Design of Steel Structures
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Module - 5
Lecture - 6
Compression Members
Lacing for Built Up Compression Member

Hello. Today we are going to focus our lecture on lacing for built up compression members. In last lecture we have just introduced the lacing systems. Why lacing is required? As we told earlier also that to make act together of the built up section, we need to tie. We need to make the built up members in such a way that it will work as a composite. That means when the magnitude of load is very high, then we need to introduce built-up compression member because of unavailability of higher sections and also, we have seen the advantage of built up members because in case of the readymade members which are available in the market, it has radius of gyration in one direction is very high and in other direction is very less. Generally in x direction, it is high and in y direction, it is less.

So, in that case we cannot take the advantage of the x direction radius of gyration. So, if we introduce the member in such a way that the radius of gyration in both the direction will be more or less equal, then we can take the advantage of that member. To take those advantages and to accommodate the high load, high compressive load for the section, we are using generally built-up section which is also called that composite section. Now, this section has to act together, so that the built up section as a whole buckle in together and for that we need to tie those things with some sort of horizontal basing systems which is called lacing or also, we can introduce battening systems.

In most of the cases, generally we used to prefer lacing systems. Lasing systems means again we have seen in the last lecture at the last part that different type of lacing systems is there. One is called single lacing systems; another is called double lacing systems. Now, to design the lacing system, various aspects are there in codal provisions. It is given various means guidance has been given. So, first we have to see what the codal provisions are there, what guidance are given and accordingly we have to find the parameter of the lacings that mean dimensions of the lacing. Dimensions means the thickness of the lacing, the width of lacing, the length of the lacing, inclination of the lacing whether we will go for double lacing system or single lacing system. What type of connections we will do with the main bar whether it is riveted connection or welded connection, all these things we will see and how to design properly we will go through with this lecture.

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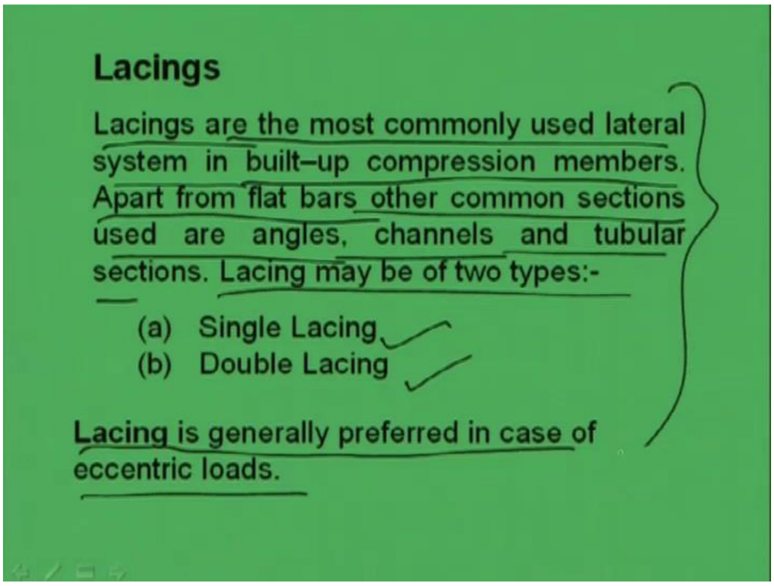

So, lacing when we used generally as I told that lacing is generally preferred in case of eccentric load whereas, battening we used generally for concentric load. For eccentric loading system, we use lacing systems. Now, lacings as we told that are the most commonly used lateral system in built-up compression member. Apart from flat bars, other common sections used are angles channels and tubular sections and as we told that lacings may be of two types. One is single lacing, another is double lacing. So, these things we have discussed in last lecture. So, I am not going into details of this.

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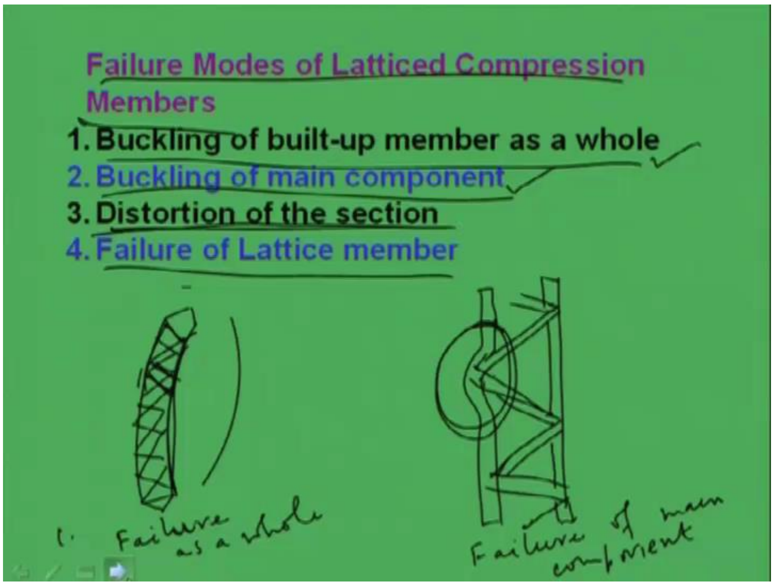

Now, we will discuss about the failure modes of lacing compression member. How it fails because accordingly if we know the failure modes, accordingly we can strengthen the system, so that the failure does not occur. So, what are the types of failure comes first we will discuss and accordingly, we can take the preventive measure, right. So, failure means one is that buckling of built-up member as a whole. As a whole it can buckle the whole built-up member can buckle along with the lacing members. Another is buckling of main component. The built-up member which comprises of the different member component like I sections, channel sections, angle sections those things may buckle.

Another is distortion of the section and another failure is the failure of the lattice member. That means, lacing member itself may also fail. So, how does it look when failure comes for the buckling of built-up member as a whole? It looks like this say sorry say two members are laced by this, right. Now, may be this is a single lacing system, maybe we can make double lacing system. So, this is called means this is basically failure as a whole buckling of built-up member that is failure as a whole. That means whole system is buckling. The main member this is going to buckle as well as this is also going to buckle because of the failure of the main member, right.

Another is the buckling of main component. Buckling of main component means say like this suppose one member is like this say this member say look like this, right. Now, say this is a lacing system like this, right where it is failing say this area is going to fail. That means, buckling of main component is happening here. So, failure is happening due to main component, right. So, this is also means one type of failure.

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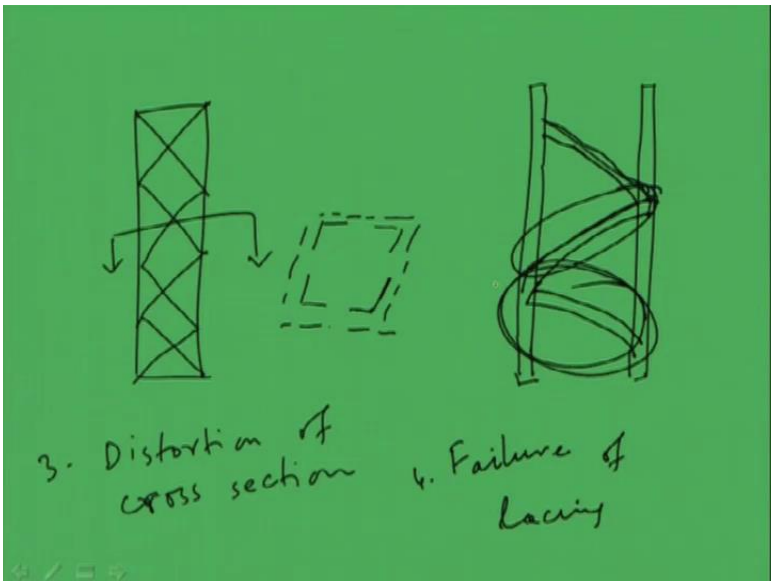

Another failure is as we called that distortion of the section. Distortion of the section means say suppose two members are laced like this. It is now if we see the cross-section of this, when we will see that this comprises of four angle sections, right. So, this will look this now if we laced together. So, the cross section will look like this. So, this is called number three distortion. Distortion of cross-section this is one type of failure. Another failure is called this failure of lattice member. That means, the lacing member itself fails. This happens when the lacing members are not designed properly with the horizontal load which is coming because of the transverse shear. So, may be the main component is strong enough to take care the load, but the lacing system has been met in proper way, so that this does not fail. This will be something like this say like this now. So, this is something like this and this is like this.

So, this is the buckling of the lacing member. So, this we can say failure of lacing that it may be local failure also means one member may fail, other member may not fail. It depends on how the load has been distributed and how the connection has been done. So, it depends on all these things. So, these are the four types of failures. It used to happen in case of lacing systems. So, what we have seen the failure is one is failure as a whole, another is distortion of the cross-section, another is the failure of the main component and then, failure of the lacing bar. So, when we will go for designing, we have to take care of all this.

Now, here we will focus the designed aspects of lacing member means how we are going to design. So, for designing, we first have to see what constrains are means what are the guidelines has been given by the code. Code means IS: 800-1982, sorry 1984.

