Design of Masonry Structures
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Module - 04
Lecture - 24
Design of Masonry Components and Systems Part - III

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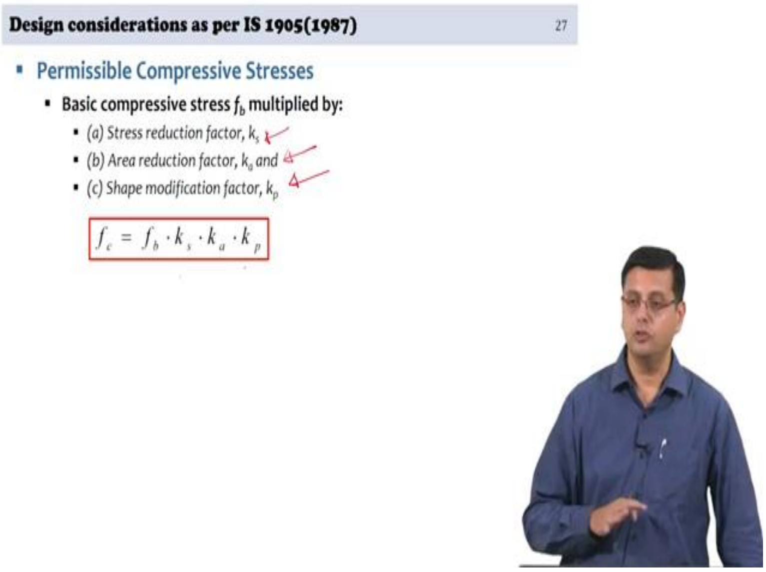

Good morning. So, we continue with design considerations as far as IS 1905 the working stress approach is concerned. So, in the last class we were actually looking at the basic compressive stress, I mean we were looking at the permissible compressive stress and how we arrive at the permissible compressive stress and where we stopped in the last class was to look at how the basic compressive stress is then factored using three important factors.

Well, the first factor is the most important factor, the stress reduction factor which accounts for slenderness ratio and the eccentricity ratio k_s followed by the area reduction factor because of the smallness of the area and finally, the shape modification factor to account for changes in the number of bed joints that might occur because of the way the bricks are being laid.

And finally, the permissible compressive stress f_c is the basic compressive stress which if you have test results we are looking at one quarter of the failure strength in compression of masonry or if you would like to choose a certain unit strength and a motor strength, the basic compressive stress is given to you in table 8 of the code.

So, use the basic compressive stress and reduce the basic compressive stress using the factors of course, among these k_s and k_a factors would be less than 1 whereas, the k_p factor would be greater than 1 and you arrive at the permissible compressive stress for the design that you are adopting. This permissible compressive stress is going to be different for different walls that is the that is something that you will realize when you start doing your design because each wall will have a different boundary conditions, different slenderness ratios.

So, the permissible compressive stress has to be arrived at for each configuration, each wall. So, that is as far as the permissible compressive stress is concerned. Again, working within the concept of the working stresses, the tensile stress- the permissible tensile stress has to be defined similarly; the permissible shear stress has to be defined and then you have the checks required for design ready.

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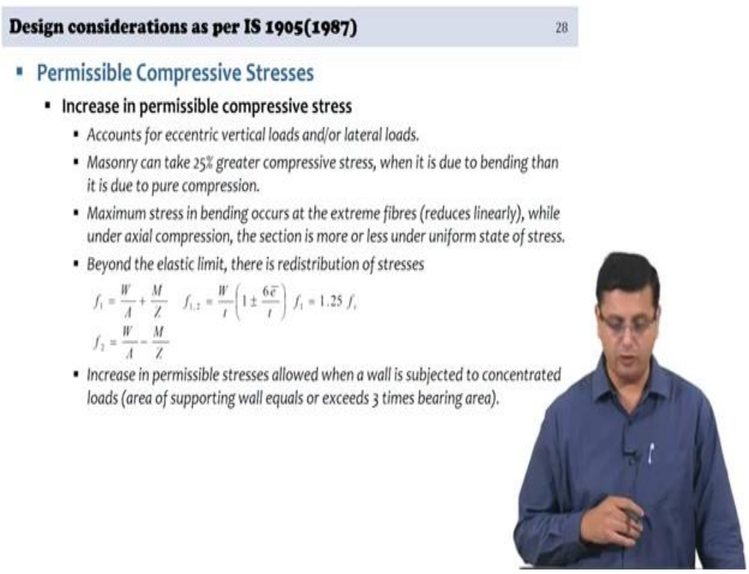

Now, the permissible compressive stress is increased is augmented under certain conditions ok. The code gives you the conditions under which you can increase the permissible compressive stress. One of the most important conditions is when you have significant eccentricity of the loads that you are considering; the vertical loads that you are considering.

When you have eccentricity, we were talking of a resultant eccentricity of the loads the compressive stresses are not uniform along the cross section you do not have uniform compressive stresses, you will have a gradient in the compressive stresses you will have lesser compressive stresses on one end of the cross section higher compressive stresses on the other end of the cross section.

So, when you have a gradient in the cross section, the wall cross section not being in uniform compression would mean that the entire cross section will not fail at the same instant, but the most compressed fiber the edge, that is most compressed would crush first whereas, the rest of the sections would have would not have crushed yet.

So, you will have a strain gradient with the edge compression fiber failing first whereas, rest of the cross section has not reached that value of the compressive stress. So, to account for this strain gradient effect, we allow for the masonry permissible compressive stress to be increased and it is increased to about 25 percent maximum. So, it basically accounts for the fact that under flexural compression masonry should be able to counteract higher compression loads.

