Welding Metallurgy

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Lecture No 58
Issues in Welding: Design for Static Loading

Welcome to the lecture on Issues in Welding: Design for Static Loading. So, we talked about many aspects in welding, we talked about the metallurgical aspects, we have talked about the cracks, then solidification behavior and all that. Now, towards the end, we will have the other aspects also need to be studied and also other issues while we do the welding.

So for the welding metallurgist, they need to know certain aspects what are the design aspects which are taken into consideration or which are to be given due importance while we go for the welding. So, first is that the design for the static loading so in most of the cases, either you have the static loading, the weld may be subjected to or it may be subjected to the dynamic loading.

So, if you talk about the static loading, so, here you are talking about the strength of the material. So, the UTS is basically taken as the strength, so, that is your ultimate tensile strength of the materials taking into consideration that how long it can sustain, then what is happening that in most of the cases you will have the occurrence of the presence of the stress concentrations.

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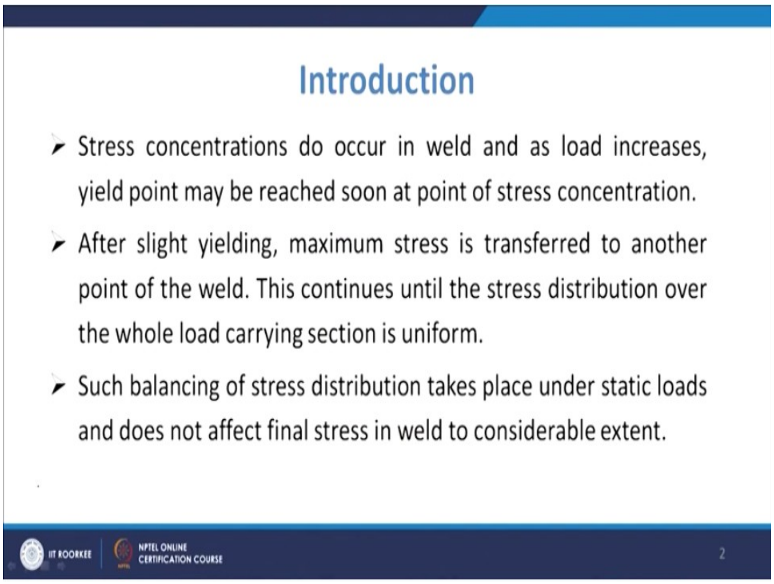

So, when you have the stress concentration in the weld and as the load is increasing, then the yield point may be reached soon at the point of stress concentration. So, what happens that, when the yield point is reached, there will be small yielding and then further, after slight yielding this maximum stress will be transferred to another point of the weld. It may be because when you have the somewhat straining may be, that other point where the other stress concentration is achieved, there the stress value will be more than the limit.

So, in that case, that will be shifted to another point. So, this way, this will be continuing until the stress distribution over the whole load carrying section is uniform. Now, this is the such balancing of these stress concentration will be taking place under the static loading cases and for the purpose of the stress calculations, they are not affecting the final stress values in the weld to much extent.

So, basically, in this lecture, we are going to have the discussion on those considerations, which are required for the designing of the weld when the weld is subjected to static type of loading. Now, in that case, if you talk about the weld design, so in these cases, normally we are designing the weld for the strength and rigidity of the weld. So, if you talk about all the weld designs, so, if you go to the design for the strength and rigidity, you are going for the design of the strength and rigidity.

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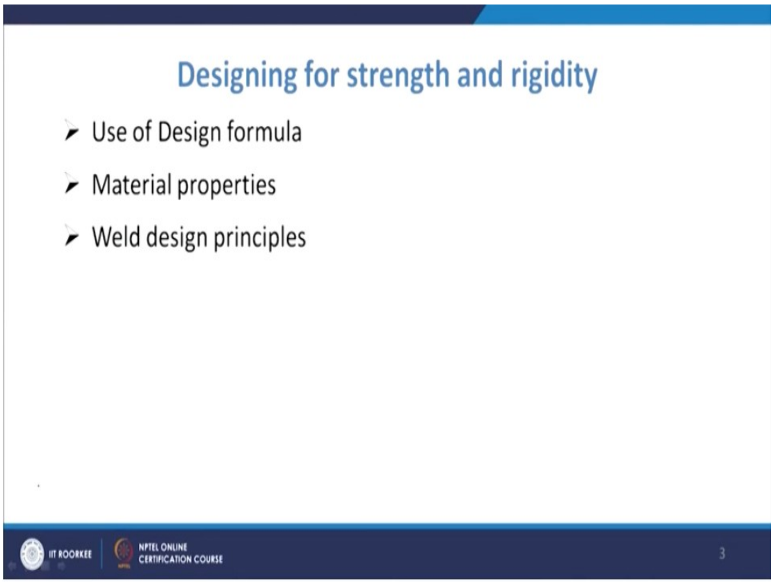