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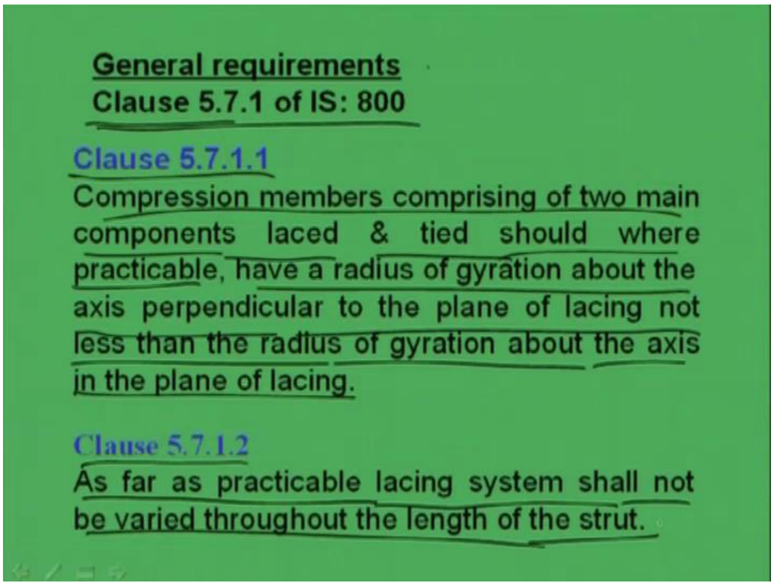

So, in IS800 in general requirement has been given in clause 5.7 about lacing or battening system. So, in 5.7.1, the general requirement of the lacing system has been given. So, let us see what the guidelines has been given by the IS code and as per that guideline we have to find out the design criteria. So, first guideline is that which has been sighted in clause 5.7.1.1. What is this? That is compression members comprising of two main components laced and tied where practicable have a radius of gyration about the axis perpendicular to the plane of lacing, not less than the radius of gyration about the axis in the plane of lacing.

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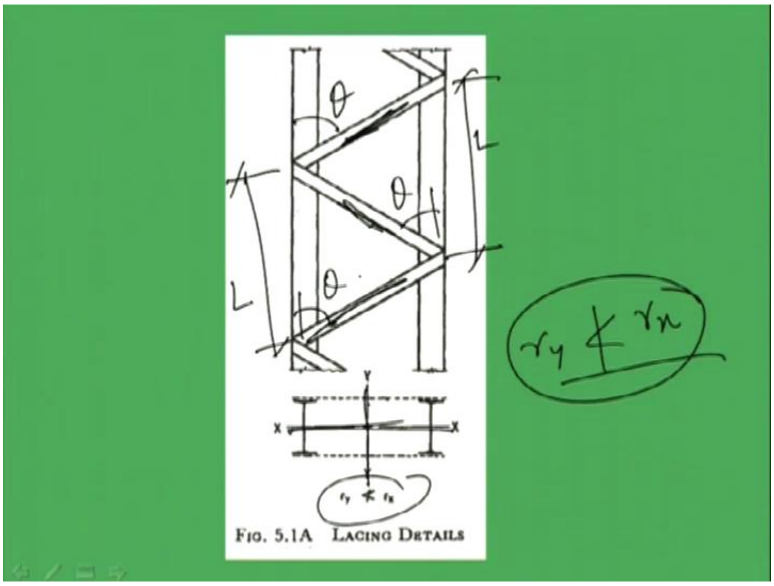

That is ry should not be greater means less than rx, where xx is in this direction and y is in this direction. So, ry should not be less than rxx rx. So, this is the first requirement which has been provided by the code. IS code has provided this criteria. So, we have to maintain these criteria as when we are going for designing the lacing systems. Another clause has been told that as far as practicable lacings system shall not be varied throughout the length of the strut. That means lacing system should not be varied as far as practicable. That means the dimension of this lacing and dimension of this lacing and dimension of this lacing should not vary. It should be uniform.

This distance should be uniform which is called generally L. This should be uniform. The inclination angle of inclination theta, this angle of inclination should be as far as possible same. That means the variation should be avoided as far as possible uniform dimension, uniform length, uniform angle of inclination has to be made in case of design of lacing system. This is another guideline provided by the code.

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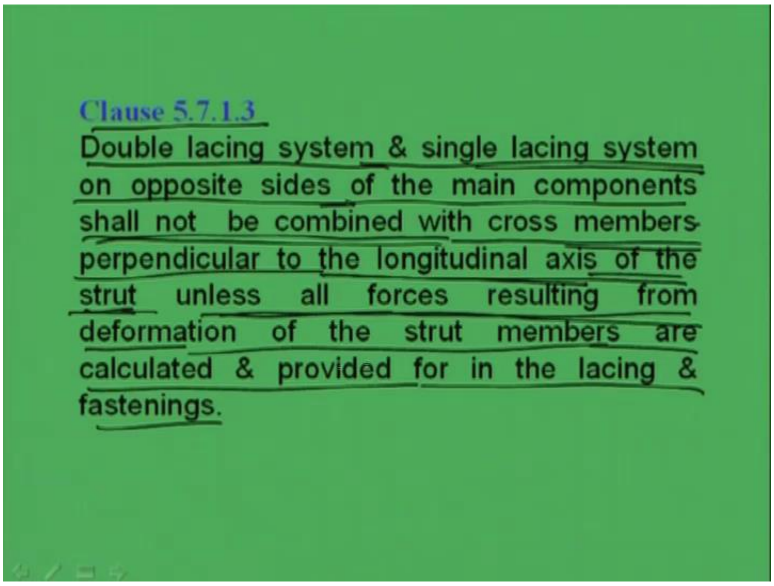

In clause 5.7.1.3, it has been told that double lacing system and single lacing system on opposite sides of the main components shall not be combined with clause member perpendicular to the longitudinal axis of the strut, unless all forces resulting from deformation of the strut members are calculated and provided for in the lacing and fastenings. I am repeating once again that double lacing systems and single lacing system on opposite sides of the main components shall not be combined with clause members perpendicular to the longitudinal axis of the strut, unless all the forces resulting from deformation of the strut members are calculated and provided for in the lacing and fastening.

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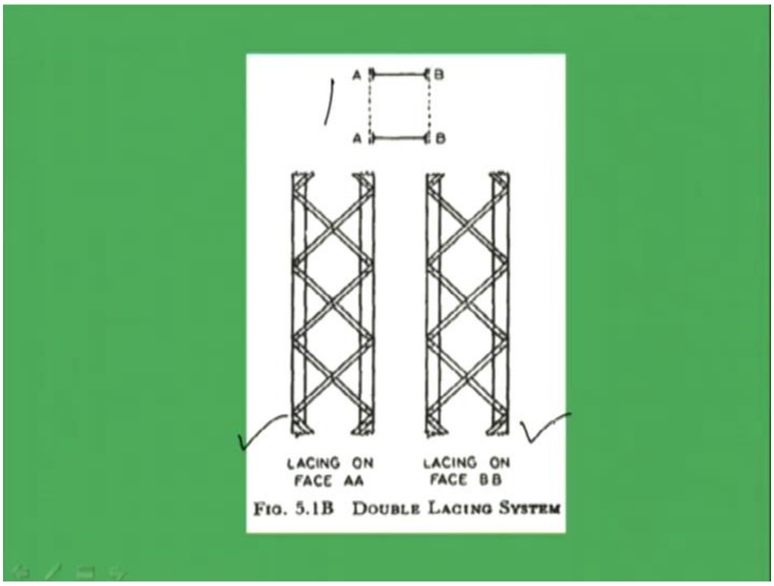

That means if we see that in case of double lacing system, this should look means face of AA, if it becomes like this and face of BB should be like this and the clause member when we are going to use it should be like this.

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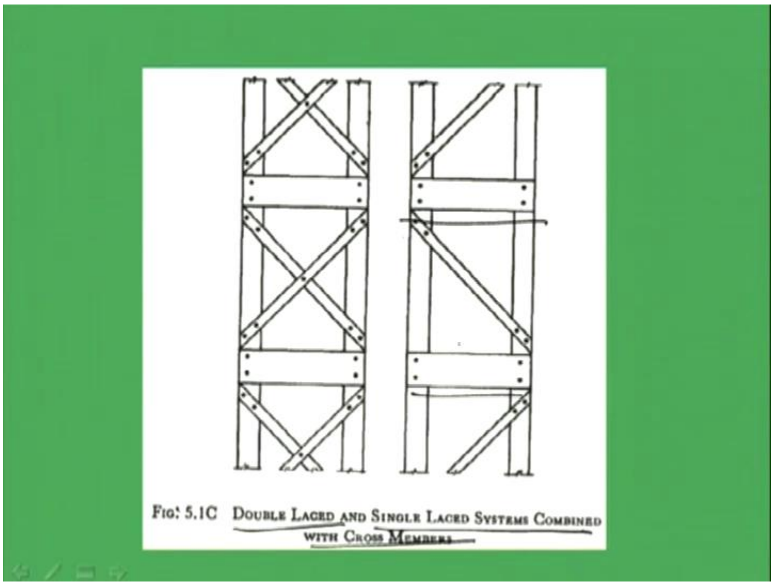

So, clause member when it is required double laced and single laced systems combined with clause member, it should look like this.

