Building Materials and Construction
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Module - 10
Lecture - 4
Masonry: Walls; Resistance against Load

In this lecture of module 10, we will look into again masonry walls resistance to load. And we shall look into today same strength of brickwork again vertical loading.

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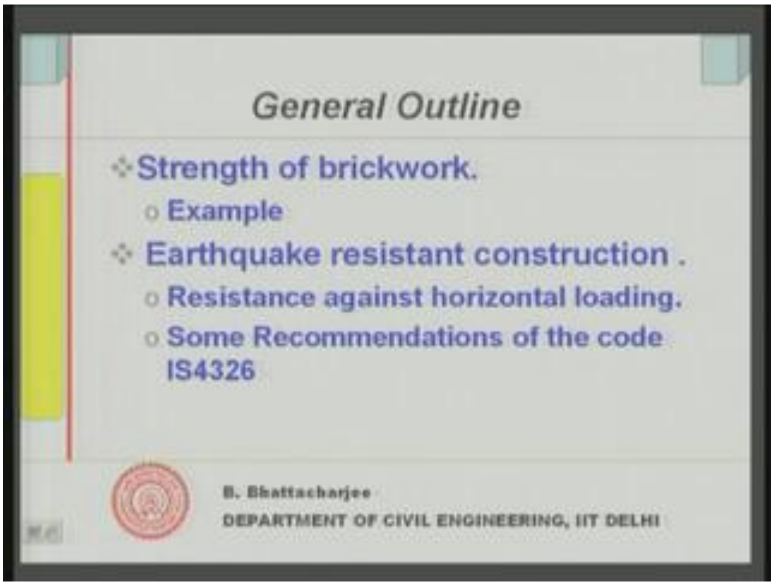

We will take up an example problem and solve it. On the basis of whatever you have done in the previous lectures, and then we will look into earthquake resistant construction. So, in this context first, we will look into resistance against horizontal loading. Some recommendation code IS code 4326 regarding earthquake resistance masonry construction.

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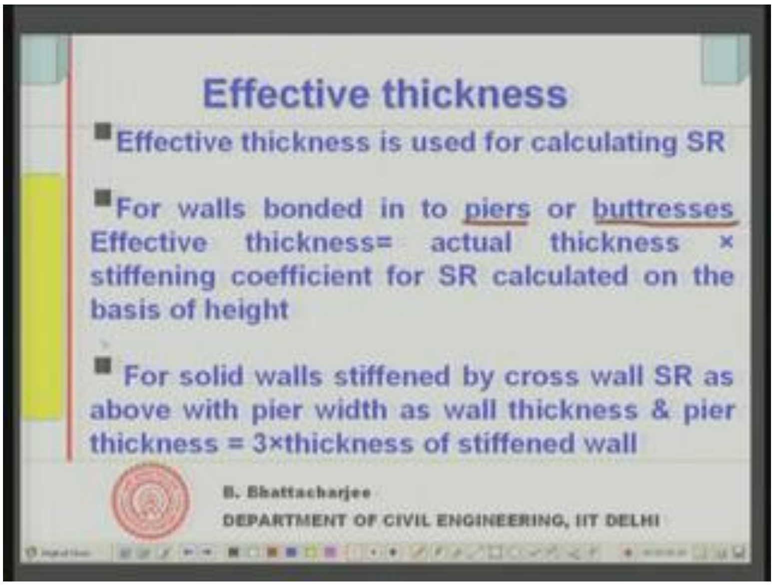

Now, one more issue we did not pick up earlier related to the load resistance to load of resistance to load of masonry structures effective thickness. Now, when we have, when you have strengthening of the wall through let us say: cross walls like cross walls or by piers or buttresses then the resistances against is provided by supports right. Hence what is done, what we do?

We actually take effectiveness thickness mode, because there is a resistance against buckling now, would become more because of something like pier; piers or because of something like piers or buttresses. Supposing, I have piers or buttresses you know they would actually provide resistance against buckling. We can understand this we can understand this. For example if we look at say this is your wall.

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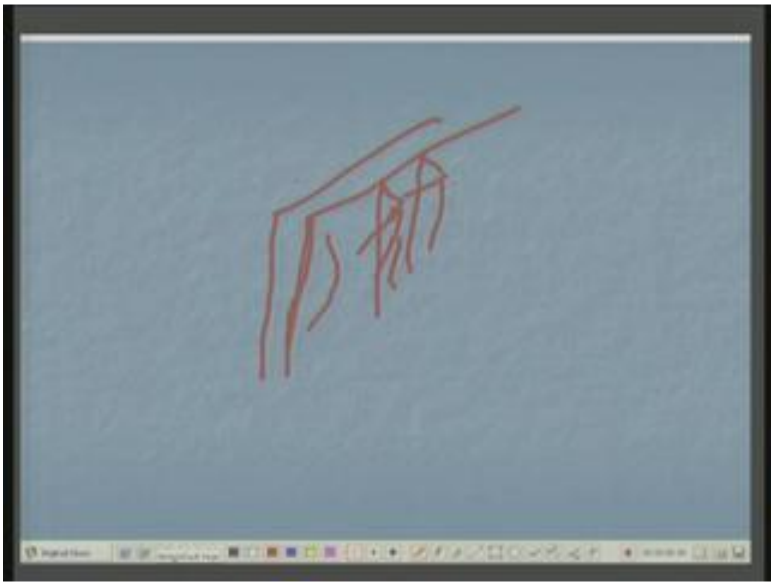

Let us say this is the thickness of your wall. Thickness of your wall right and I have somewhere you know this is the length or width of the wall and in between I have just thickened it up. Somewhere here I have thickened it up like this. This there is some thickening like you know, something of this kind let us say something of this kind I have thickened it. Let us say, in this manner and there is a thickness, I have thickened it up right. So, if I have provided additional material here; obviously, this will provide a kind of resistance against buckling about this.

For example plane if it is bending in this direction then there will be resistances against such buckling. So, that is what it is. So, when you have provide piers or buttresses effective thickness you know there is a resistance against buckling and what you do. We take the we can modify the slenderness ratio. We assume that slenderness ratio is less effective. Slenderness ratio is less and that we can do by considering effective thickness. So, we consider higher effective thickness which is actual thickness multiplied by stiffening coefficient.

Now, this stiffening coefficients are higher you know and for this is only meant for calculation of slenderness ratio right on the basis of height. So, when you have piers then piers or piers or buttresses or even cross walls, we actually its effect of slenderness will be reduce somewhat and this is taken care of by means of what is called stiffening coefficient. So, effective thickness is considered to be more than the actual thickness and we use a stiffening coefficient as a multiplying factor, and using that, we find out the effective thickness and that on that basis we calculate slenderness ratio.

For solid walls the stiffened cross walls you know solid walls which are actually cross walls cross walls effects as stiffening. Let us say cross walls then this has the you know, this we assume that this has got a same thickness. The thickness of the pier equivalent pier has got the same thickness as the wall thickness. If there is a cross wall it will have the same thickness pier thickness as wall thickness.

You know the stiffening portion will have same thickness as the wall thickness and width or the length or thickness you know, it is width will be same as the wall thickness, but its pier thickness of the pier is 3 times the thickness of the stiffened wall; the wall that has been stiffened, because you have a cross wall. This is actually relatively long. So, what we take up to the 3 times the thickness of the wall that is being stiffened we consider that as a pier. That is as a pier you know that as a pier thickness. This will be clear when you look something more right.

