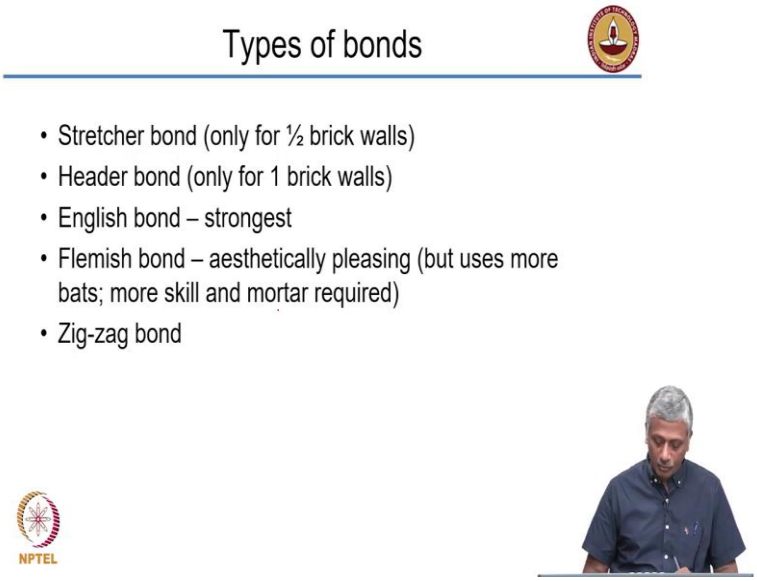
Basic Construction Materials
Prof. Manu Santhanam
Department of Civil Engineering
Indian Institute of Technology, Madras

Lecture - 23
Stone, Brick and Mortar – Part 6

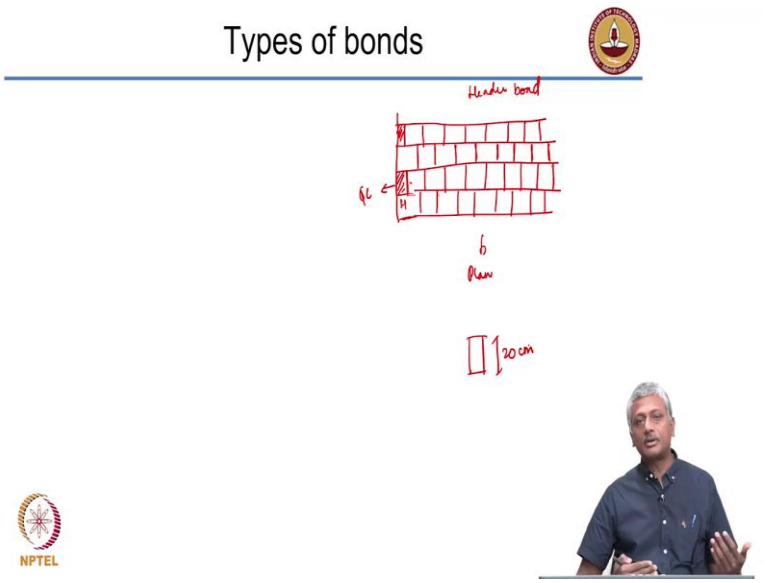
(Refer Slide Time: 00:14)



So let us look at different types of bonds that are used for bricks. One is a stretcher bond. As the name implies, all the bricks are stretchers. The other is a header bond. Again, as the name implies, all bricks are used for headers. Now, these have some limitations. A stretcher bond can only be used for a half brick wall. Because, there is no connectivity between the front and the back. A header bond can be only use for 1 brick wall.

Now English bond, which I showed you previously, has layers of stretchers and headers alternating. A Flemish bond, on the other hand has stretcher, header, stretcher, header in every layer. So obviously, that looks much more appealing or pleasing to the eye and sometimes you may have a different arrangement called a zigzag bond, in which you sort of keep shifting your vertical joints. The aim of all these bonding arrangements is to ensure that the vertical joints do not overlap. You need to stagger the vertical joints so that you do not get brittle failure of the wall.

(Refer Slide Time: 01:14)



Let us just take an example of a stretch of bond, for instance. As I said, in every course, so let us draw several courses of the stretcher bond. So every course, each brick will be a stretcher. So I am just drawing the running length of the wall, I am not showing you the end of the wall, it is a lot trickier to draw the end. So every brick is a stretcher. Now if you want to end this wall, what will happen?

Let us say I want to end this wall here. Then this will become a header, the ending brick will have to be a header so that the wall now runs in the other direction. So if I look at the wall from this direction, that will be the end of the wall and that direction. I am looking in from the left side, so that will be the first brick is a header here. That means there will be a stretcher in this direction.

Then, it will all be stretchers in this direction. But what about this brick now, when I look at this brick from this side, it will actually be a header. The next layer will again have stretchers all through and this layer also will have stretchers only after the first header. So in a stretcher bonded wall, what you will see is all your bricks arranged in the form of stretchers except the wall corner brick.

Every alternate layer will have at least 1 brick appearing like a header, and then it goes in the other direction. The same thing applies for most stone block walls also. If you look at a compound wall made with stone, this will be the appearance that you get that and is called a stretcher bond. What about header bond? I will try and draw it on the same figure so that it becomes much easier.

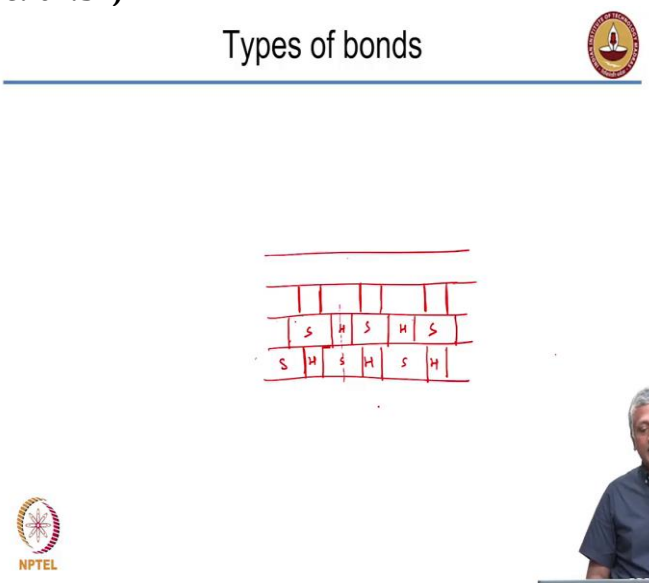
In a header bond, obviously, each and every layer should have only headers, well, that is a little bit more difficult to figure out. Because how do we avoid the overlap of the joints. So if I have to have a header, all these bricks are now headers. Now I am what to have a second layer also with the same. Let us say the third layer is same as the first layer, we repeat the third layer, the same as the first layer.

But what do I do for the second layer? I cannot obviously put start putting like this because then I will get a vertical joint overlap. So I cannot do this. So I have to ensure that I stagger. Now, how do I stagger? One way to do the staggering is to have a quoin closer at the end, and then I do the staggering I easily get my arrangement of the headers. So that is what I will do to stagger the second layer and obviously the fourth layer.

This will again repeat in the fourth layer and I again stagger my wall by exactly 5 centimeters so that there is no overlap with the vertical joints. That is called a header bond. Now, these are obviously simplistic arrangement. So what do you need to see now is if you look at it in plan, if you see the plan, all the bricks are arranged in this way? So my thickness should be at least 20 centimeters. It is only for 1 brick walls you can only have 20 centimeters thick walls with header bond, with stretcher bond you can only have 10 centimeter thick wall.

So, it is not intended for large load bearing condition. Now let us look at the most important bonds that we typically use. That is the English bond and the Flemish bond. So what happens when we use English bond and Flemish bond?