So, you require, in any weld, you require the strength as well as the rigidity and what we feel that we must have the welds in such a way that it will not be failing. It will not be breaking or yielding when subjected to reasonable overloads. So, basically you are normally designing for the strength, in normal machinery. Similarly, that in a weldment also we are designing for the calculated loading and then for that you have the design formula for the strength, which are used for such applications.

So, you also design using these deflections, in many cases, the criteria is about the deflection, because deflection should not be more than certain value. So, in that case deflection under load that is also one criteria for which you are going to design these welding. And again, if you talk about the weldments, then in the case of weldment, you may have certain part which are having the loads and in certain parts, you do not have loads.

So, that normally happens if you take any member, but you have to have also taken into consideration its own weight of the specimen also. So, if you look at the material, you will have to have all these considerations into mind, when you are designing that weld for the strength and rigidity. So, for that, you have first the use of the design formula, so, you have the standard design formula is there. And in this formula, you will have the different terms, different terms will be used.

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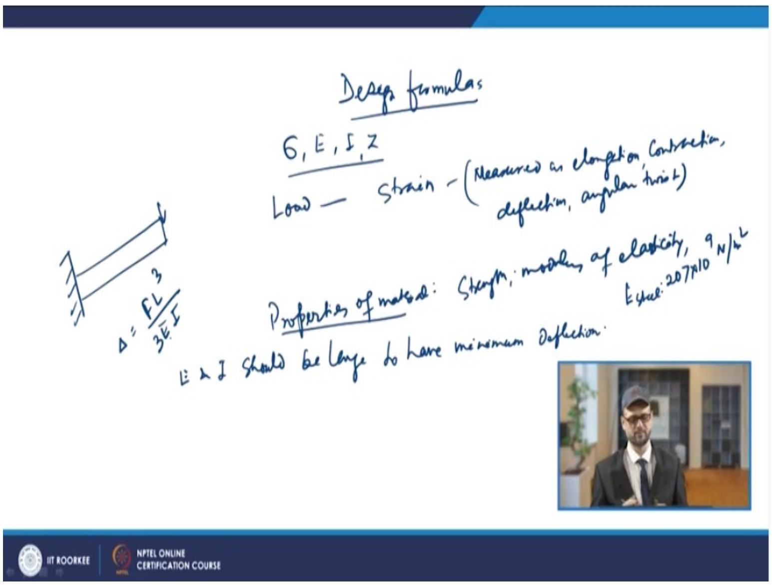

So, if you are going for the design formulas. So, now, you will have the standard terms like , like you have the stress value, E, I, Z, and all these, like you have stress, strain you have the modulus, all that, section modulus and all that terms will be coming up a moment of inertia term that will be coming up. So, these terms are basically used and the load is the force that is stresses a member, when the load is applied that will be creating the stress on the member.

And once you have that so, that will be resulting into strain. So, strain you will have, so, load will be creating the strain and this strain is measured in many terms and you may have the strain as elongation or you may have the contraction, you may have deflection, or you may have the angular twist. So, different way, you will have the strain which is measured and every member will be designed according to what type of load and what is the allowable strain which is there in that particular material.

So, you will have the allowable limits in most of the cases and you will have the material chosen for that purpose that will also depend upon the material which is chosen and then also the size and shape of the material which is being chosen. So, then the properties of the material, which you normally are thinking of on which you are focusing will be like you have strength or modulus of elasticity, that is what we have seen also.

Then you have radius of gyration and so that that also is one of the properties, so, that will basically determine the load carrying capability of the material. Now, in most of the cases the design formula which is developed. So, normally what we do is, we have if you talk about the deflections of, in a cantilever type of beams. So, in those cases, if you talk about the cantilever beam, in that case, so, as we know that if you have a cantilever beam and you are applying a load.