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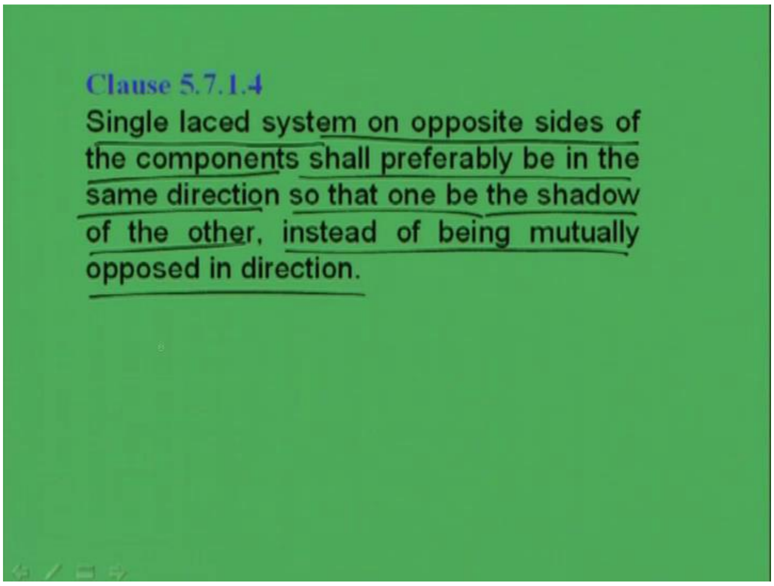

Now, in clause 5.7.1.4, let us see what is guided here that single laced system on opposite sides of the components shall preferably be in the same direction, so that one be the shadow of the other instead of being mutually opposed in directions. So, this is also another important part. That means what we have to do?

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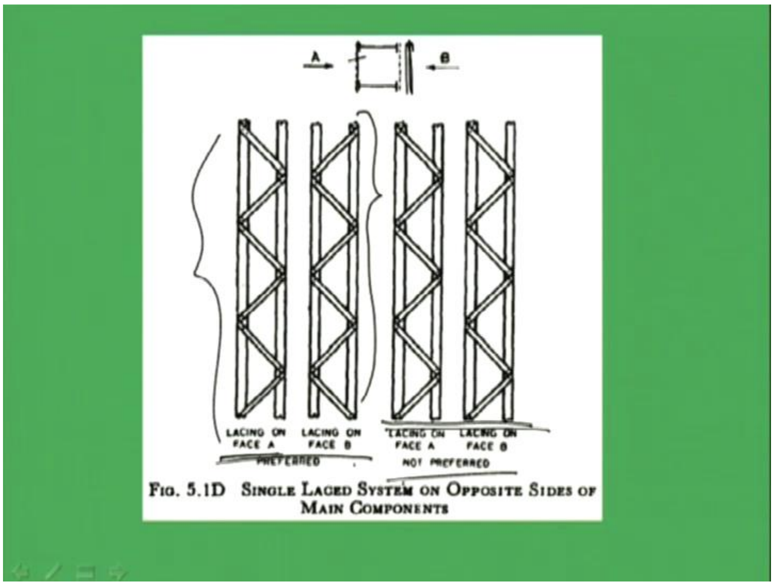

Single lacing system with AA side and this is BB side, right. Now, if lacing on face AA is like this, then lacing on face BB should be like this. Just opposite to this right, but not like this, not exactly similar. So, lacing system when we are providing the opposite side, lacing system should be matched like this, right. So, this is not preferred.

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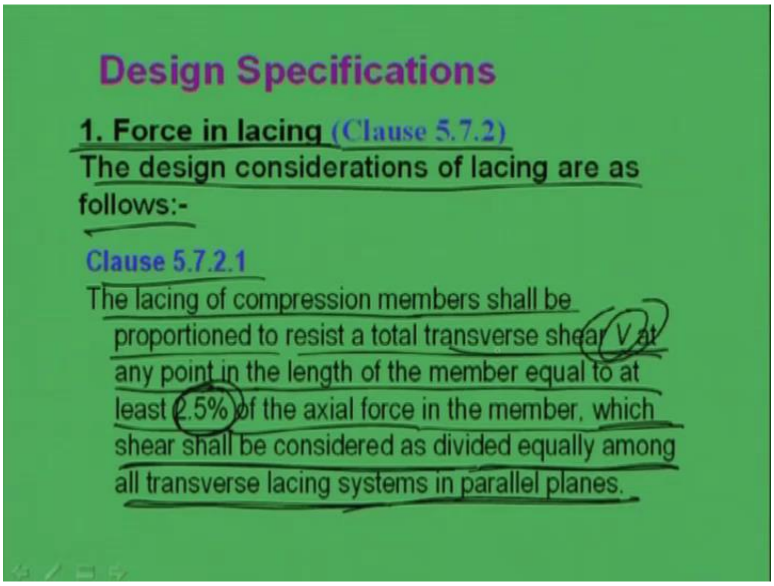

So, these are some general requirements which have been specified by the code. Now, we will see what are the design specification has been guided by the code. In IS 800 in clause 5.7.2, the design specifications in details have been given. So, before going to design, before going to enter into the design steps, first we have to know what the design specifications has been guided by the code and as per that we have to go through and we have to design step by step. So, in clause 5.7.2, the force how it has been calculated has been told that force is lacing, how the forces are coming and how it has been calculated.

The design considerations of lacing are as follows. That is one is means in clause 5.7.2.1, it is told that the lacing of compression members shall be proportion to resist a total transverse shear V at any point in the length of the member equal to at least 2.5 percent of the axial force in the member which shear shall be considered as divided equally among all transverse lacing systems in parallel planes. This will be clear when we will go through the example and when we will derive the equations, it will be clear. So, what we have seen that the transverse shear V at any point will be equal to 2.5 percent of the axial force in the member which shear shall be considered as divided equally among all transverse lacing systems in parallel planes. So, this we have to maintain.

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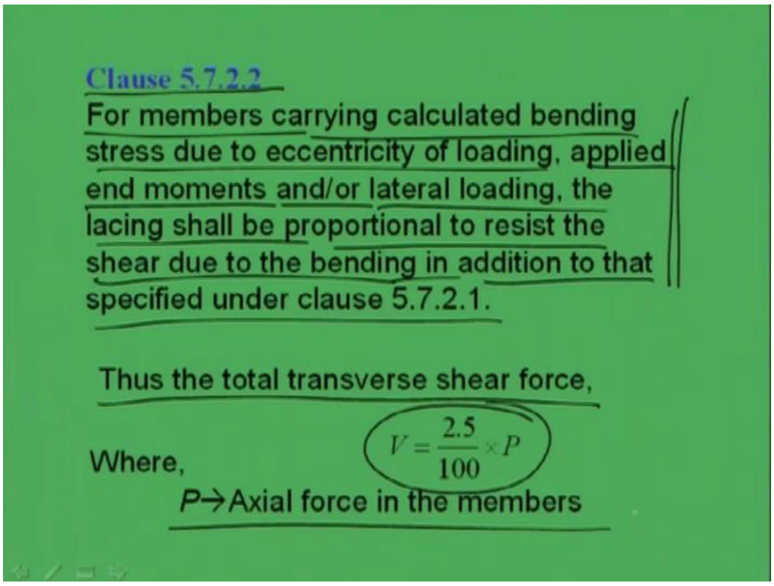

In clause 5.7.2.2 which told that for members carrying calculated bending stress due to eccentricity of loading applied end moments or lateral loading, the lacing shall be proportional to resist the shear due to the bending in addition to that specified under clause 5.7.2.1. That means in clause 5.7.2.1, we have specified that this 2.5 percent will be at least 2.5 percent of the axial force will be coming for as a transverse shear. In addition to that this clause has to be also followed. So, the total transverse shears as for the clause 5.7.2.1 will become this V is equal to 2.5 percent of the P, where P is the axial force in the member.

