Building Materials and Construction
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Module - 10
Lecture - 3
Masonary: Walls; Resistance against Load

In this third lecture of the module 10, we will continue with the resistance to you knows continue, the masonry walls resistance against load which is started in the last class. Now, if we recall what we did, in the last class, in the last lecture.

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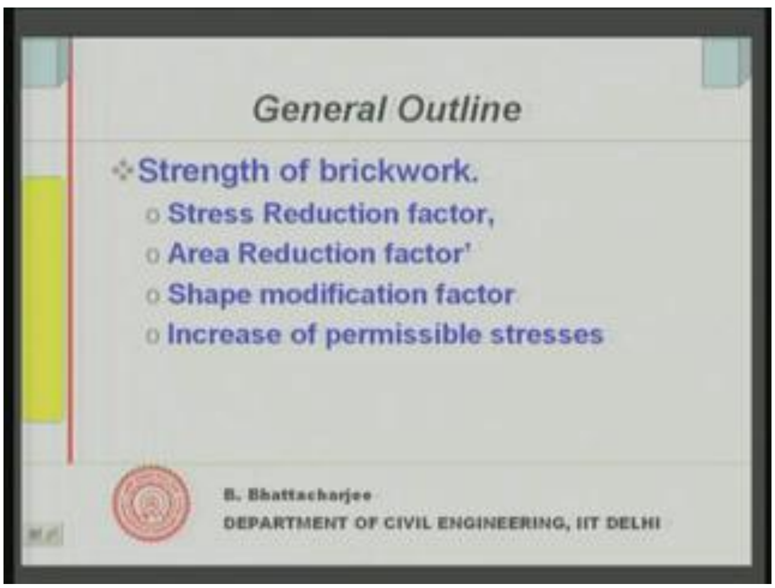

We talked about basic compressive stress, you know and which we find out from the unit strength and mortar strength. So, once you know the basic compressive stress that is permissible basic compressive stress they are several other factors, which actually affect the strength. There are other factors w one of them and that is due to effect of slenderness and eccentricity.

Then, there is something called area reduction factor if the area is very small, if the masonry area is small which is taking load. Then there is some sort of modification and shape modification factor is the third one, which we will discuss and we will discuss some aspects of increasing permissible stress not all; we will leave it for the next class. So, these are the this is what we are going to discuss today some issues related to stress reduction due to slenderness and eccentricity area reduction factor. And these factors are multiplied, with the basic compressive stress that we have seen; in the last class to obtain the permissible stresses in brick work you see this.

This is the way how we do it actually, we do it by since this is based on large scale based on empiricist and you know like mo more-not not totally understood behavior. So, what we do we take the first permissible stresses without any effect of eccentricity slenderness etcetera, as we mentioned, in the last lecture that below slenderness ratio are 6 and where h by b ratio is less than 0.75 and area is more than 0.2 meter square. We find out the basic compressive stress. So, we will now find out these factors and then finally combine them as well.

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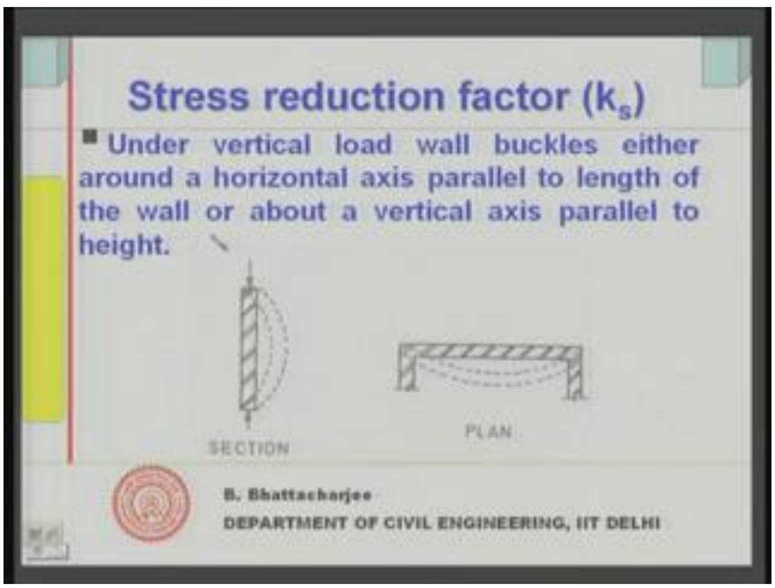

Now, stress reduction factor is associated, with slenderness of the slenderness of the member the masonry member wall member. Now, what happens the failure can takes place under buckling. If the member is slender you know like, we know that under vertical load wall buckles either around a horizontal axis parallel to the length of the wall or about a vertical axis parallel to the height that means; when you are applying a load like this when you are applying a load like this, when you are applying a load like this. It can buckle and this is our common day today experience. If you take a very thin you take a very thin, you take a very thin s or a cane and try to push it down push, it vertically downward.

You will say it will it will bendal though the material, would not have failed you would have material would not have failed, it would bend and if the bending this buckling is excessive. This is the actually, we call it buckling under compressive loaded and if we it will buckle as we call it 1 reference is made quite often is the stick on which Charlie Chaplin would stand you know, if you see if you remember that stick on which you would lean onto it and it will be always buckle sort of a curvature shape. So, this is what is buckling and this buckling takes place about a horizontal axis that x is passing through the scent you know passing normal to the screen.

Now, same thing can happen in the in another plane also in for example, this is a b buck buckling that is taking in vertical plane and this is in horizontal plane this might buckle that means; this is occurring across this is in plan. So, this is occurring across around or about a vertical axis vertical axis. So, the wall can buckle around this vertical axis under vertical loading under compressive loading you know we know that compressive loading is not as efficient as tensile loading.

Because of buckling, because under certain load it starts buckle buckling and from critical load you might be remembering that buckling is inversely proportion alto slenderness ratio, that is what we mentioned in the previous lecture. So, slenderness ratio is an important concept with regard to buckling.

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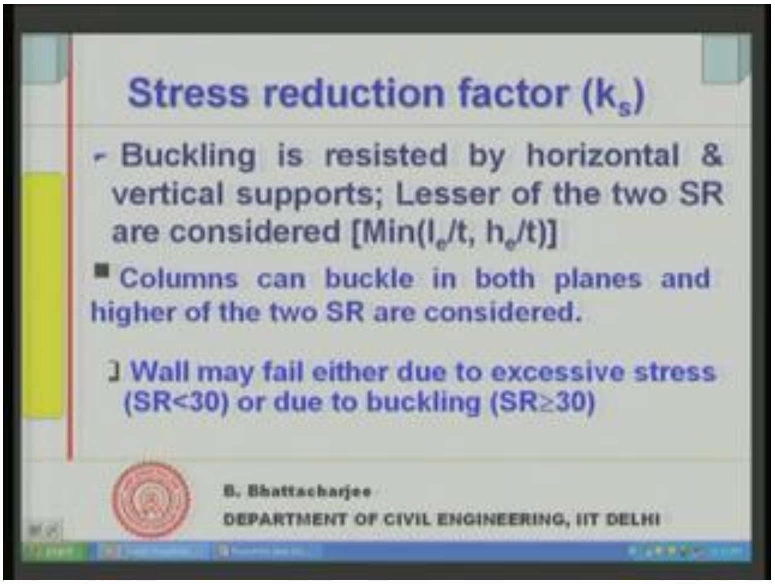

Now, this slenderness ratio we define in terms of effective length by thickness or effective height divided by thickness, you know buckling is re resisted by horizontal and vertical supports. Now, in case of a column, of course things are relatively simple as we shall see in case of column it can buckle in both the planes, you know it can buckle in both the planes.

For example, it can like if this is my column and if I am applying load like this from this direction there is a load from this direction and there is also a load from this direction right also a load from this direction, then column can buckle in this plane, it can buckle in this plane and also into the other direction as well. So, buckling can takes place in both the direction in case of column both the planes. There is no restraint but when it comes to wall when it comes to wall when it comes to wall actually, buckling is restricted to when it comes to wall buckling is resisted by horizontal as well as vertical supports horizontal as well as vertical supports the vertical member you know like supposing there is slab and the and the wall is between the slab.

So, it will be restrained when it is trying to buckle the slab would actually, resist this buckling and if there is cross they, will resist the buckling. Therefore, there is a resistance to buckling by the supports horizontal and vertical supports, and of course exact analysis would have been good but we cannot do exact analysis and therefore what we do is lesser of the 2 slenderness ratio. We, considered as a simplified manner, because we cannot find out I mean; it is not really difficult it is not easy to model the kind of resistance that would be offered by vertical supports as well as, the horizontal support.

So, what we do instead we take the lesser of the 2 slenderness ratio and consider that as the slenderness ratio for our design whereas, in case of columns there is no resistance in fact it can buckle in both the planes. So, whichever is the critical buckling that we will consider. So, what we do we consider the higher of the 2 slenderness ratios for column or p or plasters and incase of wall. We take, because of the resistance offered by the supports we take minimum of the 2 slenderness ratios and that is how we find out which is the slenderness ratio.

