Building Materials and Construction
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Module - 10
Lecture - 02
Masonary: Walls

Having looked into the properties of the masonry units and also some properties of the mortar and their combination. Today we shall look into the masonry walls some properties of the mortar selection, etcetera.

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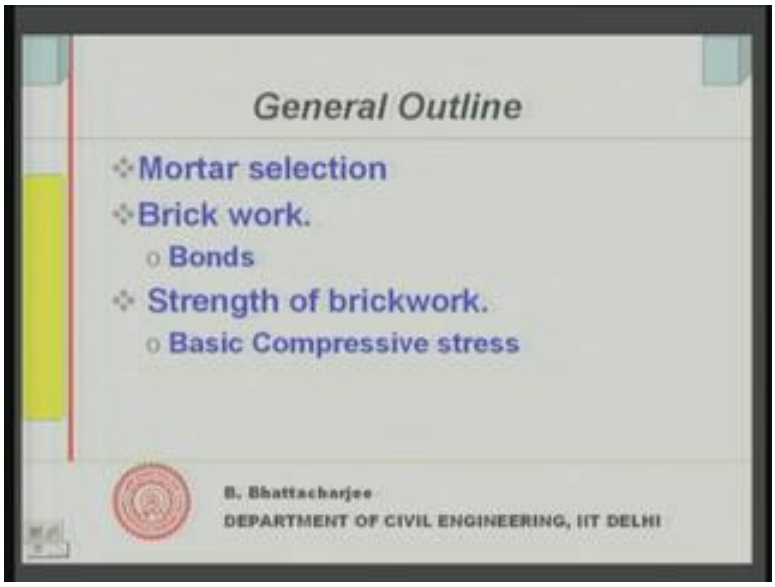

So, general outline of our today's lecture would be mortar selection followed by brick work, some introduction to brick work something about the bonds there in and then strength of brickwork we will introduce. So, we will introduce what is called basic compressive stress.

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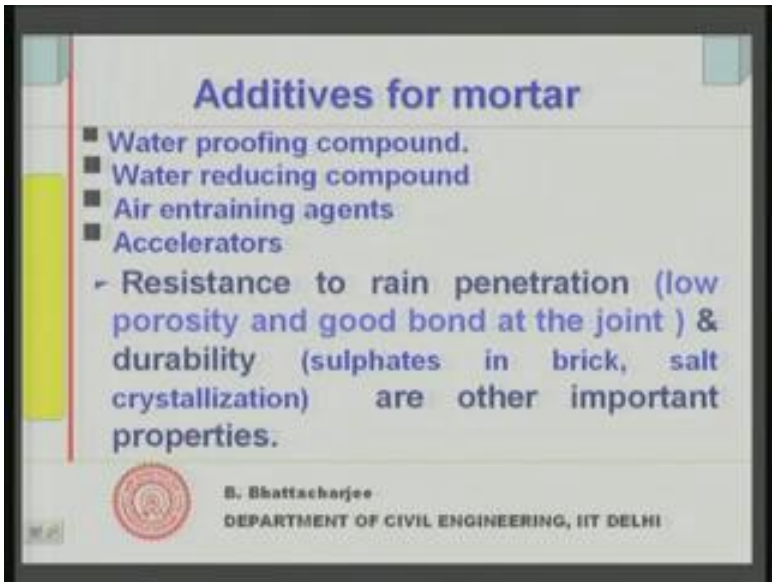

Now, we discussed what the types of mortar are you know some ideas about it. But they are certain things left out, we also tried to also introduce in the last lecture. About how strength of mortar and strength of brick combined affect the strength of masonry, but we will look into details of the same 1 today.

Now, something more about the mortar you see we can always have some sort of mortar is, after all you know it is nothing but a kind of cement and sand and water. So, it is essentially something follows from, the concrete but instead of much strength and we have seen, the properties required are totally different. Here the properties are of course strength is 1 of the property. But water is another major factor, shrinkage is another major factor and workability in the sense that; you know, 1 should be able to apply it easily with towel; those are the properties required.

So, but basically it is again the cement based material. So cement, water, lime cement or lime mortar etcetera, cement lime mortar that's what we discussed. Now, so we can use some additives like we do admixtures, we use in concrete.

Similar, we can use some additive for mortars, additives are some water proofing compound. Then something likes water reducing agent. You know we can improve the plasticity; I will come to the water proofing compound. The air entraining agent and also something like, accelerators. Now, water proofing compounds are those compounds which go into the mortar system and actually, sort of improvise the pore structure there, Such that the moisture vapor can move through it but capillary water cannot move through it.

So, it changes the surface tension characteristics of the pore surface, in kind of a surface characteristics of the pores it change, such that the pores would act like almost like non-waiting liquid, maybe we will have some discussion about this sometime later on. When we discuss about, you know other some other properties, relevant properties like surface treatment etcetera. So, when we discuss about them proofing and surface treatment sometime we might be discussing. So, essentially this water proofing compounds are the 1, which would will ensure that there is no liquid water penetrate into the mortar. A water reducing compounds are nothing but plasticizers would improve the workability like we did there in case of concrete similar 1.

So, air entraining agents again they have similar sort of properties here and accelerators are used. So, that you can it can quickly set remember we said that quick setting, I mean if it as rather quick strength gain is important. So that, you can the brick 1 layer over the other. You cannot delay too long; so, quick strength gain is important 1 more important issue, which we did not discuss much earlier, is, resistance to rain penetration. This is very important as far as walls and masonry structures are concerned.

Now, you know rain water can penetrate through this, through the wall. Essentially it can penetrate through the brick itself, and then it can penetrate through the mortar itself, but most importantly it is the joint, between brick and mortar through which water can penetrate. Normally wind and rain follows together, but it is called driving rain index we may have, some more discussion on this later. In discussion with reference to dampness;

so, it is actually driving wind and rain go hand in hand together and the wind driven rain penetrates into the wall.

So, it is actually incident or it is impinges, it impinges upon the wall and when, it impinges upon the wall, the water can be absorbed by the brick by capillary suction. That is what, we have seen suction rate. So, capillary suction it can be absorbed by the brick, and then it goes inside as it penetrates and we mentioned that by the time you know, the rain stops it should not enter into the inner surface of the wall. The drying period, before drying period starts rain you know moisture should not reach the inner surface of walls.

So, that is the issue of the brick porosity of the brick able to it plays a role porosity of the mortar also plays a role. It should not move through the mortar but most importantly most importantly, it is the joint. You know, it is the joint which is most important so mortar it should be low porous and the joint should be proper. So, it should have a good bond with the brick work. If you have a good bond with the brick work there shouldn't be crack formation and bond with the brick work should be good.
So that, the moisture should not rain penetration you know does not take place, through the joints of the brick and mortar, this is important issue. The other issue with reference to mortar is the durability. Durability the 2 issues are very important, because as usual see sometime later on. That sulphates in brick, in the long run can cause expansion particularly, a parapet wall. You can see cracks at the parapet wall, because soluble sulphates in the bricks in due course of time a in the long run of service of the brick masonry, may each out from the brick work. Brick itself, the brick units itself and then react with the mortar resulting, in expansion and this may result in crack formation in mortar.

So, sulphates presence in brick could be 1 of the reasons which can cause actually problem of durability in mortar. So, 1 as to use actually low porous mortar in such situation and high strength mortar in fact salt crystallization, soluble salt crystallizes within the pores of the mortar, salt crystallization we have talked about, both of this

issues in connection with durability of concretes. So, something similar have happens here.

