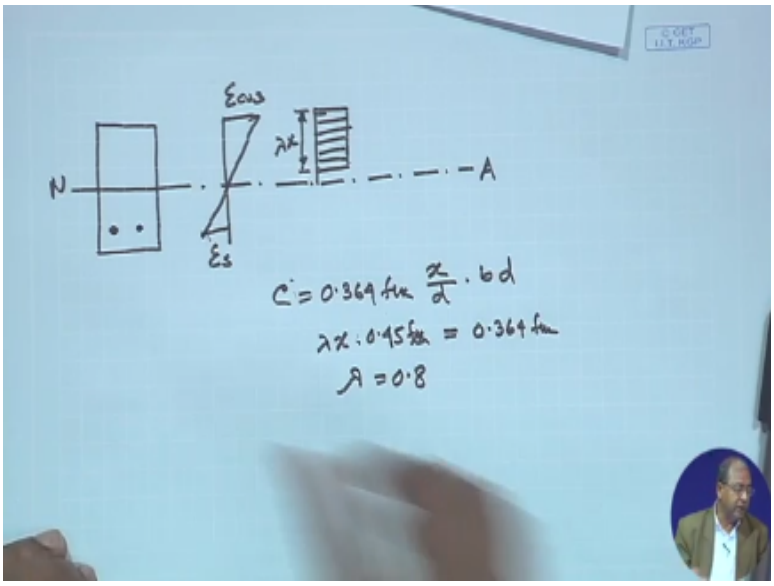

Let me draw it in a rectangular format, so what we can do it here this is our strain diagram so ε and ε_s this is our neutral axis, so what we can do it here now recall our objective is that here we would like to make a parabolic distribution from parabola just see why I have taken this one this is the one parabolic one, this area I would like to make it which is 0.364 f_{ck} that particular one we are having, so these value if we write down here, so what we can do it here in this case please note that figure which you have taken from the code.

That here that λx that means I have reduced this value, so I have considered this one as say λx that we have taken here, so this is 0.364 f_{ck} x/d bd so if I take this code section then how much will be the λ then, so λxx0.45f_{ck} will be equal to 0.364 f_{ck} so λ will be equal to 0.8, so we shall consider the λ that one 0.8 then only I can get the same area λ 0.8 η1f_{cd}, 4/9 0.445 so we can find out these values that we can find out here that we can do it.

So this is one I would like to tell you that whatever value you are getting it here that we, you can consider here, now coming to this one so coming to this one here.

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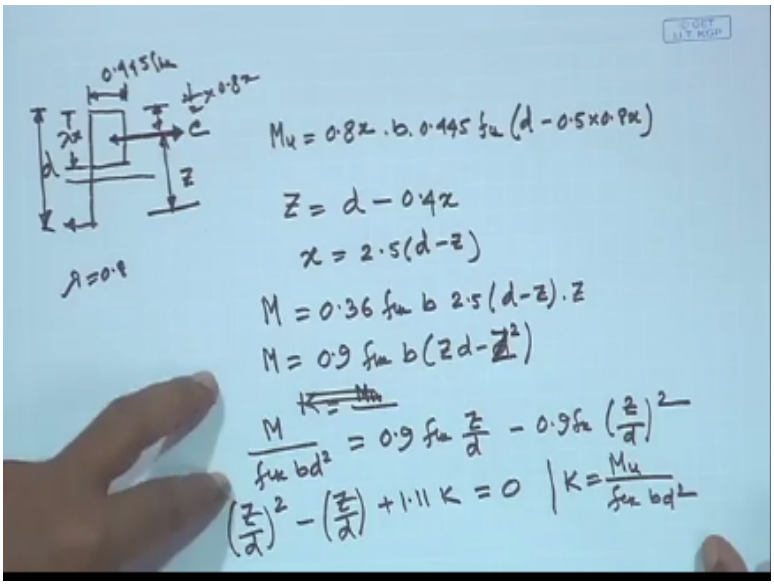

So this one, so this is z so I can write down Mu 0.8x λ=0.8 into bx0.445f_{ck}(d-0.5x0.8x) so this position is 1/2x0.8x your this is the 1.8x 1/2x0.8x that we shall get it here, that we can find out this particular one we can find it. So from this equation whatever we are getting here, from that equation we can find out that your value so I can say z=d-0.4x because ½ of these this is 0.4x so we can write down x 2.5(d-z) and as usual I can write down M 0.36f_{ck} b 2.5 (d-z), so is the equation we can get it here.