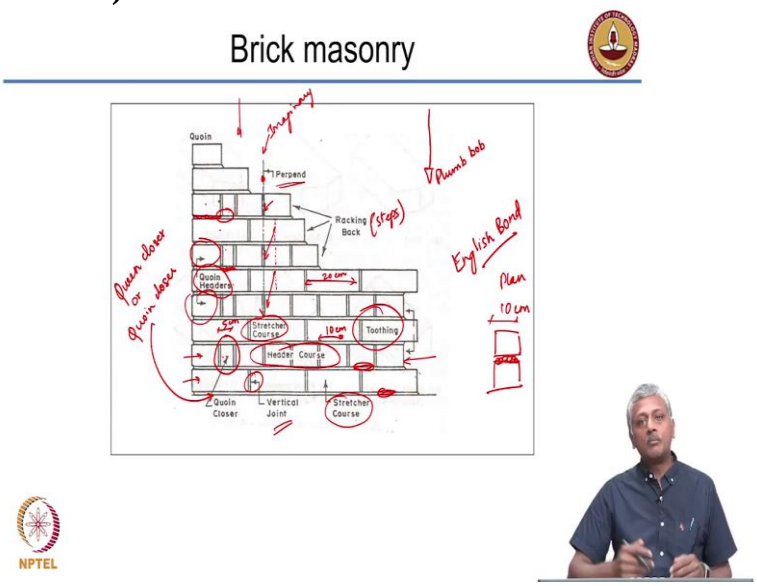
(Refer Slide Time: 04:57)



So, in the case of an English bond, as I said, every alternate layer will have only stretchers or headers. So let me draw the running length of the wall. So let us say this is my stretcher course, my next has to be header course. The headers should be arranged in such a way that they are like this. Then the third layer becomes again a stretcher course and the fourth layer again becomes a header course.

So this arrangement is called English bonded wall. Now what about to finish this wall here. Let us say I want to finish this wall here. With this last stretcher, I am finishing this wall. Now you have an overlap of 5 centimeters here that means only 15 is remaining here. So how do I reach that 15 typically what I will do is, I will use a header here and a queen closer here. This is a header and that is a queen closer.

(Refer Slide Time: 06:43)



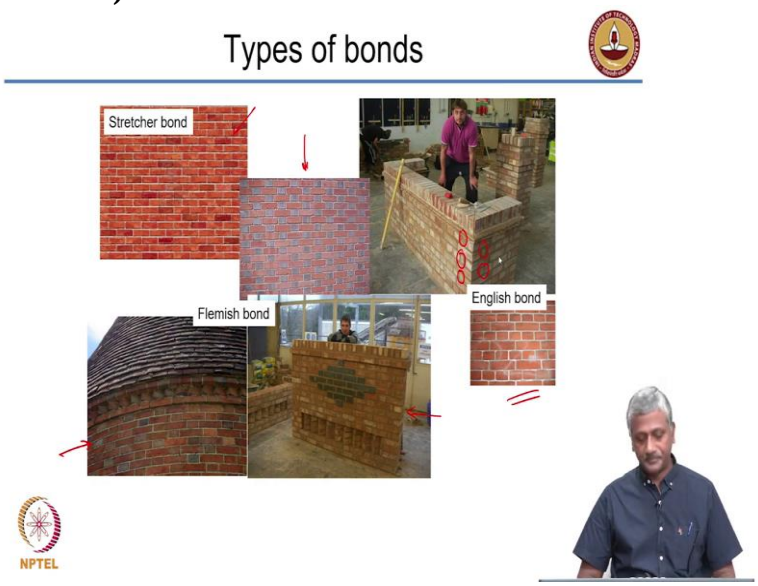
I showed you this already in the previous drawing here. So you have your stretcher here, that is the header and that is followed by queen closer. So the queen closer ensures that you get this shift in the bond by 5 centimeters. So now if you consider the case of a Flemish bond, in that case, we actually get each layer having a stretcher and the header. So let us again draw the same on the same arrangement.

So I want to now have a condition in which each layer has a stretcher and header. So I will draw again the running length of the wall that much easier for you to understand. So let us say I have a stretcher here, my first brick is a stretcher, this is followed by a header then I have a stretcher, then again header, then stretcher, header and so on. Now I need to ensure that my overlap does not happen in the next layer.

So I need to have a stretcher exactly on top like that and that is going to be a header. That is a stretcher, header, and stretcher and so on. So again, I am satisfying the rules of minimum 5 centimeters overlap. I am also satisfying the rule that the center line of the header coincides with the center line of the stretcher below it and also above it. So next layer will again be a repeat of the same layer.

So this gives a very nice, pleasing aesthetic appearance. The problem is when you start coming to the end of the wall or the corner, you will have to make arrangements of using brickbats and that is a little bit difficult, because when you start putting brickbats in it, you increase the amount of mortar available and that causes the wall to be weaker. So, Flemish bonds are generally weaker than English bonds, but nevertheless they are most aesthetically pleasing.

(Refer Slide Time: 08:51)



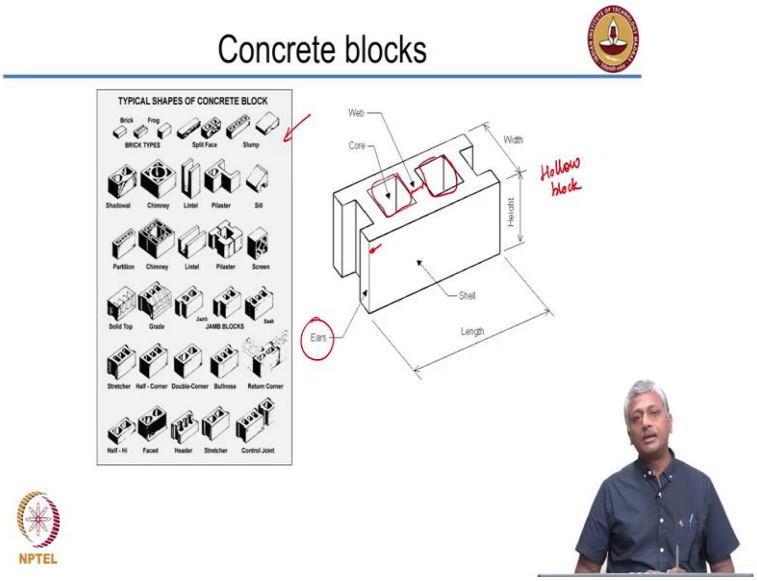
So this is just an appearance. You can see this brick wall is basically the stretcher bonded brick wall, each and every layer, the bricks are arranged in the form of a stretcher. This here is a Flemish bonded arrangement and you can see that they are coloured the header is different compared to the stretcher, which gives a very nice outward appearance of the Flemish bond.

You can again see an example of Flemish bonded arrangement on a curved wall. Very interesting to see this, very beautiful to look at. Again, this is a Flemish bonded arrangement, which is what is seen in those walls that are shown there. This is an English bond. As I said

each layer will have only stretchers or headers and you can see this mason has actually completed the construction of this English bond here you can see the location of the queen closers at the ends of the wall.

Same thing on this side, you will see queen closers on the side also. In every alternate layer you will see the queen closer displaced from the odd layer the even layer when you go to the other side of the wall. So again, you can visualize this by trying to draw it on your own. Next time when you see a brick masonry which is exposed, tried to figure out what kind of structure or what kind of approach they have used to actually construct the brick wall.