So, masonry can take about 25 percent greater compressive stresses in flexural compression due to bending rather than due to pure compression. So, that is the first and probably the foremost reason why increase in permissible stresses is allowed. So, the strain gradient effect is what is accounted for in doing so, by increasing f_c by 1.25; 25 percent itself. Also; this is in a way implicitly accounting for some redistribution that will actually happen in this in the real case because of cracking and the stresses being redistributed in the active cross section of the masonry wall itself.

So, the code basically looks at low eccentricities when your eccentricities are less than about 1 in 24 of the cross section; eccentricities are between 1 in 24 to about one sixth of the cross section that is a critical limit as you know when you start getting tension beyond which you start getting tension with cross section and above one sixth of the cross section.

So, based on these categories when you have when you have the eccentricity greater than 1 in 24 you are allowed to account for increase in permissible stress by 25 percent. So, your two edge compression stresses have to be estimated edge 1 and edge 2 as f_1 and f_2

and then you increase the edge compression stress by 25 percent to account for flexural compression itself.

The code also allows increase in permissible compressive stress in other conditions, there is an appendix that is dedicated to different situations under which permissible stresses can be augmented. Another condition in which this is done is, when you have concentrated loads versus distributed loads. Concentrated loads, the bearing area being small the code again allows an increase in the permissible stress if you are working with concentrated loads as against distributed loads.

So, you can look at appendix C which has these specific conditions under which permissible stresses can be increased, but the two most important the first one being the strain gradient effect and the second one being when you have concentrated loads is what I have touched upon here ok.

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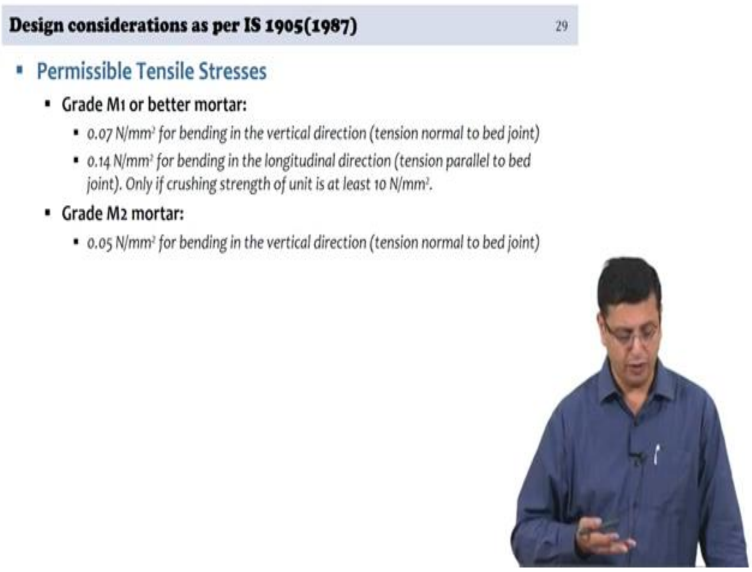

With that we also need to define permissible tensile stresses, as you know the masonry tensile strength is not something that is significant, the bed joint tensile strength is not something significant.

However, if a finite nonzero estimate of the permissible of the tensile strength is available you can then use it within your design and these values are small; however, can be used within the permissible stresses approach. So, if you are using a mortar grade that is M1 or better, M1 H 1 or H 2 grade mortars, then if you are looking at bending in the vertical direction. So, you are looking at the tension occurring normal to the bed joints right, when tension is acting normal to the bed joints, then the permissible tensile stress in the masonry is 0.07 MPa.

Now, in the same situation if you are still using M1 or better grade mortars then the tensile strength parallel to the bed joint here, you can use a value twice the earlier value. So, you can see that the tensile strength here that the permissible tensile stress parallel to the bed joint is kept twice as that of the permissible tensile stress perpendicular to the bed joint.

So, we were talking of the orthogonal strength ratio of the tensile strength parallel to the bed joint to the tensile strength perpendicular the bed joint typically being 2 that is still maintained in the code expressions as well. And you are allowed to use that increase-twice for the tensile strength parallel to the bed joint only if the unit strength is at least 10 MPa or 10 N/mm^2 .

So, that is the maximum permissible tensile stress that you can use, but if you are looking at weaker mortars, M2 mortar, then the value is typically lesser you are looking at 0.05 MPa for tension normal to the bed joint and double. And you use that as the only permissible stress if the mortar is of a lower grade M2 grade mortar.

So, permissible tensile stress is, you can make an estimate and use this. It is a small quantity and the difficulty in using a zero tensile strength condition is that, you will have to then ensure you have a cross section, a dimension which ensures the entire cross section is in compression. So, this small amount of tension that you can account for can help you overcome situations by small amount of tension is that is coming into your cross section and you can optimize the cross-section dimension itself.