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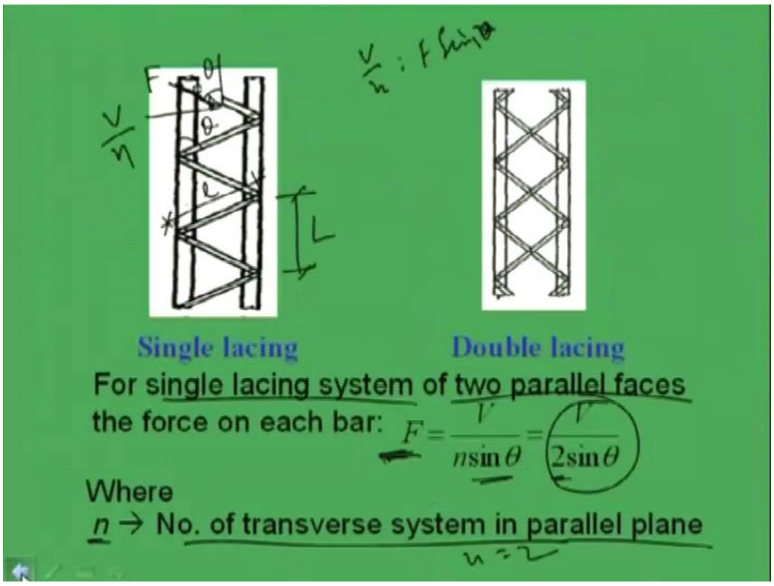

Now, we will calculate what the force is coming. For single system if we see how we look, we know this is called length L and the lacing length this is used to call L and the force which is coming, this is F, right. Now, this is theta. So, if we divide into this, this will be theta, right. So, now if this is F and if this is V by n. If we call where n is the number of transverse system in parallel plane, then we can write that F is equal to V by n by sin theta or V by n is equal to F sin theta. We can write V by n is equal to F sin theta, right. So, from that F can be calculated as V by n into sin theta and for single lacing system as there are two parallel faces. So, the force will be F is equal to V by 2 sin theta because n will become here 2. N is nothing, but the number of transverse system in parallel plane. So, for single lacing systems, this n will become 2. So, F we can find out from here that F is equal to V by 2 sin theta.

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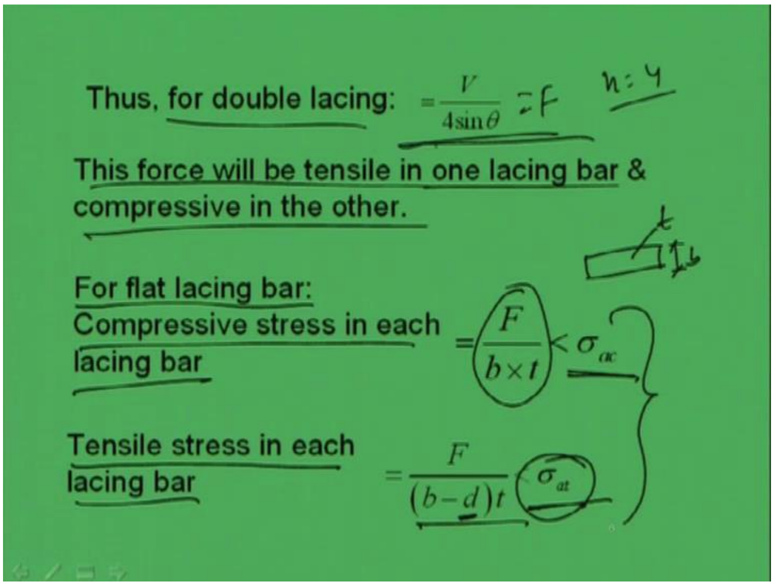

Similarly, for double lacing system, this n will become 4. Total 4 that is 2 into 2. So, V by 4 sin theta will become F. So, here F will become V by force sin theta. If we see the diagram, force diagram, we will see this is F and this will be V by n. Similarly, this is F and this is V by n and this is l and this is called sorry, this is L, right and this is theta. So, if we see V by n plus here also V by n. So, from this we can find out F is equal to V by 4 sin theta. So, this force will be tensile in one lacing bar and compressive in the other part because in one lacing bar, it will be tension. If it is tension, this is in compression. So, in one, it is tensile and in another, it is compression, right.

Now, for flat lacing bar, compressive stress in each lacing can be find out as F by b into t where b is the width of the bar and t is the thickness. If for flat lacing bar if this is V and if the thickness is t, then F by bt will be the compressive stress in each lacing bar and this has to be less than the allowable compressive stress which is sigma ac. Similarly, tensile stress in each lacing bar will become F by b minus d into t, and it should be less than sigma, where b is the width and d is the diameter of the rivet. That is why the net effective area will become b minus d into t, so that tensile stress will become F by b minus d into t and this should be less than the allowable tensile stress of the bar.

So, these two checks we have to do while designing the lacing system. That means the thickness and width of the lacing system has to be chosen in such a way that the stress developed in the lacing system has to be less than the sigma ac and sigma at, where sigma ac is the allowable compressive stress in the lacing bar and sigma at is the allowable tensile stress in the lacing bar. So, in this way we have to design it, right.

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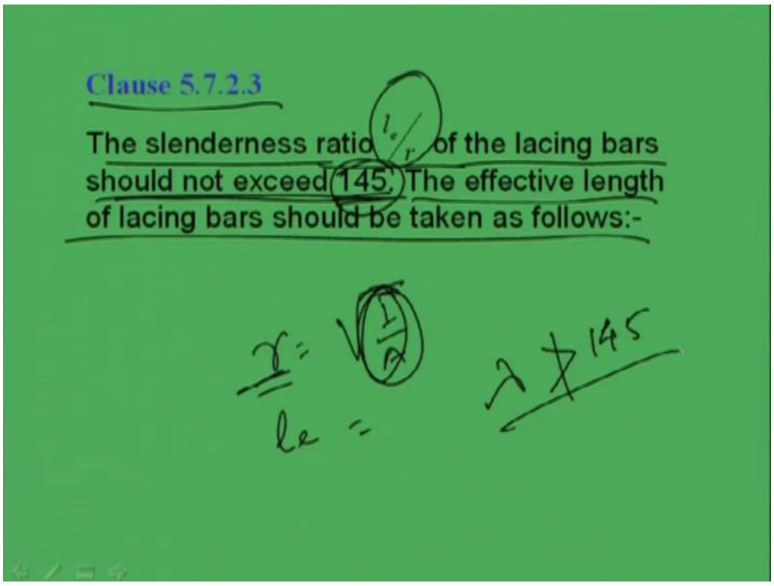

Another thing is in clause 5.7.2.3 which has been described that the slenderness ratio le by r of the lacing bars should not exceed 145, right. This is another codal provision which has been made by the code and the effective length of lacing bar should be taken as follows.

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Types of welding	Effective length (l_e)
Single lacing (Riveted at ends)	Length between inner end rivets on lacing bar *i.e.* ($l_e = l$)
Double lacing, (Riveted at ends & at intersections)	0.7 times the length between inner end rivets on lacing bars *i.e.* ($l_e = 0.7l$)
Welded lacing	0.7 time the distance between inner ends of effective lengths of welds at ends *i.e.* ($l_e = 0.7l$)

That means the effective lance depends on the type of welding or riveting. Suppose in case of single lacing system with riveted ends, the length will become effective. Length will become L, where L is equal to length between inner end rivets of lacing bar, right. So, effective length will be length between inner end rivets on lacing bar for single lacing riveted ends and for double lacing riveted at ends and at intersection in that case, it will be 0.7 times the length between inner end rivets on lacing bars, right. So, effective length le will become 0.7 into l, where l is nothing, but we have shown here. This is L, right. In this case for double lacing, this is the L.

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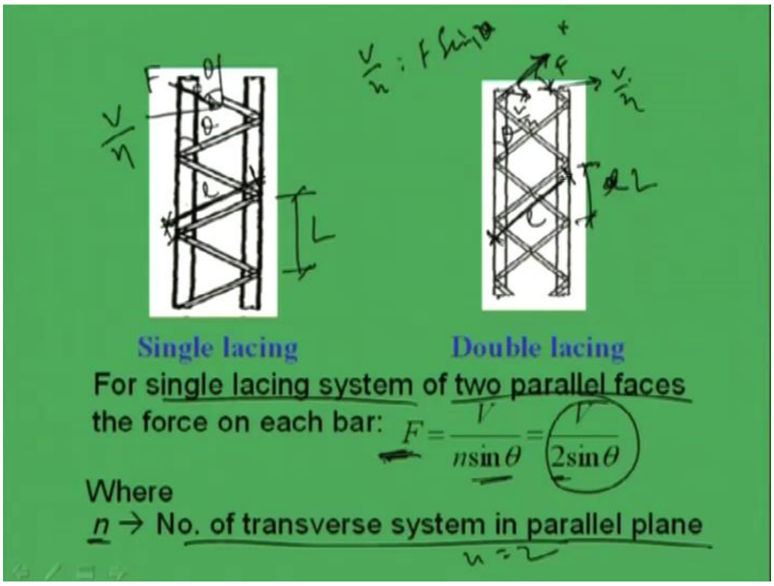

So, 0.7 times the length between inner end rivets on lacing bar and in case of welded lacing, this effective length will be 0.7 times the distance between inner ends of effective lengths of welds at ends. That means this will also be le is equal to 0.7 l. So, in this way we can find out the effective length. Why it is required? It is because the slenderness ratio has to be calculated from this length, effective length le by r. Now, we know r is nothing, but I by A of the lacing system and le we can find out from the table. Then, we have to see whether it is exceeding 145 or not and accordingly, we have to find out the dimension.