Let us see how we take the effect of slenderness ratio well; because wall can fail under buckling when it is slender it can also fail under tensile stresses if the stress level is very high. So, there are 2 issues under compression there are 2 issues; when the force is very high right, if the member is weak if the member. Let us say is strength is relatively low and but it is thick it is thick. So, you apply a load the stress itself allowable may exceed the permissible stress or the stress at which it fail. So, it fails by let us say due to stresses and stresses would be how it could be lateral tensile stresses since, it is almost like concrete, because brittle material.

So, then whenever you apply a uni-axial compressive load actually there would be lateral tensile forces as well; because of the p effects we remember divided by E effect that would be the and that would actually, result in a expansion or movement along the transverse direction and this might cause tensile stresses parallel to the load as we have seen, in case of concrete cubes or cylinders or similar sort of situations. Now the other failure could be because of buckling now, it has been observes you see it has been observed that it buckles may fail either due to excessive stress or due to buckling slenderness ratio below 30.

It is generally due to stress if slenderness ratio is above 30 that is due to buckling. So, that is the idea you know this is the idea if it is less than 30 then it is due to excessive stress. If it is more than 30 then it is due to buckling that is the idea that is the idea right ok. So, failure of the failure of the wall can be of this kind and we will have a diagram to look at it more clearly. Now, how do we find out effective height, we will come to the effect of slenderness ratio how do we find out effective height, because effective height also takes into account of the resistance provided to buckling by the horizontal supports.

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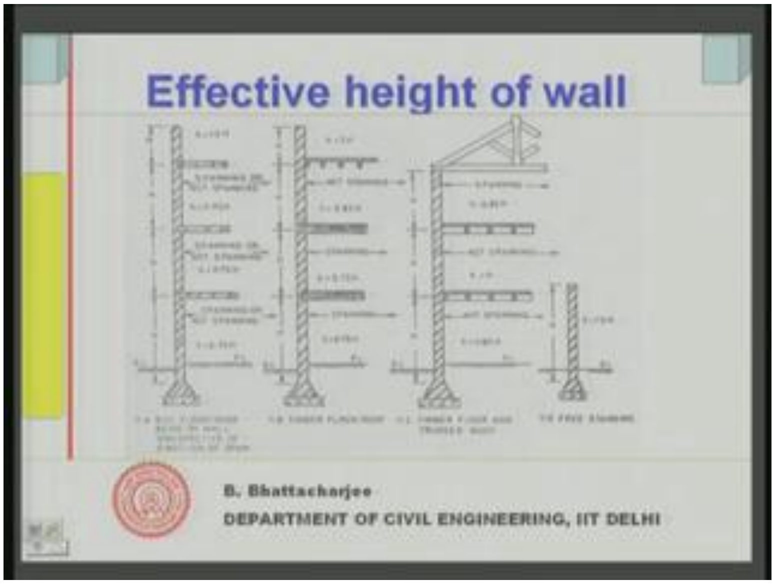

So, for example if you consider you know if it is fixed if it is providing heavy resistance supposing, it is fixed at the top and fixed at the bottom then of course the buckling will be restricted. So, effective length will be lower and if it is just not allowing just allowing rotation but no movement sort of a hinge sort of connection you know does not stop its rotation at that point, then it will nearly about 1 the effective length will be same as the length but if it is let us say open on 1 side I mean; not free at 1 side free at 1 end then effective length will be more than that.

So, let us see the some examples are here some examples are here. So, you consider this now look at this is the foundation therefore this is restricted its moment is very much restricted here there is a concrete slab here there is a concrete slab. Now, the concrete slab actually provides a kind of high resistance you know concrete slab provides a kind of high resistance to buckling along this plane and therefore, what we take effective h height and this will also resist because there is there is a foundation and this will not allow this p you know the rotation about this point.

So, we take the effective height as point seven five h same thing, if it is between concrete slabs concrete slabs are supporting, then it is 0.7 effective height is 0.72 h 0.75 h this is also 0.75 h. Now, look at this his is h and this is free at the end, so therefore effective height. Now, becomes more 1.5 h because it can now buckle like this you know it can buckle like this. So, therefore it is

1.5 h, if it is not reinforced concrete which can provide sufficient restraint against buckling, if it is something like timber. Let us say timber floor or roof you know then this is of course foundation is 3.75.

This is also it s say rigid it is entering here not just supported, but so therefore 0.75 and this is just at the end. So, 1 side it is fully fixed this side it does not provide it allows for rotation here actually and this is 0.85 and this is this is now, it is almost like hinged you know this does not allow rotation I mean; allows rotation and therefore this is 2 edge. So, this is 2 edge, so free and this portion which allows rotation like a timber flooring which is just supported not embedded inside because this can now, this can actually buckle and its mode of buckling would be you know, it will buckle like this. So, this would be 2 edge this is 1.5 edge it will be something like this 1.5 edge this is 2 edge and similar when you have similar restraint here.

So, it becomes edge this becomes equals to edge because these are not embedded inside will not you know resist it fully the buckling and this is these are the examples, if it is just free standing wall this side of course the foundation is there which is nearly fixed. So, it will be 1.5. So, that is how we find out the effective height effective height, we can find out like this because when you want to calculate out the slenderness ratio, we need to find out the effective height.

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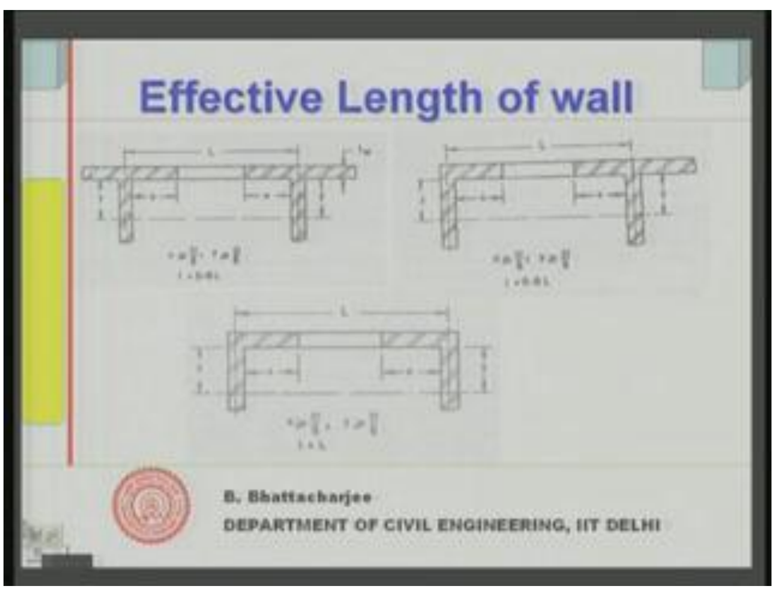

So, example of finding effective height is like this effective length effect effective length is we find out something like this you see their 2 distances x and y you can see 2 distances x and y you can see 2 distances this distance y right this distance y and this distance x up to the opening x up to the opening. So, how much movement will be or what is the effective length for buckling or how much resistance these walls are actually offering would depend upon minimum length of this wall how long it is. So, this is y and this y and also how much length is there between, the openings this is opening.

So, if there is opening solid there is no problem since there is an opening so depending upon x and y. Now, when x is greater than h by eight and y is greater than also h by eight that is this is greater than eight this is also h by eight h is the height, then this is given as 0.81 this is given as 0.81 the effective length is given as 0.81 percent of this l, similarly when similarly when it is greater than h and this is also greater than h and its also greater than h right this is this 1 you know this is y is greater than h by 6, sorry and this is greater than h by 8. So, this is given as 0.9 similarly, h by 8 y greater than h by 6 is equals to l.

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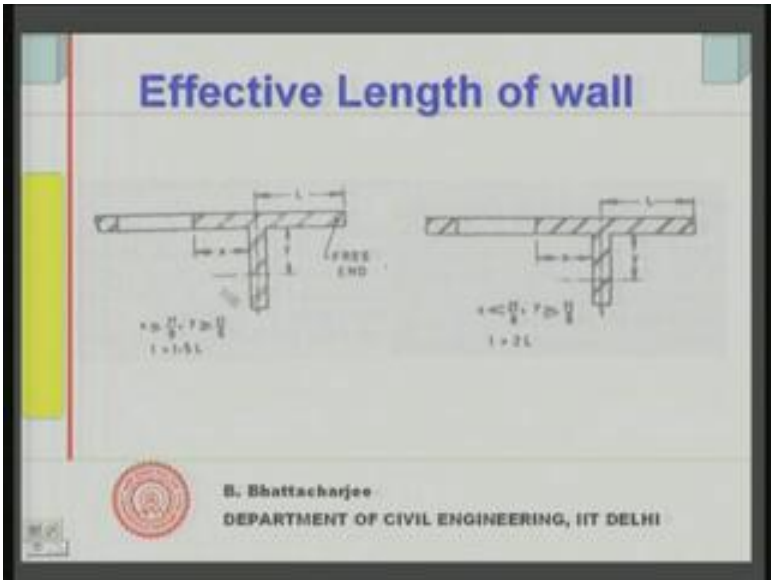

So, these are three cases which are shown here similarly the other cases are given this is based on the effective resistance that would be provided by the wall against or the cross walls against buckling. So, the similar other 2 cases for example this is this wall is not very long it is greater than y is greater than h by 6 x is greater than h by 8 this and this is the my l.