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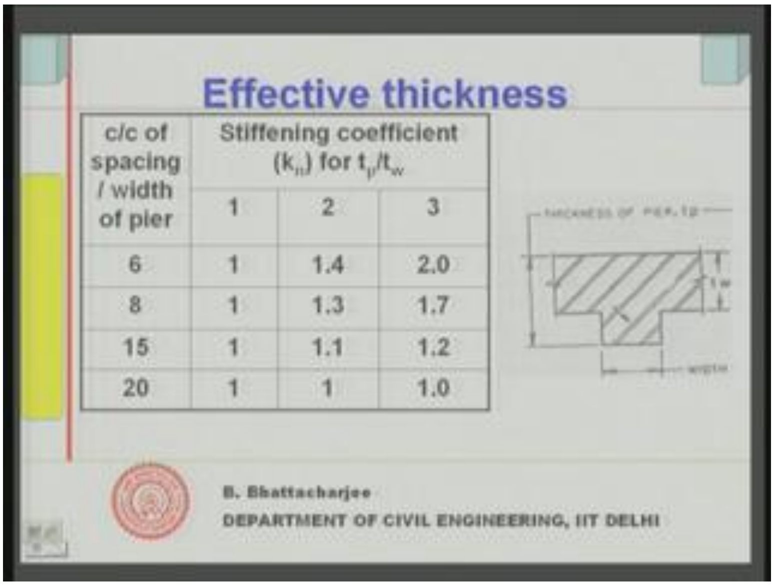

Now, code gives you an idea to actually idea of about this stiffening coefficient. It is recommended. For example when you have you know the basis is 2 things center spacing of the piers divided by the width of the pier. Now, what is width of the pier width of the pier is this 1. You know this now gives you a clear cut idea about what a pier is. Now, this is our main wall appearing something like this which is nothing, but a thickening of the wall at certain portion. So, when you have got uniform.

This is uniform throughout the height then I will call it as a pier and when it is possibly inclined in a retaining wall it will be like a buttress. So, these are stiffening mechanism by which what you are doing because this is a cross section of the wall.

As you see from top after cutting. Now, which means; that it will actually resist buckling right. So, effective thickness is now more, because some places my thicknesses are higher and that is why I find out effective thickness equals to some stiffening coefficient multiplied by the actual thickness of the wall. Actual thickness of the wall is T w. Thickness of the pier of course, here it is very clear cut. It is this much from this point to this point thickness of the pier that you call as t p.

Now, supposing it was a cross wall. Supposing it was a cross wall then would have supposing this was a cross wall instead, you know it was a cross wall instead then this you know it would have continued. In fact, it would have continuity of this wall. In that case we would have taken the thickness of the pier as 3 times the thickness of tw 3 times p w. We take 3 times the tw you know 3 times tw right. So, that is how we define width is here thickness of the wall thickness of the pier right, in case of cross wall it will be 3 times the tw and width of the width of the pier is this.

Now, this will have some spacing center to center you know there will be another pier somewhere there. So, this center to center spacing of the pier divided by, width of the pier divided by this right. If this increase as you can see this spacing is more spacing then; obviously, this effect will get reduced. If they are closely spaced this effect will increase for a given value. Given value of tp by tw what is tp by tw tp is this divided by tw is this that is thickness of the pier divided by thickness of the wall; thickness of the pier divided by thickness of the pier. So, if the thickness of the pier is 1 then of course, it is just no stiffening. So, all these values are 1. If it is 2; that means, this tp is twice the tw then this is the column and this is for if it is 3.

Now, this is this also corresponds to cross walls. This also corresponds to cross walls you know this will corresponds to cross walls. This corresponds to cross walls. So, what you can see is as the spacing increases; obviously, this value reduces. As the spacing is small this value spacing will with width of the pier is small. This value is higher. So, for a cross wall generally if the cross wall spacing is 6 times the thickness of the cross wall itself, then we will get a stiffening coefficient twice, because more close they are they would oppose the buckling more.

So, this table gives us the stiffening coefficient. We will denote it by k n and it is a function of tp by tw that is tp and tw and also spacing of the center to center spacing of the pier divided by width of the pier right. So, that is how we find out equivalent ratio. So, if you calculate equivalent randoms ratio, we will use this value. This stiffening coefficient values these values.

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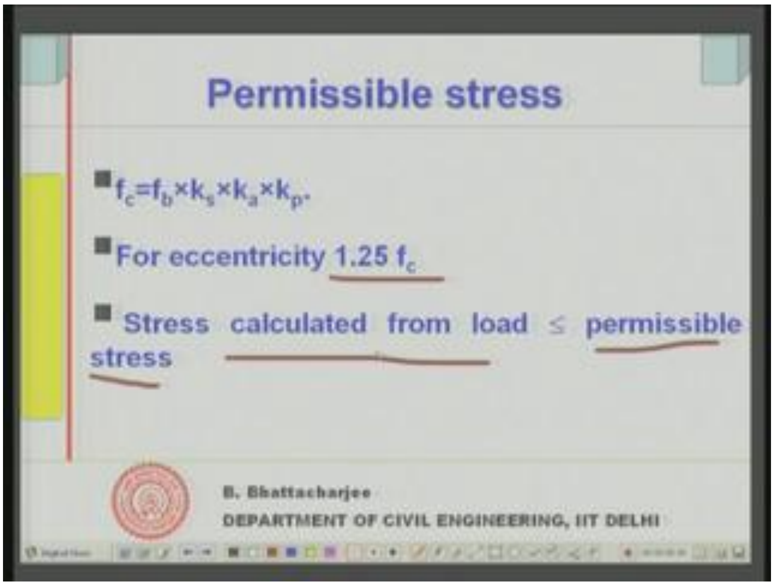

Now, we can look into now the complete permissible stresses. You know the permissible stress therefore, I can calculate out. First of all as the product of product of as a product of basic composite stress multiplied by a strength reduction factor due to stress reduction basic composite stress given in table a stress reduction factor due to slenderness and eccentricity. Now, here remember the slenderness I will calculate out based on the actual thickness multiplied by the stiffening coefficient. So, this would be smaller than 1, but depending upon the slenderness ratio, which might become lower; if I have a cross wall or things like that. This is a area reduction factor and this is we have seen that the shape modification factor.

So, that is how I can find out the permissible composite stress in brick wall and for eccentricity between 24 t by 24 and t by 6 I take, I can increase the I can increase the you know the permissible stress by 1.25 f c. Finally then I calculate the stress coming out from the load and this must be less than the you know permissible stress. Permissible stress it should not exceed the permissible stress it should be less than permissible stress. May be the factor of safety of course, is already taken into account of all this. So, that is what it is to have same.

Now, structural design of course, in involves calculating the stresses from load. In case of masonry it is also can be done. This we are not looking in this part of the this part you know this program, but what we are looking is how we calculate the resistance of the of the masonry you know which is more to us construction and materials. So, that is what we are looking at and therefore, we will see now take up an example calculation for calculation of permissible stresses.

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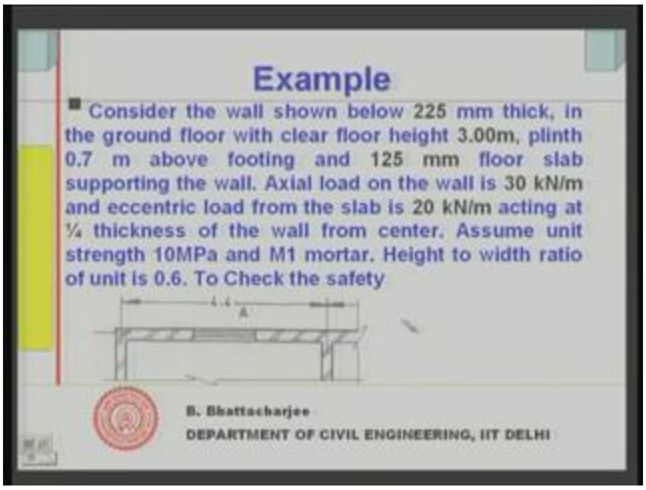

Now, consider a wall consider a wall you know which we will show you by figure 225 millimeter thick and is a in ground floor with a clear floor height of 30 meter plinth is 0.7 meter above footing and 125 millimeter floor slab supporting the wall. Axial load on the wall is thirty kilo Newton per meter and you know there is an eccentric load from the slab coming in from top. This must be coming in from the other floor top floor wall itself. So, this come from a slab acting at 1 fourth thickness we assuming of the wall from the center.

There is a way to actually estimate this and we assume also unit strength masonry unit strength ten MPa and M 1 mortar, we are using and height to width ratio of the unit is 0.6 to check the safety.

Let us see the wall section. The wall section looks like this I have a wall just I have taken a portion of the wall and you know this is the wall and there are cross walls 1 side is free. This side there is a continuity. This side cross wall. These are continuous and height is given as 3 meter and this distance is 4.4 meter.