So, if you are applying the force, in that case, you will have the deflection and that deflection will be $FL^3/3EI$. So, as we see that you will have F is the load which will be bringing into the deflection delta, then L is the length of the cantilever beam, similarly E is the modulus of elasticity of the material and I will be the moment of inertia. So, what we normally design our basis of design will be that we should have the minimum amount of deflection.

So, for that, as we see that we will try to have the material with large and large values of E and I. So, normally if you talk about the different materials, so, among the different materials, if you talk about the values of E and I should be large, to have minimum deflection. Now, if you talk about having the larger and larger values of E, so, if you talk about the value of E for the steel, so, it will be something like $207*10^9$ N/mm^2.

So that is the value of E. Similarly, another is the I that is your moment of inertia and that will be depending upon the different type of cross section of the material. So, accordingly and also another factor which is going into while consideration is the cost also while you are making the different cross section. So, accordingly you can have this cross section formed by the different forming processes, so, that you have larger value of E and I.

So, you can think of having the smaller amount of deflection. So, that is how design formulas are used and you design for a better loading. So, when we talk about the loading conditions.

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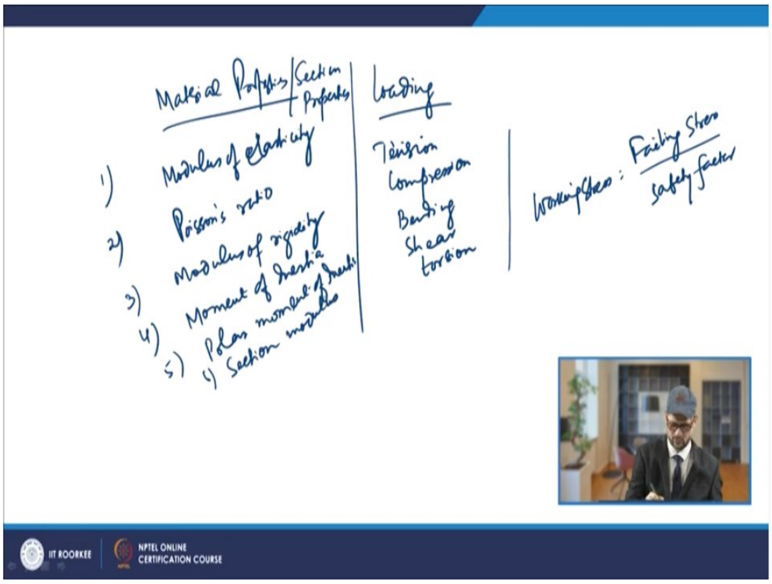

So, if you talk about the loading condition, then there are different types of loads, which are applied you may have the tension, you may compression, you may have the bending, shear and torsion. So, these are the different types of loads, which are applied and when these loads are applied, then the material comes under stress and that stress will cause the movement inside the member.

And how much movement will be there, that we have already discussed that, will be depending upon the value of the modulus of elasticity of the material. And certainly that shift which will be governing the moment of inertia of that particular shape. So, what we do is we normally we have the definition of the working stress or allowable stress and for that, we define a term known as factor of safety.

So, you will have a (failing stress /factor of safety), so the safety factor. So, this way, you have the definition of the allowable stress or working stress, which is what is set so that you can have the performance of the welded specimen satisfactory in the long run. Then, the next point which is important is the material selection properties. So, material properties or the section properties.

So that is your material properties, so, if you talk to the material properties or the section property also, so under that you will have the different material properties are there, you have the, or we will also talk about the section properties and that is what we have studied that you have material property that is E and then section properties will be depending upon that, it will have a moment of inertia.

Or you will have other parameters, other terms will be there which we are talking about the section properties. So, you will have the, commonly we use this modulus of elasticity, so that is one property of the material, then you have the Poisson's ratio, you have modulus of rigidity, then you have section property you have moment of inertia. Then you have polar moment of inertia and section modulus. So, these are the material and section properties, which are used for the design process, when we are dealing with the welding process.

So, to discuss about the properties, now, among them the first property is the modulus of elasticity.