So, salt crystallization taking place within you know, within brick eaching out salts. If the crystallizes they can cause expensive pressure and that can again results in durability problem of the mortar. So, these are the 2 issues related to durability and rain penetration other properties of mortar and we have discussed about. Now let us see, throat clearing what happens?

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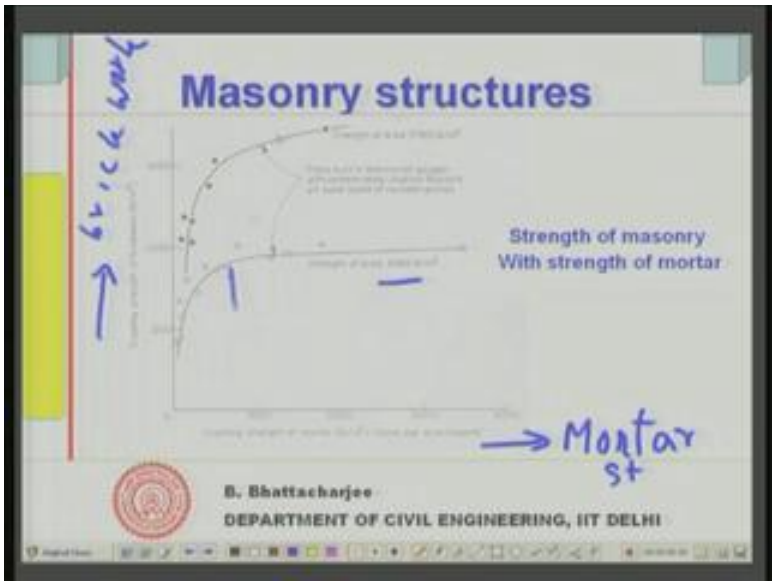

Now, if you go on increasing the strength of the mortar, the strength doesn't increase beyond this point and this is for a lower strength brick, for a relatively higher strength brick same thing happens, initially of course, as you go on increasing the strength of the mortar. There is an increase in the strength of the brick work, but beyond a point there is hardly any increase in the strength of the brick work, although strength of the mortar as increased. So, what we see higher strength brick of course gives you higher strength of the brick work.

But increasing the strength of the masonry I mean mortar progressively does not increase the strength of the strength of the brickwork.

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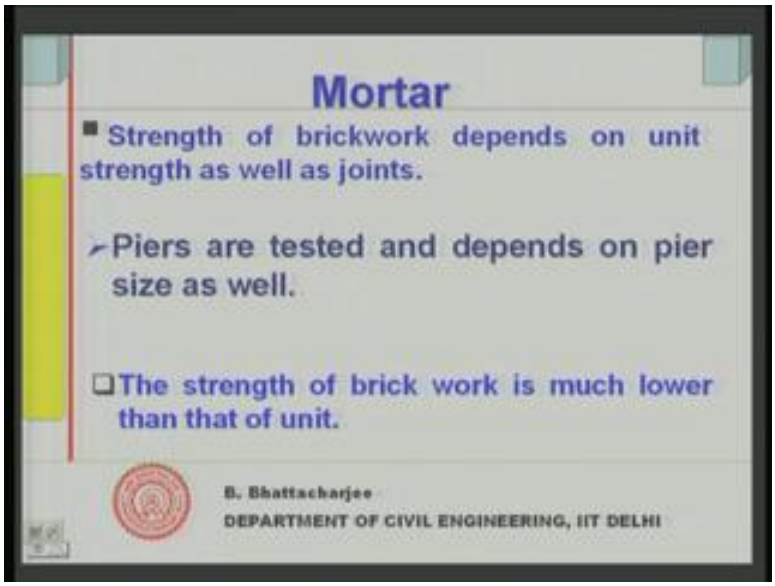

So it flattens down it flattens down. This is 1 important issue, we look back again, and then similar figure as far as bricks are concerned strength of the brickwork depends on, unit strength as well and as well as joints. So, that is what the idea, so we test actually piers; we generally test the piers are tested, because you cannot derive the strength of brickwork strength of the brick and mortar, I mean, I might individually test them

But we will see that the strength of the brick work is far different then strength of either of them that is what we have seen the strength of the mortar if you go on increasing it doesn't proportionally increase and we will see the ratios in fact it is much lower, the strength.So, what is tests are piers made out of brick work themselves and not individual bricks and mortar and load. I mean, this test you do to find out the qualities of the mortar and qualities of the brick, but then strength of the brick work, is directly tested piers are tested or tests are done. The Indian standard code of course allows you to do a kind of prism test.

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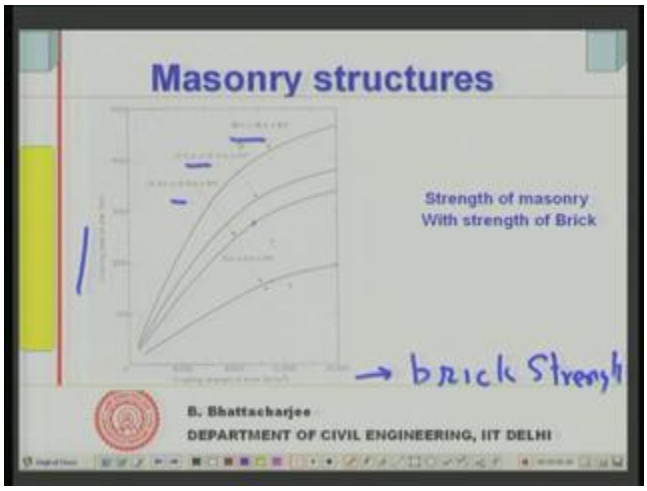

So, these are done and we would see that, strength of the brick work is much lower than that of the unit and as well as of the mortar, depending upon the situation some of these we will see today itself. Now, strength of the masonry now this is if you see; I this diagram again we are repeating this diagram, but if you see this axis is the strength of the brick. This axis is the strength of the pier, different sizes of the pier this is actually 9 inch by 9 inch means; 25 millimeter by 225 millimeter by 2.7 meter high, pier and this is something like 38 millimeter by 38 millimeter.

You know, this is 1 and half brick thick this is just a 1 brick thick pier 2.7 meter high and this is also 2.7 meter high. All this are nearly about 2 .5 to 2.7 meter high, this is also 1 brick, I mean, 1 and half brick, there 1 and half brick this is 1 and half brick and this is about 2 brick thick walls i mean piers. So, when you test them you can see strength of the brick increases the strength of the pier does increase, but there is a point beyond which it really doesn't exist I mean doesn't increase, further the mortar used here is of course the same mortar and as the size increases strength increases lower the size actually strength is less.

So the 2.3 we note 1 is that it doesn't increase monotonically it increases, then it clutters down and as the size increases the strength also increases somewhat. So, brick pier strengths are something like this, you know brick pier strengths are something of this kind.