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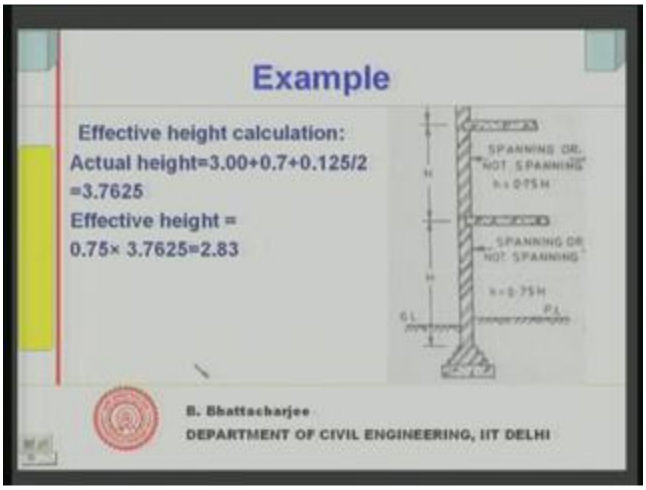

This distance is 4.4 meter and this is. So, we are going to check take this as an example and do calculation. First thing I do is effective height calculation because first thing I want to do is of course, I have to find out the what I have to find, I have to find out the basic composite stress and that depends upon the mortar and also depends upon the unit strength. That you know. So, we will look into later on, but next step would be to find out the stress reduction factor Area reduction factor shape modification factor etcetera.

So, first let us see what is the you know we want to find out what is the stress reduction factor and if, I want to find out the stress reduction factor as we have seen in 1 or 3 slides before. Stress reduction factor depends upon the slenderness ratio. So, we are we are now first interested in finding out what is the effective height. Now, this is the ground floor and this distance from footing to this height is h right and this is we have seen that this is equals to 3 meter, what is this.

This height is 3 meter you know this height is 3 meter. This is 3. This is this is 3. This is 3.0 up to this and this value is 0.7 this value is 0.7. So, 3.7 and take half the it has to go up to the centre of the thing. So, 3 meter was a clear height up to this as 3. So, this height is 1.125 divided by 2, because slab thickness is 1.525 divided by 2, because slab thickness is 1.525 divided by 2.

Now, if you have a situation like this, when it is supported by the concrete slab at the top you know. So, effective height you know will be 0.758. This is h. This will be 0.758 because this slab will be resisting its buckling in vertical plane right. So, effective height calculation actual height is this. This effective height is 0.7. So, this is what it is. This 2.3 is the effective height 2.2 is the effective height right, before I calculate out the slenderness ratio I must calculate out I must calculate out first the effective length also and effective length calculation is something like this. Effective length calculation is something like this.

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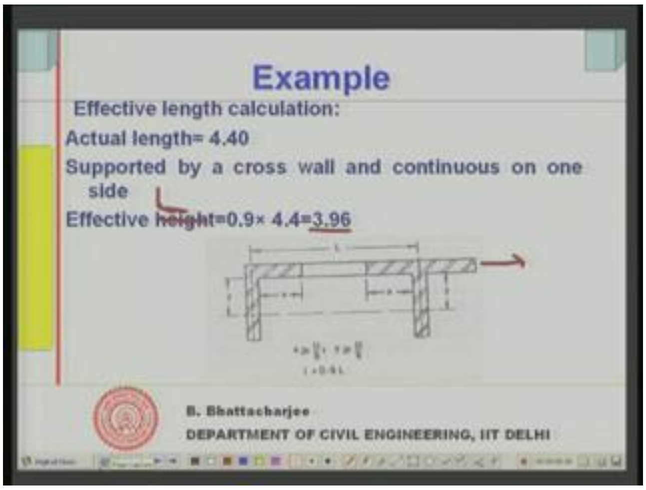

We know that actual length is 4.4 supported by cross walls. If you remember in the previous slides before when we have shown and its continuous on 1 side and free on other side. So, effective height will be given by this you know this follows. You know my wall looks like this from the first diagram this side is continuous. This side is continuous and this side is continuous. It is you know only its direction is continuous and its 1 side it is free and for situation, because these dimensions are greater than this.

This is you know this that was a window. So, pretty small and therefore, it is given as l equals to 0.9 L. So, 0.9 into 4.4 makes it 3.96. That is my effective height effective length this should be effective length actually this is effective length not height this should be effective length. So, effective length is given by 3.96 effective height is 2.83. That is what we have seen effective length is 3.96.

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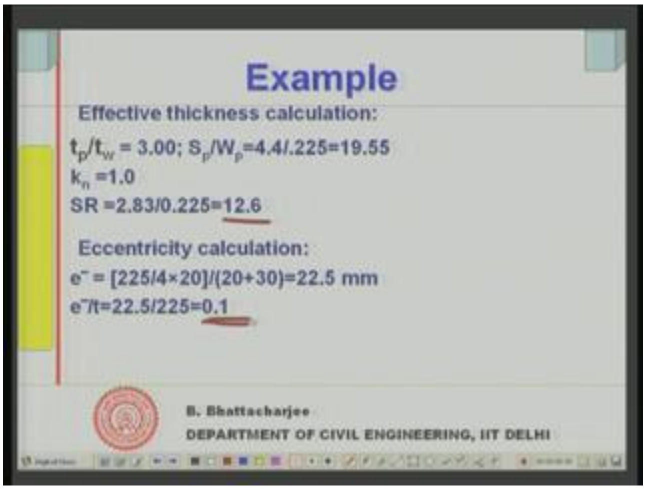

Therefore, I must now find out what is the effective thickness because I have crossed walls. Since I have crossed walls, I have effective thickness and simply this case is this case is tp by tw is 3, because the cross walls are continuous and for the cross walls. We take the thickness of the pier is equals to 3 times the thickness of the wall. So, this automatically comes out to 3 spacing is 4.4 because the wall is 4.4. So, 2 cross walls are there. So, since the spacing is you know spacing will be 4.4 divided by the thickness of the wall itself which is a thickness of the is the width of the pier which is the width of the pier.

So, width of the pier is the thickness of the wall itself the cross walls are also 225 we are assuming. So, this value comes out to be 19.55 and if you have seen in the previous table we will find that above 20 above this value of 20 actually stiffening effect is not you know when this spacing is very large stiffening of width is not there. So, k n is simply equals to 1. So, much slenderness ratio therefore, 2.83 divided by 0.25 is 12.6, because I am taking 2.83 instead of 3.9 which came as effective length whichever is lower I should select that remember, in the last lecture.

We said whichever is lower we should be selecting that why, because it is the resistance provided to buckling by either the either the vertical supports or the horizontal supports and as an empirical or simplified measure, we take whichever is the smaller because we really cannot estimate this resistances this resistances it becomes difficult. So, therefore, we take this ratio as the least of the 2 and in this case it is 2.83 divided by 2.25. So, 2.58

and it comes out to 12.6. Let us look at eccentricity, because we said the load is eccentric.

So, equivalent eccentricity we calculate how do we calculate it out, first we you know our eccentricity is given as 2.25 by 4 1 fourth of the. So, this is in millimeter 2.24 by 4 millimeter multiplied by the 20 kilo Newton that was acting 20 kilo Newton is eccentric load divided by the total load 20 plus 30, because in our example we said that it is loaded by loaded with 20 kilo Newton eccentrically load at 1 fourth of the thickness of the wall. So, 1 fourth thickness is the distance 1 fourth away from the center which will be 1 fourth away from one of the phases as well.

So, if something like this it will be something like this if this is my wall at you know at this of course, this is what is acting 30 kilo Newton acting is thirty and at 1 fourth of the wall is acting 20 it is acting 20. So, therefore, this is the actually the eccentricity which is 225 divided by 4 divided by 4 25 divided by 425 divided by 4. So, effective eccentricity I will find out. This 225 divided by 4 multiplied by 20 divided by 20 plus 30, which comes out to be 20.25 millimeter which comes out to be 20.25 millimeter, which comes out to be 225 millimeter. It comes out to be 225 millimeter, so e by t. Now, you can see is equals to 225 divided by 225 millimeter is equals to 0.1. So, effective you know ratio of effective eccentricity divided by the thickness of the wall is 0.1. So, 2 things I have got. So, now let us assume and the effective eccentricity. Now, I can calculate out the stress reduction factor from this. Stress reduction factor from this you know and if you remember we can go back to the table that was meant for stress reduction factor. Now, my slenderness ratio is 12.6.