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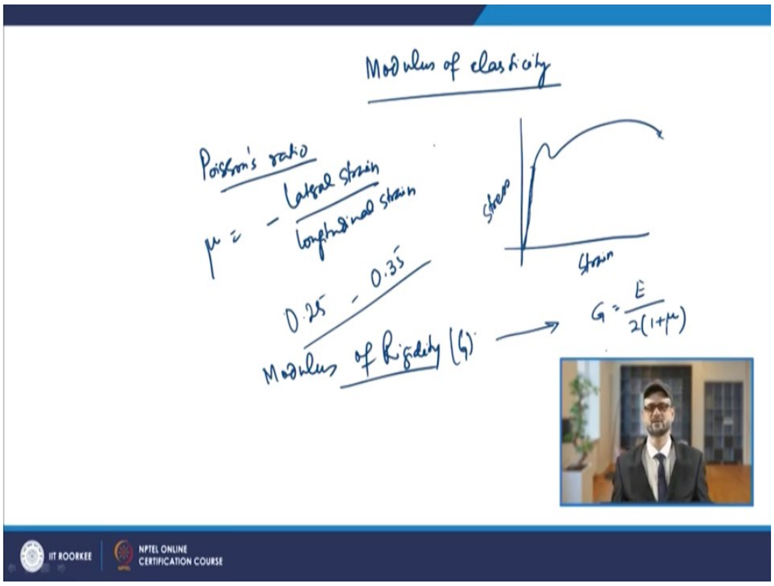

Now, what we see many a times we require a high amount of ductility in the structural members and because having that property basically it will be taking up, accommodate presumable amount of strain and also it will be redistributing the stresses without the permanent premature fracture. So, that way, these properties are desired. Now, if you talk about the stress strain diagrams, so, these properties are basically defined on the basis of the stress strain diagrams.

As we see when you typically see the stress strain diagram of one steel, the stress strength diagram logo is like this, the stress strain diagram. And what you see is that you have a linear portion, which is there up to this point and then it becomes nonlinear. So, the modulus modulus of elasticity of the ductile material in this region it will be defined, so, it will be ratio of the stress to strain for this reason. So, that will be a constant value.

So, that way, this modulus of elasticity will be defined and it will be representing the stiffness of the materials, so here it will be fracturing and you will have the slope of this region that is a constant value, which is obtained. So, this is stress upon strain that slope will be known as the rigidity value or modulus of elasticity and normally in tension and compression, it is assumed to be same for the material. Then you have the rigidity or stiffness.

So, that is the amount of stress of the material that can withstand so that is the rigidity of the material. So, then second point is the Poisson's ratio. So as also we know that the Poisson's ratio is the ratio of the lateral to the longitudinal strain, which is happening because when you are straining the material in that case, you will have the change in length whereas where we will change in reduction, so increasing the length will be because and there will be strain also in the lateral direction also, so that will be negative.

So, normally you will have the Poisson's ratio which is defined is minus of lateral strain to longitudinal strain. So, so, the negative sign tells that the lateral strain has the negative sign to longitudinal strain because the μ has to be positive. So, in that case, this is your Poisson's ratio and mostly the Poisson's ratio will be varying between 0.25 to 0.35. But for the rubber it is approaching close to 0.45. So, that can be correlated about the elastic properties of the material.

Similarly, you have the modulus of rigidity also and that is known as the bulk modulus of rigidity, that property is there. So, when you use the tangential or shear stress, in those cases, you will have the ratio of stress to strain that is defined as the modulus of rigidity. So, that is defined by the term G. So, if you try to see the correlation between this G and the elastic modulus, modulus of elasticity, so, there are also correlations like you have $G = \frac{E}{2(1+\mu)}$.

So, this way you will have these terminologies which needs to be understood in such cases.

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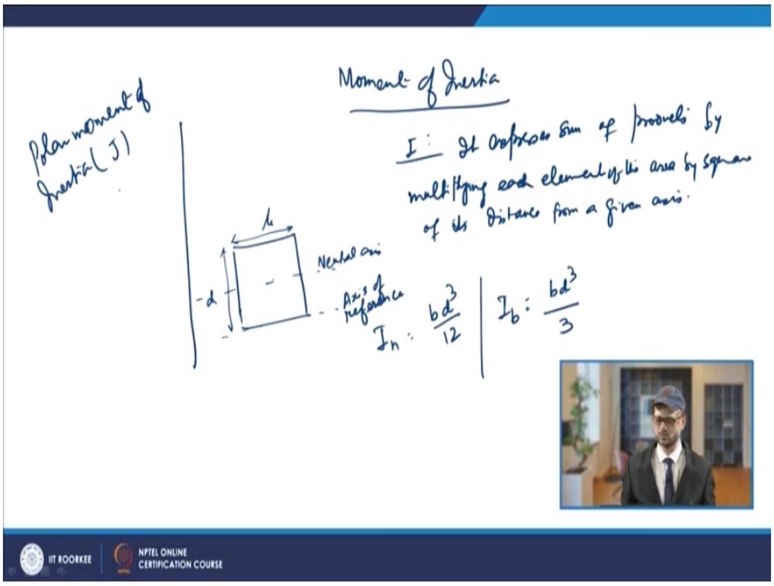