So, this will be 1 free end 1.51, this is 1.51. So, because here there is no restraint and similarly here again l and h is less than h by 8 and this is less than h by greater than h by 6 and then this is l. So, this is l is equals to 2 l, so depending upon the restraint that is available you know at here or resistance offered by the cross wall against buckling. This l value effective l values are taken right similarly, effective length for 2 other cases are something like this.

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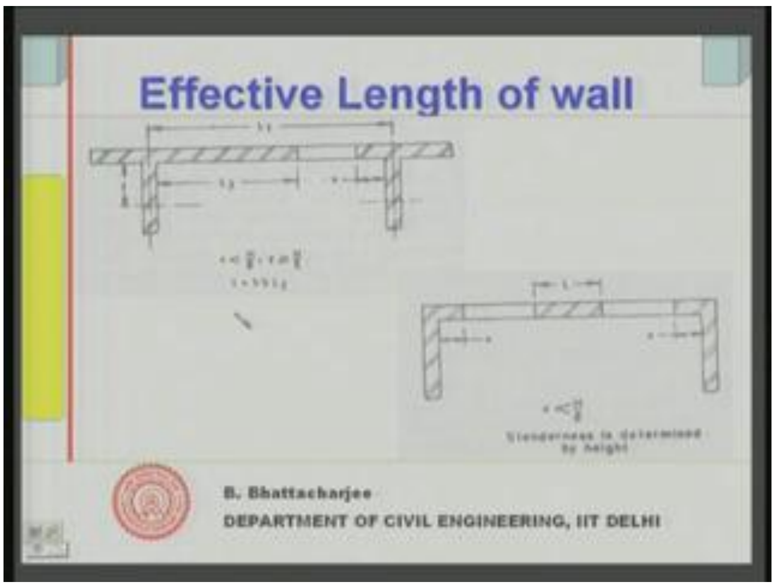

You know the opening very close to this here this is given as l equals to 1.511 is equals to 1.52 this is what it is when this is long it is taken as l equals to 1.512 and here, again you have small this is l and slenderness is determined by the height. So, here slenderness is straight away determined by the height x being less than h by 8 very small mostly there are 2 openings only small portion is there, because now it can it will be determined along this direction there will be no buckling, but along the other direction about the horizontal axis there will be buckling and it is only determined by height it is almost like a column this is almost like a column.

So, that is how we find out the effective length and effective height and once we have found out the effective length and effective height, we know the slenderness ratio because effective length divided by the thickness and effective height divided by the thickness we find out there are 2 slenderness ratio whichever is less we take that because the resistance offered by the horizontal and vertical sup support that is what we are taking into account right.

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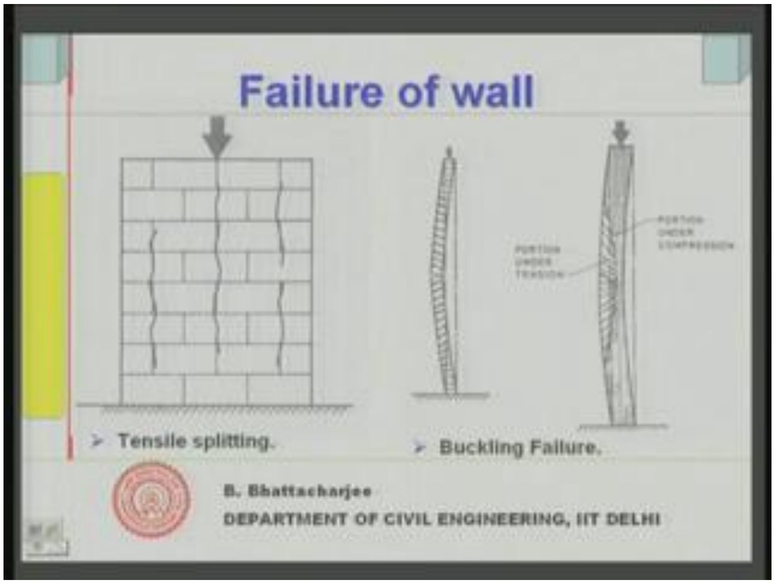

Now, the failure of the wall as we said this is tensile splitting because when you apply vertical load this will actually, there will be transverse movement onto the other direction right remember something similar to the concrete cell in the right tensile splitting. So, this there will be there will be you know there will be like when you try to apply this along this direction, there will be lateral expansions sort of and there will be formation of lateral expansion sort and therefore left hand side cracks will come like this.

So, you will have a zone this zone will be under tension because of the buckling finally it of course, results in tension. So, this will be under tension and this side is under compression because it is almost like buckling and finally the stresses will become very large to cause failure. So, buckling failure is something like this tensile splitting is something like this so what you see then in effect in effect we see that when you have the slender member or slenderness ratio can bring down your load carrying capacity, it can bring down your load carrying capacity right when it is not slender it will fail like this, but a slender member will fail earlier then this sort of member.

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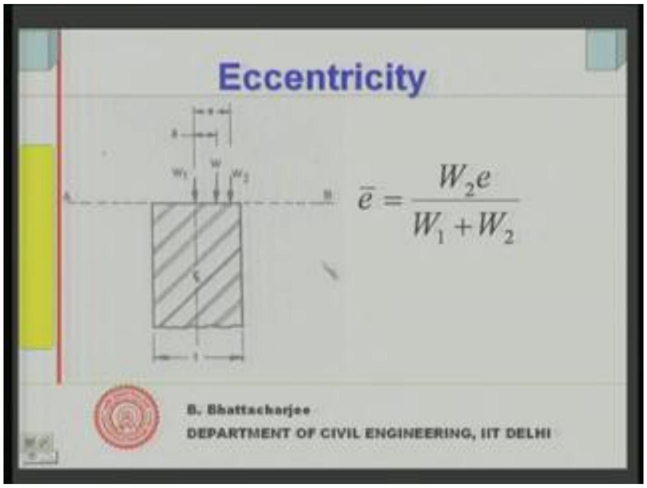

So, slenderness has some effect on load carrying capacity and we take it through a multiplying factor as I mentioned earlier whatever takes eccentricity well as we know because for all practical purposes we never will be able to put the load right onto the center of the load you know effective lo effective cent of the action of load or effective the point through, which the load is acting will hardly be coinciding with this I have given some example, in the last lecture saying that when let us say when you know when you have a slab coming from this side and slab coming from this side.

If the spans of the slabs are different you know the pressure that they will apply here they would not be they could be you know the there could be eccentricity due to that or supposing I have got only 1 side slab. So, stress block that will be acting will be somewhere, here and in fact the load will come somewhere here you know like if you remember what I said the other class is that supposing I have got 1 sided load slab co from only 1 side then I m I will have actually the load will be transferred the a triangular.

You know like the slab coming from the is a slab coming from only a slab coming from this side slab coming from this side and the load will be transferred like this. So, (( )) of the load will not be conceding with the center of the wall rather it will be somewhere in between. So, when I have a slab from only one side there will be eccentric loading many other situations there will be eccentric loading it is very difficult to have concentric loading most of the practical cases there will be its very difficult.

So, when you have eccentricity the you know total eccentricity this load is concentric load some amount and eccentric load is W2 net eccentricity. We find out like this the e bar as shown here as the point where the total load is acting will be calculated like this where W2 into e is the eccentric load.

W is act load this act load will come from a wall on top a wall on top the actual load will come, but if there is a slab or a beam resting onto it this will always introduce some sort of eccentric load. Because I said the load transfer from the beam to the slab I mean; beam to the wall or from slab to the wall will be always a triangular kind of distribution. So, its net effect will be to transfer it somewhere in between and not exactly at the center. So, we will always some concentric loading plus some eccentric loading.

Let us say e is the eccentric loading eccentricity of the eccentric loading then effective eccentricity could be defined something like this which is W2 into e taking movement about you know this point. So, W into W is equals to W1 plus W2 W is equals to W1 plus W2 this is W; W. So, taking moment about this W into e bar must be equals to W2 into e and that is results in this sort of relationship. So, e bar the effective eccentricity where all the load is acting I can find out in this manner.