(Refer Slide Time: 10:04)

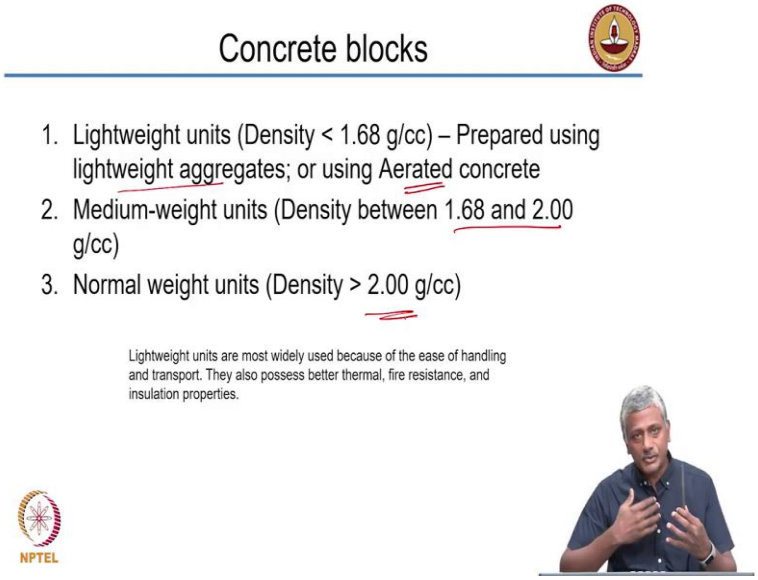


Now, from stones and brick, let us now take a look at concrete, I am not going to talk extensively about this, I will talk about concrete as a material later, but I just wanted to give you a flavour of what type of bonds or what type of blocks are actually available. This is a typical hollow concrete masonry. So, typical height is around 20 centimeters width is 20 and the length is 40.

In between you have these cavities and then you have this wall between the cavities that is generally about 4 centimeters. In the end, you have a projection beyond the last web and that is called the ear so that you can actually hold these blocks, those are called ears. Now, interestingly, because concrete has the capability of being moulded in several shapes, with brick is a little bit more difficult concrete can be poured in a wet condition moulded.

And you get all these kinds of blocks from concrete. You can see there are tons of different types of concrete blocks and that gives you an advantage of actually constructing very efficiently or very effectively with concrete blocks.

(Refer Slide Time: 11:13)

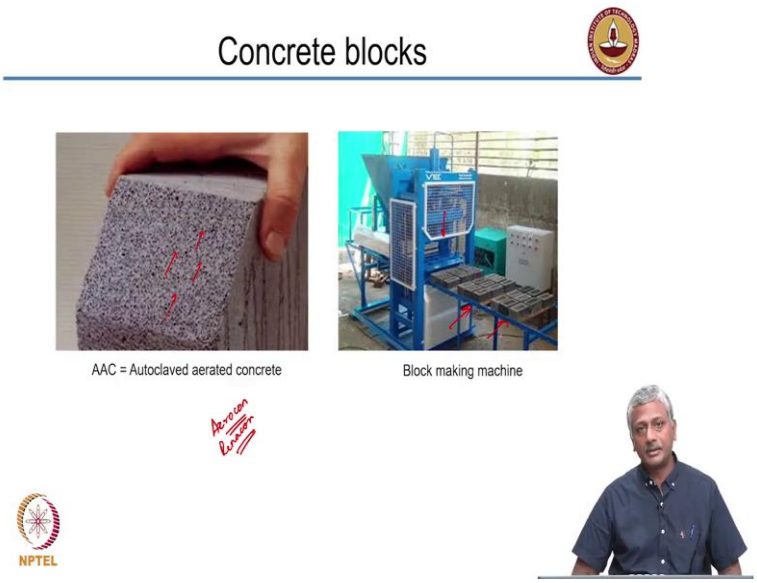


Now, concrete itself, the other advantage is that you can actually adjust the weight of the concrete by introducing elements in it which make it lightweight. So, for example, the lightweight units include the concrete which is prepared with lightweight aggregate. So instead of sand and stone, we start using pieces of rock which are very low density, for example, some volcanic rocks like palmists and scoria.

Those are lightweight volcanic rocks, and those can actually reduce the amount of density of your concrete and that causes the blocks to be very light. So, when you have a lightweight concrete block of the same size, you can then lift it and easily place it, so it reduces the effort of the person or you can put an air inside the concrete and call it aerated concrete block. Then you have medium weight units, which are between 1.6 and 2 grams per cc and normal weight units which are much more than 2 grams per cc.

Now, the lightweight units are not only easy to place and transport, they are also much better in terms of thermal properties and fire resistance, because again, when you have a lot of porosity inside the concrete, it will reduce the amount of heat conduction, whenever you put air inside materials that reduces the heat conduction.

(Refer Slide Time: 12:25)



Now an appearance of a concrete block which is aerated as shown here. Basically this concrete block has been cut through and you can clearly see the amount of air voids or air bubbles that are trapped inside. How this is generated is by actually introducing aluminium powder into the concrete. What does aluminium powder does? it interacts with the calcium hydroxide that is available from the cement reaction with water and this reaction basically generates hydrogen gas.

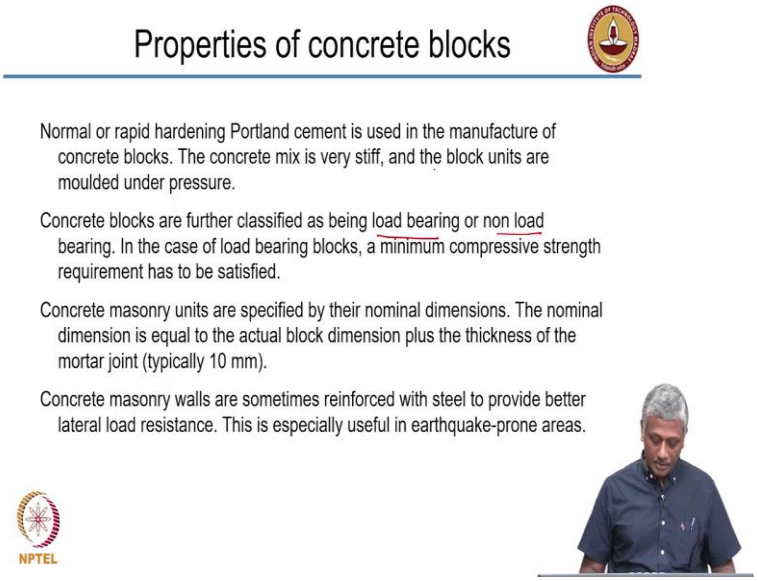
Hydrogen gas is generated and that hydrogen gas gets trapped inside the concrete structure like bubbles. You might have also seen how bakers typically bake bread. They put yeast that basically ferments and releases air and that levels the bread that causes all these nice pores appearing inside the bread, the same process happens in the case of aerated concrete also and because of this what happens is that block itself which is quite large now becomes quite easy to handle.

And many of the construction sites you will probably see blocks which are having the trade name of Aerocon. Common trade name that you see for aerated autoclaved aerated concrete blocks or Renocon. Many of these blocks are used in different construction sites, these just trade names, there are several others obviously which are used, but I am just giving you some examples here.

In some cases, you can actually work with very stiff concrete and use these block making machines which basically extrudes the concrete out and makes the shapes of blocks or you

can even make bricks with concrete, which are the same size as traditional bricks, but they are not made with red clay.

(Refer Slide Time: 14:05)



So, concrete blocks are made with normal or rapid hardening Portland cement, so that you can get much quicker hardening of the concrete block. Generally from the block making machine the concrete mix is very stiff so that the blocks can be simply pushed out up in the desired shape and they maintain that shape properly, even after getting pushed out. But concrete does not gain strength immediately, it needs to be kept in an environment where it slowly gained strength. We will talk about this when we reach the concrete chapter.