Then, coming to another term which is important in these cases is the moment of inertia. So, it is also known as the second moment of inertia and it is basically denoted by I. So, it will be expressing, so it expresses some of products by multiplying each element of the area by square of its distance from a given axis. So, this way, you basically find the moment of inertia and this axis will be lying in the plane of the cross section. So, you will have one axis and over that you will be having these value of, the moment of inertia.

And normally you will have the unit that is area of, so you will be multiplying the each element with the square of the distance. So, you will have the unit that is in mm^4. So, what we do is that normally it will be talking about its tendency towards the rotation about the axis and this is a measure of the resistance to that rotation offered by the geometry and the size of that section. So, it is basically a very useful property of the material in solving the design problems, when there is involvement of the bending moment.

So, normally, it will be used while solving the rigidity problems and there are different methods for finding these moment of inertia of the structure and normally what we do is that if you talk about the any rectangular section with different axes of reference, so, you will have, although you have different methods of finding this moment of inertia. So, what we do is, if suppose you have this is the b and this is d and if you are talking about this axis, so, you will have, this is your basically neutral axis and this becomes the axis of reference.

So, you will have the finding the moment of inertia, if you try to have it about the neutral axis, so, about neutral axis, it will be $I_n = bd^3/12$. Similarly, if you take the moment of inertia of the same rectangle about its baseline. So, if you try to find out its baseline, it will be $bd^3/3$. So, basically the knowledge about the moment of inertia will also be used in finding the value of the polar moment of inertia that is your J. So, that is used for finding the polar moment of inertia, that is J.

So, this J is also found out about the axis which is right angles to each other and also the section modulus. So, that also has a role in solving the problem for the design that is related with the rigidity. So, in case of rigidity design problems, these terms are also requires.

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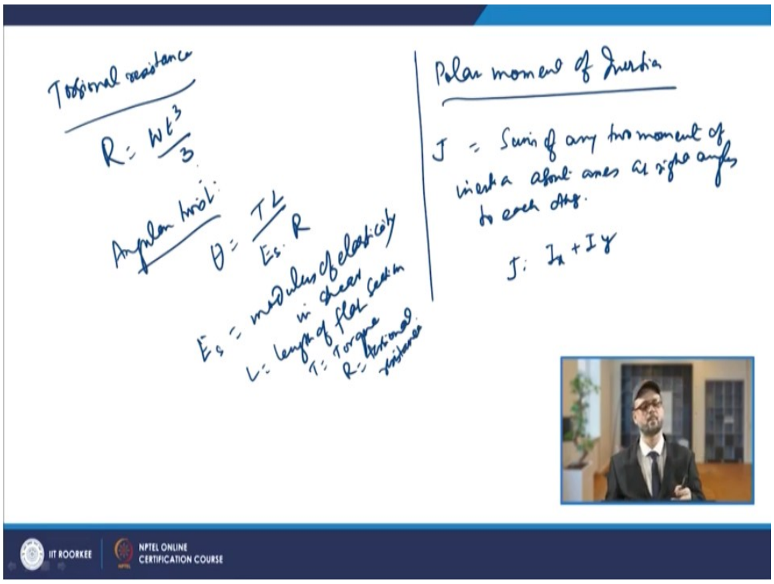

If you come to know something about the polar moment of inertia, so the polar moment of inertia that is J, it is basically the sum, of any two moment of inertia about axis at right angles to each other. So, you will have the polar moment of inertia, which is taken about an axis which is perpendicular to the plane of the other 2 axis. So, in that case $J = I_x + I_y$. So, that way you find this polar moment of inertia.

Then other parameter which is found to be useful while we talk about the designing that load weld under the static loading, so that terminology is the torsional resistance. So, it will be normally replacing that less accurate polar moment of inertia and normally, torsional resistance you will have $Wt^3/3$. So, R is normally the torsional resistance, W is the width of the flat section and t is the thickness of the flood section.

So, normally when you have the torsional type of loads are involved, so in those cases, for the flat section, we normally use this formula R equal to $Wt^3/3$ and once you have the R found out, so once you find the R, then angular twist can be also found out. So, angular twist will be $TL / (E_S * R)$. So, your E_S is the modulus of elasticity in shear.