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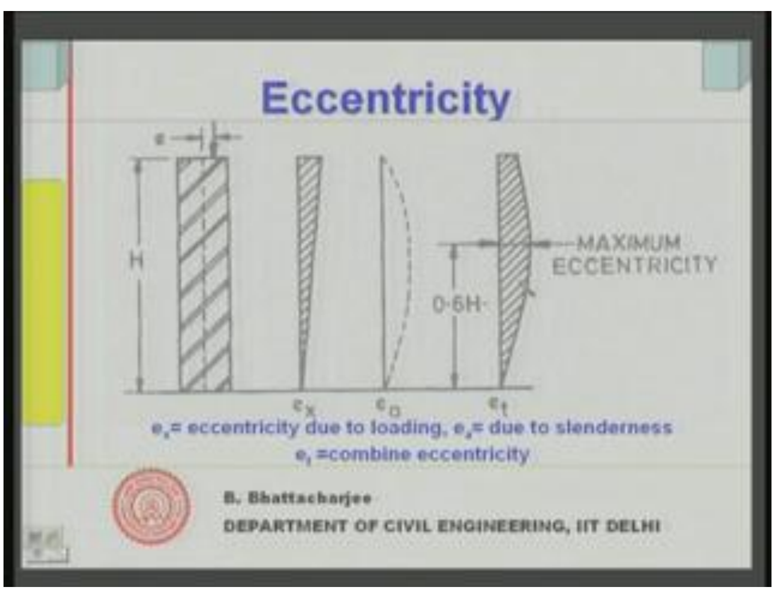

Now, what would be s what does this do when I have eccentric loading like this lets say effective load eccentricity is e and this eccentric loading would cause a kind of effective eccentricities here, will be maximum and gradually.

Since, the load will get dispersed even at 30 degree angle as we know so eccentricity will go on reducing, because this load gets dispersed we mention that effective dispersion angle we take at 30 degree in case of masonry of course concrete 1 can easily take it to a 45 degree. So, eccentricity will go on reducing as I go down and it can be taken as nearly 0 at the bottom. So, eccentricity will reduce in this manner but the shape of the member would be something like this. So, if the load is acting somewhere here let us say effectively due to buckling, if it is buckling also there will be you know due to slenderness there will be if it is buckling also.

So, act of the member will shift so net effect of the e eccentricity will look like this you know like buckling it is a this eccentricity further enhance the effects of this buckling effect. So, you will have net sort of eccentricity something like this and the maximum eccentricity possibility is 0.6H.

So, there is a, they act together in a way eccentricity and slenderness both act in a slender column the eccentricity will adapt to the eccentricity first due to buckling and then due to further due to the eccentricity itself, in other words it will buckle more and the failure would be failure would be, would take place earlier when you have eccentric loading together in a in a slender member. So, that both this aspects are taken care of in stress reduction factor.

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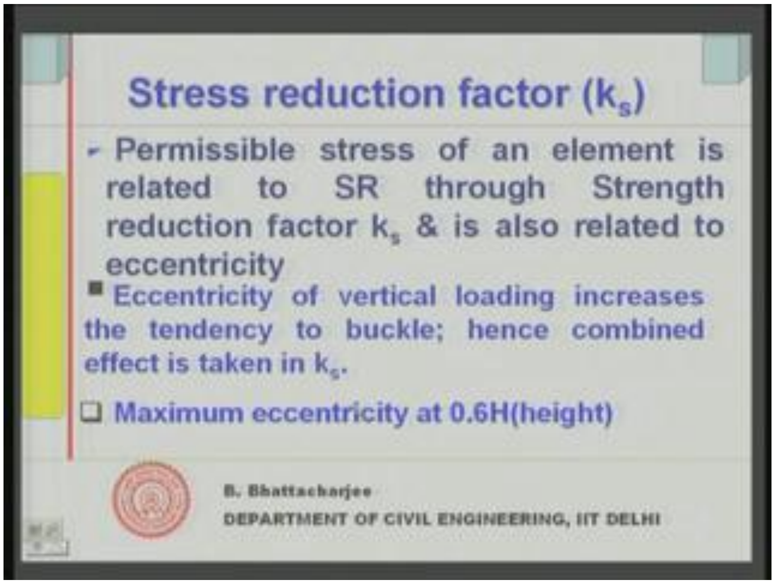

So, permissible stress of an element is related to slenderness ratio through strength reduction factor and this is also related to eccentricity right eccentricity of vertical load increases the tendency to buckle that is the idea hence combined effect is taken in k s, well as we have seen maximum e eccentricity takes place at 0.6H. So, this is all clear now that eccentricity that this is all clear now, that buckling takes place when the member is slender and if it is eccentric the buckling will be still enhanced, and therefore my load carrying capacity will get reduced and this we take care of through stress reduction factor.

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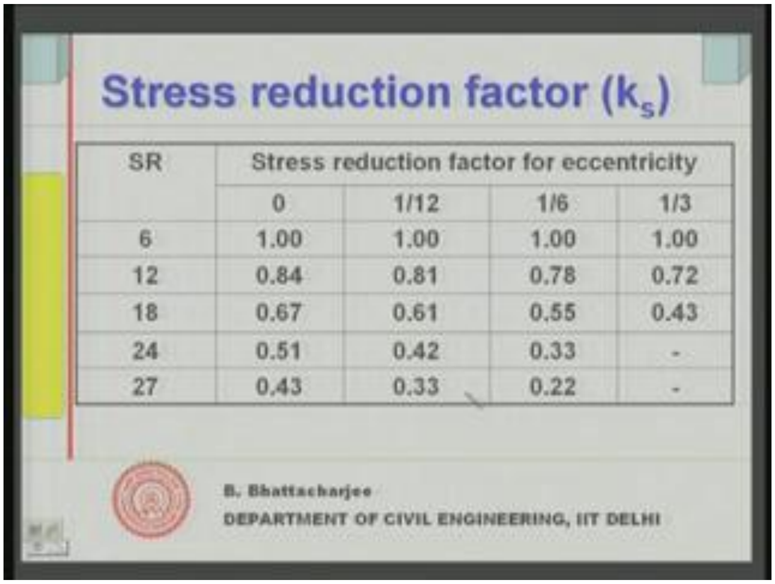

This stress reduction factors are something like this the stress reduction factors are something like this for example: we said that below a slenderness ratio of below a slenderness ratio of 6 I need not worry about buckling ok 6 need not worry about buckling whether whatever, is a effective eccentricity this is actually t by 12. This is 0, this t by 12 I mean 1 by 6 or you know 1 third of the t 1 third of the thickness. So, this is 1 by 12 1 by 61 30. So, we define the eccentricity in terms of the thickness.

So, 1 by 12 of t 1 by 6 of t and 1 by 3 of t in fact the table given in the code is much wide I have taken a small portion of the I have taken a small portion of the small portion of the this table and trying to explain so up to 6 there is no up to 6 there is up to 6 there is no correction it is all 1 whether we have eccentricity up to 1 third or not and when it is slenderness is increasing you can see even at 0 slenderness as a slenderness ratio increases slenderness ratio increases even at 0 the eccentricity I mean; the stress reduction factor reduces.

So at 27 eccentricity 27 the stresses reduce to 43 percent just due to this and similarly, when you have eccentricity also the together the of course allowable, because load it cannot take that load at all. So, permissible stresses is effectively allowed with so much of eccentricity and so much of slender member its slenderness as to be as to be brought down. So, as you can go along you go along this direction this values are reducing as I come down this direction this values are reducing as I go along this direction values are reducing values are reducing. So, for example slenderness ratio 12 you have 0.84 0.81 0.78 and 0.75.

So, stress permissible stresses are reduced using this stress reduction factor stress reduction factor, so permissible stresses are reduced due to stress reduction factor right now, then there are other factors one of them we call as area reduction factor one of them we call as area reduction factor

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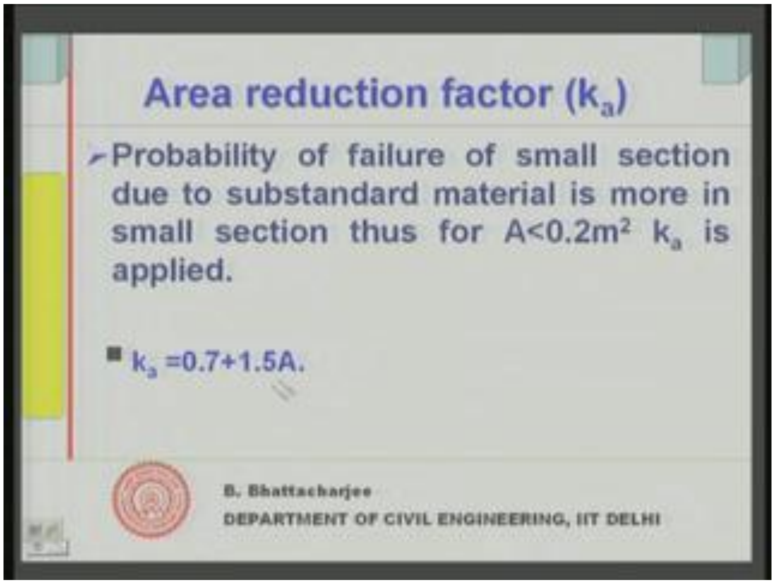

And what is this area reduction factor well you see unlike concrete the 95 percent characterized characteristic strength etcetera here, we are not dealing with such situation therefore we the strength on average strength, if you remember average strength of unit strength of masonry we also talked of average strength of motor.