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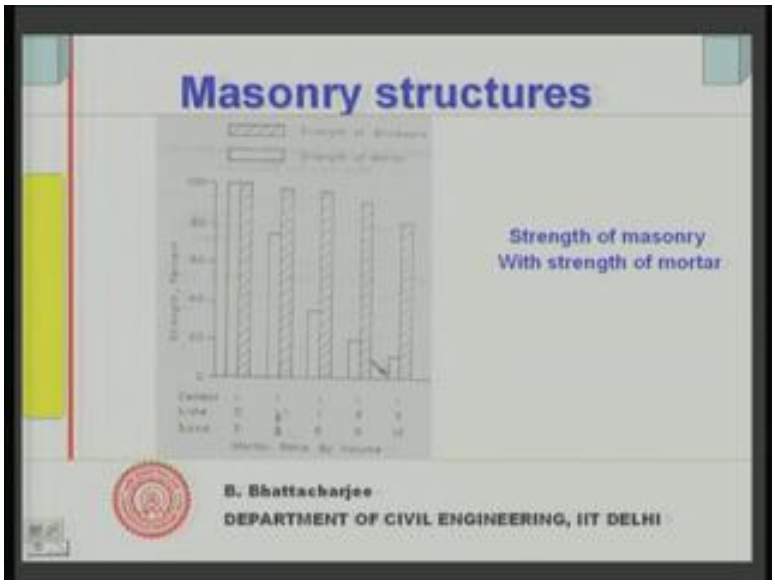

A third diagram of the similar kind which you are repeating we have seen it earlier also the is the diagram which shows different mortars here. For example, if you look at it. if you look at it this is 1 is to 3 mortar, in fact this is H 1 mortar the strongest mortar that we have we mentioned H 1 to L2 there are several types of mortar H1, H2, M1, M2, M6 and L1 and 2. If you remember if you recall the type of mortars when we were talking about, in fact Indian standard codes as standard co- standard code, defines 26 mortars different kind of mortars within, this variety of H1 to, H1, H2, M1, M2 and M3, L1 and L2. Now, this is the heaviest mortar.

This is the heaviest mortar 1 is to 3 cement sand mortar no lime here, 1 is to 7 mortars. Now, you have a same strength brick, uniform strength brick strength was same, but you changed only the mortar strength. So, this is the strongest mortar and then this is the lightest. You know, 1 is to 3 is 12; so, it is actually 1 cement, 3 lime and 12. So, you can see its much lean, much leaner mortar and strength of the, this is the strength of the mortar, this is the strength of the brick work. So, strength of the mortar to brick work they are nearly same here.

You know like, this is this percentage if you see and here the strength of the mortar is much less, but still the strength of the brickwork is not much less and as you go to a very weak mortar, the strength of the brick work diminishes, but doesn't diminish very much.

So, there is no point using unnecessary very strong mortar that is idea we get; we get that idea that right, that very strong mortar is possibly not necessary anyway that's the corresponding mortar or an optimal mortar.

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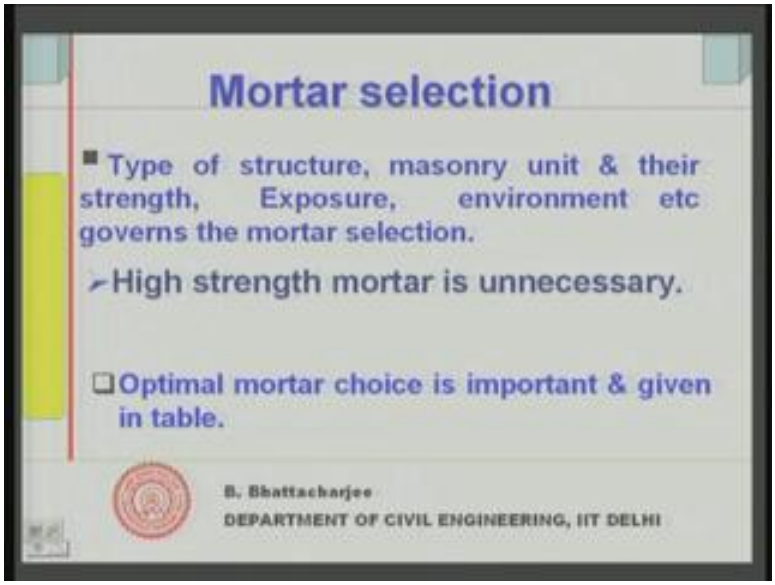

So, if you look into now mortar selection we will see that types of type of structure type of structure type of structure right type of structure, masonry unit strength you know masonry unit type. So, there is brick stone etcetera and their strength the exposure condition environment etcetera governs the mortar selection. The optimal mortar would be dependent on all this factors, it will dependent on type of structure, the unit masonry unit because the issues are not only the strength of the brick work, but the issues are also related to durability rain penetration. So, therefore optimal mortar selection is based on this and Indian standard code gives you some guideline and as we have seen that, high strength mortar is not really necessary. I mean, a very high strength all the time you should not use 1 is to 3 cement mortar.

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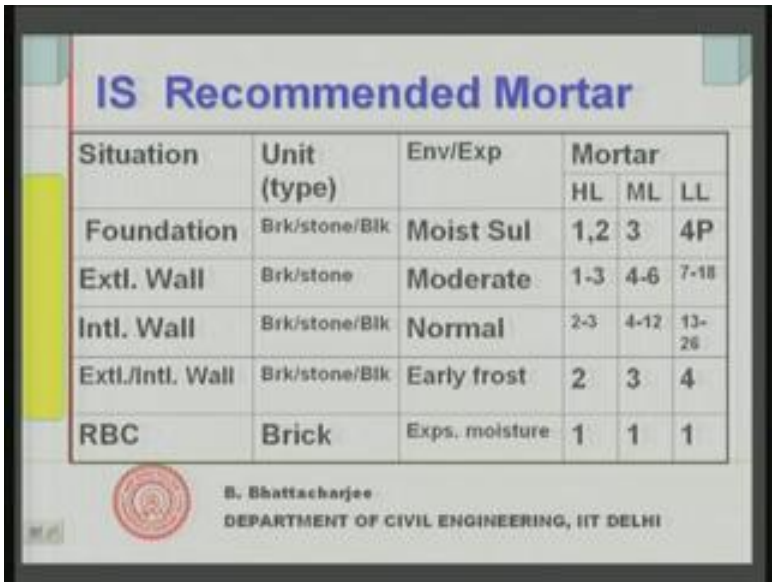

So, which is the strongest mortar with a strength of about 10 MPA optimal mortar is a choice is choice is important and this is given in a table in our code and that is what we look into. Now, this table looks like this; you see this table looks something like this table looks So, which is the strongest mortar with a strength of about 10 MPA optimal mortar is a choice is choice is important and this is given in a table in our code and that is what we look into something like. This first of all it gives you, I have just taken the part of the table, because full table it is impossible to take the full table. This very large table but you can have the rough idea from which you can understand how this table is and then of course choose accordingly.

So this is the situation for example; foundation, external wall internal wall, and reinforced brick masonry this is reinforced brick masonry. So, for the various condition you need type this is not as I said for foundation this is not the only you can have brick stone block etcetera and several other parts of the table actually i have deliberately omitted, because I just wanted to explain the table 1 can look back into the code and choose, the appropriate mortar accordingly.

Now, when you have brick stone or blocks this is block; this is means, block Brk stands for brick stone or block for any types of unit if it is a moist and Sulphate environment for heavily loaded. This is heavily loaded heavy load medium load and this is lightly loaded structure. So, which is loaded heavily use very strong mortars; so, it is an aggressive environment I can see very strong mortar, you use strong mortar H1 and H 2 in fact. As I said 126 are the mortars you know and you use strong mortars. If it is lightly loaded then you use 3 and otherwise you know medium loaded if it is you use 3, lightly loaded you use for with plasticizers P stands here for plasticizer.