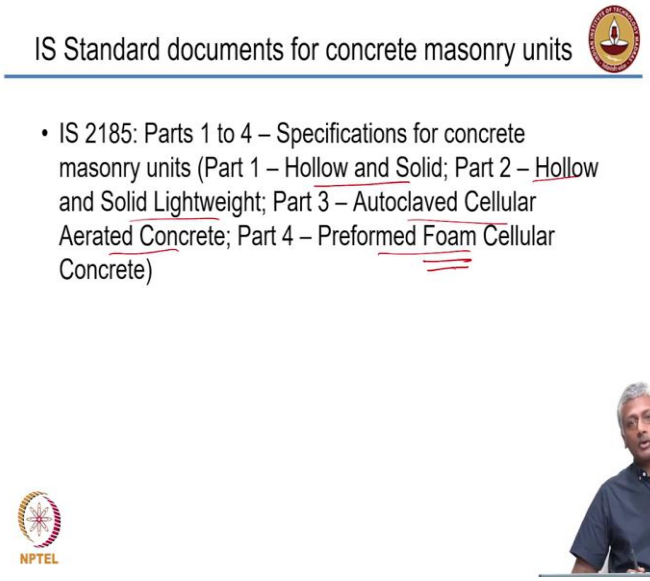
So concrete blocks could be used for load bearing purposes or non-load bearing purposes. So, when they use for load bearing purposes, obviously, they need to satisfy a certain minimum compressive strength. So, I have not covered here the IS codes that deal with concrete. I have talked about stone and brick earlier, but with concrete I have not really covered this code IS code for blocks here. But you can actually have some idea about this from reading the content in IS codes.

So, you need to have some minimum compressive strength to satisfy the requirement for load bearing masonry. Now, in case of a non-load bearing masonry, where do you find that? In most of our modern structures, you have frames of reinforced concrete and the walls are basically filled in afterwards and the filled up walls do not really take up the load of the structure.

They have to only support their own self weight, those are called non-load bearing walls. In such cases you can use lightweight concrete blocks, they speed up construction like anything and also improve your insulating properties of the wall. Again, the nominal dimension in a concrete block is taken in a similar way as in the case of a brick and concrete masonry blocks is sometimes reinforced with steel.

So, if you look at this hollow masonry that is shown here that gives you an ideal location to put your steel rod inside and steel rod inside is held in place by putting some concrete or a flowable grout into it so that it holds the block the bar in place. So, again you can create reinforced concrete block masonry with a lot of ease. Again this is very important especially when you have a lateral load problem in earthquake-prone area. So, concrete block masonry is very good for reinforcing in earthquake-prone areas.

(Refer Slide Time: 16:19)



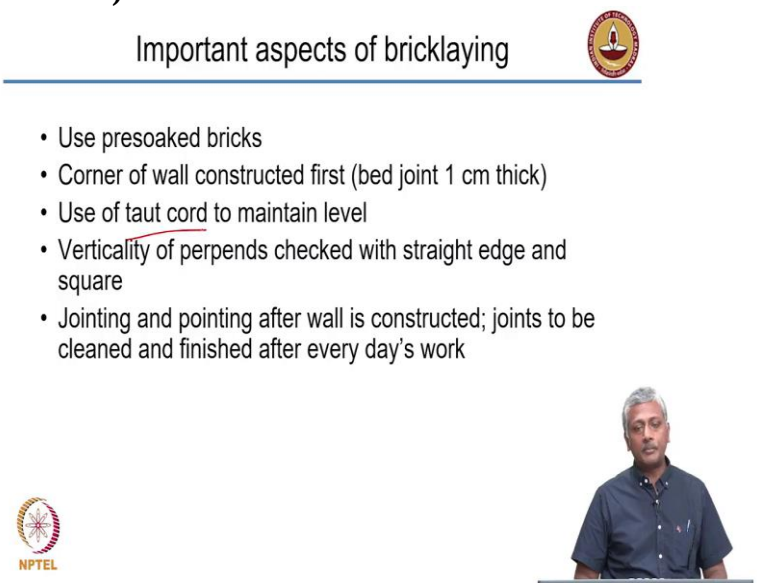
So, again, some examples of concrete blocks are given here with respect to masonry units which are hollow and solid, hollow and solid lightweight units, autoclaved cellular aerated concrete and preformed foam cellular concrete. So what is the difference between autoclave cellular aerated concrete this is exactly what I showed you here. This is actually an autoclaved aerated concrete.

That means you put in this aerating agent into the concrete and allow it to create this gas inside. That is called autoclaved aerated concrete. You can also have a foam concrete. Supposing let us say just for an example, you take a shaving foam and mix it into the concrete what happens is the shaving foam will lead to some stable air bubbles being formed

inside the concrete and that is what we do in foam concrete. We simply introduce some sort of a form not exactly shaving foam, but something which is quite similar.

The chemical forms are quite similar to shaving foam, you put that into the concrete and the stable air bubbles lead to a very highly porous structure. That is called a preformed foam cellular concrete. So IS 2185 basically covers the specifications and properties of concrete blocks of different types.

(Refer Slide Time: 17:31)

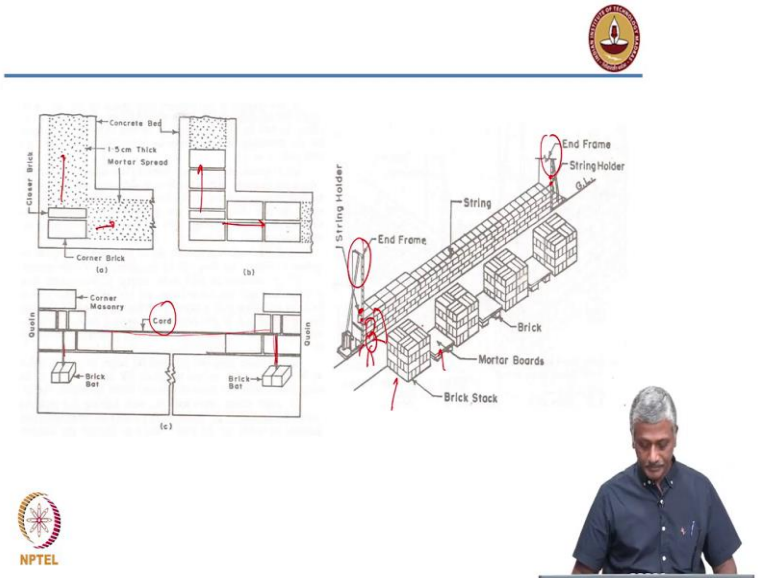


Now, again, coming back to the overall process of masonry, you need to use pre-soaked masonry units or pre-soaked bricks. Again, this is to avoid the absorption of moisture from the mortar. The corner of the wall as I said is constructed first and then you move towards the center. The level in each masonry has to be maintained properly and that is maintained by using a string or a chord which is held very tightly.

And then you establish the verticality of the plumb bob and use this cord pull it very tightly to ensure that each brick is placed exactly in a horizontal line and the verticality of the perpends, perpends again are imaginary lines joining alternative joints, and that is basically checked using a straight edge and square. So you have used a straightedge and square in your engineering drawing classes.

That is exactly what we use to check whether you have a perfectly perpendicular or perfect lining of the vertical joints along the line and as I said the after the day's work, the pointing is typically done to ensure that the mortar joints are cleaned up properly.

(Refer Slide Time: 18:39)

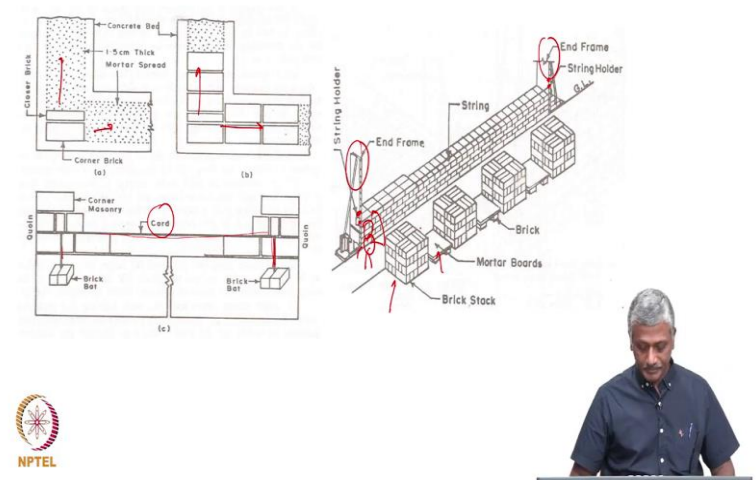


So this is an example as I said of laying the bricks, you start from the corner move towards the center and that is what is being shown in this picture here and the horizontality is maintained by using a cord which is actually tied to heavy weights at the ends to ensure that it is very tight and it defines the what the horizontal level properly. Sometimes we may see that people are using these frames which are at both ends of the brick wall.