So, when we are talking of average strength in fact our factor of safety is somewhat reduced now, it has been observed that if you if you are a small member, since I am dealing with not with the strength which will be exceeded large number of times 50 percent of the time the masonry strength can be actually may not be exceeded and 50 percent of the time the unit you know the mortar strength may not be exceeded not the unit strength can be exceeded. So, you will have actually some chances of finding and substandard material in the section.

Now, you will find a 1 or 2 substandard material in our large section this does not create any problem but when you find when a section is small then this might have significant influence and this is taken care of in case of area reduction factor in case of a area reduction factor and therefore A k if applied therefore k a is applied and k a is applied something like this below point 2 meter square so when the area is sufficiently small. So, let us say below 0.2 meter square area of the brick work you are dealing with or the wall area is less than that then k a is equals to 0.7 plus 1.5 into area itself for example if I put A equals to point 2 this value will be equals to 1, if it is 0.3.

Let us say it is equals to 1 obviously you can see it is much higher than 1 so we don't take into account. So, only if this A is less than 1 then we take it. For example if it is point 1 then this would be 0.85 this will be this value will be 0.85. So, when you have small area less than 0.2 meter square you have another reduction factor which is which we call as area reduction factor which is which we call as area reduction factor right.

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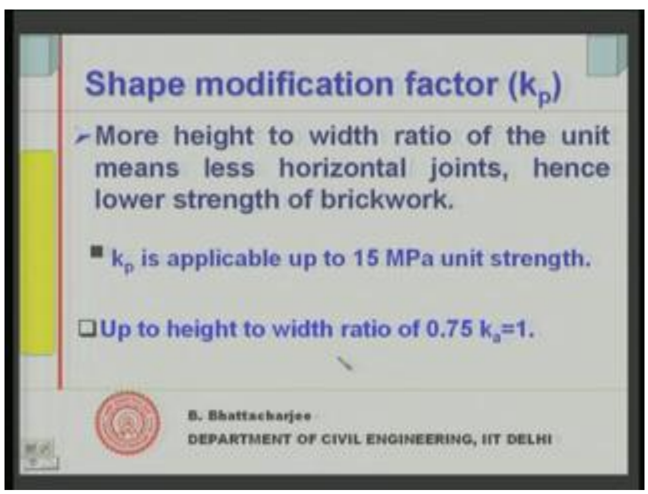

There is something called a shape modification factor when I have more height width ratio, you know it is under the concept it is the concept that when you have more number of joints the load it can carry is lesser the masonry can carry less load when there are more horizontal joints.

Because joints are the necessary you know weakest link where the failure takes place. So, if you have number of joints reduced, if the number of joints is reduced then it can carry more load it can carry more load. So, more height to width ratio of the unit means less horizontal joints hence lower strength of brickwork, so that is what the idea is and then we apply a shape modification factor called k p and it has been observed is the strength of the masonry unit is relatively high this affects get nullified, because in that case you know the aspects of shape is taken care of it is taken care of by the strength of the unit of the masonries relatively large.

So, in such situation you know the modification due to it can withstand higher load and modification due to the shape modification you know the modification due to this number of joints. This is relatively less this is relatively less in case of stronger masonry units. So, anything above fifteen MPA unit strength is usually you know you can ignore the shape modification factor but unfortunately most of the bricks clay bricks particularly, in India is of course, below this. So, most often we will have to use this and this is not also applicable if l H by b ratio is less than 0.75 as we shall see from the… So, up to height to width ratio of 0.75 this value is equals to k is equals to 1, so beyond that is only some corrections are needed.

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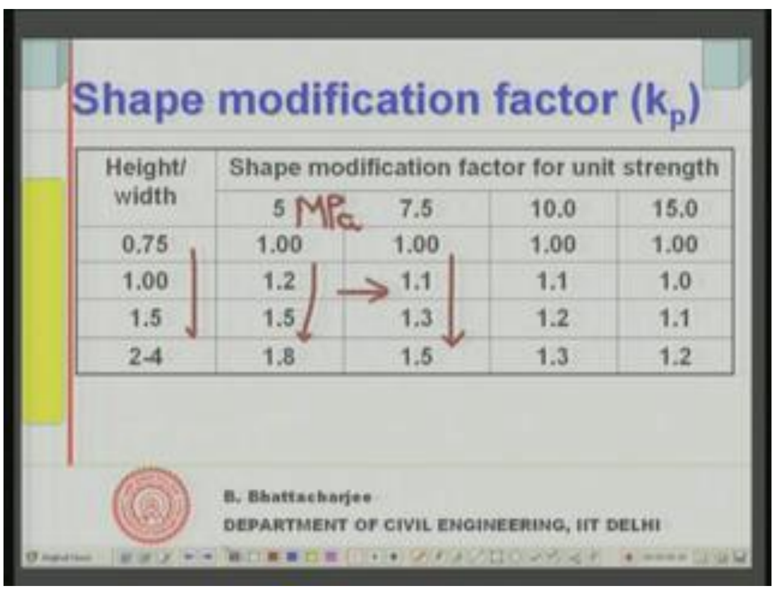

And this correction as been suggested in the form of a table again, so this correction as been suggested in the form of a table again. So, height to width ratio 0.75 shape modification for unit strength 57.510 and fifteen as I said this depends upon the unit strength higher the s unit strength this effect vanishes because then this you know the brick work is sufficiently strong and in this effect relatively becomes much less modification due to the shape becomes much less. We can take a lot more lot more load in the such situations and number of joints effect of the number of joints actually somewhat gets reduced.

So, what we observe here then we observe here that as my strength increases 57.5 MPA 10 MPA 15 MPA. These are all in MPAs 5 MPA 5 MPA you know this is this is MPA this in MPA. This is M P A so these are all in M P As 57.51015 MPA and this is height width ratio. So, as I increase this height number of joints reduces and therefore my strength increase strength increase my strength increase takes place my strength increase will take place, because number of joints will increase and as I go to the higher strength this effects gets reduced.

So, as I go along this direction these effects is less you know 1.2, 1.1, 1.1 and 1.0. So, beyond 15 MPA strengths of the unit I will not have practically, I will not have any effect and as I go down higher this ratio is higher this ratio is I find that the strength you know the strength the masonry can withstand this higher. So, because I will have lesser number of joints I have lesser number of joints right more height. So, there will be lesser number of joints actually, so that is the idea that is what is the shape modification factor is all about right ok. So, these are the 2 so far we have seen first what we have seen.

Let us just look back into it to remember, we have seen basic compressive stress which is based on masonry strength unit strength and the and the and the mortar strength you know mortar type mortar type. So, first we find we call it f b and then we have found out, then we have a stress reduction factor which is dependent upon the eccentricity and also on the slenderness and slenderness again we calculate from 2 consideration height to height to height divided by effective height divided by thickness and effective length divided by thickness right.

Then we have seen the 2 other reduction shape modification factor and are a reduction factor. Now, some cases we allow increase in permissible stresses, so far we have seen there is a reduction there are some cases or some modification factor, of course can increase some cases we allow for some cases stresses are allowed to be 1 allows increase in permissible stresses right, but before that.

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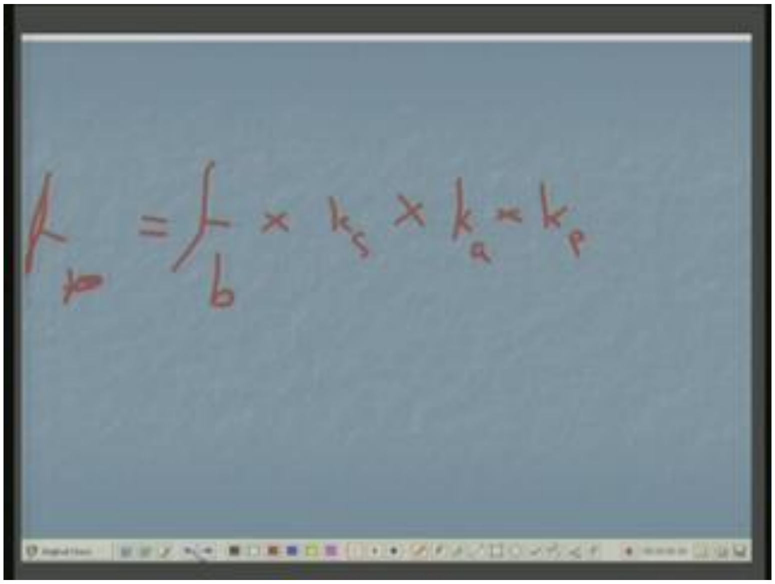

Let us just we will discuss this again in slightly more details but let us look at let us look at you know this is what you call is f b is the basic stress, we have found out multiplied by the factors you know slenderness ratio factor due to k s multiplied by k a and if required multiplied by k p. This will be my permissible stress f permissible would be permissible stress would be given by this. So, my I should calculate out the load and the load should be less than this if there is of course no effect of eccentricity, we will look into this in a little bit more detail sometime take up an example calculation also but...