So, this is an example in foundation if you have moist condition, wet condition, the foundation is likely to be exposed in wet condition. And you have either brick stone or block and Sulphate condition is expected there, then you if it is heavily loaded, then you use 1 2 stronger mortar. If it is lightly loaded you use relatively less strong mortar with plasticizer, but you see you are not using very weak mortar at all; you are using sufficiently strong mortar because foundation would have to carry a significant amount of load.

So strength is required if you down strength of the unit would strength of the brick work would definitely reduce down but durability is a major issue here and therefore you use a strong mortar. If you seize the external wall you know case of external wall, can brick and stone just another example, I have picked up from the table moderate condition moderate environmental exposure condition and there are 3 mortar selection for heavy load heavily loaded, medium loaded and lightly loaded 3 cases are shown, that is what is given in the table and we have just reproduced the same thing.

So, for moderate condition it is suggested that you take 1 is to 1 to 3 mortar or 4 to 3 mortar, for medium loaded and if it is lightly loaded take 7 to 18 mortar. So, for external wall this is what, you can choose similarly if you have internal walls which are not exposed to environment, even normal condition which you can call, not very severe condition normal condition you can call.

In such situation even for heavily loaded if 2 to 3 mortar medium loaded 4 to twelve and you can go to the lightly loaded you can go 13 to 26. So, this is the situation where you actually can use even weakest mortar, see another situation if you have early frost in external or internal work. You are using any kind of units, then you can choose only 2, 3, 4; type of mortar recommended is for heavy loaded 2 for this is 3 and 4. Basically, the point is here it should very strong mortar possibly, I mean the 1 mortar H1 as not been selected here.

So, instead 2 has been selected because frost section means 1 thing protection against the moisture, very weak –one you cannot take, it should be able to withstand the cycles as many cycles as possible and when, you have reinforced brick work. You know and you have exposure to moisture condition you can't use for any kind of load, because in any case you are you are using reinforced means you expect a lot of load. So, when there is lot of load or even in, especially in ductility you might provide. In case of zones reinforced concrete brick work reinforced brick work are used for that purposes, both it should be able to carry load also as well as resist horizontal loading; since such situation you use only mortar of the 1 type that is the H 1 mortar; so that is what we use 1 mortar.

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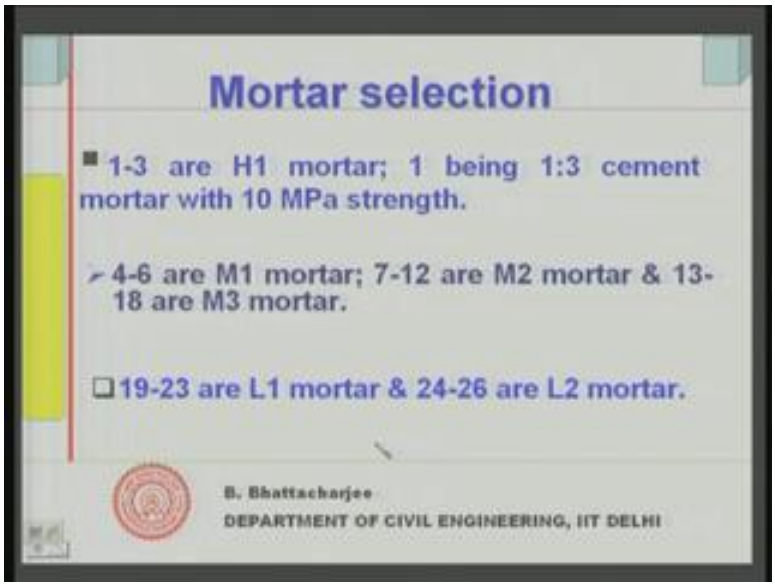

Let us, see what these mortars are 1 to 3 are H1 mortar. 1 to 3 are H1 mortar, 1 being 1 is to 3 cement mortar with ten M P A strength in fact the 2 is also H1 mortar with a strength of 7.5 MPA 2 is also H1 mortar with strength of 7.5 MPA and so on, so forth. And the L you know 23 is the actually L2 type of mortar with least strength. So the combinations of these are given I think, I have given some of the combinations earlier. Let us see, if I have something more here 4 to 3 mortars are M 1 mortar 7 to 12 are M2 mortar and 13 to 18 are M3 mortar.

As you go down along this table another table which gives you the actually cement is less sand, you increase same sand and of course lime is also used lime or some cases is lime sand mortar. So, that is what it is, the types of mortar 19 to 23 are L1 mortar 24, 23are L2 type of mortar. So, this is the mortar actually types of mortar you know, so details 1 can look into the code and find out the relevant actual proportions of the mortar actual proportions of the mortar. So that is the idea that is how we go about mortar selection; so, we select actually appropriate mortar and that is…

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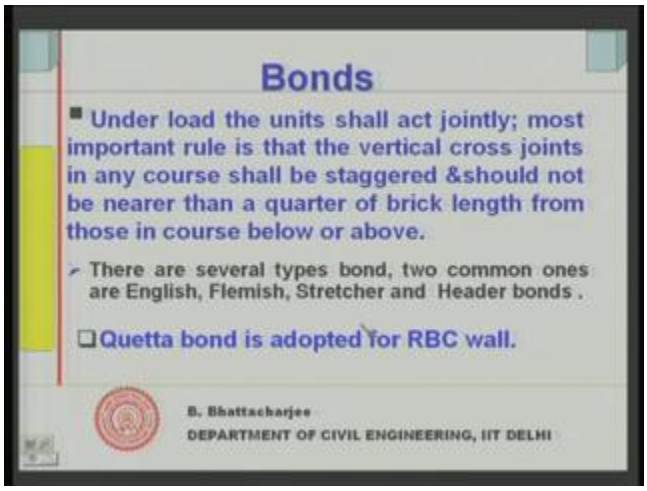

Now, let us look into different kind of bonds that exist in brick work. Now, we are interested in the brick work itself; so we have seen the motor we have seen the unit's varieties of units those are there. Let us see, how they join them. So, we join them there are certain you know certain types of bond. First of all let us look at this under load under load the units shall act jointly, because basically the units joining together. So, they

should act jointly they should act together load must be transferred from 1 unit to the other.

So, they should be bonded is done by the joints and there as to be a pattern, so the pattern that has selected the bonds between the bricks are selected. Such that, it should be able to withstand the load fully; now, 1 principle is most important principle is that vertical cross joints. In any course shall be staggered and should not be never, nearer than quarter of a brick length from those in course below or above, now what are you know vertical joints Supposing, this is your brick as we shall see. This is your brick this is another brick.

This is another brick let us say in some form and this is your mortar joint. What is stated here is that, next layer should not have the vertical joint here. So, here than in that case you are creating a vertical weak point; it can separate out very easily. Because in you know this joints will be the weakest link mortar themselves, are strong brick themselves are also sufficiently strong, but the strength of the brick work is much lower and this governed by actually the mortar. In fact, it is also governed by the kind of ratio of the you know, differential ratio that, exist or differential modulus.

You know moue by e that is what we have seen, because whenever you apply load to this sort of system actually, there will be movement along the transverse direction, under vertically downward load there will be movement along the transverse direction. And in any case 1 depending upon the modulus of elasticity and the Poisson's ratio, of you know Poisson's ratio divided by modulus of elasticity of the brick and the mortar themselves. 1 would possibly poor audio move more in the transverse direction compared to other the 1 which moves less will actually induce a tensile stress into the other.