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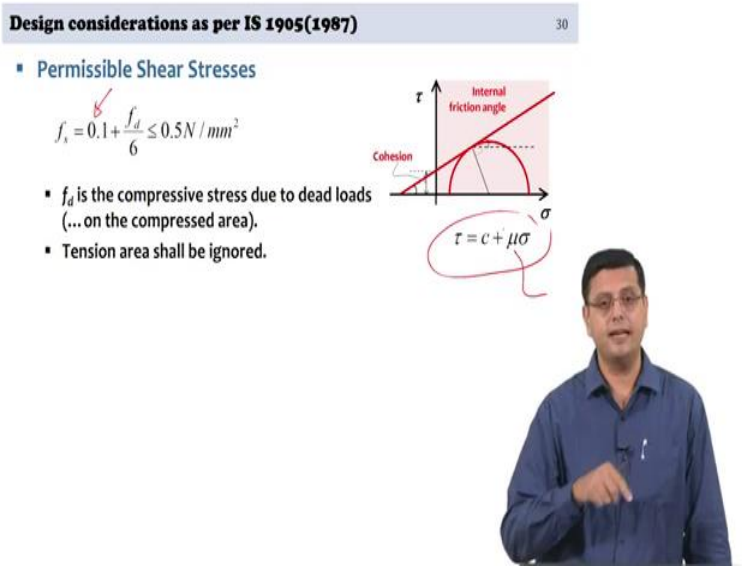

The third item is what we have seen earlier as far as the shear stress is concerned. In terms of the shear stress again the this is something we had seen when we looked at the material strengths that the format in which we are considering the shear strength is from a Mohr coulomb criterion; where the strength comes from the bond strength cohesion and the internal friction angle or the frictional resistance available given the type of material that you are using.

So, in this case we have seen earlier that the permissible shear stress in the code is f_s = 0.1 + f_d/6. Here 0.1 is the value that refers to the cohesion that you can get, the bond that is there between the unit and the mortar whereas, one-sixth into f_d where f_d is the compressive stress due to the dead loads only on the compressed area of the wall cross section you neglect area which is in tension.

And therefore, if you can actually compare this to the strength equation, we are talking of a value of frictional resistance, the coefficient of friction of about one sixth which is really small in comparison to what you will actually get in materials such as masonry 0.4 and above is what you would typically get in real conditions, but we are working within permissible stresses.

So, 0.1 referring to the cohesion and one-sixth referring to mu and the compressive stress on the compressed zone of the wall cross section has to be taken into account. So, you have the permissible compressive stress defined, you have the permissible tensile stress defined and the permissible shear stress defined. And if you see the three different definitions the permissible compressive stress is going to be different for different walls.

Because the wall configurations length and height would vary, the boundary conditions would vary and therefore, the slenderness ratios will change and the factor ks can change from wall to wall. The permissible tensile stresses will not change that is going to remain standard for the mix that you are looking at. Permissible shear stresses will also change permissible shear stresses will change because it depends on the compressive stress in the wall in that location that you are considering.

So, again permissible shear stresses have to be estimated wall by wall as the permissible compressive stresses. So, with this, you have the framework required for making the necessary checks to ensure that the stresses are within the permissible stresses for a combination of gravity and lateral forces acting on the wall acting on the structure itself, ok. With that there is one other aspect that I want to examine, which is the concept of arching action which is taken into account in masonry and the masonry code actually accounts for arching action.

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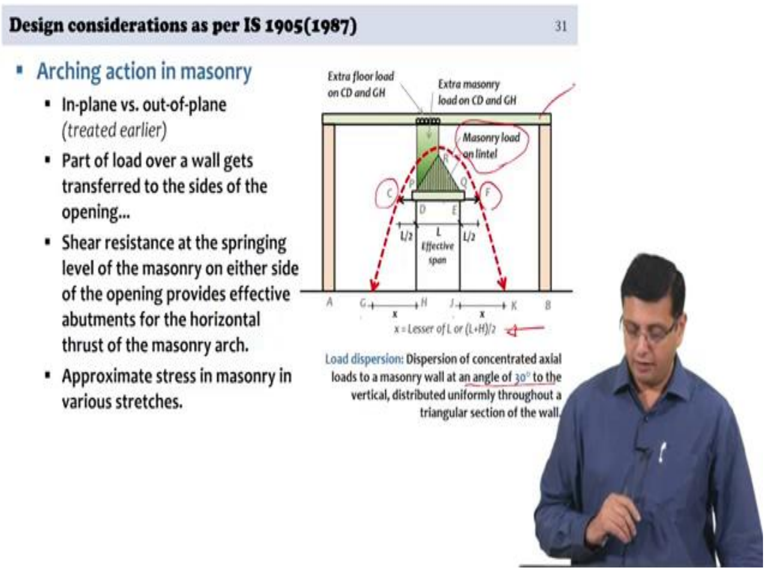

But this arching action is a little different from the arching action that we have seen earlier. So, we will we will spend a few minutes on this. The arching action that is being referred to in the code versus what we have seen earlier. We have seen earlier arching action occurring due to the out of plane deformation of the wall, an arching action allowing for greater out of plane load resistance of the wall. We looked at how due to the presence of non moving supports or rigid supports as a wall is laterally loaded by wind loads or inertial loads and when the walls starts deforming depending on whether you have gap or no gap between the supports and the wall, you can get additional clamping forces which increase the capacity of the wall; that is the arching action that we have seen so, far therefore it is in the out of plane direction.

What the code is talking about here is arching action occurring in the in-plane direction when you have openings in walls, ok. So, we will examine the first case, we will examine the case which is the in-plane arching action that occurs in masonry. The concept is more or less the same that you actually have a thrust line that is developing of the forces of the compressive forces which takes the form of an arch and allows for load resistance.

So, what really happens is, when you have an opening in a wall which is a vertical load carrying element, now does not have a continuity in the vertical load path. So, what happens to the load at that point? The load is then is it going to be completely carried by a lintel that you are going to provide over the opening or is the load actually going to get transferred to the sides of the opening? And if it does get transferred to the size of the opening what guarantees that action is actually what we are examining and the phenomenon that occurs is the arching action and under what conditions does this occur is what we are trying to examine.