And they have these strings tied exactly at different locations in the frame and as each layer is constructed, the string will be tied in the next layer or at the next level. So that you can continuously mark the levels or horizontal levels of each masonry layer. These are the bricks which have been stacked on the side. The mason would stand here pick up the brick and then lay it here.

So this is a typical arrangement of stacking the bricks to ensure that many bricks can be stacked together and these in between our mortar boards or containers on which the mortar will be mixed and kept so that the masons have easy access to the brick as well as use the trowel to lift the mortar and put it in place.

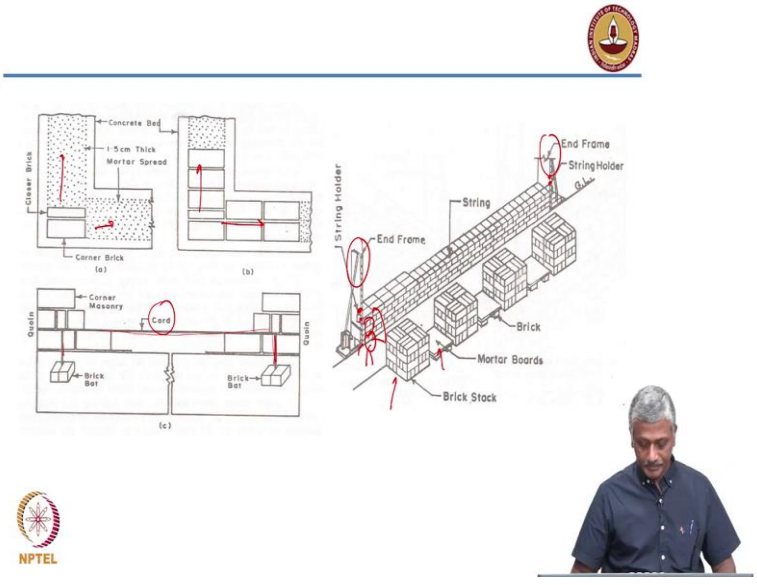
(Refer Slide Time: 19:57)



Again, just an example of the use of the taut cord system. See here concrete block construction is being done and the blocks are being laid and this cord here, which is held in position by a very simple arrangement of using just a block is a weight. You have a taut cord that forms the level of the horizontal masonry units. Again, it is not very clear here, but this person, what he is doing is actually checking the level of the masonry unit by using a bubble spirit level, which is typically used in workshops, you may have used it yourself.

The bubble spirit level helps you to check whether the blocks are aligned perfectly horizontally or not. Again, you are here you see an example of the taut cord being used. This is the masonry wall that is being built slowly and there is a nice video also, which captures this entire process.

(Refer Slide Time: 20:50)



Now, generally, when you use different types of materials, you may have to change your procedure. For example, with common lime mortar or cement mortar, the brick or the stone block or concrete block has to be wetted and only then used. But when you are using fat lime, or mud mortar, you do not have to soak the blocks, because what happens in that case is the mud mortar or the fat lime mortar does not give out any of the water.

It basically keeps the water within, it does not easily lose the water. Because of that you do not have to use wetting. The frog that is a depression on the brick where the name of the manufacturer is there, typically is laid on top while lying that is just for uniformity. In thick walls, it is possible that you may not be able to have proper jointing or joints between the bricks and many gaps may be left over.

In such cases, you have to ensure that at the end of the wall construction, you do grouting to fill up all those gaps. So in thick walls, we typically do joint grouting. As I said, again, the brick wall is uniformly raised, continuously raised upwards uniformly, or if we leave for the day's work we leave behind the steps or the toothing. Another common feature that you will find in most major masonry structures is the use of expansion joints.

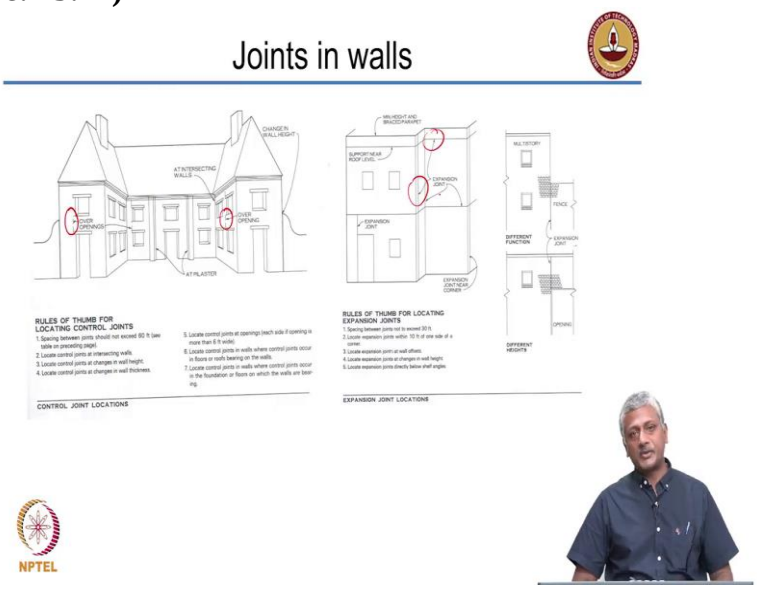
And this is very important because when you have very long running wall, as the brick wall is subjected to the daily changes in temperature, the material expands when it is subject to heat and contracts when it is subjected to cold. When the temperature increases, the wall basically expands, when it reduces the wall contracts. So, if the wall is of a very long length, the accumulated stresses over a very long length will be too high and cause the wall to crack.

So, instead of this what we typically do is, in between the wall at every about 30 to 45 meters length of the wall, we leave what is called expansion joint. Of course you do not see this in the regular residential household because your walls are not really that long. But when you see buildings which are used for schools or for other purposes, you have very long walls and to ensure that this wall does not start cracking in random areas, you leave behind what are called these expansion joints.

The joint ensures that the effective length of the wall is reduced and the wall does not really crack anymore. So when you leave behind these joints, obviously you need to fill those up with some sort of rubbery material to ensure that the water does not come through it.

Otherwise the point of providing a joint is lost. So again, these are some nice videos you can see of a brickwork type construction that is being done. Again, there are several videos, obviously I cannot list everything here in this chapter, and you can do a search and find more effective videos than this also on the web.

(Refer Slide Time: 23:47)



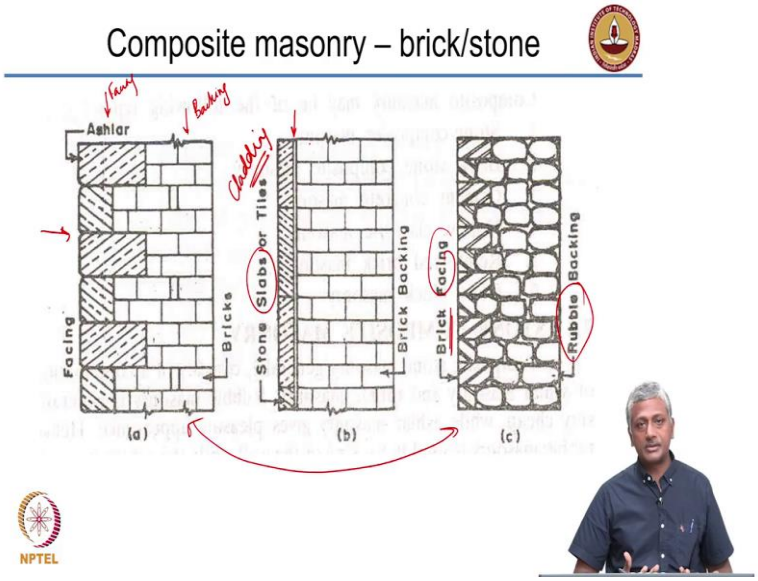
Now, again, the expansion joints are not only provided for running length, you may also want to provide it wherever you are seeing openings, wherever you are seeing window openings, because one of the common features you will observe when you see the your own house for instance, you will see that many of the cracks are emanating at corners and emanating wherever the openings are there. So, to avoid such cracking and avoid failures, generally, your joints may need to be provided over such regions.