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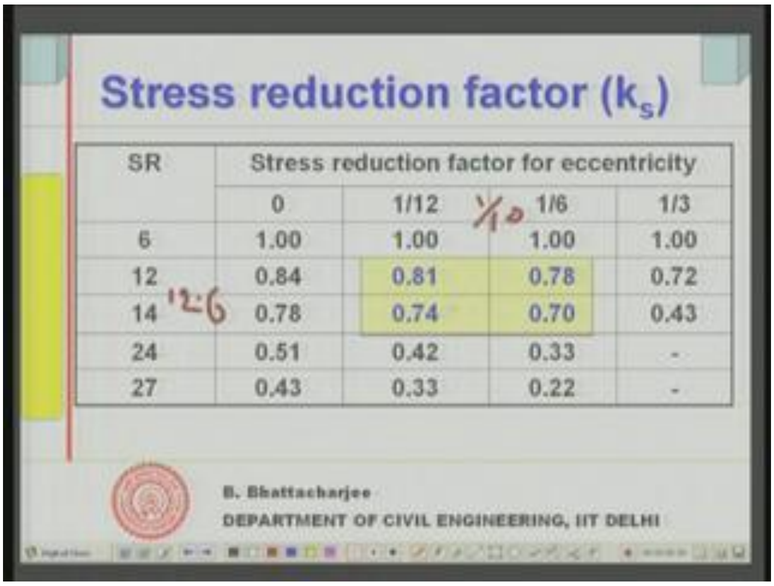

So, between 12 and 14 and my uh e over t e bar over t is 0.1. So, this is 1 by 12.1 is 1 by 10 0.1 is 1 by 10 and 1 by 6. So, in between these 2 so I can do actually the interpolation between this 4, I can do interpolation between these 4 you know because 12 and 14 deliberately have put. Now, 14 the earlier when I showed parts of the table that part did not contain fourteen in one of the lectures, but this lecture had got with this. So, that we can interpolate between these 2 and these 2 and again interpolate between these 2 to find out the stress reduction factor for our case, which has got SR equals to 12.6. Our case SR is equals to 12.6 actually somewhere in between. This is 12.6 and here actually this is 1 by 10 1 by 10.

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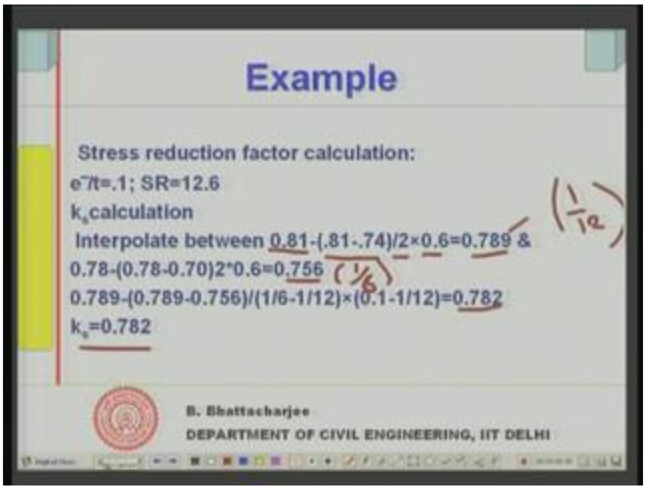

So, I will interpolate between these 4 to get the stress reduction factor. Stress reduction factor and if we interpolate it comes out to be something like this e by t is 0.1. Interpolation between this will be you know interpolation between this will be 0.81 as we have seen 0.81 minus 0.74, because the gap was between 12 and 14 divided by 2 and 12.6 is 0.6. So, this is 789 and interpolation between, the you know between 12 and 14 slenderness ratio for 12.6 I get corresponds to 1.6.

So, this is 1 by 6. This value corresponds to the k s for e by t equals to 1 by 6. This value corresponds to you know 1 by 12. E by t equals to e bar by t equals to 1 by 12. So, this 1 by 12 this for 1 by 6, I want to find out for 1 by 10 7.89 and 756, I just interpolate between these 2 and for 0.1 and I get the value equals to 782, I get the value equals to 0.782. So, by this time interpolation I can find out what is the value of the k s. So, that is how you find out k s in this manner.

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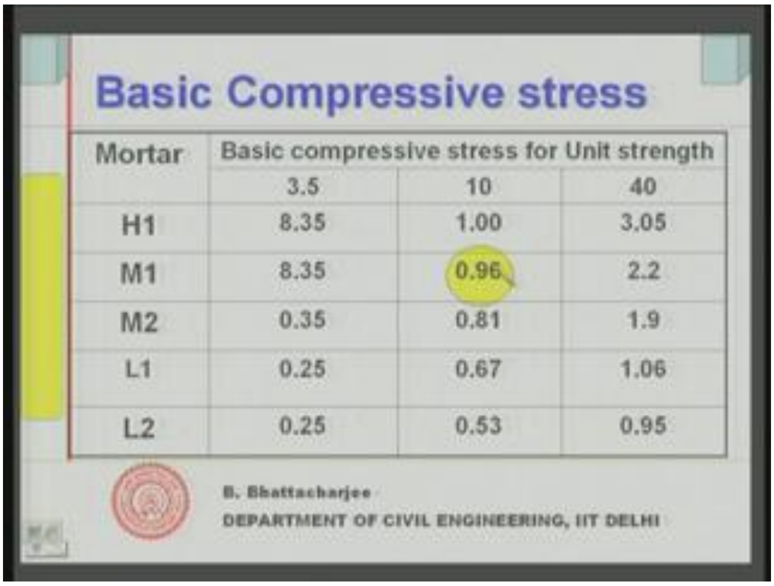

Mortar	Basic compressive stress for Unit strength		
	3.5	10	40
H1	8.35	1.00	3.05
M1	8.35	0.96	2.2
M2	0.35	0.81	1.9
L1	0.25	0.67	1.06
L2	0.25	0.53	0.95

Once I have founded next step I do is to find out the basic composition and we remember we are using the unit we said 10 Mpa strength, 10 mps strength right, 10 Mpa strength and mortar M1. This should be this should be my basic compressive stress. So, basic compressive stress reduce 0.96, right.

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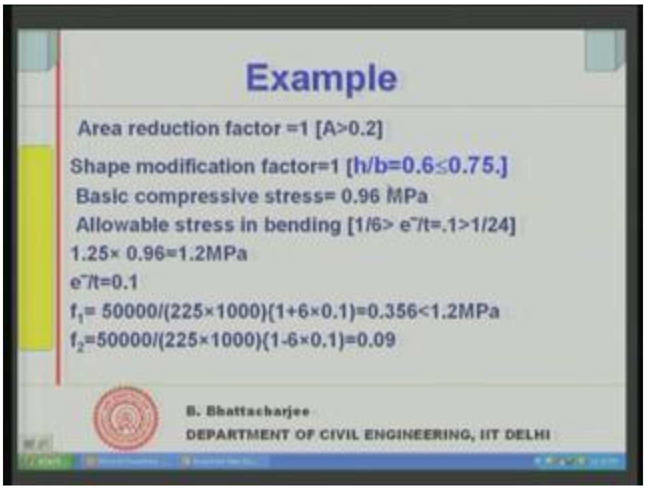

So, now I know my basic compressive stress, I know stress reduction factor, I know basic compressive stress and stress reduction factor. Therefore I can find out the permissible compressive stress in direct compression of course, then I can find out also for that under bending and compression you know pure compression and bending plus compression etcetera. So, area reduction factor in our case will be equals to 1 because A is greater than 0.2. Area of the wall is greater than 0.2 meters square, because it has got a length of 4.4 multiplied by 0.2 4.4 into 0.2; would be 0.8 and that is greater than 0.2.