So, let us look at this situation, we are looking at a wall as I said we are looking at the plane of the wall. And in the plane of the wall we have an opening, it is a door opening of a clear span L, and you have a lintel that is provided. So, every opening is typically provided with a lintel. Now, we will come to the design loads that we consider for the lintel; however, we look at the opening and the load that is actually present above the opening.

So, you have the spandrel of the masonry wall, you have the two piers on the two sides the spandrel of the masonry wall what happens to the load of that spandrel is the question. Now, if you have sufficient size, sufficient space on the two sides of the opening and that is an important requirement. If you have sufficient space on the two sides of an opening the load that is present above the opening can actually get completely transferred by forming a resultant of the vertical forces in the form of an arch and you get you get the possibility of forming this complete arch.

If this complete arch can be formed, then the load that is actually coming down to the opening gets diverted to the two sides. However, there are some geometrical constraints which have to be adhered to if this has to occur or not and that determines how much will you design the lintel itself for.

So, we are going to be examining that in under different conditions in a few minutes. So, what we are saying is the load that is sitting above the opening can get transferred to the sides and the two sides will then carry greater load than it was originally carrying. So, if you look at these stretches in the figure, these stretches at the bottom of the wall GH and JK will actually be carrying additional load and additional stresses now, in comparison to what the wall would have been carrying if the opening was not present right.

If I take the average stresses at the bottom of the wall A B, if there was no opening that would be lower than what the wall stresses would be in segments GH and JK if then an opening is present; which means the load now that is above this opening additionally gets diverted to these two segments GH and JK ok. However, there is a certain constraint on how much of space is available on the two sides. If you do not have sufficient space the arch cannot form and then you will not have load being resisted in the in the form of an arch or the arching action itself cannot be fully, you cannot fully depend on the arching action in case geometrically you do not have this sort of a configuration.

So, what is really happening is the load that is sitting on top of the opening is getting diverted and acts as a thrust in the form of an arch to the sides of the sides of the wall. This if you look at points C and point F those are almost like the springing points of the arch that is where the arch is formed and you have the springing points of the arch at those two locations, the additional vertical load which is getting diverted is acting in the form of a shear force on these two sides.

So, that is going to be the that is going to be taken care of by shear resistance available in the two sides of the arch itself right. So, you must have sufficient wall area on the two sides for that shear resistance to be provided for the arching action, for the arch profile itself to form. So, this is really what is what is happening the two sides of the wall are actually acting like abutments for a for an arch.

So, let us keep that mechanism in mind and examine different situations under which this can actually happen. So, this region over which the additional load above the opening is going to get transferred to the size of the wall, an estimate of how over what length are you going to get additional load and compressive stresses thereof can be estimated. So, if this length GH and JK are x then, it is approximately lesser of the effective span of the opening L or L + H (the inter storey height) divided by 2.

So, you can make an estimate over how much area would you see an increase in the compressive stresses? So, if you if you actually make a finite element model of such a such a configuration, you will see that region AG in the wall has compressive stresses almost unaffected by the opening as though it was just the plain wall the GH portion would have additional compressive stresses and that comes because of the formation of the arching action itself. It is going to be difficult to estimate from a design perspective how much is the compressive stress in AG, in GH, in JK and in KB we typically would then look at the stretch AH and have the compressive stress uniform in that stretch.

So, we approximate the stress in the stretches of the stretches of the wall. So, we approximate the stress it is not going to be easy to say this part has higher compressive stress and so, you make a make an estimate of what is the design requirement for that compressive stress, we approximate the stresses over the entire stretch ok. One important aspect that I would like to mention at this stage is, if you are looking at the load coming on the load distribution in a masonry wall from a concentrated load.

Let us assume that you have a beam sitting on a masonry wall, then the load distribution from the beam to the masonry wall is assumed to occur by a dispersion of 30 degrees from the vertical right it is an assumption that you take an angle of 30 degrees with the vertical you have a concentrated load the dispersion is at 30 degrees, 30 plus 30 is what will be the load dispersion is that concentrated load then becomes a uniformly distributed load at the at the plane of the masonry in the wall.

So, the code prescribes the use of 30 degrees there are some codes some studies that would take this value at 45 degrees, but then several studies have shown that it is better to take a value closer to 30 degrees. So, 30 degrees dispersion is what is typically used to look at the concentrated load being converted into a uniformly distributed load at the wall plane itself we use a similar estimate for the masonry load on a lintel as well.

We will come to that triangular this equilateral triangle that I am looking at, I will explain that in a moment. If arching action were actually going to happen; you have the geometrical condition for arching action to happen- that is sufficiently wide wall on either sides of the opening is available to you and the spandrel is also sufficiently high that is if you draw an equilateral triangle above the lintel and within the equilateral triangle you do not have other loads coming in.

We will look at a situation where there are other loads that that come in let us assume that the roof slab that is shown here at the top this green roof slab that is shown here at the top, assume that is really low and if that roof slab we are to interfere with the equilateral triangle above the opening then you have a disturbed situation.

But assume a situation where the roof slab is significantly away from the triangular from the apex of the triangle, this apex I mean this equilateral triangle is the only load for which you will have to design the lintel, the rest of the load above the opening gets transferred to the sides by arching action right. So, this arching phenomenon gives you the possibility of defining the load for which you will design the lintel itself yes. And therefore, if arching action is not occurring because of configuration you should know what to design the lintel for right. So, that is the criticality of this of this problem itself.