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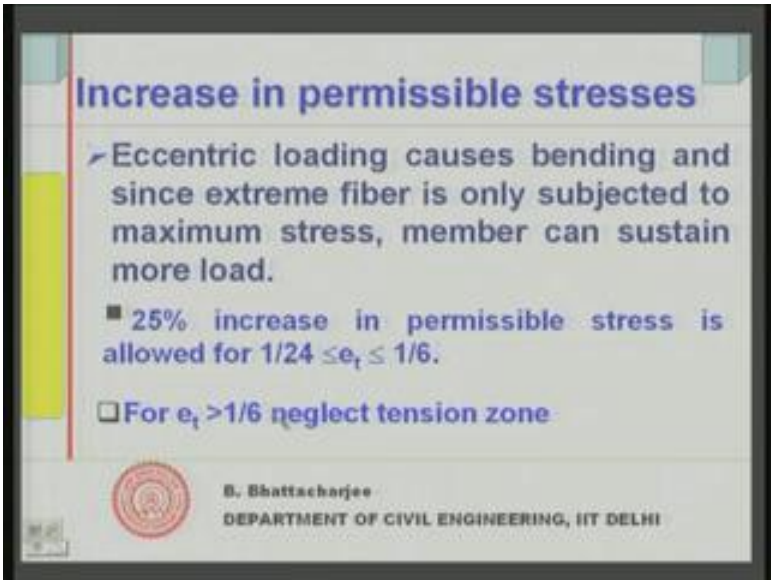

Let us look at the eccentric loading now eccentric loading now, so let us look at eccentric loading you see when you have eccentric loading as we shall see let us say of course, the member can be member can be non slender for the time being. Let us say it is not a slender member what we have observed that under eccentric loading there will be movement which will be W into e and this moment will induce actually, bending and the bending stresses will be tensile can be tensile in some direction or compressive in the some direction but normally com tensile stresses are not allowed in masonry.

It is assumed that masonry will crack under tensile loading, so we are talking of bending in such a manner that I will have compressive stresses in the work brick work only compressive stresses in the brick work only right, but then what is the situation when you apply bending we have seen earlier also in case of concrete when in bending extreme fibers are actually subjected to maximum stress, in case of pure bending we will have maximum compression at the top and tension at the bottom the other phase in between lesser tension and lesser compression. But here we are talking of situation where it is not pure bending, but bending plus some axial load.

So, effect would be some compression maximum compression or higher compression in 1 fiber and somewhat lesser compression in another fiber of course there can be situations where the tensile stresses also come, but as I said the masonry cannot take tensile stress we have assumed that it does not take tensile stress. So, that portion it would crack and the load will be withstood by only the un-cracked portion, so in masonry actually this tensile stress allowable tensile stress is actually practically, we take it to be 0 practically we can take it to be 0 although it can take some amount.

So, what we are doing in such situation as we shall see through the diagram s 1 phase you know since I do not allow tension so the max the minimum stress could be 0 compression you know 0 and to a maximum s compression. So, 1 phase will have maximum compression other phase will be 0 the limiting case and beyond that of course, tensile stresses will come into the other phase since such a situation the whole element is not under the full maximum stress direct compression the whole section will be under full stress full maximum stress whereas in case of bending only 1 phase is under maximum stress.

Since, such a situation possibility of withstanding this stress is more, then if it was under pure compression you can recall when we discussed about modulus of rapture test, in case of concrete and the direct tensile test split or even indirect split tensile s strength you recall that split tensile strength was lower than the modulus of rapture 1 of course, the stress block that we assume but the second reason of course was that that in case of bending only the extreme fiber is subjected to the maximum stress and other portions are not. So, therefore probability of a weakest link being there exactly at the extreme fiber is somewhat low.

It can possibly take more load then weakest link, so what happens is there is a tendency generally there is a it is observed that it can withstand somewhat higher load so that is why you see since the extreme fiber since only the extreme fiber is subjected to extreme since only extreme fiber is the only you know is the only is the only 1 subjected to maximum stress member can sustain more load. So, that' is right so eccentric loading course is of course is bending and therefore some amount of increase in stresses are allowed and this has been observed to be twenty five percent.

So, 1 allows 25 percent increase in permissible stresses right if the eccentricity is 1 by 2 four t you know it is more than 1 by 2 four t and less than 1 by 6. Now, what are this 2 limits well we will see that in case of 1 by 4 e bar being 1 by 24 t e t stands for it is in you know ratio of actually e bar divided by the t. So, that is 1 by 24 and this is 1 by 6. So, when this is 1 by 24 we will see the maximum stress itself, is about 25 percent more than, 25 percent more than maximum stress is 25 percent more than the average stress and when it is 1 by 6 that corresponds to the case where there is 0 stress at 1.0 and maximum compressive stress at the other point.

If you increase the eccentricity beyond this point e bar you know equals to 1 more than 1, I mean if it is more than 1 by 6 t when it is greater than 1 by 6 t there will be tension as we shall see we will just see this we will look into this. So, in such situation there will be tension.

So, this 25 percent increase is allowed only when it is between this below this below this where the eccentricity is lower than 1 by 24 t e t stands for that ratio. So, 1 by 24 t eccentric is lower than that the maximum stress will anyway be anyway be maximum stress will be anyway be less than 25 percent less than 25 percent, so right. So, that is what it is for e t less than neglect we neglect the tension zone, if it is more than 81 then this is the this is the cases how we handle the eccentric loading of course, all other factors are always there, but you will have you can increase the steel s you know stress s by 25 percent we will see through an example.

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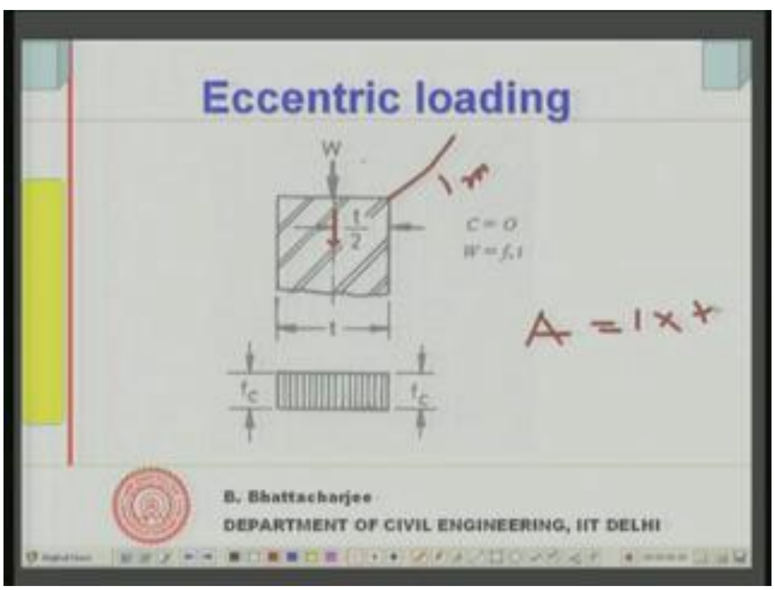

Let us see why this how… And now, eccentric loading if you remember if I have a ok. Let us say before eccentric loading let us see, the pure compression, so my concentric loading you know W x straight away here W x straight away here and I will have this is t by 2 and this is also t by 2 and I will have uniform stress throughout which I call as f c. So, uniform stress throughout and since 1 meter of the length this side I will take 1 meter right, so area is equals to area is equals to 1 into t 1 into t. So, area is equals to 1 into t, so if since this area is equals to 1 into t. So, W is equals to f c into t W the load that carrying is equals to f c into t, so 1 can 1 can f c into t so therefore 1 can it can carry you know the f c is the stress level f c is the stress level when it is concentric loading.