So, therefore, we not need calculation of area reduction factor shape modification factor we need because our h over b is 0.6 given and which is a kind of brick that is available in this part of the country in northern part of the country somewhat about you know height is 75 millimeter divided by about 1.75 125 millimeter width. So, roughly about this 0.6 we thought. So, this is less than 0.75. This less than 0.75 and therefore, you do not need any corrections here. So, basic compressive stress we have seen is 0.96. It is 0.96.

Allowable stress between this then you can find out since this is between 1 and 6 and 1 by 24. So, 0.96 multiplied by 1.25. So, permissible stress in compression plus bending is 1.2 and in pure compression it is 0.960. Let us see what are our stresses coming, because we have got eccentricity equals to 0.1. So, if you remember our formula was w by t. Now, this is my total w; w equals to 50 kilo Newton w equals to 50 kilo Newton you know 50 kilo Newton, because 20 plus 30 coming in. So, 50 kilo Newton would mean 50,000 Newton. So, I have put it 50,000 Newton here divided by the thickness of the wall 225 millimeter divided by. So, I have put everything in Newton this is in millimeter 225 millimeter and this was you know 50 kilo Newton per meter.

So, 1 meter is the width I have taken. So, 1000 millimeter. So, this is Mpa this is come out to Newton per millimeter square right. So, that would be the stress that would be the stress and that stress when you know in compression in pure compression plus bending. So, maximum compressive stress will be 6 plus e bar over t. So, if you remember 6 e t the formula that we gave yesterday, in the last lecture you know last lecture 6 e bar over t and e bar over t in our case is 0.1. So, 6 into 0.1 and if I calculate out based on 0.356 which is much less than 1 0.25 Mpa 1.25 Mpa.

Then on the other face because allowable stress distribution is something like this you can see. It will be something like this kind allowable stress distribution is something like this where this side is the eccentric loading acting somewhere here. So, I will have a you know eccentric loading somewhere acting like this. So, I will have a stress distribution of this side, but this side I will have higher compressive stress and this side I will have low less compressive stress and this value comes out to be 0.356 and this value comes out to be 0.09 you know this value comes out to be 0.09 which is much less than 1.25 1.2 Mpa that is permissible in this particular case.

Therefore it shows that it is actually it is stable this is stable. So, it shows that is a structure is stable. It will not fail right. So, this is an example calculation how we calculate out the stresses with, eccentricity and of course, if the values are different here we could have chosen the appropriate value and find out.

Now, 1 thing remains close wants to calculate the load coming on to the wall and there are several related issue concentrated load for example, you have not looked into at all. Concentrated load there are certain amount of pressure can be increased at bearing etcetera; which we have not looked into because masonry design itself, can be much bigger and wider part of you know it itself could be half a course or something like that, but then we are trying to look into masonry construction on materials.

So, some issues of the resistance against loading we have seen move towards the you know from material point of view how it resists the stress the brick wall and that is what we have tried to explain in this.

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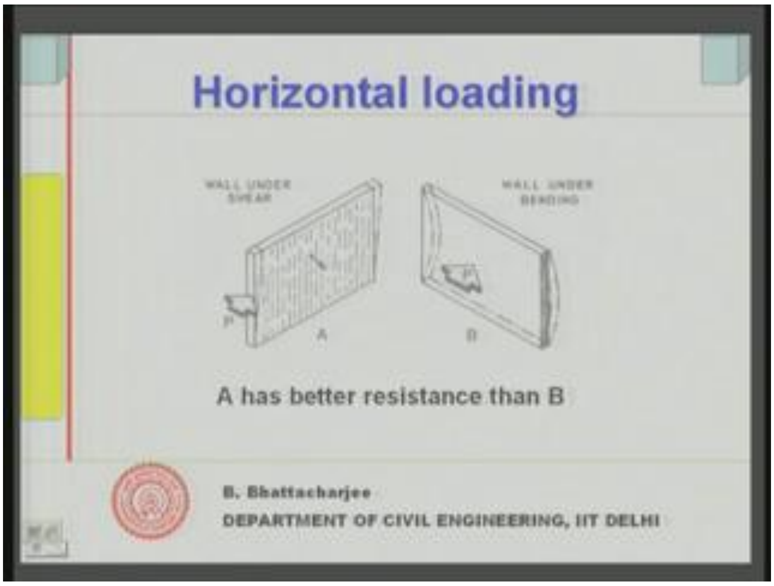

So, this is what is as far as load carrying capacity is concerned now let us see how masonry behaves, in case of horizontal loading, in case of. So, far we have looked into vertical loading with and without eccentricity. Let us see how it behaves against horizontal loading and, then there are some construction practices towards earth quake resistance construction given in the course.

So, I will just try to pass on this information to you case of horizontal loading first of all you see the load can come from this side to the wall and also, it can come from this as well wall under bending. So, when load is coming like this its actually like a plate bending you know it is like bending. So, it will bend along this direction depending upon what is the support condition here. So, it will bend something like this. It will have a tendency to bend about this axis and in this case when load is coming like this load is applied like this P is being applied here and case A load is applied like this.

This is this being fixed, it will have a tendency to shear. This is wall under shear and this is wall under bending. Obviously, A has better resistance than B because you have lot of materials. It can withstand more load more P than in this particular case. So, this is 1 issue you must remember and therefore, if you know the direction of the load then there is no problem,

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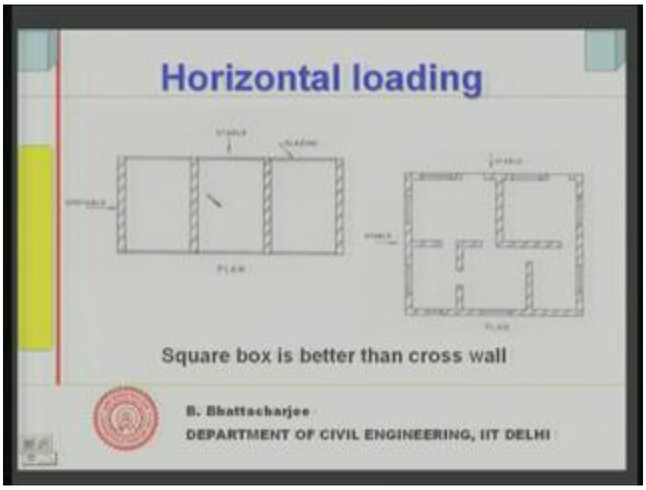

But normally one would not know the direction of the load. So, what happens we can construct things you know you can have cross walls construction you have cross wall construction. This side of course, is glazing and things like that something of some sort of some sort of its not a strong wall here. So, I have just cross walls and thin members here.

If I apply load from this side this through this panels it will transfer the load you know glazing let us say glasses are there glasses are there. Through this it will transfer the load to this place, when it transfer the load to this place this actually stable because this will be under you know it is a kind of shear load that will be existing, shear load that will be existing here you know. It will be actually a kind of shear load that will exist here. So, shear will be transferred. So, you know we have seen it is strong around shear, but what happens along this direction because it is bending, it will be unstable along this direction.

So, it is not a it is not a very good it is not a very good kind of arrangement. The reason is we do not know which direction either the wind or the force transfer even though you are prevailing wind direction, but once in a while it comes in the other direction also.

It is very difficult because wind directions are not straight. So, depending upon those situations it is difficult to actually know. This is not a good construction whereas, if you look at this 1 which is which is you know like square box type of construction cellular box you have lot of you have walls along this direction along you know here. So, if you have load from this direction this walls this walls together they would resist all by shear you know through the action of shear this walls will be under shear and they will resist better.

Similarly, if the load is coming from this side; all this walls all this walls be in shear and they will resist the load better. They will resist the load better.