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I have this very interesting photograph that tells you what is arching action and what is the load that the lintel will carry. And this is from one of the site visits this is the Indira

Awas Yojana construction 6 meters by 4 meters construction using brick masonry and reinforced concrete floors you see that there is no lintel. Since there is no lintel you will have damage and damage in masonry, but it is very clear how the lintel should be designed only for that triangular load right.

So, if you had a lintel there the rest of the load whatever is coming on to the masonry above the opening has actually gone down to the sides by the arching action. So, this is this is arching action demonstrated to you thanks to no lintel being placed there; if there was a lintel we would not be we would not have been able to demonstrate this. In fact, very instructively you can actually see that there is a lintel on the other side and there is no crack there whereas, on this side there is a there is no lintel and there is a crack.

So, I think this picture will remain in your mind that is the load that you must design the lintel for if the conditions so, permit ok. And therefore, it is useful to examine what are the conditions that deviate from this and you should be careful in designing the lintel itself.

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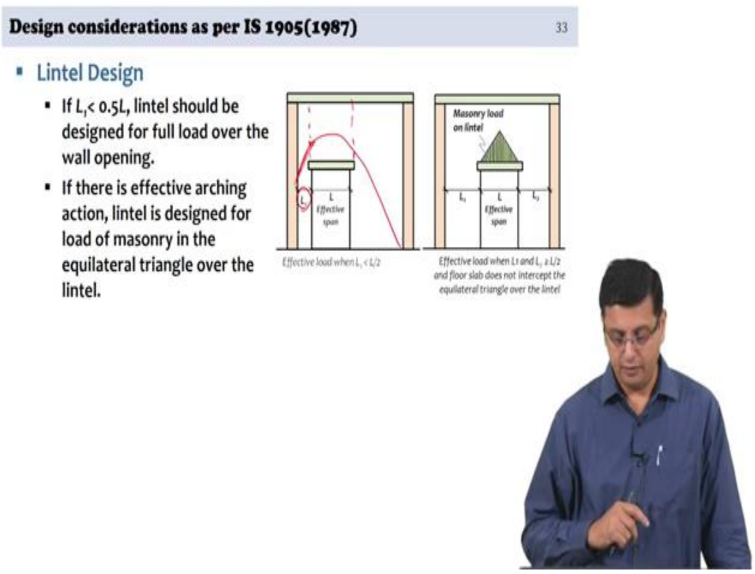

So, we look at a few conditions, if you do not have significant length on the two sides of the wall. If the two sides of the wall if you have an unsymmetric placement of the door opening or a window opening for that matter, then you should be careful to check how much of width of wall do you have.

And again, this is a prescription that is the length L $_1$, this length L $_1$ that we are looking at L $_1$ on one side and L $_2$ on the other should at least be half of the effective span of the opening itself. I case you have a situation where L $_1$ is less than half of L, the only option that you have is make an estimate of all the load that is coming right above the opening the load that actually is above the opening and design the lintel for all that load.

So, this is the important effect as far as the availability of geometry for arching action to develop or otherwise. And if you have L $_1$ and L $_2$ on the two sides such that L $_1$ and L $_2$ is greater than 0.5 L, you will have the possibility of the arching action the resultant arch forming and you can design the lintel just for the equilateral triangle. You can see that in the figure in the middle this first figure, the arch cannot form it gets interrupted.

If you try to put an arch there the arch gets interrupted that is the problem you if the arch gets interrupted you cannot it will not form a symmetrical load transfer mechanism and therefore, you cannot design the lintel only for the triangular load you have to design it for all the load sitting above the opening itself ok.

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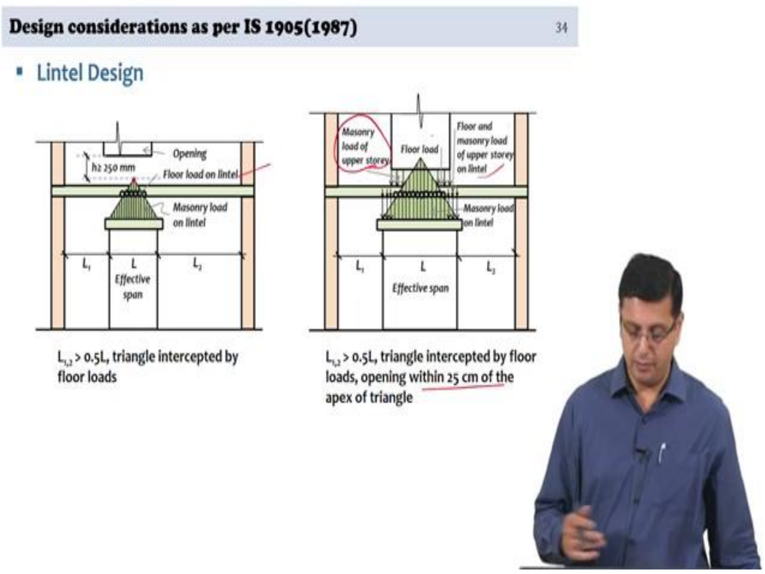

Some other conditions where the region that we are talking of, the equilateral triangular region that we are talking of can get disturbed. And if it gets disturbed in the sense if there are other loads that come within that area or under what conditions will you consider only the equilateral triangular area is what we will examine in a moment. So, let us see a situation where on both the sides of the opening you have significant lengths of walls. So, L_1 and L_2 are greater than 0.5 L requirement that we have.