So, that kind of behavior is here also that kind of behavior takes place. So, therefore we would not joints are tend to be weak so therefore we would not like the joints to be in the same line, poor audio that most important the vertical cross joints in any course shall not shall be staggered. So, you can't have you know this should not be in the same line, and then if you have a joint; if you have 1 joint here and the joint in the next 1 is somewhere

here, the minimum distance between these 2 is said to be 1 quarter nothing less than 1 quarter of a brick length from this course.

You know; so, there should be this distance should between should be least quarter of the brick length. So, that is being suggested and that is what ensures that, actually failure plane does not exist at 1 point and that is why different types of bonds are used, that is why different types of bonds are used. So, well these are very conventional because the people or the who work onto that, they really know it. It is not necessary that every time you tell what the type of bond is, but that's a idea behind having different types of bonds. They have specific purpose for having different types of bonds as we shall discuss.

So, there are several types of bond English Flemish, then stretcher and header bonds and Quetta bond is adopted for, these are the common 2 common, but stretcher and header are other types of bond and this bond is adopted for reinforce brick wall. This bond is adopted for reinforce brick wall.

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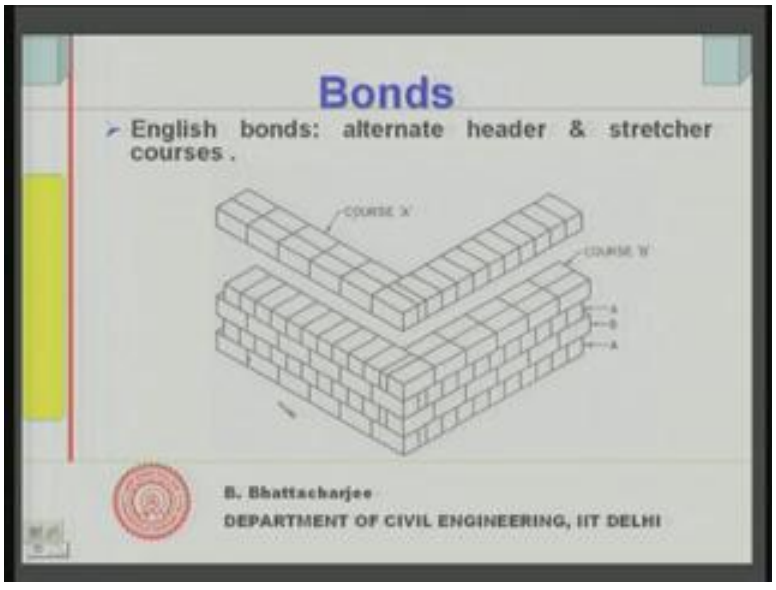

So, let us go to the next 1 and see the bond English let us say, now this has got alternate header and stretcher courses the diagram will make it clear, say this we call as header and these are stretchers.

So this is header this is stretchers; so, in this 1 course A let us say, and then this course B course A , course B, course A. Now, A course as got headers along this direction these are the stretchers here, perpendicular direction another part of the wall like wall goes like this and this you can see, is 1 brick thick wall. In fact 1 brick thick wall 2 bricks with mortar and this is the 1 brick thick wall and the next course will have the stretcher here next course will have stretcher here.

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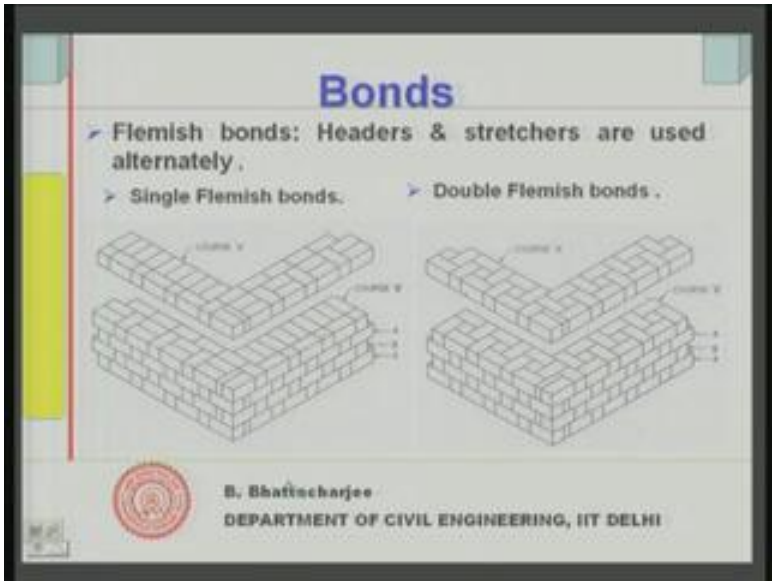

So, that in you know in the elevation it looks like; this is your joint this is another joint so on, so forth. They are not they are staggered actually this 1 you will see that this is staggered so that's the idea is in case of English bond this is called English bond. There is something called Flemish bond. Now, here headers and stretchers are used alternatively you can, have, 1 and half brick wall; you can have single Flemish bond or you can have double Flemish bond. Let us see, each of them. You can have single Flemish bond or you can have double Flemish bond.

Now, you see in this 1 it is something like this, in this 1 you has something like this. In this 1 you have something like this, you see you can you have this course A if you see this is a stretcher, this is these are headers. Now, if you look at if you look at any 1 of

them header then stretcher header and that is how it follows. So, this is 1 and half brick thick actually there are 2 possibilities in case of one- half thick brick it is called single Flemish and this is called double Flemish bond.

So, we have header stretcher header stretcher situation, in this kind of bond this kind bond header stretcher situations; header stretcher and so on so forth, header stretcher header stretchers etcetera. As you can see, so this is the kind of Flemish bond. this is some Flemish bond and again you see the vertical joints, vertical joints are vertical joints are you know they are not in the same line. There is a gap between the 2 and this gap is 1 fourth more than, 1 fourth of the faintly brick lime. So, that is the idea about the types of bond and the Flemish bond that we are talking about.

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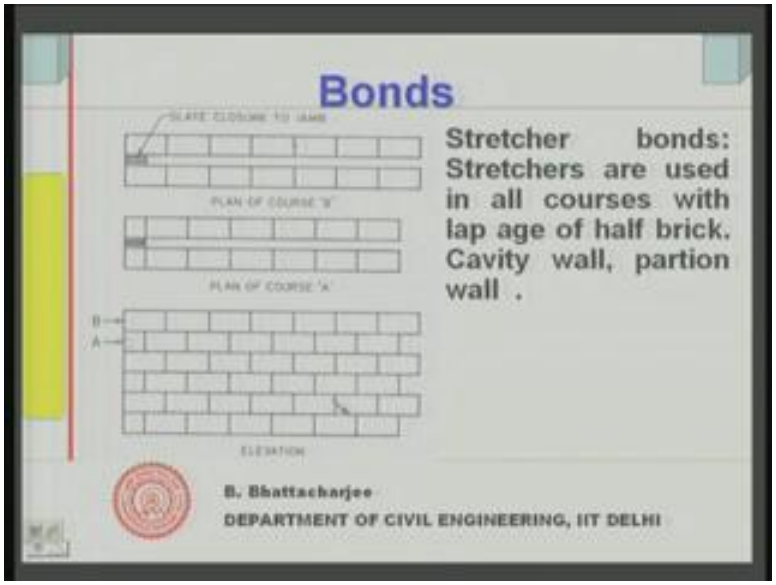

Now, you can have simply stretcher bond say when we use in half brick partition wall.
You know in this case, you have just stretchers just stretchers just stretcher this planned just in just stretchers and this course, this for a cavity wall we will come to that, but you can see this is a just stretchers stretcher and you have stretchers. So, they are staggered they are staggered this is this; first one is you know then this 1; you have to fill in it with a brick in the header and stretcher, etcetera.