All you are simply doing is providing some free movement of the different structural components in your construction. So, those are some examples. So, again here, expansion joints are provided between materials which may be different. For example, you have a brick wall and then you have a slab which is made with concrete. So, in such cases you want to provide something that corresponds to or which is there to allow the expansion of the brick wall and expansion the concrete at separate rates.

Because concrete and brick are different materials. So the brick wall may actually be expanding and contracting with a different coefficient of thermal expansion and concrete will be different. So whenever you have dissimilar materials, you may also want to locate your expansion joints. So, again, there are several rules of course, this is not something that is part

of this course, I just wanted to give you this information. So, that next time when you observe your own house, you will start locating these aspects.

(Refer Slide Time: 25:15)

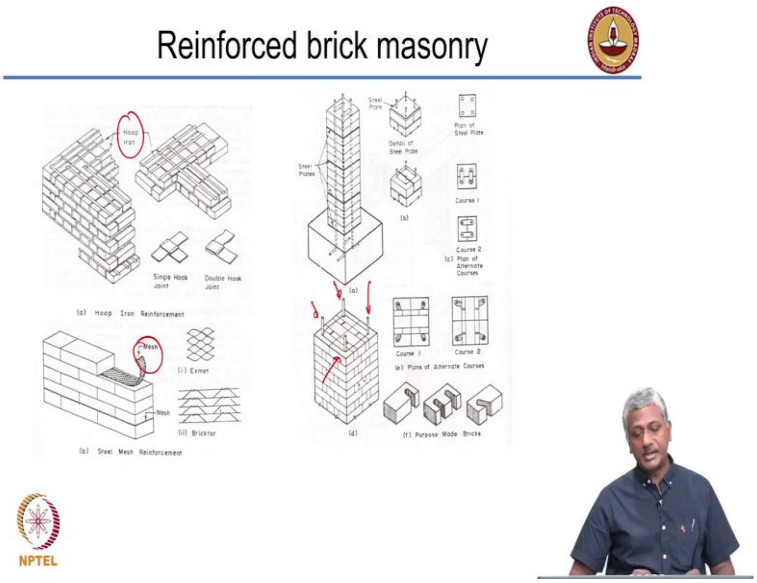


Now, sometimes we use composite masonry in which we use more than one type of material to make the masonry wall possible. So, this is an example of a brick stone composite. So, you have bricks as the backing that means, the main part of the wall is a brick wall and ashlar fine cut stone as the facing material. You are looking at from the outside the ashlar facing followed by a brick backing.

Sometimes we may not use ashlar blocks, you may actually use stone slabs or even stone tiles to give an outward appearance of a stone building or cladding, and this is also called cladding. But actually the wall is made out of brick, brick and mortar wall which is cladded with stone. Now, this is an opposite example of the first one where the actual masonry is in stone or rubble and you have a facing made with brick.

So, all kinds of arrangements are possible all you need to do is ensure that whatever facing material you have is properly embedded into the backside or properly glued. So, here of course, when you are using stone slabs or tiles, it needs to be glued to the surface of the brick wall and this glue is basically mostly made with cement based materials.

(Refer Slide Time: 26:31)

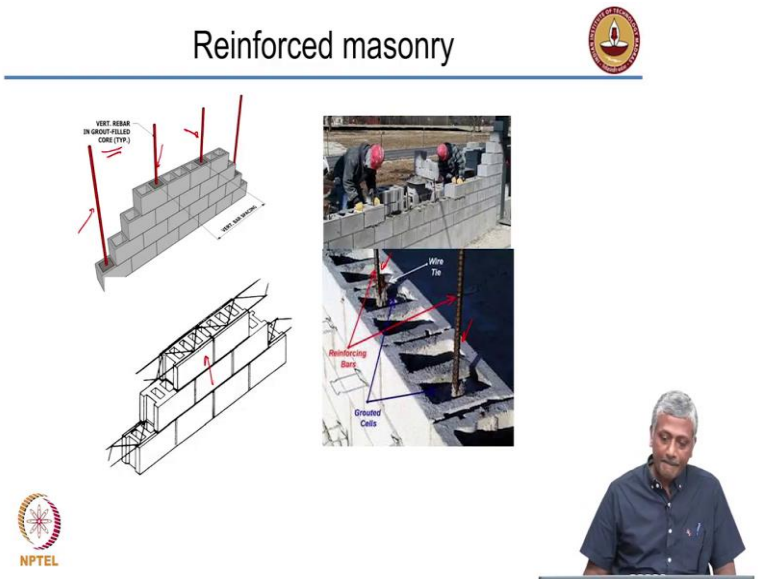


Now, when we talk about composite masonry, what we are simply trying to allude is that more than one type of material is used, it could be stone and brick or stone slab and brick. But more often than not, when we talk about composite masonry, we are referring to reinforced masonry, where we are able to put steel to introduce much greater tensile resistance in the masonry, just like concrete, masonry materials are good in compression but weak in tension.

So to provide tensile strength, you need to ensure that you have a very high tensile property introduced by the introduction of steel inside the masonry. How do you put steel inside masonry?, one way to do it is to put it in the joints, you put steel in joints, hoop iron, or you can also put meshes in the joints, but that is only the horizontal direction. What about the walls standing like this?

It is subjected to a very high wind force or even earthquake forces horizontal forces, the wall is going to try and bend in this direction. So, if you have to reinforce a wall in that direction, you need to provide a vertical steel bar which helps in bending in this direction. So, in such cases, obviously, you will have to provide gaps in your masonry where the rebar or reinforcing bar can be inserted. So, for instance, you see how these bars are actually inserted by using special bricks, which have these gaps inside where the bars can be inserted.

(Refer Slide Time: 28:07)



Now, of course, all this becomes much easier when I use concrete because concrete can be made into hollow blocks and these hollows provide ideal locations where you can insert the bars. Now of course, once these bars are inserted, they are not big enough to actually completely fill up the hole. So we need to keep them in position by grouting. You need to put a grout to keep these bars in position. So that is basically a reinforced concrete block masonry.

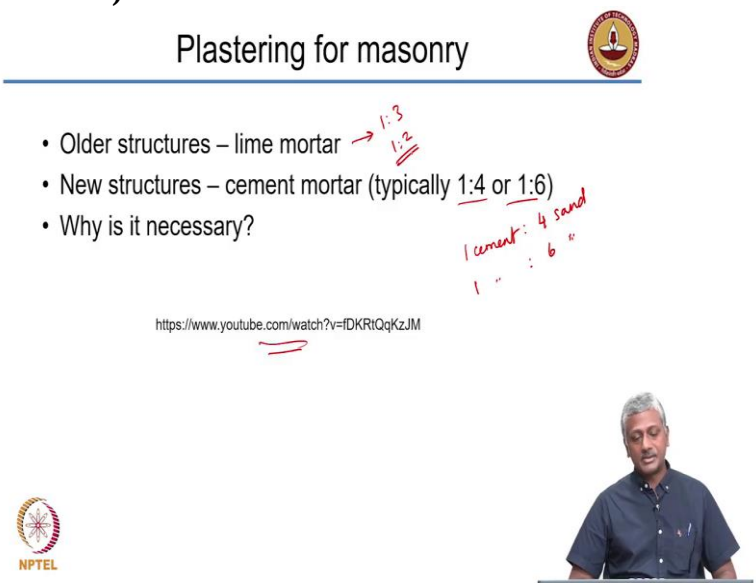
So again, you see here reinforced concrete block masonry, we can also get horizontal steel to reinforce it, but mostly we are talking about these vertical steel members that impart the lateral load resistance for the wall. Again, just to give you an example of real construction, you see these blocks where the steel has been inserted not in every cavity, but in every third cavity.