So, arching action will develop. But however, arching action since arching action is developing you are actually looking at the triangular area above the lintel, but if the triangular area that you are examining is disturbed by certain other loads that come in to that region, then it is not only the masonry load that fits into the triangular equilateral triangle, but the additional loads that come into that area.

So, in this particular case you can see that the spandrel above the opening is not significant in it is dimension and the roof is the floor slab is rather low interest or height can be low, it can be as low as 2-2.3 meters and some constructions. So, in this particular case you have the floor load actually interfering with the equilateral triangle. So, once the equilateral triangle is established you will have to look at what is the magnitude of the floor load which is again a uniformly distributed load coming from the floor above, what is the floor load that actually sits within the equilateral triangle.

And design the lintel for that additional load, you then use the uniformly distributed load that you can see here coming from the floor load and transfer it to the design of the lintel itself. Again if you have in the floor above in the story above you have an opening that is occurring and you have masonry below the opening. Let us say you have window opening you have the masonry below the opening as long as the height of that opening is such that, the apex of the triangle the apex of the clutter triangle that you are looking at this point to the opening is 250 mm or more you can consider only the equilateral triangle.

If instead the opening is close to the apex, you will have to look at other loads as well coming from the floor and coming from the story above. So, two conditions here, one is that the floor itself is intercepting the equilateral triangle. So, you will consider the floor load of the portion intercepting the equilateral triangle as part of the design load for the lintel and you will consider only the floor load within this portion as long as the opening if any above is actually 250 mm or more from the apex of this equilateral triangle.

So, what is happening above in the above story is again arching action. You have an opening and there is arching action on to the size of the opening in the first story. So, if significant distance between the apex and the opening is not available, there is additional load that will actually come to the equilateral triangle which you are using to design the lintel in the ground storey.

Another situation where the opening above is also intercepting the equilateral triangle that you are examining. So, in this particular situation you have both the masonry load from the upper storey, a part of the load from the wall is actually carried you can see these arrows here, the masonry load of the upper storey is onto the masonry floor, that load of the masonry wall and the floor of the upper storey also will be transferred to the lintel; also will be transferred to the lintel below.

So, the floor load and the masonry wall load from the upper storey will also be transferred to the lintel and that is the that is the load that you are looking at here which is the portion that the equilateral triangle is covering as far as the upper story is concerned and then the part of the equilateral triangle which is in the ground storey itself. So, you should be able to account for all the loads that would be intercepted by the equilateral triangle in estimating the load coming on to the lintel.

So, what is important is for you to check whether the apex of the triangle to the bottom of the opening is within 25 centimeters or more. Again, this is an empirical requirement that is put. So, you will have to check the geometry to be able to estimate what additional loads would have to be considered for the design of the lintel itself.

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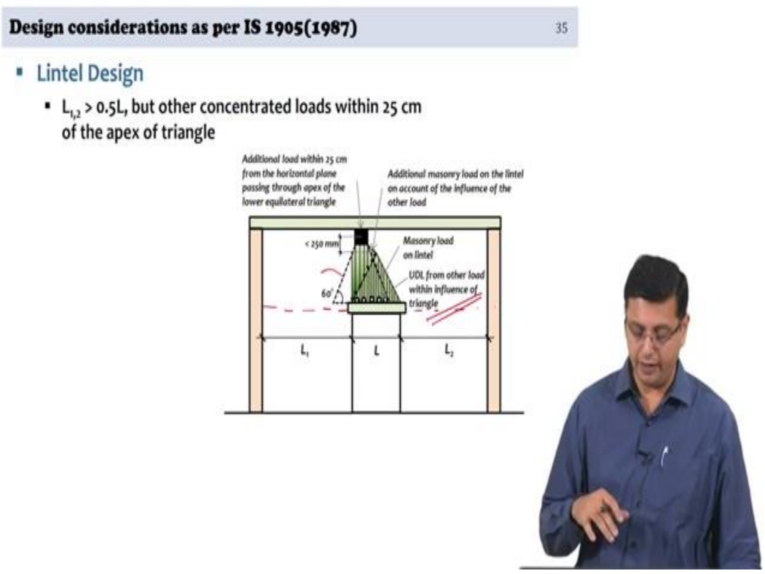

Now, you can have situations where in the same story you have additional loads that the wall is carrying and this actually is disturbing the zone above the opening ok. A simple case here is let us assume that you have beams reinforced concrete beams or a steel beam that is placed in the roof of the room, in the roof of the structure as part of the load carrying system and this beam is then supported on two walls. So, when you have this sort of a situation the black cross section that you see there is a beam that is coming and resting in the masonry wall. So, if you have that sort of a situation.

So, here we are considering the cross section and the centerline of this cross section, if the centerline of that cross section is actually less than 25 centimeters from the apex of the triangle that we were looking at, then additional loads from this concentrated load would have to be considered in the design of the lintel right. Now, if you have a distance more than 25 centimeters, then you need not consider; you will have enough of dispersion and the masonry will be able to carry the load. But if it is too close to this equilateral triangle the equilateral triangle area gets affected by the dispersion of the concentrated load.

So, depending on this gap between the centerline of the beam and the apex of the triangle, you will consider additional loads coming because of the dispersion of the loads from the concentrated force. So, the concentrated force needs to be converted to a uniformly distributed force with an angle of 30 degrees. So, what you see here is this triangle with the dotted lines is actually the dispersion of the concentrated load coming from the beam converted into a uniform distributed force.