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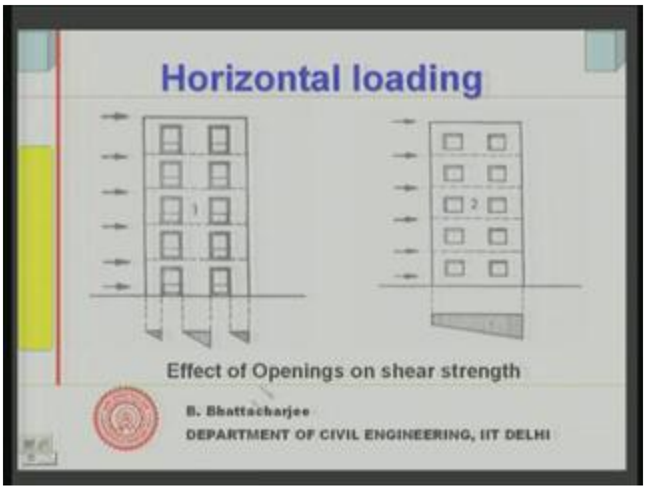

So obviously, this sort of a construction is better than; this sort of a cross wall connection against horizontal loading right. Let us see some more things. Secondly the issues of openings, when you have horizontal loads coming like this and you have large doors here let us say large openings existing here. Then you will have stresses if you look at the stresses the stresses high stresses you know it will have a tendency to actually compression high compression here and less compression here, you know it will have a tendency to really bend or kind of whole body of the bending it sort of have a compression here.

It will try to it will bend along a something like this like you can think in terms of a cantilever bending in this manner almost like this whole bending will bend like this. So, you will have you will have stresses of this kind. High compression here, because this is you do not want tension in the whole structure at all So, you will have no tension, but if you have opening this whole of this structure as a whole will not really together right unlike this 1 where you have openings all right, but they are smaller openings you know 2, in construction 2 in construction 1.

So, in this case the whole structure behaves together it tries to resist, you know provide resistance against this horizontal loading and you will have possibly stress distribution of this kind rather of this sort of stress distribution. Obviously you can understand that this 1, this 1 could not be as good as this. This is better. So, openings you know the shear strength of this particular building will be much better much higher when this particular building too much of opening here opening, you will have problems right against horizontal loading.

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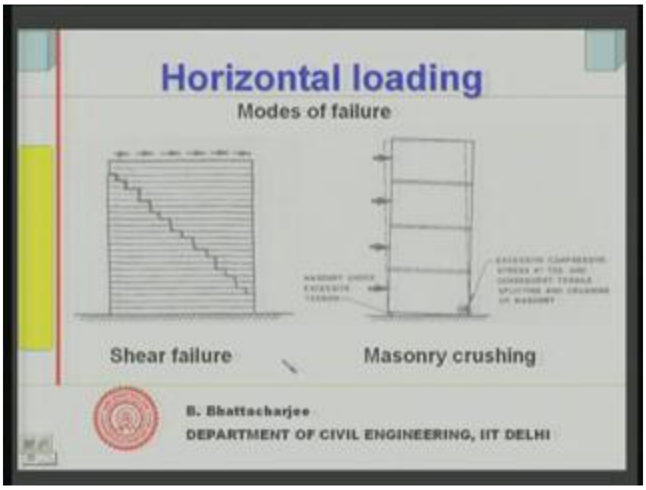

See what are the kinds of modes of failure? Under shear if you have shear failure it can show you know the shear effects will there is a shear force here. This can result in this can results in crack formation like this you know this is trying to it will separate out somewhere. So, diagonal cracking we would see. We will see diagonal cracking.

Now, supposing you have a opening here. Let us say you have a opening here you know you have a opening here in this wall. You have a opening here in this wall. So, usually material being less there is no material here. Obviously the crack passes here and then it passes through this.

So, opening allows through the opening normally the crack would pass in case of in case of shear. This shear can come from horizontal loading some time even when you have settlement of the foundation, let us say 1 side has settled 1 side has settled the other side has not. This might also results in this sort of crack formation. This is 1 the second 1 would be. This is shear failure. The second mode of failure would be failure under masonry crashing.

Whole thing actually the crashing of the base masonry you know excessive compressive stress at the toe and tensile splitting and crashing of masonry, because we know that when there is compression in the material then the transverse direction will try to expand and this results in cracking.

So, tensile splitting takes place and crashing of the masonry can also take place. If tensile splitting takes place some amount will get crashed and. So, on and masonry under excessive tension here of course, the masonry and stress is tension right. So, this is other kind of failure of course. As you have seen earlier the stress distribution I had more stresses more stress distribution we have seen that most stresses here and less stress here. So, what we are assuming that there is no tension, but if it is beyond this very high then there will be some tension there also.

So, excessive tension at this point. So, masonry crashing here and excessive tension takes place here. So, under horizontal loading this could be the these are the modes of failure right.

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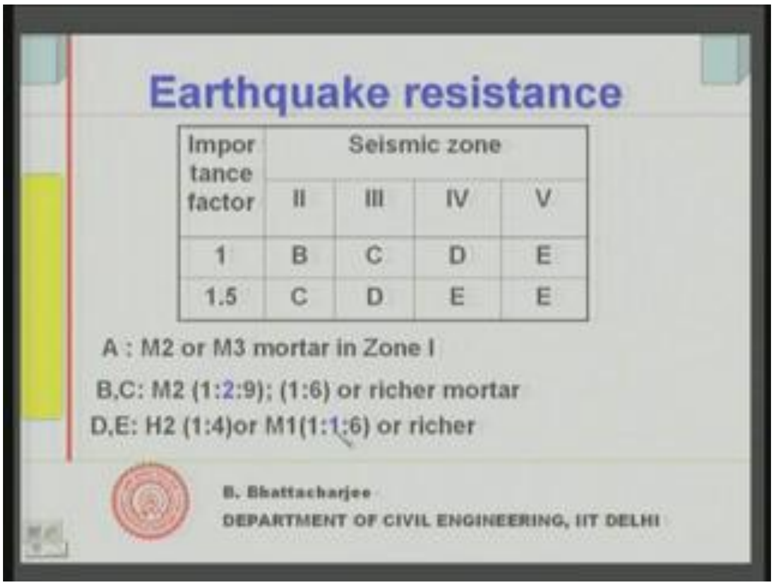

Let us see something about earthquake resistance now all right. Now, we are aware actually of course, we are not go into details of analyzing things like that in case of masonry you have some construction practices and that is what we are trying to actually look into you know there are certain construction practices and we are trying to give you some idea regarding this construction practices, because detailed analysis is perhaps is not easy to give and normally in masonry structures such detailed analysis is not done.

But, certain construction practices are to be followed and the code, I mentioned already is IS 4326 is the code which gives this details in this construction. Now, you must be aware some time, I might have also stated you in the beginning itself that our country has been divided into several seismic zones 1 2 3 4 5 you know one of course, is now, but 2 3 4 5 are the zones seismic zones and this is the most critical where the seismic activity is maximum. This is the next. This is still and this is the least and you know part of the mostly the Himalaya and areas in the north east they belong to this many part in the northern region belongs to this right.

These are the ones and some of the regions in the they belong to this. Other which have the least chance of least chance of here seismic activity is come to this. So, there is a map seismic map and I think I just want to mention this earlier right in the beginning when you are talking about the initial modules module 2. So, when you talk of different kinds of loads we must have mentioned about this zone division right. So, activity is maximum here. So, in this and then depending upon the structure important pattern of the structure, the structures which are more important where failure could relative to other structures.

So, depending upon higher end structures the buildings have been actually divided into five categories ABCD and E. You can see that A does not exist because A was originally meant for zone 1 and now since the zone one is not being considered whole over the country. There is no zone 1 least earthquake or sensitive to seismic activity or vulnerability earthquake you know earthquake susceptible to earthquake attack or sort of load susceptible to. So, this A is now least susceptible to earthquake load and now this is being, therefore the A type of construction is also not there which is, but it you will see that what are done there, but B and C and D and E are the other categories and to first 1 thing.

There are strategies which we shall discuss next, first of all in the you know failure of the brick masonry mortar places a very strong role right, in which we have seen the mortar place a very role, because it will it is at the mortar brick interface where the failure takes place. Brick rarely fails under all circumstances it does not fail. So, much, but it is the first to fail with you know weakest link is the brick mortar junctions right. So, that that and if you want to improve that junction then strength of the mortar is an important issue

So, therefore, you must have strong mortar relatively stronger mortar to ensure that you have better bond between the brick mortar junctions. So, that is why what has been suggested is you have specific mortars to be used in each of these category of building. For example if B and C category it is suggested that you use M2 mortar; which we have mentioned earlier and 1 is to nine where 2 blue color means its lime mortar, it is lime mortar right and this is 1 cement 2 lime 9 sand. So, this lime mortar or 1 is to 6 cement sand mortar or any richer mortar.