Accordingly, we have to find out the radius of gyration and if it is exceeding, then we have to change the dimension in such a way that we have to change the r in such a way that it should not exceed the slenderness ratio as 145. That means, lambda should not be exceeding 145 that has to be checked, right.

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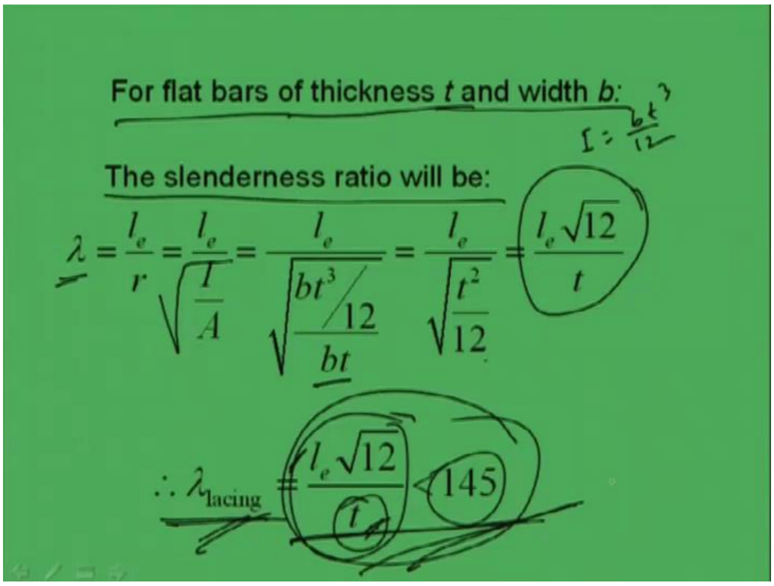

So, now for flat bars of thickness say t and width b, what the slenderness ratio will be that we can find out. Slenderness ratio is nothing, but le by r. Now, le by r means le by root over I by a, right. So, le by I means bt cube by 12 and area is bt Ie will be nothing, but b t cube by 12, right. So, if we divide bt, then this will become t square by 12. So, this will become le into root over 12 by t. That means, lambda lacing will be basically le into root over 12 by t which should be less 145. So, directly we can find out this. That means, the slenderness ratio does not depend on the width of the lacing. So, whether increasing or decreasing of the width of the lasing, it does not matter because we have to see what the thickness is and le more or less becomes fixed because of the spacing and angle of inclination.

So, what we can change is the t. If we increase the thickness of lacing system, then the lambda will decrease. So, if it is going to be more than 145, then what we have to do is we have to increase the thickness of the lacing, so that the slenderness ratio of the lacing become less than 145. So, from this we can make it. So, this is true for the flats bars, but for other system like say angle, if we use say angle section as a lacing bar or say channel section as a lacing bar, then we have to again calculate accordingly.

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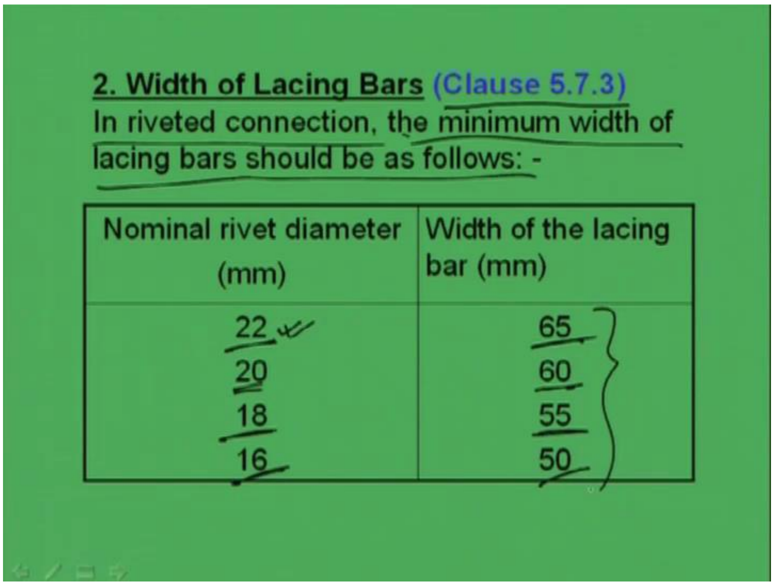

In clause 5.7.3, the width of lacing bar has been mentioned like in case of riveted connection, the minimum width of lacing bars should be as follow. That means if the nominal riveted diameter is 22, then width of lacing bar can be made as 65 millimeter minimum width. That means if it is 22 mm diameter, we are using the minimum width of the lacing should be 65 mm. If it is 20, then it is 60 mm. If the rivet diameter is 18, the width of the lacing bar will be 55. If the riveted diameter is 16, then the width minimum width of the lacing will be 50. So, these are the codal provision which has been given which has to be maintained while designing the lacing. That means the minimum width has to be find out from the nominal rivet diameter.

What type of rivet we are going to use we have to first see, and then we have to find out what is the minimum width. At least we have to provide for the lacing, then we can provide more or more than that if it is required, but we cannot give less than that as the codal provision has been given.

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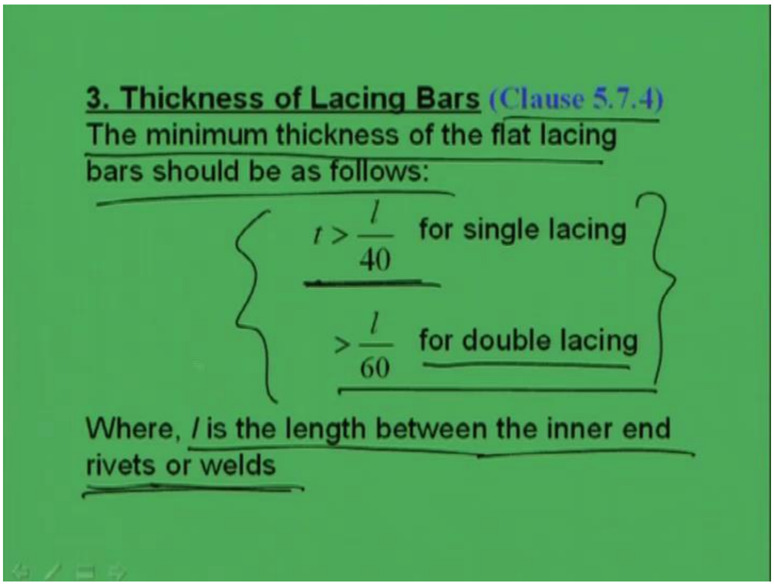

Another thing is in clause 5.7.4. The thickness of lacing bar has been given. The minimum thickness of the flat lacing bars should be as follows minimum thickness. How much it will be? That should be at least l by 40. It should be greater than l by 40 for single lacing, and for double lacing l by 60. So, this has to be also maintained. Earlier we have seen the slenderness ratio has to be maintained at 145. So, accordingly the thickness can be decided. Other aspect is that minimum thickness of the lacing bar has to be like this l by 40 in case of single lacing system, and l by 16 in case of double lacing system, where l is the length between the inner end rivets or welds. It is not the effective length. This is the length between the inner end rivets or welds. So, from this we can find out the thickness of the lacing bar.

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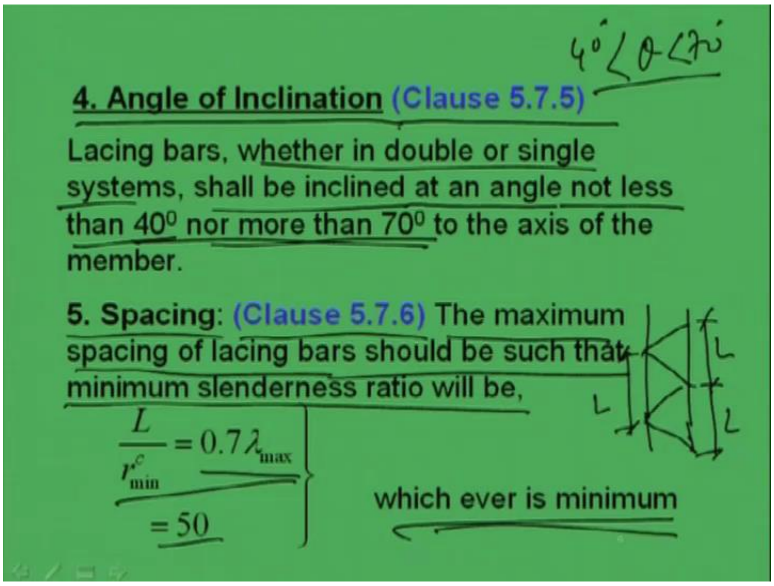

Another aspect is angle of inclination which is given in clause 5.7.5. So, angle of inclination can be in between 40 to 70 degree as for the clause 5.7.5. What is told is that lacing bars whether in double or single systems shall be inclined at an angle not less than 40 degrees and not more than 70 degrees. That means theta should be less than 70 degrees and should be greater than 40 degrees with this it has to be made. So, angle of inclination also has to be followed from the codal provisions. Another thing is the spacing which is given in clause 5.7.6. So, in the clause 5.7, it has been given step by step for different parameters. In IS 800, the parameters of the lacing has been given in clause 5.7 step by step which has to be maintained while designing a lacing systems.