If the apex of the triangle and the concentrated load are within 25 centimeters then the shaded region the green shaded region additionally is considered within the design of the lintel itself. So, this is the other condition which you need to check. So, the design of the tensile load resisting element, the bending element, the lintel has to be looked at carefully as far as the design is concerned. I would like to state at this stage that what we are talking about are cut lintels; just lintels which are provided for the opening with some bearing on either sides typically about 25 centimeters of bearing on either sides of the wall.

However, we have seen that it is it is requirement as far as IS 4326 is concerned that you provide horizontal seismic bands. And horizontal seismic bands at this level are extremely effective in earthquake resistance. So, this cut lintel would actually be effective not as a cut lintel, but as a continuous lintel running through all the load bearing walls and connecting them together. There are prescriptions for the cut, there are prescriptions for the lintel band; the amount of steel that you put in is actually very is nominal.

You have to be sure that when that lintel comes to a portion of the opening, you take care to check how much of loads should the lintel above the opening be designed for whereas, the remaining part of the lintel band the seismic band can have the minimum steel that is prescribed by IS 4326. You will see when we come to the detailing by IS 4326 that the steel that is prescribed for the lintel band is quite small; it is actually a tension resisting type; it is not a flexural element in reinforced concrete.

So, even if you are providing the seismic bands with steel and dimensions as prescribed in 4326 when it comes to the portions above the openings you would take care that it has the necessary design resistance to take into account loads in the triangular area above disturbed or undisturbed ok.

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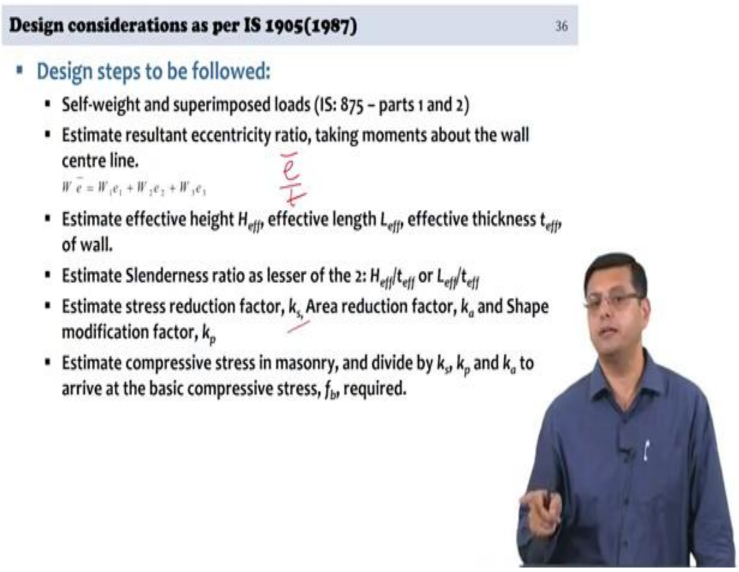

So, with that more or less the overall considerations as far as design with IS 1905 have been touched upon of course, there are many more intricacies which with some of the exercises you will be able to appreciate.

But I wanted to touch upon one little exercise if you were to design a masonry wall of a masonry structure, load bearing masonry structure- unreinforced masonry is what we are considering, let us take zone 2 structure seismic zone 2 structure then what are the steps that you will follow to arrive at the choice of cross section, choice of material for a wall. So, this is sequence of steps that we should be following.

Of course, I am assuming that we are looking at gravity forces here, but of course, 1893 would have to be considered if you are also working with earthquake forces and of course, and the wind load code also has to be considered, but assuming and looking at design of a single wall for gravity forces, get the estimate of the self-weight, get the estimate of the superimposed loads for which you might have to take use of prescriptions that come from the code that deals with loads IS 875 part one for dead loads and part 2 for imposed loads.

So, let us say you have been able to establish the different loads that are acting on the wall, you begin by making an estimate of course, it may or may not be a single load acting on the wall. If it is a single load acting on the wall with or without eccentricity that is a simple case for you, but if you have multiple loads acting on the wall then you will have to make an estimate of a weighted eccentricity of the load itself.

So, make an estimate of the resultant eccentricity ratio and here you can basically idealize the different loads acting on the wall with their respective eccentricities and take the moments about the centerline of the wall to arrive at annex at the resultant eccentricity. So, you could look at the total load W into the resultant eccentricity $\bar{e}$ as being from the moments about the centerline of the wall as W_1 one load into its eccentricity e_1 plus W_2 into e_2 and so, on and arrive at what e cap should be the resultant eccentricity.

$$\bar{e} = \frac{W_1 e_1 + W_2 e_2 + ...}{W}$$

Knowing the resultant eccentricity, start working with a cross section which comes from architectural considerations, let us say you are working with a 230 mm wall or 340 mm wall, then you have thickness with which you are working and you can get your eccentricity ratio which in this case would be $\bar{e}/t$.

So, you have eccentricity ratio established, your initial eccentricity ratio established; with the eccentricity ratio, with the plan configuration and the elevation of the wall based on the boundary conditions imposed by the ends the wall along the height and the edges of the wall in length, you will be able to estimate what the effective height of the wall is, what the effective length of the wall is and the effective thickness of the wall..

So, we have seen how three of these parameters have to be calculated. Once you make an estimate of $H_{effective}$, $L_{effective}$ and $t_{effective}$ you need to make an estimate of the slenderness ratio and the slenderness ratio airing on the conservative side we take the lesser of the two ratios $H_{effective}$ by $t_{effective}$ or $L_{effective}$ by $t_{effective}$. Once the slenderness ratio is arrived at you have the eccentricity ratio and the slenderness ratio you can now make an estimate of the stressed stress reduction factor k_s from table 9 that we were looking at earlier.