So, least mortar that you can use in B and C category is this and D and E still use richer mortar namely 1 is to 4 cement sand mortar or 1 is to 1 is to 6 where 1 stands for cement 1 stands for this 1 stands for lime.

The blue 1 stands for lime 6 is the sand or richer mortar. So, you can see that D and E category we use actually B and D this category we use very strong relatively stronger mortar. The minimum you know the least mortar that you can use is either H 2 or M 1 and the stronger mortar we use and whereas, in B and C we use slightly lower you know not as good as strong as mortar like this.

So, this is the zone where I use B and C like where the importance is less where I have my importance is less. This is either importance is less. So, this B and C is used here and D and E are used here.

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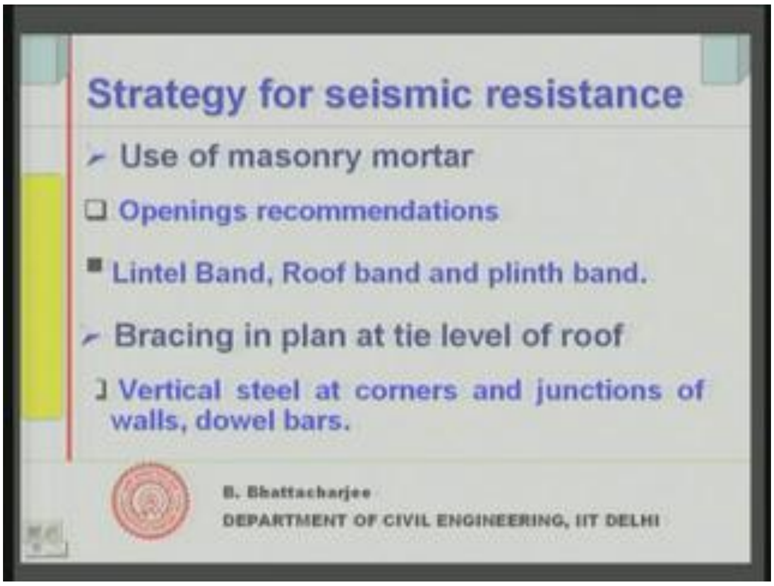

So, the mortars that has been suggested are you know for this type of this type of buildings are these right. So, let us see what are the strategy first of use the masonry mortar the appropriate masonry mortar. That is the first strategy, that is what I was talking about. That use appropriate masonry mortar use appropriate masonry mortar right. Use appropriate masonry mortar. Then some recommendation on the openings because we have seen that openings can lead to you know the resistance against shear is less when I have openings.

So, dimensions of the opening some recommendation has been made about dimensions of the opening, then there are some recommendation on what is called lintel band roof band and plinth band as required, I mean; all places you will not be using you know all of them. In fact, it is suggested for which category of building what kind of strategy you should adopt although it is not possible to discuss all in detail, because it is more of an information sort right.

So, this is available in the code, but some idea about what we mean by lintel band roof band or plinth band and try to give some idea regarding the same. Then you can have bracings in plan at the level of the roof in some cases. Some cases vertical steel at corner and junctions of walls at dowel bars you know specific junctions. Junctions are to be actually cornered.

Junctions of wall where there are 2 walls meeting their junctions should be constructed in a particular manner. Some places you might have vertical steels and some dowel bars etcetera. So, there are some of those strategies. There are few more in the code and one can refer to IS 4 3 2 6 for details right.

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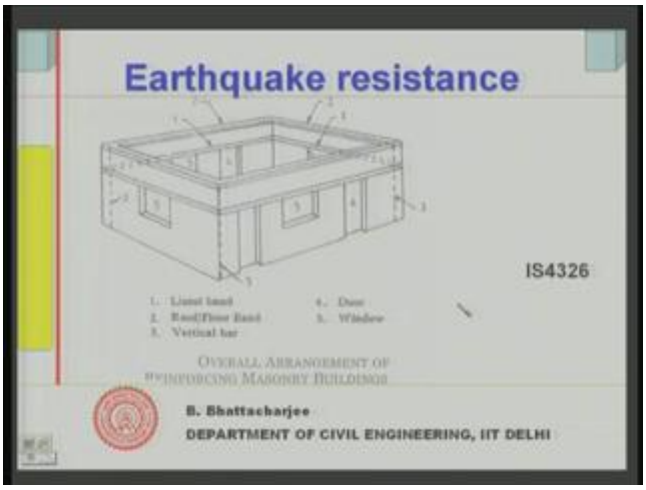

Now, here if you look at this diagram you can see various features various features you can see. For example you know you can see first of all this is the lintel band 1. This is lintel band Lintel band and this is lintel band.

So, this is a RCC band throughout RCC band throughout, because against horizontal loading this band provides a kind of resistance kind of resistance crack cannot pass through this band. This and dimensions also the reinforcement that should be provided in such band is also suggested.

Also you know some recommendations are available for some constructional details of this bend. So, this band is provided throughout over the windows top level lintel level as we call it or the door top level. So, this is my door. This is my window just at the top of this. Just at the top of the openings, I provide throughout a band in the building. This is what we call as lintel band and you see in north east. If it is in north east or even in zone 4 say Himalaya and Uttarakhand areas or north east, you will have definitely this zone five most of the buildings 1 would be using this sort of similar band you can have in the roof or floor level and that is 2.

This is 1 you know this 1 roof or floor level you can have similar band all around the building all around the building in the masonry construction. These walls are of masonry. So, lintel band and then roof band, you can have plinth band beam right in the foundation level. So, you have the foundation level you can have plinth level you can have such lintel band and they definitely do not allow crack to propagate and that is a kind of protection against protection against you know earth resistance against earthquake Hazards or earthquake load.

So, then you have then you have the 3 of course, vertical bars vertical bars right not only that this 1's provide better resistance, but you know reinforce concrete is definitely more ductile with the reinforcement being there steel is ductile. So, it would not fall off. It would rather you know, because it can accommodate a lot of deformation and which is needed as we have discussed some time in our module 2; one of the properties needed on the materials is its ability to deform before failure you know after the useful load after the load which I have failure load it must be able to deform.

So, at that load it should show up some cracks or something, but it should not collapse straightaway. It should show long deformation capability after that and steel has that property and therefore, providing steel not only that it resists you know do not allow crack to grow. Do not it provides a kind of resistance against various kind of loading, but it also provides sufficient amount of ductility's. So, that even if even if there is there is failure of individual member the structure will not collapse. So, that is the idea. So, vertical load and doors and windows are shown here 5 is the window.

This is the window. This is the door and above the door and window you have the lintel band and roof band and sometime we can have plinth band as well. So, this is the. This is one of the strategies, I have mentioned providing bands all around the building and then let us say you know this is one of the ways of reinforcing the masonry building through bands right. This IS 4 3 2 6 gives you this diagram and also details and any more details. It is just a little bit introduction has been provided.

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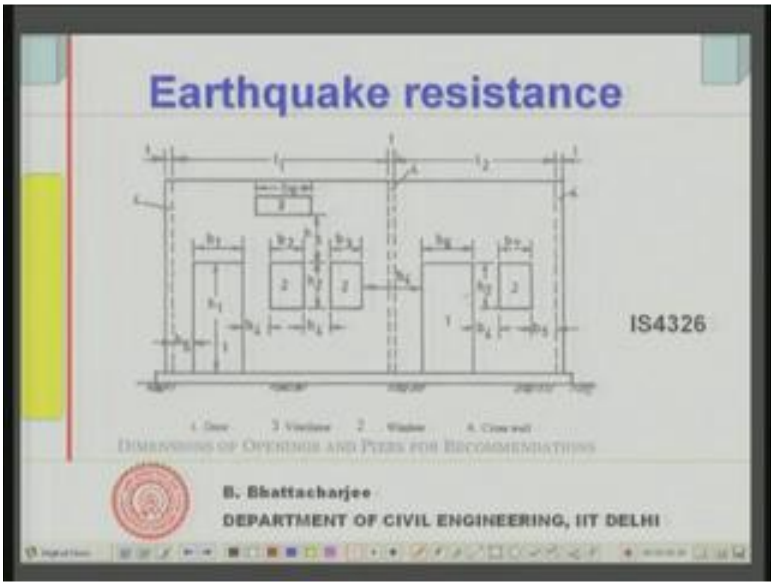

Then this diagram shows you about openings. Then this diagram shows you about openings actually and this also comes from IS 4 3 2 6. Now, you see this it gives you recommendations for all these values of you know like 1 is this is door 2 is the window. 3 is the ventilators. This ventilations are used for natural ventilations especially in Himalayas and areas of north east or similar sort of areas very much for you know natural ventilation flow of air. So, we shall look into some of these issues some time in connection with the wall. In fact, they form part of what is called fenestration.