Here in case of spacing what it is told that the maximum spacing of lacing bars should be such that minimum slenderness ratio will be this or this, whichever is minimum. That means L by rc minimum. What is L? As we have seen if the two main bars are there and if this is the lacing system, then this is called L. This is L, right. So, L by rc minimum should be equal to 0.7 lambda max or 50 whichever is minimum.

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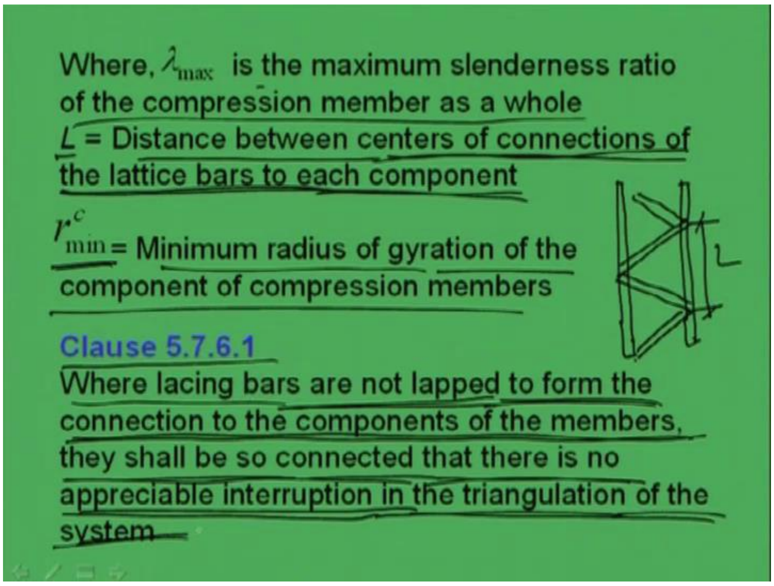

So, this also has to be maintained, where lambda max is the maximum slenderness ratio of the compression member as a whole lambda max is the maximum slenderness ratio of the compression member as a whole and L is the distance between centers of connections of the lattice bars to each components. That means if we see say suppose this is a main component and this is another component which has been say type by the lacing system, then what will happen? So, this and if I see like this, like this, then this will be L. So, L is the distance between centers of connections of the lattice bars to each components and rc minimum is the minimum radius of gyrations of the component of the compression member.

In clause 5.7.6.1, it is told that where lacing bars are not lapped to form the connection to the components of the members they shall be, so connected that there is no appreciable interruption in the triangulation of the system. I am repeating once again that where lacing bars are not lapped to form the connection to the components of the members they shall be, so connected that there is no appreciable interruption in the triangulation of the system.

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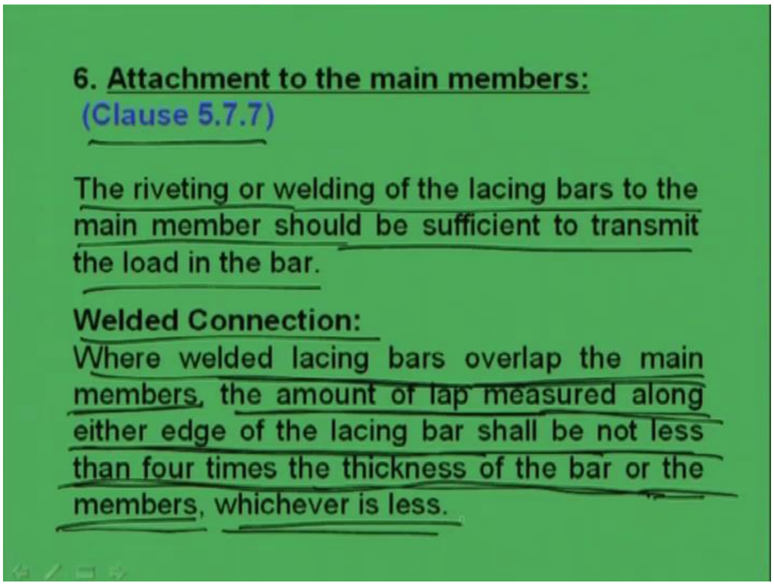

Now, the attachment to the main members means how it should be connected to the main members with the lacing system. That means connection between the lacing system and the main components. So, these connections may be of riveted connections or may be of welding connections. So, for that also the codal guidelines has been given which has to be maintained. In clause 5.7.7, it has been given. The riveting or welding of the lacing bars to the main member should be sufficient to transmit the load in the bar. So, riveting or welding should be sufficient, so that it can transmit the load.

For welded connection what are the guided lines that where welded lacing bars overlap the main member. The amount of lap measure along either edge of lacing bar shall be not less than four times the thickness of the bar or the members whichever is less. So, what it is telling that where welded lacing bars overlap the main members, the amount of lap measured along either edge of the lacing bar shall be not less than four times the thickness of the bar or the members whichever is less. So, in that way we have to follow.

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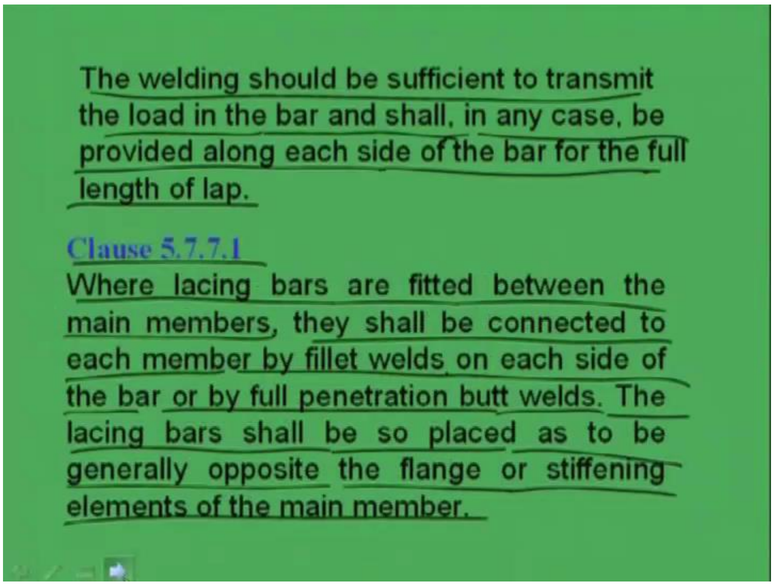

The welding should be sufficient to transmit the load in the bar and shall in any case be provided along each side of the bar for the full length of lap, and in clause 5.7.7.1, it is told that where lacing bars are fitted between the main members, they shall be connected to each member by fillet welds on each side of the bar or by full penetration butt welds. The lacing bars shall be so placed as to be generally opposite the flange or stiffening elements of the main member. If there is some confusion, I will suggest that you just go through the codal provision which has been given in IS 800.

In clause 5.7, in sub clause 5.7.1 to 5.7.7 or 8, it has been given systemically which has to be known by the reader, so that he or she can design properly. Before going to designed lacing system, we must know what the provisions are given by the code, what are the guidelines given by the code which has to be maintained. So, as per the guidelines if we follow, easily we can design lacing systems.

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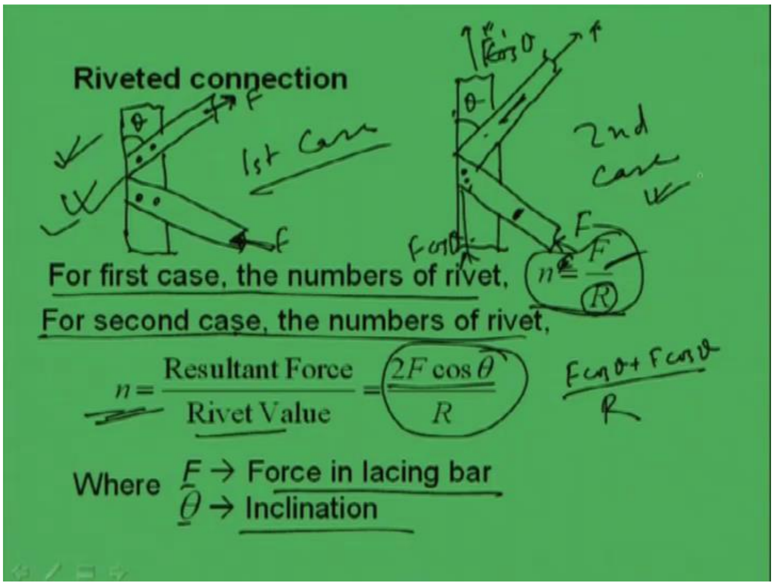

Now, for riveted connection say riveted connections of two types of cases can be as I am just repeating this one. A riveted connection can be made of two types. Let us see. First is say, lacing may be like this. It may go say one lacing is like this and another lacing is say like this and this is say F. This will be definitely F, right and this is the member, right. This is one type of connection where this is theta angle of inclination say we are providing the rivet here say for this, we are providing rivet here. So, for this the number of rivet can be found out from this n is equal to F by R, where F is the force exerted in the lacing bar whether it is tensile or compression and R is the rivet value.