Now, this is used for partition wall half brick thick just not full brick length half brick length. So, that is there that is what is useful and they are used also for cavity walls
so this is the cavity, in-between there is cavity in between. There is a closure here slight closure to actually; so this is the cavity this is the cavity and this is the 2 like the headers in. I mean, stretchers this is the stretchers, in stretchers in plan. As you can see, so these are all stretchers and no headers here no headers in this particular 1; if you go back go to the other 1 this is called header bonds.

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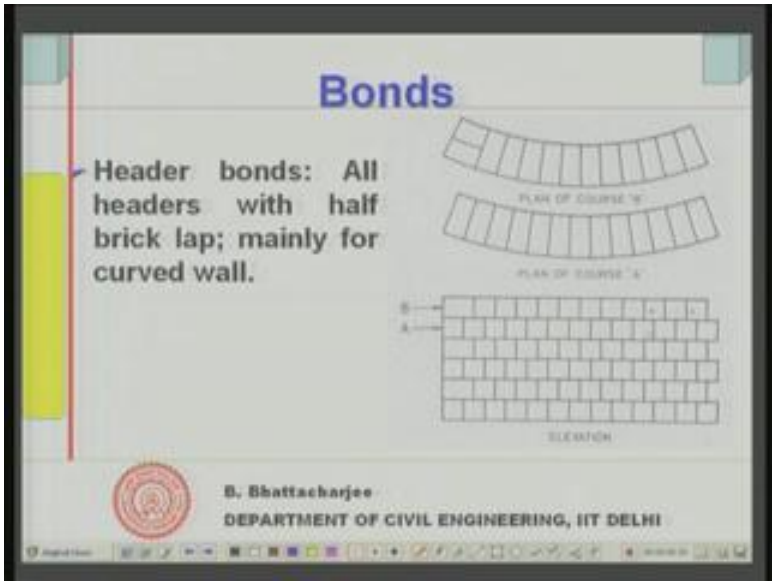

And this is a just all headers used mainly for curve mainly for curved wall and you have a of course, you can see that, this is just a headers. First 1 should be something like this. So, it will look something like this.
So, this is the header and header and this is how it looks like. So, with sort of with sort of lap length half brick lap length, exactly at the center these joints are and in the previous case also it was in the same l same type; Because you had joints just at the center so you have a lapping length of half brick. So, this is the half brick length, this is another half exactly at the center and that's how you stagger it. So, that is how you know you have the bonds which ensure that, there is no vertical joints are formed together that is the basic idea and this 1 may not bother too much about it, but we must understand what are the

basis of this 1. We don't want vertical we don't want vertical joints along the same direction. I mean, they should not you know create a weak point so that's the idea.

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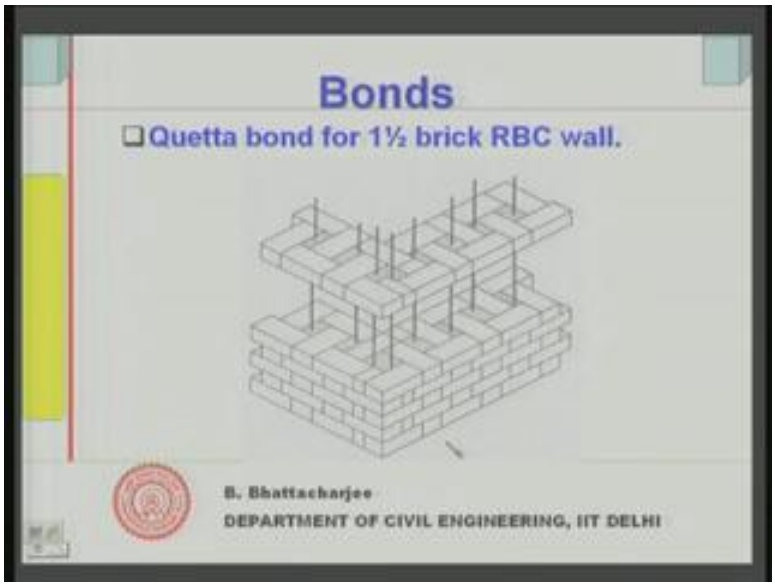

So, 1 has to follow the standard bonds there is not much to be done about it, standard pattern of the bonds and not really big engineering goes into it. this is how it looks like in this case, you have the reinforcement here you have the reinforcement here and the mortar goes in here, reinforcement mortar and therefore, this as to have the gap. So, this is the I mean this as stretcher header etcetera and in-between you have a gap and where the reinforcement goes so these are the reinforcement. Usually is used in places where you want you know slightly taller building maybe taller not just 3 or 4 stories maybe 5, 3 stories construction you have got to have this is reinforce brick- masonry can be used. l k l keddhy, but and especially where you have considerations are there.

The earthquake resistance structures you need in load bearing masonry there you might be using this, strength required is more. So, usually it is nothing less than 1 and half brick wall. So, 1 and half brick reinforce- brick wall where you use this, where is use- where you use this kind of bond. So, this is all about the bonds.

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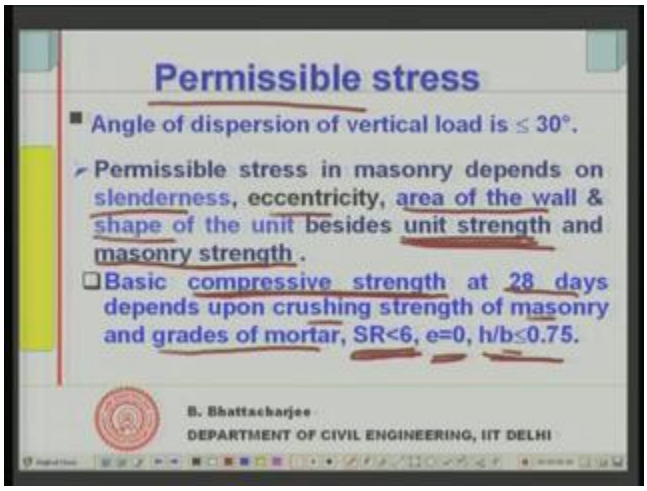

Now, let us come to the wall strengths; see we assume that, in case of if you have a brick work, The load will be transferred, if I have a point load onto the brick wall. The load will be transferred angle of 30 degree, vertical it is transferred angle of 30 degree. You know vertical load is angle of dispersion of the load disperse 30 degree angles, these are 30 degree angles. So, this is what we assume concentrated load and accordingly we calculate out the load, etcetera

The second issue important issue is the strength of masonry depends upon several factors slenderness, strength of masonry wall; strength of masonry wall. First is of course the strength of brick work itself that is somewhat, something we have discussed about it, but the wall the load it can carry would depend upon the slenderness of the wall. Now if we can remember the slenderness that is the thickness minimum thickness. So, length by effective length divided by the thickness that's what is the slenderness of wall.

So, the load it can carry not only depends upon the strength of the masonry itself, but it also depends upon several other factors. The most important being slenderness because as you know, wall is a vertical member and such vertical members are mostly subjected to compressive load gravity load compressive load. Usually if you have undergone a course on reinforce- concrete design or similar other design you would know that, members like

beam they take the load by bending they take the load. They you know respond you know respond to the load by bending.