You estimate the stress reduction factor k_s and if applicable the area reduction factor to account for smallness of the cross section and the shape modification factor if the bricks are being laid in a different pattern. So, at this stage you have k_s, k_a and k_p. Once you have these three factors make an estimate of the compressive stress in masonry, because you know the total load acting on the masonry wall, you know the cross section of the masonry wall, make an estimate of the compressive stress. You make an estimate of the compressive stress and if you remember to arrive at the permissible compressive stresses f_s, we took f_b and multiplied f_b by k_s, k_a and k_p.

Here what you are doing going to do is you are making an estimate of the compressive stress from the demands acting on the wall and divide that by k_s, k_a and k_p. So, that you get an estimate of the basic compressive stress because you are designing now. So, make an estimate of the compressive stress due to the loads divide that value by k_s, k_a and k_p and get an estimate of what the basic compressive stress you require is in the design f b.

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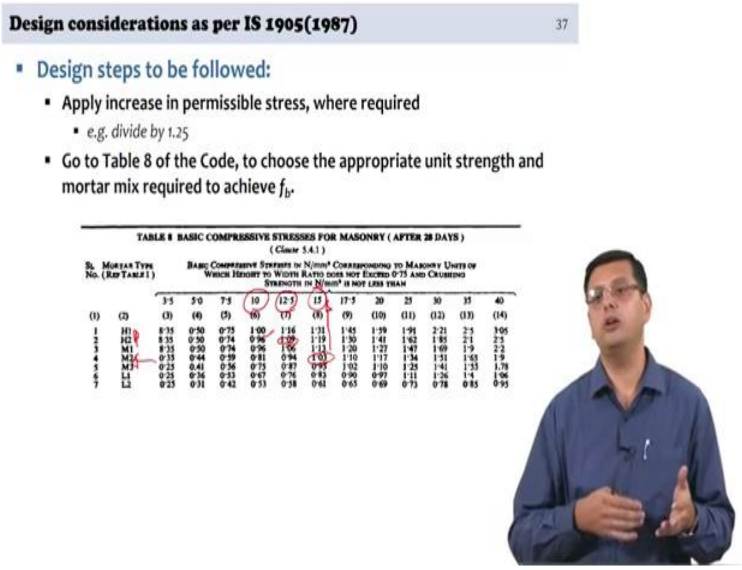

So, once you have the basic compressive stress, you need to check if permissible compressive stress in compression can be augmented particularly if you have a condition of eccentricity significant eccentricity you will apply an increase in the permissible compressive stress.

So, here what you would simply do is, you have arrived at the compressive stress divided by the reduction factors k_s, k_a and k_p you further divide that by in this case, increase in permissible stress due to eccentricity is allowed up to 25 percent. So, divide the value of the compressive stress that you get by 1.25 you get the basic compressive stress. So, we have looked at the permissible stress equation as f_s is equal to k_s, k_a and k_p multiplied in by f_b, we are now working the other way around and therefore, the demand stress is being divided by the stress reduction factors and also the increase in permissible stress that you can allow.

If it was on the permissible stress side f_c, the permissible compressive stress would be increased by 1.25 it would be f_c into 1.25, but now we are working on the other side and therefore, 1.25 goes to the left hand side of the equation. Once you have arrived that f_b the required basic compressive stress, you have two options you can either go directly to the table if you are not planning to do some tests in a in a laboratory, you can go to the code IS 1905, go to table 8.

And then in table 8 you can actually choose, let us say your basic compressive stress after the application of the stress reduction factors and after the application of the increase in permissible compressive stress works out to be about 1.03. Let us say you are somewhere there 1.03 MPa N/mm^2 then you actually have the possibility of going with an M2 mortar and a unit of strength 15. But then you have other constraints coming in there are several constraints one of the first constraints may be depending on the zone in which you are constructing, the earthquake zone and which are constructing you also have limitations on the mortar type that you will use.

So, you will you might not be able to choose some mortars you might have to go for higher mortars. So, then you start working with higher mortars and then see, is that can I go with 1.09 and then I can go with a 12.5 MPa brick or a 10 MPa brick with a H1 mortar. So, you have the possibility of now playing around because with f b established, you have this handle with which you will choose the mortar type and the unit strength.

But mind you are making this calculation for one wall; you will be repeating this for every wall which means you will have to have some rationality in terms of the final choice of compressive strength of unit and compressive strength of mortar, you cannot have different values for different parts of the structure. You might have some difference between what is used for the ground storeys versus what is used for the upper storeys, but in a given story changing these parameters mortar strength and unit strength is not practical.

So, you will have constraints coming in one from what the earthquake resistance code 4326 imposes in terms of what mortar you should use in which zone and the second would be the practical considerations of design as different walls are being designed in this manner right. So, this is the overall framework with which you will be designing each wall of course, for the same wall you will also check permissible tensile stress if the wall cross section is experiencing tension and for a combination of gravity and lateral forces if shear stresses are expected in the wall, you will also estimate the shear stress in the wall due to the demand and compare it against the permissible shear stress f_s.

So, that would complete the design checks that you make for a given wall itself. However, it is the compressive stress that will dictate your choice of unit and motor strength right. So, this brings us to the end of the approach to design as far as 1905 is concerned; the code does not prescribe anything more, it just gives you this basis with the requirement that some of the overall geometrical considerations be adhere to and the three stress levels- shear, compression and tension be checked and verified that they are within the permissible limits ok. I will stop here and we will continue our design problems in the next lecture.