So, from this we can find out number of rivet for the first case and another case of joint can be made in this way. Sorry, say this is F say other is this one. So, here we are going to put it. This is theta. Now, this is second case and this is first case. In second case what will happen? For second case the number of rivet can be find out from the resultant force by rivet value. Resultant force how much it will be? If we see if this is F, this will be F cos theta F cos theta and this will be also F cos theta, so 2 F cos theta. That means, F cos theta plus F cos theta for this for this vertical F cos theta and for this also vertically F cos theta component will come by R. That means 2 F cos theta by R, right whereas, for first case this will be n is equal to F by R and for the second case, n will be equal to 2 F cos theta by R, where F is the force in lacing bar and theta is the inclination.

So, what type of connections we are going to provide accordingly we can find out the number of rivets. In fact, from this we can find out which one is required less and accordingly we can provide the number of rivets. That means if for this case rivet is coming less, then what we can do is, we can follow this or if for this case the number of rivet is coming less, then we can follow this type of connections. So, which one will be economic which one will be easier that we have to see and accordingly, we can make it right.

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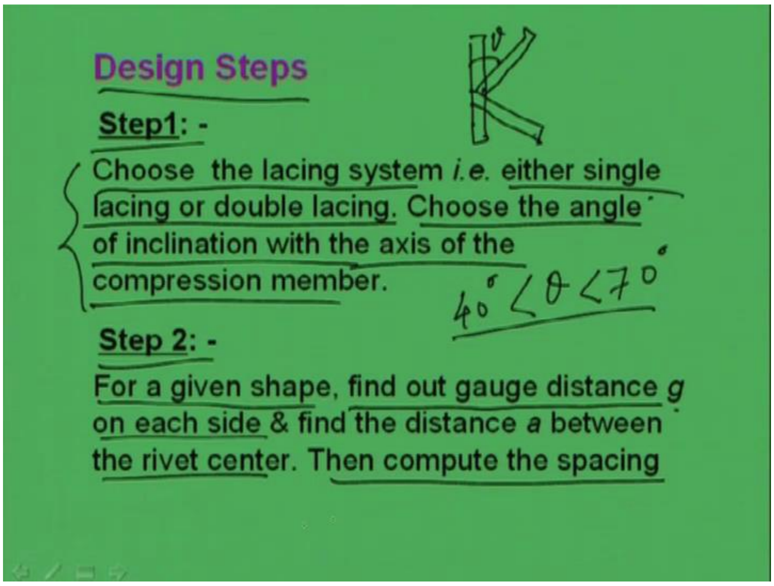

So far we have discussed about the detailed guidelines given by the code. In IS 800, it is explicitly described different aspects of the lacing parameters. Lacing parameters means lacing length, lacing spacing, and then lacing width. That means dimension width and thickness and angle of inclination. So, all these things can be find out from the codal provisions and when we will go for designing, we have to maintain all those codal provisions. So, keeping those things in mind, we will try to find the lacing parameters in a step by step method. So, now we will discuss about the design steps of the lacing system.

Step by step if we can remember, if we can start step by step, we can easily find out the whole parameters of the lacing systems. In design steps we are assuming that main component is already designed. So, accordingly we will go for the design of only the lacing components, right. So, let us come to the design steps. So, what will be the steps?

First step will be to choose the lacing system. That means either single lacing or double lacing first what we will do? We will first decide whether it is single lacing or double lacing. In fact, before that we will choose whether it is lacing system or battening system. That will come later, means when we should go for battening system when we should go for lacing system.

So, if we prefer lacing system as we told when the eccentricity is there, when the load is acting not concentrically, it is acting eccentrically for the compression member. So, in that case lacing system will be economic and will be better performing. So, the movement we are going to decide lacing system, next step will be whether single lacing or double lacing how we will decide. It basically can be decided by the experience of the design engineer. Design engineer if they see what the spacing of the built-up members means two members are there. If it is or four members are there what is the spacing in between and what is the load is coming, how much magnitude of load is coming into the compression member, what is the available size of the lacing bars or lacing member sections. So, on the basis of all those, he or she can assume whether we will go for single lacing or double lacing.

However, at this starting point, we can use either single or double lacing and accordingly the lacing dimension should come into picture. If we consider single lacing, lacing dimensions will come. Accordingly if we consider double lacing, dimension will be going to change, right. So, first step will be to choose the lacing system whether single or double lacing and then, choose the angle of inclination with the axis of the compression member. Angle of inclination means if this is the component. That means compression member and then we can see if this is the lacing. So, what is the angle of inclination? That is theta and that theta what codal provision has told theta should be less than 70 degrees and greater than 40 degrees. So, we have to choose a theta angle of inclination in between 40 to 70 degrees. This is first. Second step is for a given shape. Find out gauge distance g on each side and find the distance a between the rivet center and then compute the spacing I am coming.

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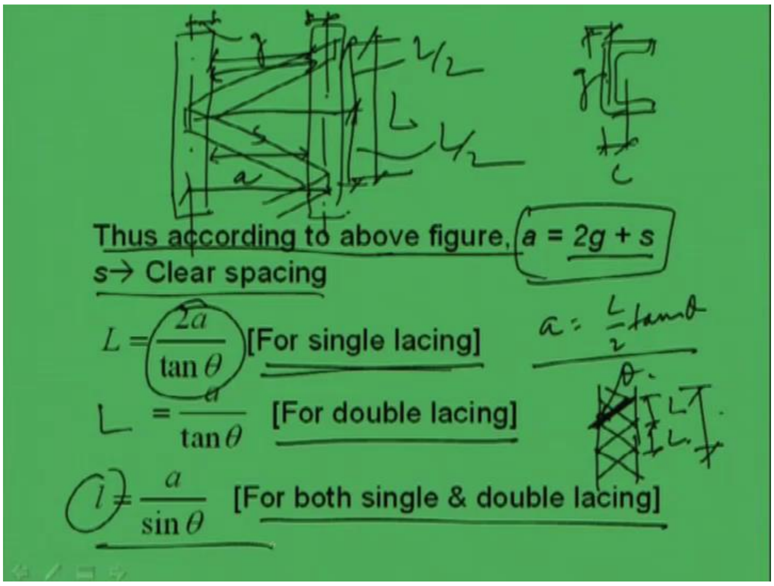

What is gauge distance? That is a distance I am giving here details. Suppose this is a member and this is another member. Now, this is called clear spacing, right. Now, if lacing is given like this, then the member has some gauge distance and this gauge distance can be find out from the handbook SP 6. From this we can find out gauge g which is given in the handbook. For particular channel section as we know say suppose this is a channel section which has been used as a main component, then we know what is the gauge distance and other things, sorry. What is the gauge distance? What is the CG? All these things we can find out. This is called gauge distance. So, this we can find out the moment we find out for a giving shape, the gauge distance. Then, we can find out also the distance between the rivet centers. That means this is called a, right.

So, what will be a? According to the above figure, this will be a is equal to 2 g plus s because this is g, this is g plus and this is s. So, 2 g plus s is where s is the clear spacing between two main components. So, from this we can find out, right. So, first step is to find out a which is 2 g plus s and then, we can find out L. What is L? This is L. So, L will be for single lacing. What will be L? L will become basically this is L by 2 and this will be L by 2. So, from this we can find out L is equal to 2 a by tan theta. That means, L by 2 is equal to a by tan theta or I can write a is equal to basically L by 2 tan theta.

So, from this we can find out a is equal to L by 2 tan theta. From this I can find out for single lacing system, this will be 2 a by tan theta and for double lacing system similarly we can find out because for double lacing system, what will happen is the L will be becoming half of that because in case of double lacing system, this is L, right. So, in case of single lacing system, this was the L, right. So, for double lacing system, L is becoming a by tan theta and for both single and double lacing, small l the length. That means this one will be a by sin theta because theta is this one. This is theta. So, we can find out l is equal to a by sin theta. So, the dimensions of different aspects we found.