So, whereby the top portion compresses bottom actually if it is a simply supported system or in any case members; normally, as we have seen earlier that the top portion would shorten and bottom will actually elongate and thereby, that is how it actually resist the load, direct tension is usually unusual expect for members like very thin members thin structures of cables and similar sort of cases. You know or in you might have members in direct tension and that is a very efficient way of more efficient way of taking the load Because whole cross section will be acting under the load, then when it comes to compression, compression induces what is known as buckling.

if you remember; for example if you have a stick thin stick and you try to put pressure onto it bends like this, although the material failure may not have taken, but it bends. So, this bending can cause failure due to buckling, so compression member it buckles it bends under the actual load itself it bends and that is buckling can results in failure. Now there- something in case of structural I mean, strength of material you would have studied there is something called buckling load buckling load. And it is seen that this buckling the stress, which it can critical stress associated with buckling is inversely proportional to L by R and this L by R is nothing but slenderness ratio

So, in case of brickwork we define slenderness ratio by effective length by t, why effective length because it will depend upon the fixity of the fixity of the end. Supposing the end is totally fixed then this portion will not be available for buckling it will buckle you know, it will buckle between this length. If it is let us say, simply hinge between the 2, then full length will be available for buckling. Because it will depend upon what is the kind of restraint is available here.

If this place is fully restraint like this, then no buckling can take place here. This will be this will have, 0 rotation and effective length will be smaller than the length. How much it is we will look into in details? So, we define the slenderness ratio in case of slenderness

we can we define, in terms of effective length divided by the thickness of the wall. And in as usual see later on in the next class possibly or in some other subsequent lecture, that it can buckle in both you know the buckling can take place against about a horizontal axis.

For example: wall can buckle in this plane and also it can buckle about a vertical axis that means, in plan it can take a bend shape like this due to buckling. So, this is an important issue and this governs the strength or load caring capacity of the wall. Strength is 1 thing, but this is other issue; second issue is that, you know loads are rarely applied. Actually quite often if this is my thickness of the wall load t, instead of load being here effective load may be somewhere there.

So, this is the eccentricity this is the eccentricity; so, load might be applied not at the center of the wall why because for example, something coming a slab coming from the other side let us say in load bearing wall and only from 1 side let us say, so t- load slab load would be transferred not- exactly at the center. In fact this portion maybe if you look at the distribution of the load from the wall, it may be something like this. I mean load from the slab to the wall it may be something like this.

So, net location effective location or the center of action of the force that is the load that is coming from the slab may not be exactly located at the center of the wall itself that can result in kind of eccentricity. If I have slabs on both the sides 1 has got larger span other has got less smaller span. So, that kind of various situations would be there where eccentricity maybe, induced because load is not right acting right onto the center of the wall. And when it is not acting onto the center of the, this eccentricity induces are kind of movement. And let us understand that, brick masonry really cannot take tension. It is a material like concrete material and such material, cannot take tension that's what we have seen and that is why you know earlier days also.

All the brick masonry was there for very very long time as we s- historically mostly arches or domes were constructed out of them. you couldn't have flat slab like

construction in brick masonry so that is why because it cannot take tension. so the bending member you cannot just cannot make out of brick masonry it cannot take tension so we assume that practically although it can take small tension. practically we assume that it doesn't take tension. now when you have a moment induced due to the eccentricity there will be some amount of some amount of tension coming onto the you know it may come depending upon what is the eccentricity.

There can be tension coming into thematerial coming into the material and again buckling and eccentricity together. they may act together because when something is bending vertically due to buckling and if you have eccentricity this will further cause this movement. so all this issues together eccentricity slenderness both of them play a role in the load caring capacity of the member or the brick work brick wall right then the issues related to area of the wall and shape of the unit shape of the unit and area are related to
so these are some other factors which affect the how area works as we have seen that smaller the you know nine like 1 of the 1 of the figures we have seen that- 1 brick thick wall could carry less load compared to that to the stresses would be you know the area has some relationship actually area has some relationship of course the stresses. one as to see the stresses not simply the load if you make it thicker it will carry definitely more load. But stresses also are observed that area has got some effect why it is we will discuss this sometime later on in detail.

But area has got some role also the shape of the unit has got some role as far as the load carrying capacity is concerned. this can be quickly understood although, we will again discuss ,this in some more details. Supposing you have got smaller units, then what will happen; if I have smaller units more number of joints would be there, if I have larger units possibly less number of joints.

So this has got some sort of effect now more number of joints means strength would tend to be smaller. It would tend to be weaker compared 2 here it is less number of joints Because, we have seen this is a joints which actually plays the major role as far as strength of the masonry is concerned. So, all this factors actually affect the strength of

brick masonry besides of course, the you the unit strength and masonry strength besides of course the unit strength and masonry strength.

We will look into this issues somewhat later on, but let us look at this issues, fast that is masonry strength, unit strength and masonry strength. So, what how does 1 does you see this brick masonry design as by and large been not; so, not well understood behavior of brick masonry not well understood. In fact behavior of steel is very well understood, because the effective produce material will well behave very well and in a course of materials and construction or in any course of a material, we give a very little time to steel, because say well behave material is very well known. When it comes to concrete we know some of its behavior, but then we make it ourselves it is not necessarily effective produce- material.

So, we devote some more time and to understand both, concrete well masonry is more even even relatively not so well understood. Like concrete or possibly very less understood than concrete. So, it is based on mostly empiricity again and therefore, what does code or similar sort of. You know code or similar sort of documents do guidelines for design value, the first give you strength based on unit strength and masonry strength and that will call, as basic compressive strength permissible stress we are talking of this stress that, is permissible on the material.

You know the load, you can calculate out the stresses because load and eccentricity known on a wall. You can calculate out how much will be the stresses. Now, this stress must be less than the permissible stress. It is like an working stress method of design in case of brick masonry. We design it based on working stress method simply, load divided by area or eccentricity we calculate out what is the load and stresses and this stress must be less than the permissible stress.

Now, this permissible stresses suppose there is certain in all of them and permissible stresses comprises of first the basic compressive strength. Now basic compressive stress you can say, permissible stress basic compressive strength. Basic compressive

permissible stress at 28 days and this depends upon the unit strength and masonry strength.

Once you know this basic compressive strength or basic compressive stress that is permissible, which is depending upon the crushing strength of masonry and the grades of mortar. This is of course valid for slenderness ratio less than 6. The eccentricity being 0 and the height to width ratio of the unit is less than equals to 0.75; the shape at shape is not you know this is for a so, for a given shape, given eccentricity, and given slenderness ratio this is given. Then you have certain multiplying factor related to this one's slenderness ratio eccentricity etcetera, area reduction factor and then shape factor etcetera.

So, we have some multiplying factor and finally by multiplying by this factor you come to the permissible stresses. So, first you find out the basic compressive permissible compressive stress based on the strength of the masonry and strength of the mortar. And then this is valid for slenderness less than 6 eccentricity equals to 0 and height to width ratio 0.75 once you have known this then you can calculate out the rest.