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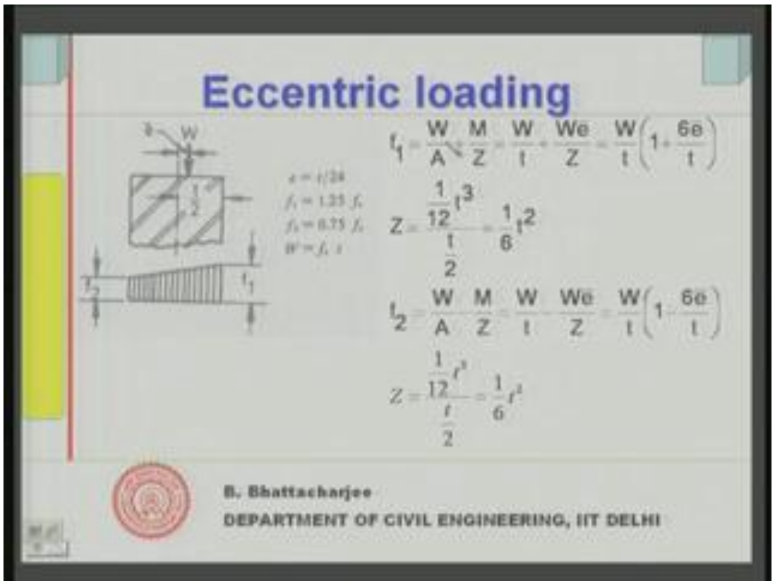

Let us say eccentric loading ok when it is eccentric we will come to this later on, but let us look at the equation when you have eccentric loading what happens you have a direct stress plus a bending and you remember, if the bending moment is M and if the modulus section modulus is zed then the maximum stress compressive stress will be f 1 which will be equals to W plus A plus M by zed because bending introduce a introduces a compressive stress on 1 side and tensile stress on the other side.

For example, here bending will introduce bending will introduce compression along this phase, because the load is acting here. So, it will actually more compress here you know along this along this direction there will be more compression here it will have more compression, here this bending W into e bar will cause a kind of tension. So, there a tension it will cause here it will try to press more on this side it will try to cause tension you know. So, it would be something like this the bending so this phase if you look at it will bend like this phase this part of the wall this phase of the wall will bend like this.

So, it will get actually shortened whereas this will get elongated a little bit you know it will bend in this plane it will be something like this bent, in this plane and therefore bent in this plane. So, you will have shortening here I mean sorry this will not be this will be other round actually, you will have you know since this is, it will have something like bending in this manner and this side you will have some sort of s this side you will have some sort of shortening this side you will have some sort of shortening. So, some shortening here will take place you know this side is a shortening and this side is elongation.

So, compression will be here, so you have actual compression W acting divided by A plus the compression due to bending here you know compression due to bending here both. So, this compression I compressive force due to bending is given by M by zed where M is the bending moment and how much is the bending moment W into e bar. So, W into e bar divided by zed and what is the zed here the section modulus, because I have got 1 meter width along this direction if you remember, if you recall we said it is 1 meter width along this direction 1 meter we take 1 meter 1 meter along this direction 1 meter right.

So, the 1 meter we take you know per meter t is area, so area is simply t into 1 that's what we said and this will be b d cube b t cube you know this will be 1 by 12 b t cube s I mod I mean moment of area of this section 1 meter by t is 1 by 12 t cube divided by t by 2 divided by t by 2 that will be section modulus, which will come out to be 1 by 6 t square this will come out to be 1 by 2 t 6 square. So, if I put here W by e bar and put here 1 by 6 t square I will have 6 e 6 you know W by t I can take common W by t I can take common and this t 1 t will remain inside and here I will have 6 going up there.

So, this f 1 the compressive stress will be 1 plus s 6 e by t bar 1 by 6 e bar by t and correspondingly the least compression f 2 which I am calling as f 1. So, f 1 will be given by this where the compression is more and f 2 where the compression is less will be given by 1 minus 6 e by t, because some of the compression will be neutralized by the tensile you know tensile stress bending tensile stress that will come here and if I have e equals to t by 24 you put e equals to t by 24 here. So, this will be 6 divided by 24 you know 6 divided by 24 and this will be 6 divided by

24 so this will be 6 divided by 24 is 0.25 6 divided by 24 you know this will be this will be 6 divided by 24, which is equals to 0.25.

So, 0.25 will come here 0.25 you know this will be 0.25 so 1 0.25 W by t. So, when you have e equals to t by 24 f 1 equals to 1 0.25 f c where f c is the pure compressive force simply W divided by t and f 2 will be 0.25 less, because this will be 0.25 less will be point seven five f c. So, W is equals to f c into t, so up to this therefore you know you assume that up to up to 24 percent maximum load is 24 percent. So, you allow this twenty five percent I mean it can withstand this load it can straight away with withstand permissible stresses it can withstand and beyond this, beyond this, beyond this.

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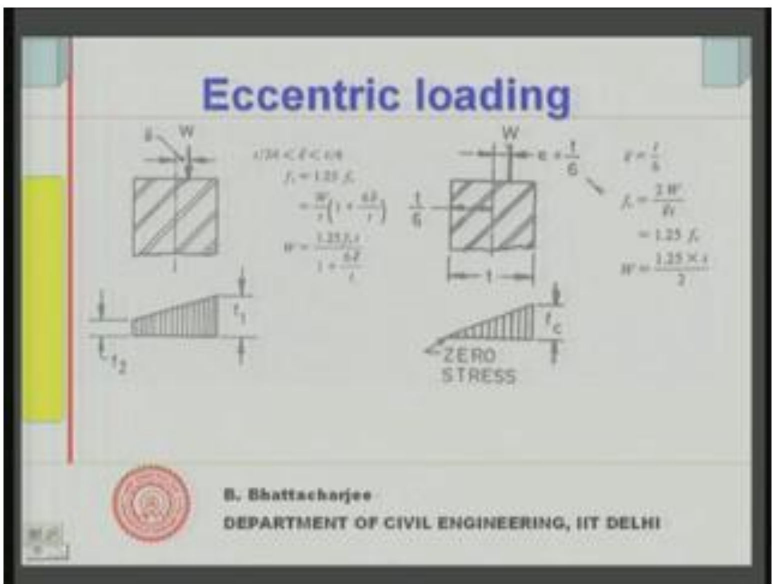

When it is less than t by 6 right, when it is less than t by 6 the maximum allowable f 1 should be equals to 1 0.25 f c. So, up to that there is no problem because it was coming anyway within 25 percent maximum stress up to 24. So, less than eccentricity less than 24 less than 1 by 24 permissible stresses would be whatever, you find there is no problem, because if you exit by 25 percent there is no problem but beyond this stress will be. Now, actual stress will be more than you know this will be more than this will be more than 1 0.25 f c f 1 will be more than 1 0.25 f c. So, permissible stress is actually f 1 is 1 0.25 f c and f 2 will be whatever the corresponding value is, so the load that it can carry if I want to find out.

If the eccentricity is more than you know 1 by t by 24 and it is less than t by 6, then I can the load it can carry is given 1 0.25 f c t divided by from this formula straight away 1 you know 1 0.25 f c into t divided by W t. I mean W I want to find out 1 0.25 to t divided by 1 plus 6 e bar by t. So, that is the permissible maximum load it can carry that is the maximum load it can carry when it is between t by 6, because we said that we can increase it by 25 percent we can increase it by 25 percent, but anything beyond that is not allowed that means you cannot although your stresses here would be actually would have been more, but what is permitted is and 25 percent increase is allowed permissible stress 25 percent is allowed.

So, accordingly therefore you can calculate out how much load it can carry provided the eccentric eccentricity is more than t by 6. Let us see with the case of t by 6. So, when it is equals to t by 6 when it is equals to t by 6 e equals to t by 6 put back into the formula 1 minus you know put it 1 minus 6 e by you know e is equals to t by 6. So, this term will become equals to f 2 will become equals to 0 f 2 will become equals to 0 f 2 will become equals to 0 and here the stress will be maximum and that is equals to 1 0.25 f c. So, f 1 is equals to 1 0.25 f c, so W the load it can carry the load it can carry.

Let us look at it again, because you see what we are trying to do is we are saying f 2 is equals to 0 and therefore f 2 0 will corresponds to 1 minus 6 e by 1 minus. This corresponds to 1 minus 6 e bar by t t equals to 0 and if you put find out value for e bar you will find that it comes out to be t by 6. So, this is equals to t by 6 when this would be equals to 0 and what is the permissible load so e bar is equals to t by 6 that is what we have seen and then what is the permissible load, because this is value can be 1 0.25 f c. So, 1 0.25 f c is value this value 1 0.25 f c.

So, what is the load it can carry because total load is equals to you know total load is equals to W should be equals to f this value multiplied by this value multiplied by this value multiplied by the length t half. So half you know half f you know this is the maximum stress let us say f c or f 1 let me call it, so half f 1 into t must be equals to W. So, half you know half f 1 into t that is f half of f c this value into t that must be equals to W that must be equals to W that must be equals to W is equals to therefore f c therefore I can find out half f c into t that was that was equals to W.

If I take moment of this 1 this is the area is equals to half of the stress multiplied by the my 1 meter plus this length that is the force and that must be equals to W. So, half of this load whatever is the load and that is equals to 1.0 stress here so that's equals to 0.25.