Similarly, you will have the L is with the length land and you have L is the length of flat section. Then you have, so other terminologies are known T is the torque, so that is what we know and then R, as we know, R is the torsional resistance. So, this is basically these formulas are used for finding these angular twist in the flat member.

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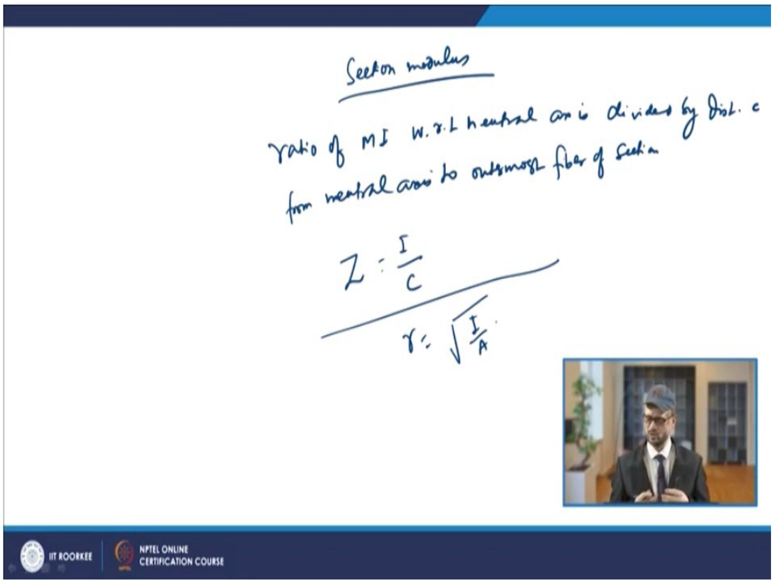

Then also, as we discussed you have another, parameter which is important is the section modulus. So, section modulus basically it is ratio of moment of inertia with respect to neutral axis and divided by distance that is C from neutral axis to outer most fiber of the section. So, basically it will be ratio. So, if you talk about the Z, that is your section modulus, that will be I/C. So, it is the measure of the strength of the beam in bending.

So, there we normally use these section modulus. Then apart from that, you will have other terminologies like radius of gyration. So, that is also the distance of the neutral access to the imaginary point, where at that point the whole area of the section is assumed to be concentrated, having the same moment of inertia. So, in that you find the $r=¿\sqrt{\frac{I}{A}}$. So, that is, dividing by the area you will find the radius of gyration.

So, normally, when you talk about the welding design features, what we have normally to do in the case of welding is that in order to decide upon the size, shape, and the type of weld.

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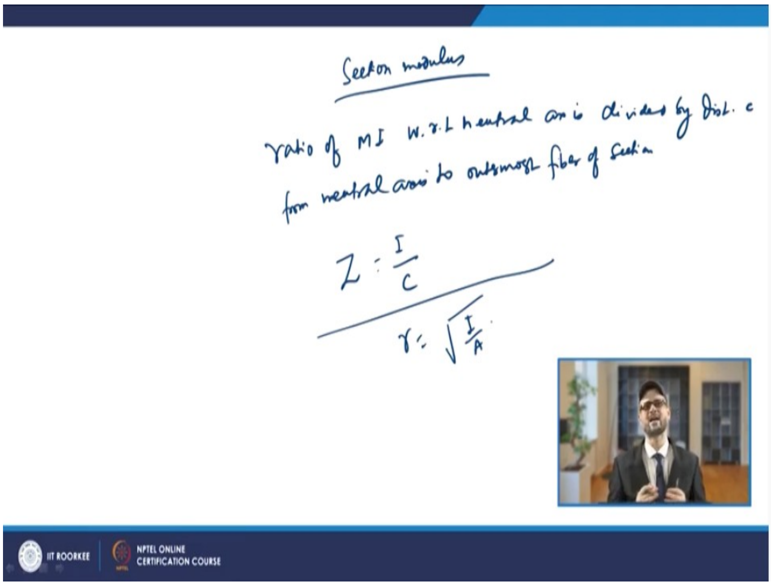

So, to know you need to have the ultimate and permissible safe stresses, you need to have the load to be transmitted to the weld pool. So, these things are required, so once you know that, then you can have the, depending upon these values, you can have the calculation of the stress from the weld, all that can be done. Thank you very much.