They are not inserted in every cavity, you do not need that level of lateral resistance, but you can calculate the amount of resistance required and provide only in every alternate or every third cavity and these are all grouted to ensure that the material is in place. Again grout is nothing but a flowable mortar which goes and fills up the gaps and hardens, so that the steel bar is kept in place.

(Refer Slide Time: 29:19)

Again, another example of a reinforced concrete block masonry. Not reinforced concrete, but reinforced concrete blocks masonry. So, again here, cavities where the reinforcement is provided are marked quite nicely.

(Refer Slide Time: 29:38)



Plastering, just coming back to the plastering after the wall is completed, obviously you need to do plastering. As I said older structures were done with lime mortar. New structures are done typically in cement mortar and generally when you talk about plasters, they talk about ratios like this, 1 part of cement to 4 parts of sand or 1 cement to 6 parts of sand depending upon the consistency of the plaster that you require, or depending upon the strength of the plaster.

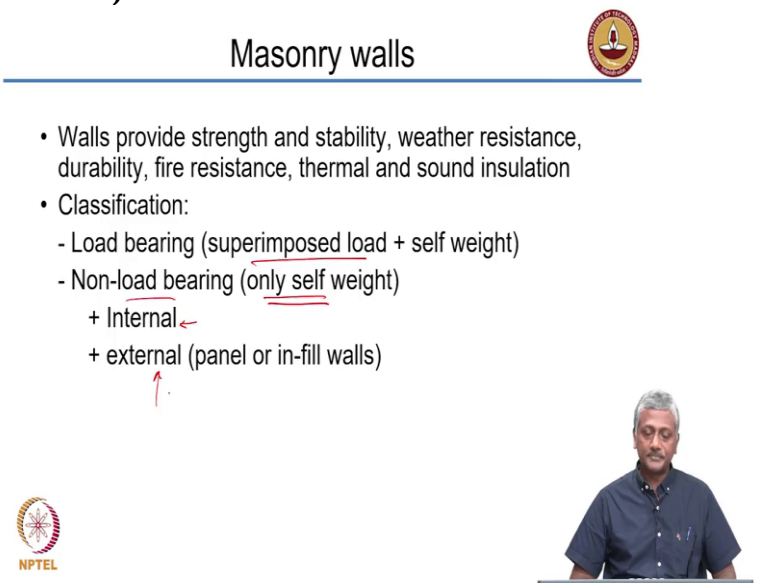
In the plaster case, strength is not all that important. However, interestingly, in our country strength of the plaster also seems to be given a lot of importance. Why because you want to

put a nail into the wall. So then the process of putting the nail drilling and all, if it completely fails off and chips off the plaster, it is not something that you want. So some level of strength is required to handle the process of drilling nails and so on.

But sometimes people do very random tests, like take a hammer and start striking the surface of plaster. It is not a good idea to do that, because plaster is not supposed to be a very strong layer. Now, because of all this, people have started making the plasters as very strong mortars, and that is not a good idea, you have to make up plasters as weak mortar? Because all it has to do is cover the top surface ensures that you reduce efflorescence, provide a level surface and so on.

And there is a good example of videos from the company called ultra tech which manufactures cement. They have a good range of videos which cover basic construction practices, and this video basically talks about plastering. So, this here, this ratio provided is 1:4 to 1:6. This is in terms of volume, not exactly in terms of mass, but this is typically in terms of volume. So, even in cement, typically, also in lime, the ratios typically are 1:3 or 1:2, you have more lime availability or more lime needed to get some minimum strength of the mortar as compared to the cement plaster.

(Refer Slide Time: 31:44)



So, we have looked at masonry materials, we have looked at how these are combined together to make the masonry walls. I just wanted to give you a brief idea about how you should consider the design process of a masonry wall. First of all, what are the walls there for

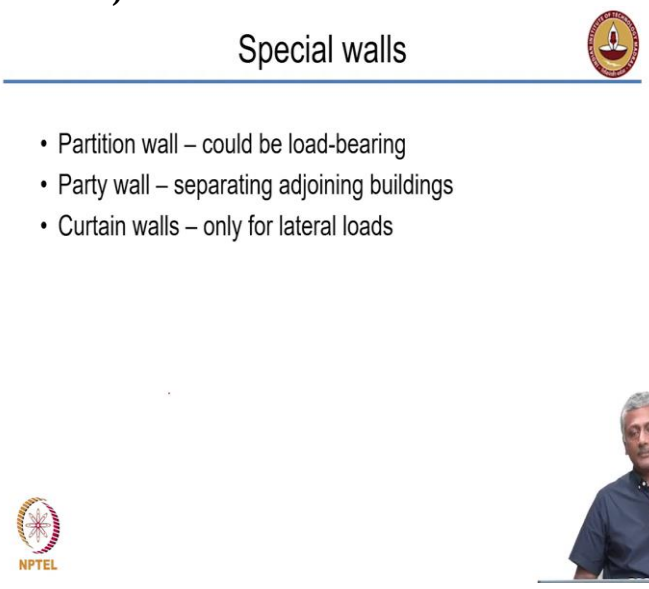
in a building? They provide strength and stability obviously, walls provide resistance from the weather because ultimately, they are protecting you from what is outside.

So, in cold countries, this would mean that they keep the interior warm, in warm countries or in warm locations for example, like in southern India, the walls are there to ensure that the heat from outside does not easily get into the inner part of the building. Then they also provide obviously durability to the structure, fire resistance and thermal and sound insulation. Now, based upon the amount of load they carry, and where they are placed, they can be called as load bearing walls which are actually getting the superimposed load from the top.

The wall is bearing the load that is coming from the top and its own self weight. In the case of non-load bearing walls, they have to bear only the self-weight. In most cases these non-load bearing walls are used as internal walls. That means, they are in between the outer walls of the of the building, which now two walls basically make the more load bearing components the inner walls are not really doing that much of a load bearing thing.

The outer walls or external walls which are non-load bearing are basically the panel walls or in-fill walls. As I said in a reinforced concrete frame, we just fill up the location in between using a wall where you can actually have lightweight units also used so, that is called an in-fill wall.

(Refer Slide Time: 33:29)

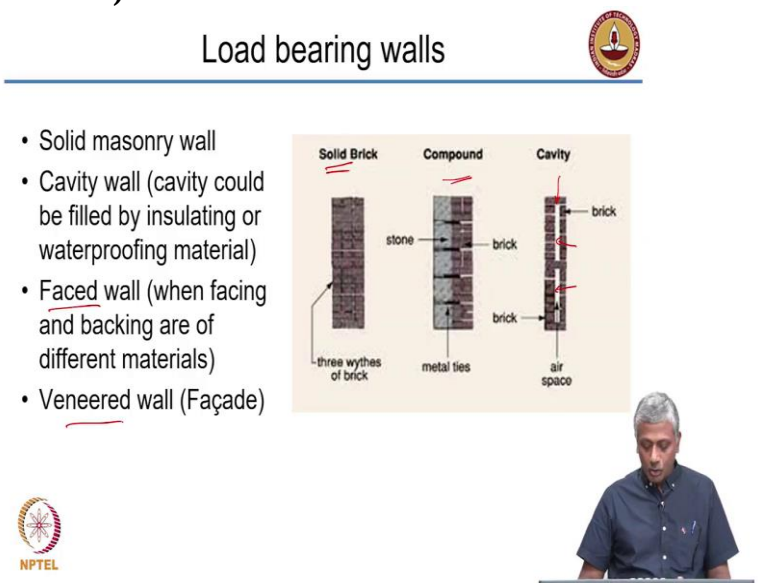


A partition wall could be load bearing wall. The function of a partition wall is to simply partition 2 spaces. If you have a very large hall for instance, you put a wall in between called

a partition wall which partitions 2 spaces. Now, the partition wall in some cases can be designed as a load bearing wall also. But in most conditions, most circumstances you will see that the partition wall is a non-load bearing wall and typically made with these lightweight concrete masonry units.