Now, the dimensions, this relative dimensions are actually for example, the spacing h 3 or h 2 or b 4 b 4 etcetera between openings and b 1 b 2. These values l 2 etcetera t and relative values; these are all given you know like for example, 1 is the door, 2 is the ventilator, 2 is the 3 is the ventilator, 3 is this ventilator, 2 is the window and 4 is the cross wall. It is shown, It is just cross wall shown cross wall is been shown. This is the cross wall in the other direction. This is the long wall. The cross wall in the other direction.

So, t is the thickness of the cross wall etcetera. Now, foundation level is shown. This is the foundation level. So, now this opening this dimensions are given in the code, I did not bring it up, I did not put it up here, because it is just an information part of the information. The code gives you recommendation of this values of b1 b2 b3 b4 b5 b6 b7 etcetera; b4 b5 b6 and b7. All this values are given. Similarly, recommendations on h1 h2 h3 these are also b8 h1 h2 h3. This values are relative values are suggested in the code.

So, 1 can refer to them and by providing this opening restricting the opening, in this manner 1 can actually improve the resistance against earthquake 1 can increase the resistance against earthquake. All right let us see some more some more issues.

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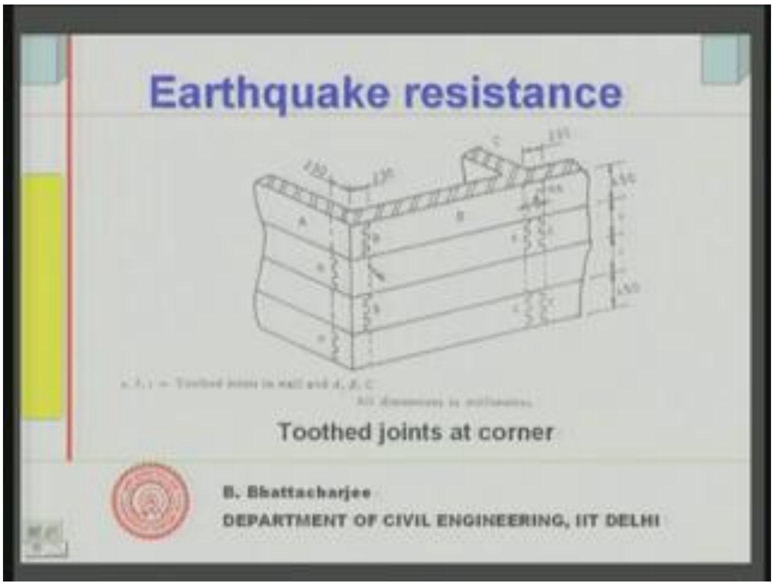

Now, we can see the joints actually. The joints you can see again this is you know toothed joint at the corner alternative to joints. This is another recommendation. The joints if you have seen earlier when you talked about strategy. Some places 2 joints are recommended. The code gives you this value places using some strategies and what combination should we use at what condition. That again as, I said these are information.

So, 1 can look into the code and then use them, but they are such thing exist and what they look like which is important to know and that uses even more; 1 must adopt them to provide adequate resistance against. So, let us look at what is the toothed joint at corner. In some places you might use this toothed alternative joint you see. This is the toothed joint here and then there is that means your codes brick codes would have possibly followed like this.

The joints would have been some other, but you ensure that here of course, you are not leaving any joints. So, you just continue the joints and here you have put the joints. So, alternate to joints you provide it at the corner. Alternate to joints are provided at the corner. This actually improves the resistances. It improves the resistances with a better joint. Here sort of effect will be there and dimensions are also mentioned here dimensions of this joints are also mentioned here, dimensions of this joints are also mentioned here because you can see these are layers.

So, above 450 same 450, 450 and 450. So, 450 into 4 let us say: 1.8 meter and so on. So, this kind of joint corner you know it is a cross wall. This is a cross wall. So, the corner the joint should be something like this. So, that provided proper bonds are available proper they are almost act together they, should act together as possible should not separate out under horizontal loading right. So, this is these are the issues related to earthquake resistance. This is the issues related to earthquake resistance right.

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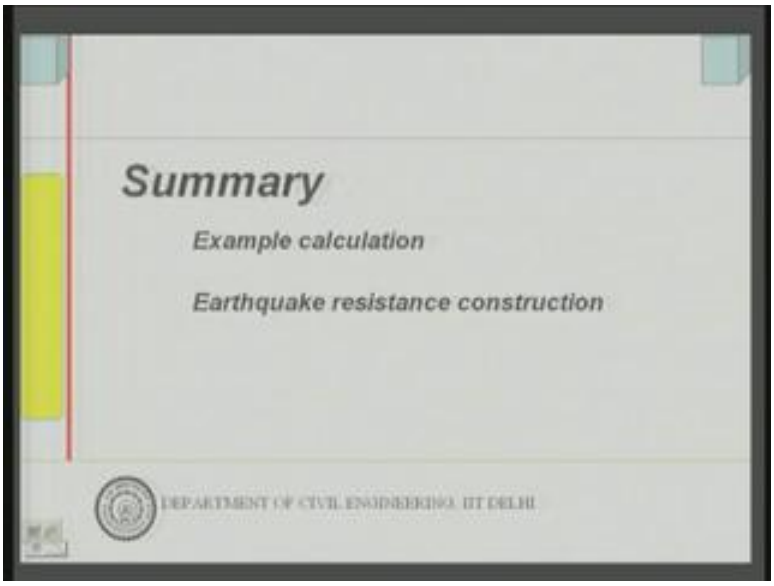

And then with this we can look into basically you can summarize the load resistance issues. So, what we have seen today. We have gone through an example calculation. We have gone through an example calculation. And whereby whatever, we have learnt earlier you know the principles the most of them you apply and we now, after this module after this lecture 1 should be able to find out the load carrying capacity of a masonry wall under both direct vertical loading and eccentric loading eccentric loading. This you have covered most of it practically with example, then we also we looked into how the masonry buildings behave under horizontal loading.

If one understands the basic behavior then since, it is mostly otherwise the practices that has to be adopted during the construction as well as design phases 1 can 1 can adopt them keeping them, in mind. And then lastly we looked into the resistance against resistance against earthquake load, and then remember it is not really based on calculations or something of that kind. Simply, they are practices some of the practices suggested based largely on experiment experience and understanding. Largely empirical understanding you know common sense based empirical practices that has been there.

Now, whole lot of this practices are available whole lot of this practices are available in our discussion, we tried to just give you some idea something about the strategies those are adopted and some ideas about some ideas about what are those what are those measures namely: let us lintel band water lintel band and what are the kinds of toothed joints and so on. So, we try to give you some idea regarding the same. So, I think this would finish our discussion on load resistance of masonry structures.

Then next lecture, we try to look into the functional aspects of the functional aspects of the masonry construction that is you see, in addition to being stable as you have seen in the beginning, in the first lecture. That is addition to being stable the masonry wall or masonry structure should provide us some sort of you know it should cater for such sort of thermal performance. Some sort of performances against you knows some sort of performances against acoustic performance.

Then, some problems associated with the associated with the masonry construction namely: the dampness you know protection against dampness some issues related to durability. Then since, they are part of the world part of the fenestration is also part of the wall. We will try to look into some issues related to the fenestration, in the next lecture and that would actually conclude our discussions on masonry module 10 that is module. I think with this note, we will likely finish our day.

Thank you.