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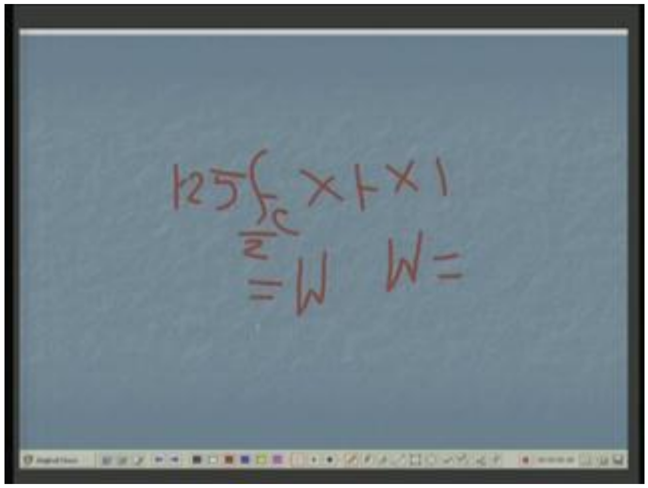

So, one can find out from this expression W is equals to this much you know, let us let me just write it down there. Let us just explain 1.1 0.25 f c into t that is the total this is the stress multiplied t into 1 into 1. So, this is the total area and this is the maximum stress permissible that must be equals to and half of this, because divide this is a triangle this is a triangle.

So, divided by 2 that must be equals to W so if I calculate out W from this formula, I will get the maximum permissible W is equals to you know 1 0.25 t by 2 you know W I can get an expression for W from this and that is what we have done in the case you will see W is equals to 1 0.25 t divided by 2. So, W is equals to 1 0.25 by 1 0.25 by 2 into t because the area of this triangle is 1 0.25 this value should be 1 0.25 f c this value should be equals to 1 0.25 f c multiplied by this length t into half that is equals to W total force must be same and that is what we are doing and we find W equals to this W equals to this that is right. So, that is how we find out when it is purely under compression that is the limiting position when it is purely under compression.

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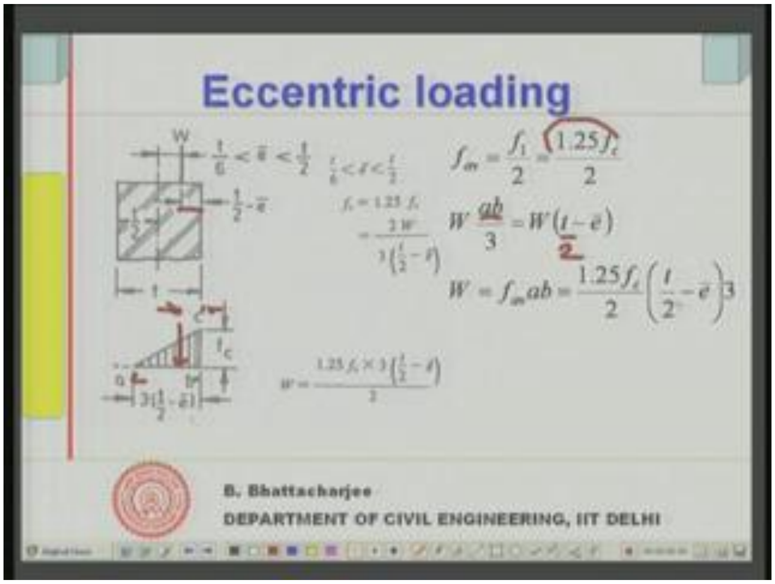

Now, if you have further load increased above this then what will happen there will be tension in this zone and we assume that it cannot take the tension and it will crack it cannot take the tension it will crack. So, I will have some length here I will have some length here I can derive an expression for such length and this will look like this. So, average stress I can think in terms of is half into f 1 by 2 if this is f 1 in this side if it is f 1.

Let us say in this side if it is f 1 then the average stress will be, because the other side is 0 so average stress will be f 1 by 2 and maximum permissible stress is 1 0.25 f c maximum permissible stress is 1 0.25 f c. So, this we know this is known to us, so f 1 that would be f 1 would be equals to 1 0.25 f c 1 0.25 f c you know, so f 1 will be equals to 1 0.25 f c. So, that is what is known to us this is known to us so f 1 divided by 2 f 1 divided by 2 is the average stress because this is maximum here 1 0.25 f c and 0 here.

So, average is this 1 0.25 f c by 2 now, this if I take the moment of this force if I take the moment of this force about this phase then I get W this length. Let me call it as a b this length is a b you know this length is a to b this length is a b. So, this is a b length so the moment of this force about this phase is W into a b divided by 3, because it a triangle. So, the whole force can be thought to be acting at this point at 1 third point. So, this is 1 third you know this will be 1 third, this will be 1 third, this will be 1 third a b, this will be 1 third a b.

So, 1 third a b a b by 3 this will be a b by 3, so W into a b by three must be equals to I am taking whole of this whole of this stresses, you know stress would be acting the whole stress would be acting and that must be equals to total stress must be equals to W. Because load as to be same you know the W must be equals to the f c into this length right f c into this length as it is shown here f c into average. So, that must be W and this is acting at. So, W into a b by three must be equals to W into t minus e bar because this W is nothing but equals to into a b right which is acting here and that must be equals to applied load W.

So, taking moment about this is t minus this distance is t minus t minus this distance is t minus e bar into W. So, that is the moment and the stresses is moment due to the stress b this stress b is also W into a b by 3. So, 1 can get an expression for a b equals to 3 t into e bar t 3 t by you know t into e bar 3 t in minus e bar 3 t minus e bar. So, right so that is it so 1 can get right and this is remember this is t by 2 1 third of the t by this distance is t by 2 minus e. So, this is t by 2 minus e that is a this is there is a small error this should be 2 t by 2 minus e bar.

So that is t by 2 minus e bar into 3 that is the value of a b a b is equals to from this it follows that a b equals to 3 into t by 2 into e bar this term is nothing but equals to a b this is a b and the total load it can car I can carry the is equals to f average into a b right. So, what is f average f average; we have seen is equals to 1 0.25 f c by 2. So, I put 1 0.25 f c by 2 into this that's equals to W. So, maximum load it can carry is this maximum load it can carry is this maximum load, it can carry is this maximum load it can carry is f average into a b which is given by this.

Now, this length therefore the length 3 t by 2 minus e bar and what is happening to this portion the crack would have come up to this portion and it would have you know this portion. So, this is the ineffective portion the effective portion is this much and we assume the maximum stress it can carry is 1 0.25. So, total load it can carry is W now, we have al f c is the what is f c f c we find out from basic compressive stress multiplied by the effect of slenderness ratio and eccentricity right that is stress reduction factor multiplied by any shape modification factor. If there is any or area reduction factor if there is any.

So, all multiplying this I have got f c and therefore maximum load eccentric load 1 can carry would be known to us provided I know that e belongs to e is greater than t by 6. But obviously, less than t by 2 t by 2 is the maximum e possible beyond that of course, we do not allow I mean;

it can have but usually you will not have unless I have a coming out and then I apply load to this the there can be more than that but generally in walls such situations are not encountered usually and it is between t by 2. So, that is how we can find out what is the maximum load 1 the masonry wall can carry under eccentric loading and the also we have seen why there is an there is an you know increase or you allow an increase, in the allow an increase in the tensile stresses right.

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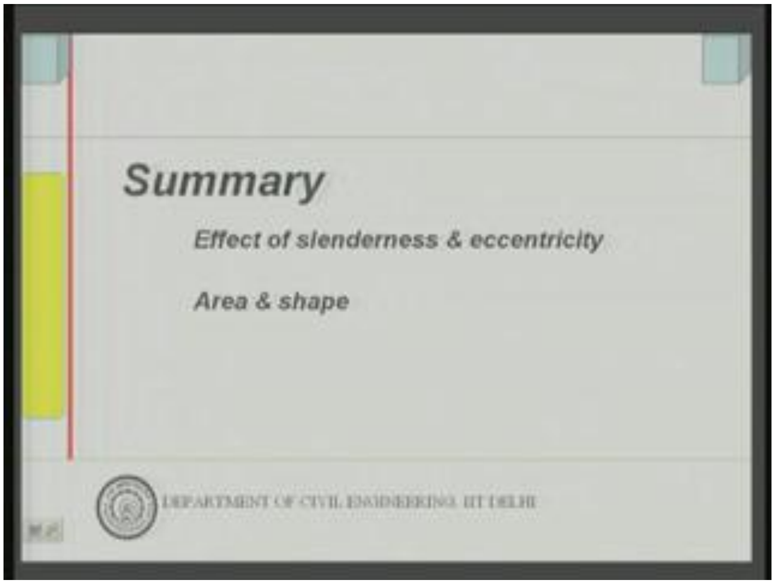

So, we can summarize therefore what we have done we have looked into the effect of slenderness and eccentricity, we have looked into the effect of slenderness and eccentricity and we have also looked into the effect of area and shape and we have seen that the how we calculate out stresses in case of eccentric loading.

Now, we will combine all this effect and try to show through an example, calculation how we find out the load carrying capacity of a masonry wall and also look into another, you know the increase in permissible stresses allowed by the code under certain other circumstances. So, I think with this, we can conclude today is discussion and we will look into the other issues of resistance to load both vertical as well as horizontal, in the next lecture ok. So, that is what it is...

Thank you.