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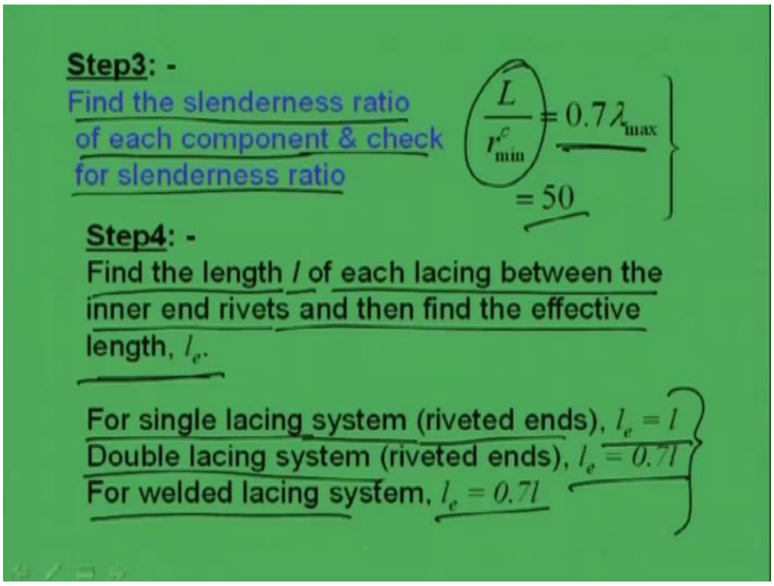

Next we have to find out the slenderness ratio of each component and check for slenderness ratio. That we will find out the slenderness ratio here and then, we will find out L by rc minimum whether it is becoming less than 0.7 lambda max or 50, we will see and we will take the minimum one. Then, what we will do in step 4? Find the length l of each lacing between inner end rivets and then, find the effective length. Effective length can be found out from what you call the table given earlier. So, from small one we can find out the effective length.

In fact, the table what it is told that for single lacing system with riveted ends, le will be equal to l and for double lacing systems with riveted ends, it will be 0.7 l and for in case of welding system also, this will be 0.7 l right. So, the effective length le can be found out from this.

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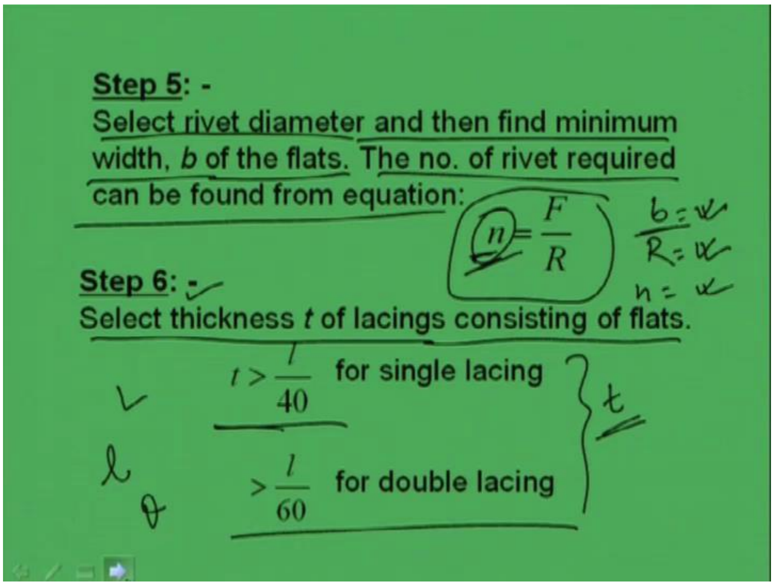

In step 5, what we will do? We will select some rivet diameter say whether it is 22 or 20 or 18 or whatever and then, on that basis we will find out the minimum width b. So, minimum width we can find out and then, the number of rivet required can be found out say n is equal to F by R. So, minimum width of the lacing will be find out, rivet value for a particular diameter of rivet can find out, then n can be find out, number of rivets and now number of rivets also depends means whether F by R or something else it depends, how it has been corrected. Earlier we have shown 2 F cos theta by R or F by R depends on the type of connections, how it has been arranged.

Then, in step 6 what we will do? We will find out the thickness. That means, minimum thickness of the lacing if it is a flat bar, that means t should be less than means greater than l by 40 at least for single lacing system and t should be greater than l by 16 for double lacing system. That also we have to ensure. So, what we are getting now the thickness of the lacing also has been found, width of the lacing we found, number of rivets we found. Earlier we found the length of the lacing system and the spacing of the lacing system and of course, angle of inclination has been already decided whether it is single lacing or double lacing that has also been first we have decided.

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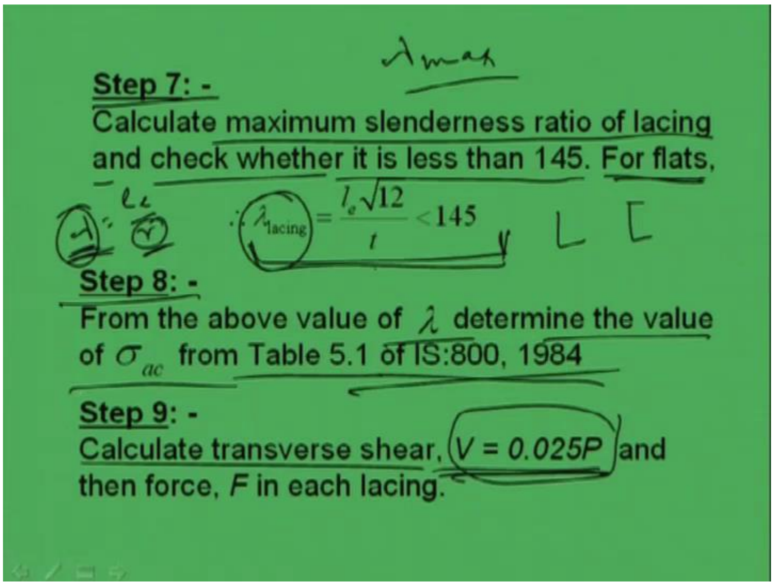

Now, in step 7, what we will do? We will find out the maximum slenderness ratio of lacing. Maximum slenderness ratio lambda max and check whether it is less than 145 or not and in case of flat bar, we can directly find out from this equation that lambda lacing will be equal to le into root over 12 by t which should be less than 145. So, lambda lacing can be found out from here. If it is angle section or channel section, means lacing member then we can find out the slenderness ratio from the equation le by r, and r is given in the code in the handbook SP 6 for a particular type of section, and with a particular dimension, the slenderness ratio in different direction has been given.

From that we have to find out what the maximum slenderness ratio is coming. That minimum radius of gyration we have to find out. From that we have to find out maximum slenderness ratio and then, whether that is becoming less than 145 or not, that you have to check. Then, what we will do? Then, in step 8 we will find out the allowable compressive stress of the lacing bar. Available compressive stress how do we find out? As you know that on the basic of the lambda we can find out from table 5.1 of IS: 800-1994 from table 5.1, we can find out sigma ac on the basis of lambda which has been calculated here. In case of lacing so from this I can find out. Next what we will do? Next we will calculate the transverse shear which is 2.5 percent of the compressive load. So, transverse share will be 0.05 P. So, from this I can find out.

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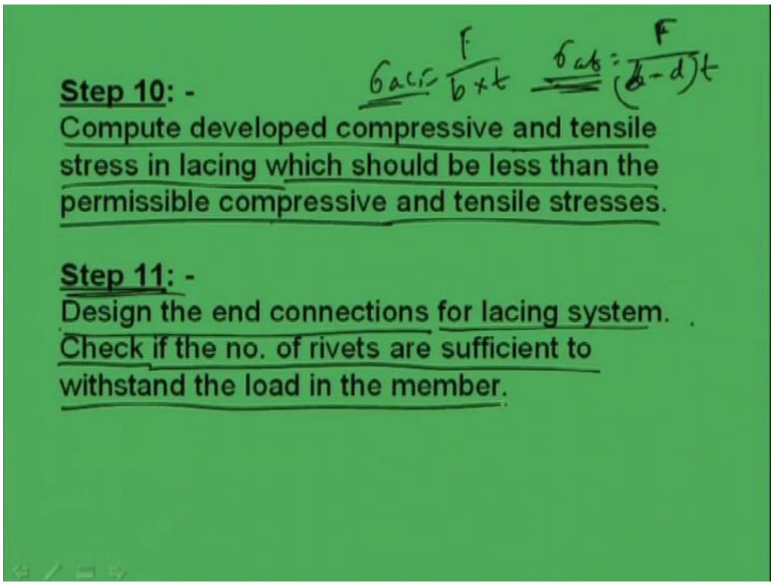

Next what we will do? Next we will compute that developed compressive and tensile stress that we know how to calculate. One is F by d into t. If it is a flat bar, this is sigma ac and sigma at will be F by d. Sorry, b into t b minus d into t, where b is b is the width of the lacing bar and t is thickness of the lacing bar in case of flat bar. So, from this we can find out the compressive stress and tensile stress in lacing which should be less than the permissible compressive and tensile stress which has been given. Permissible compressive stress we can find out from this table 5.1 on the basis of lambda and permissible tensile stress can be found out as 0.6 into a Fy. It is around 150 in case of 250 Fy still, right. So, we have to see whether it is or not. If it is not, then we have to increase the dimension if it is fine.

Next what we will do? Next we will go to step 11. That means the end connection design. So, design the end connections for lacing system and then, check if the numbers of rivets are sufficient to withstand the load in the member. Now, end connections will do we will check whether number of rivets which we have provided is sufficient to withstand the load of the member that we have to check. So, with these steps we have to design one by one. So, today the design procedures have been discussed. Next day we will be discussing, we will be working out one example through which we will be clear about the lacing systems.