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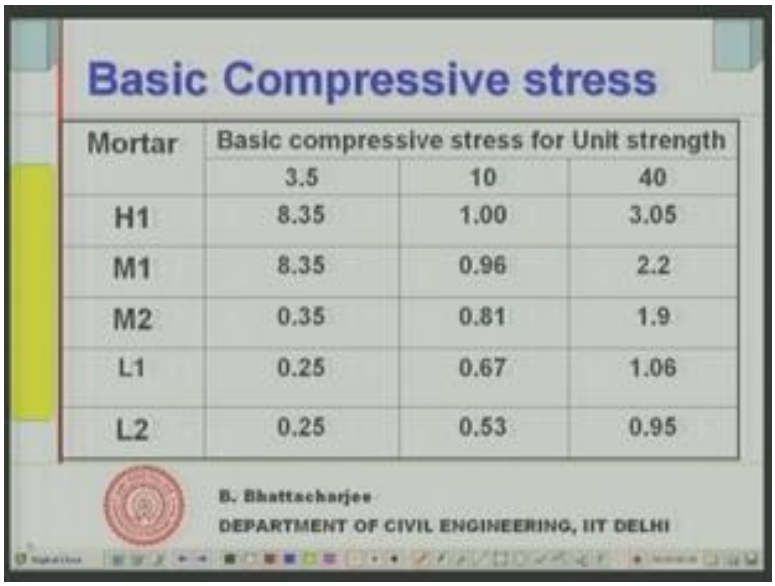

So let us today look into the basic compressive strength and the other ones we will look into later on so basic compressive stress, permissible stress. Well I again there is a large table given in the code and I have picked up only a small portion of the code, just to show you the how the table looks like because 1 can find out how much will be the value one can find out; how much, will be the value from the you know, like table. So table is readily available, but just for the understanding, I have picked up a small portion of the table. So, you can see that in this 1 the mortar different types of mortar are given different types of mortar are given and basic, compressive stress for various unit strength starting from 3.5 to forty MPA. These are all in MPA.

You know, this is all in MPA; so MPA 3.5; so, very weak unit strength to high- strength that's what I have just picked up the left hand corner of the table and here again, I have picked up only 5 mortars out of the 7 mortars. If you remember, I said there are something like H1, H2 mortar then M1, M2 and M3 mortar and L1 and L2 mortar. So, all mix I have just omitted 2 of them because we want understand, how this table is rather, then looking at the table because we can always look at the table in the code and find out the values as and when you require.

So, let us see for the weakest mortar as my you know this is only strongest mortar and the mortar strength, reduces along this direction. Now, this mortar as got a strength of 10 MPA minimum strength of 10 MPA and unit strength is 3 .5 since mortar strength is 10 this is about8, 3, 5. You know when mortar strength and the unit strength is nearly same. we have seen the strength is as good as the mortar strength itself when strength of the you know mortar strength. I mean mortar strength for strong mortar strength is as good as the brick work strength, is as good as the mortar strength.

So, mortar strength governs it significantly so whenever even if you brick work the mortar strength seems to controlling, it and this is about 8.3 5 MPA much higher than this because this has got a strength of 10 MPA. This has got a strength of nearly about same you know this is got same strength but when it comes to a weak mortar it quickly diminishes and in the weakest mortar it is about, 0.25 MPA whenever strength is much higher now, it is similar you have 1 MPA strength here. This is 0.93 and 0.8167 53 and etcetera, when you have 40 MPA.

So, by and large this is the case in you know you have much less strength of the brick work much strength less than, your strength of the brick work compared to actually mortar strength. Using this particular table 1 can select the basic compressive stress. Permissible stress in the brick works and then multiplied by the correction factors that are the correction factors. Namely then ratio and you know what is called stress reduction factor. The stress reduction factor is based on slenderness ratio and eccentricity. And then you have something called area reduction factor and the state factor.

So, this multiplication factor 1 can use and find out what is a permissible stress of the brick work. So far in this case class we have looked into the basic compressive stress in the next class, we will we will concentrate ourselves onto this factors those are there and how 1 calculates out. The overall permissible stress of the brick although design is not really an aspect of this course design is fairly simple ones you know because the design would be dependent upon how do you calculate out the load.

So, first find out the load and the load is found out you would have done similar courses in structural analyses and design. You know, how to calculate out the load that will come onto a wall that means; how much I mean; for example, you can know you know how to calculate the load onto a beam in a front structure from the slab how the load you know how much contribute. How much load is contributed to the slab to a beam? In the similar manner 1 can find out, how much load is contributed by the slab to a wall. So you once you know the load that come to the wall then simply load divided by, the area plus if there is an moment.

So, moment divided by zed you know that would give the stress plus minus M by zed that, would give you the stress and the- once you know the stress this stress must be lower than the it must be lower than the lower than the permissible stresses, in the brick work; so, we in this course of course we look into in this discussion in the next lecture

we will just tell you, how to find out the permissible stresses load calculation etcetera, could be part of some other structure in analyzes and design course and they go in the same manner.

So, we will not look into the full design because that's not part as it involves; so, many things so part of the construction, which is you know how to calculate out the permissible stress that's what we will look into anyway; so coming back to the summary of this discussion.

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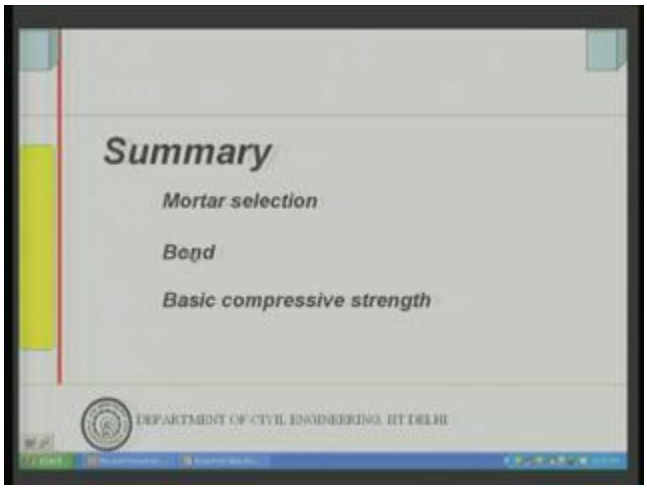

We have seen some issues today related to mortar selection, mortar selection how do you select the mortar we have understood and we have from, which you can find out which mortar should be used in which situation although only part of the table, I have given, but if you look at the IS 1905 I S 1905.

This the code which deals with I S 1905 this is the code which deals with this brick masonry design and also special publication 20, which is the commentary on the above code this gives you the details of masonry design for brick masonry, 1 can look into this commentary and this together both for understanding purpose, as far as the tables that, I have mentioned

So I have given you the tables part of it, but overall table is available from which you can find out how to select and which mortar to select in a given condition. And then we have looked into the different type of bonds. Now these are basically ideas of construction practices and this has been so standardized doesn't really require much really, much you know, there is not much to be really memorized about it, but what you know is that vertical joint should not come, in the same line. That is the whole idea , then we have given you the concepts of basic compressive stress basic compressive, you know permissible basic compressive stress or basic compressive strength, which is; which we find out from the strength of the masonry and the strength of the unit. I mean strength of the mortar.

So far corresponding mortar I mean; for a given strength of the mason-unit and mortar, we can find out what is the strength. And this is to multiplied with stress reduction factor slenderness etcetera, due to slenderness and eccentricity it as to be multiplied with area reduction factor and shape factor, to come to the permissible stresses in brick work. In the next class we will look into those 2 issues, effect of slenderness and eccentricity on permissible stresses effect of area and shape on the permissible stresses in a brick work. I think with this we conclude our discussion on the you know discussion of first part of discussion onto the, walls. First part of discussion onto the walls and the second part we will continue, I mean; walls we will continue second part of course related to strength in next 1.

Thank you.