So M=0.9f_{ck} b(zd-z^2) and K Mu by this particular one you can consider here distinguish, so we can write down this one here that M/f_{ck} bd^2=0.9 f_{ck} z/d -0.9 fck$(z/d)^2$ and from here again we can find out that equation, we can again find out from this particular one M/fck bd^2 0.9 fck z/d – 0.9 fck and we can find out this equation again, that we can consider over here z/d^2 – z/d +1.11K = 0. K = Mu/fck bd^2.

So you can find out here what I mean to say earlier we had 1.11K and there we can get this one z/d^2 from there we can find out the value of z/d, we can solve the z/d and from there we can find out, again the same kind of equation, we can do it and then we can go for it and who shall give us the solution of the same format Z/d^2 - Z/d +1.11 K = 0, there we can get the value of z, earlier whatever I have told you that equation, so here finally we can get the equation over here

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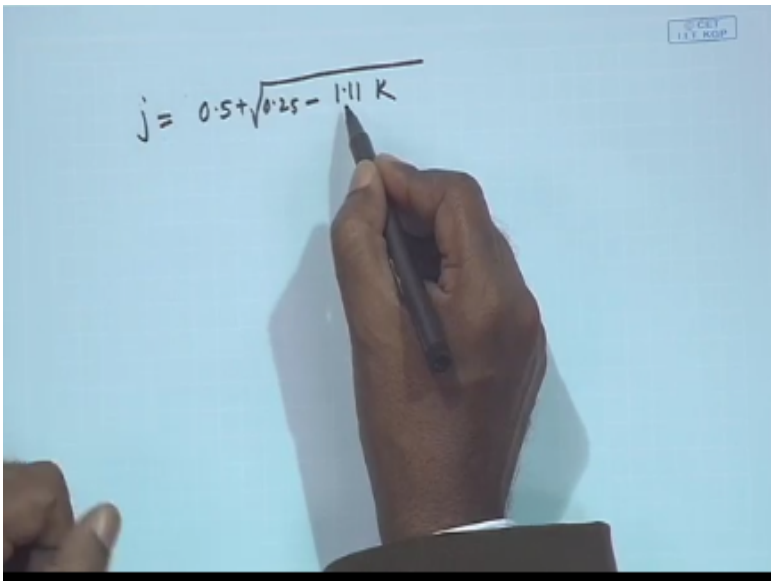

J you can say 0.5 + √0.25 – 1.11 K like that you can get it here, this is the value you can get. That means here earlier whatever value we have got it here and 1.15 and here you are getting here the value of 1.11 and similarly working state method you come then also you get the same value we can find out. So I would like to say that the working state method again, this particular one here, whatever we have discussed one in the beginning. So if σcbc, which is nothing but fck/3 and similarly k also we can make it.

So all the terms if we make it here we can get the same expression that j can also make it there. So that is why I am telling you that working stated method whatever given in IRC 21 OR IR 46 or living state method used for IR46 or the simplify method with that rectangular block whenever you are going for IR12, you will find out the it expression remains same only in the few parameters you will change the particular one.

From there you can find out how much is actually changing? You say from the depth of the beam or you say enforcement. So this is the one just to give you certain orientation before going to the actual problem design the solid slab, we are just given that, this particular one that your orientation or design and previously we have done, whatever the loading we considered and whatever your dimension we considered. So those things we have discussed, so in that way at least in ready to go for design.

So we shall start the first problem with the solid slab then we go for accessorily. As I have told you the objective of the course is that, you should know that how to design the particular one and

whatever the steps you have to considered, what the methods you have to consider are and the loading combination we have discussed that we have to solve the problem thank you.