A party wall is a common wall between 2 buildings. Like you have row houses. When you have row houses commonly, every 2 buildings typically share at least 1 common wall that is called a party wall. In some cases, in front of the main structure, you have these walls called curtain walls, which are sort of protecting the structure against lateral loading. So all these are examples of different types of walls that you will see in construction.

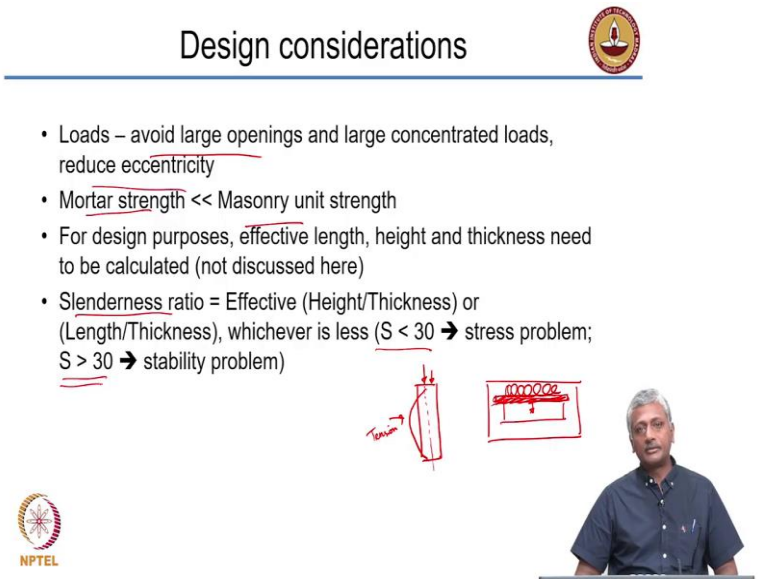
(Refer Slide Time: 34:23)



Now the load bearing walls themselves, as I said they need to provide resistance to the load of the superstructure that is obviously there and then transmit this load down to the foundation. At the same time, they should also ensure that the weather inside is nicely protected from the conditions outside, so for that, we always do not use solid brick walls we sometimes may use these compounded walls where brick and stone are together.

But more often than not, we will use these cavity walls where the cavity or air gap inside will tend to reduce the transmission of sound and heat into the building. So, there are other examples of load bearing walls also, a faced wall where facing and backing are of different materials like composite walls or compound walls, veneered walls where you use a façade.

(Refer Slide Time: 35:15)



I showed you earlier about a veneered wall which can be made with modern materials where you had a concrete block wall and there was a air gap and some vapour barriers and all that then there was a veneer or a facade which was made with a brick wall. So, all these are examples of different types of walls. Now, how do we design these walls obviously, we want to design the walls to take up the loads that are coming on top.

So, to ensure that the load distribution is uniformly given to the foundation, we want to avoid any concentrated loads coming onto the walls. Because concentrated loads can be not taken effectively by walls, they need to have well distributed loads. Secondly, we want to avoid large openings, if we have very large window opening for example, you have a wall like this and I tried to carve out a window in between like this that means this part of the wall now is unsupported, where does all this weight go?

Typically, in our construction, what we do is we use a lintel on top here, which is made with reinforced concrete typically, to take the load of the material that is on top of the lintel. But then, we want to avoid such openings because the requirement of the lintel becomes more and more stringent in terms of the load carrying capacity when you keep on increasing the span or size of the opening. We want to reduce eccentricity when the loads are coming onto the wall from the top as far as possible they should be axial and not produce any bending of the wall.

As I said, if I take the wall cross section like this, and the load which is coming on top, it has to be exactly in the central axis of the wall. If it is on one side, if it is eccentric, it is going to cause the wall to bend. And when that bending happens, you will have tension on one side

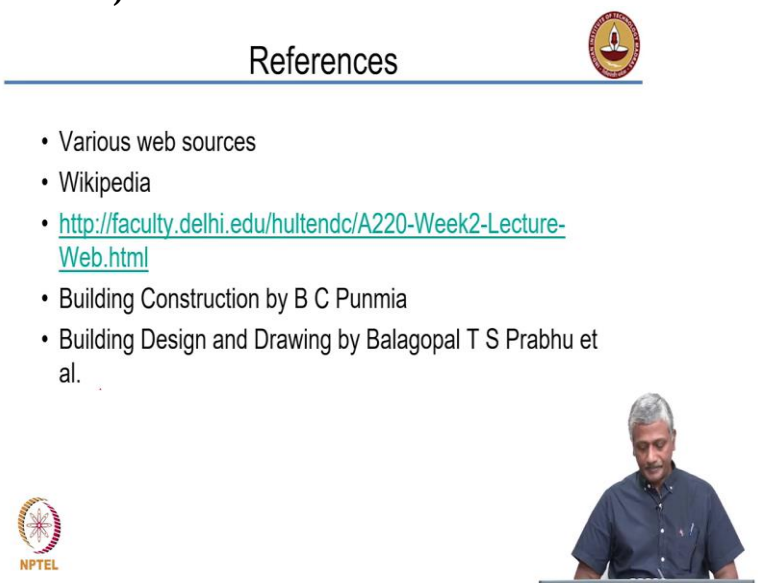
and the wall is not able to take tension. So, you have to reinforce it to be able to take that tension.

Again mortar strength is typically much lesser than the masonry unit strength, because the mortar failure will lead to a slow and steady failure of the building, it would not lead to a sudden collapse. For design purposes, generally what we do is, we calculate the effective length, height and thickness and calculate what is called the slenderness ratio.

So, if you think of a wall like a paper, you stretch the paper along the length, the length divided by the thickness of the paper is the slenderness ratio in the length direction, the height divided by the stiffness of the paper by the thickness of the paper is slenderness ratio in the vertical direction. So, the paper can be bent in this way or this way. So, if it is very slender, if the length to thickness ratio is very high, then it will easily tend to bend along this direction or height to thickness ratio being very high, it will easily tend to bend along the vertical direction.

So, you want to ensure that you are able to control the design based upon the slenderness ratio and again when the slenderness ratio is less than 30, the strength of the wall governs the overall behaviour. Whereas, if the slenderness ratio goes to more than 30, the stability of the wall is an issue. So, walls can be defined based on different ways.

(Refer Slide Time: 38:36)



So, with that, we come to the end of this chapter on stone, brick and mortar. As I said these are traditional masonry materials which are used even in the modern era. A lot of the bricks

and stones are giving way today to concrete blocks because they are much more efficient, easy to construct and easy to mould. Nevertheless, many of our ancient structures and many of the structures in rural parts of the country are still with stone and brick.

And one has to understand what the properties of these materials are in order to construct effectively these materials. So there are several sources are referred to with respect to the pictures and information that are provided in this chapter. Some of them are captured here, I request you to also read the content that is present in these books by Punmia and other authors who talked about building construction, like the list that was provided in the introduction to this course.

So that will help you understand the materials with a much broader perspective and also learn about applications with these materials in different locations of the world. So thank you all very much. With this, we end the section on stone, brick and mortar.