Design of Masonry Structures
Prof. Arun Menon
Department of Civil Engineering
Indian Institute of Technology, Madras

Module - 02
Lecture – 08
Masonry Materials and Properties Part - IV

Good morning. We will continue examining the behavior of the masonry assembly under compression, get an understanding of the compressive strength behavior of masonry and the role played by different factors on the compressive strength of masonry. And then examine the deformability characteristics of masonry.

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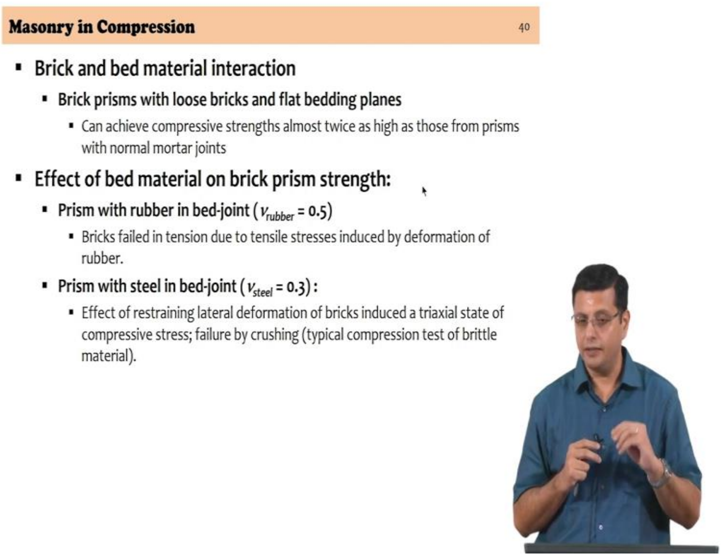

So, in continuation from the last lecture, it is quite instructive to look at several experiments that were carried out in the past to gain a deeper understanding of this co-action between the unit and the mortar. So, it is instructive to note that the interaction between the brick unit and the material that is used for the bed jointing. If you were to consider just a stack of bricks right, assume it is dry stack construction- there is no mortar; in this condition let us assume that there is the contact surface which is acting as the mortar.

So, if you just have a loosely stack set of bricks, but assume the bedding planes are perfect; the bedding planes are perfect implying that the contact is established in a perfect manner between the units. It is found that the compressive strength that you will achieve in the stack is twice as much as you would achieve or more when you have a mortar joint. So, the mortar in reality contributes to reduction of the compressive strength of masonry, which means if you can go for thinner and thinner joints tending to almost disappearance of a mortar joint you would approach the compressive strength of the unit; you would approach the unit compressor strength right, I hope that makes sense.

So, there is a role that this co action is playing, but since the jointing material is of lower strength, as an outcome you have lowering of the overall strength of the masonry assembly in compression, right. A few experiments done in the past in the 1970s actually gave a good understanding of the rationale behind keeping mortar weaker than the unit and then contributing to the co-action itself.

So, a couple of experiments that were conducted- one of them look that the stack of bricks instead of the mortar had rubber in the joint ok. Now rubber as you know has a Poisson’s ratio of a close to 0.5 and it is classified as a incompressible material, right. Now when you have incompressible material, but deformable highly deformable in the stack of bricks the bricks failed intention because tensile stresses were developed in the brick unit because of the deformation of the rubber.

The rubber incompressible, but deformable much more than the unit led to the brick being able to fail in tension because of the tensile stresses that were developing at the interface, when this is replaced with a material which has a lower Poisson’s ratio of the order of 0.3 for steel the Poisson’s ratio of the mortar would be off the order of 0.25.

This created a restraining effect in the mortar itself because now it is more compressible than the previous case in the rubber we looked at an example which is highly incompressible material whereas, you are looking at steel which can be compressed relatively more and this causes lateral confinement of the mortar and as you would expect in a material that is brittle under triaxial compression, the mortar actually would fail in crushing as you would see what happens in this sort of an experiment.

Where the brick is now able to create the restraining effect lateral deformations are controlled, you get the triaxial state of stress and the typical failure that that would expect in a material in compression, a material that is brittle and in compression failure by crushing is seen.

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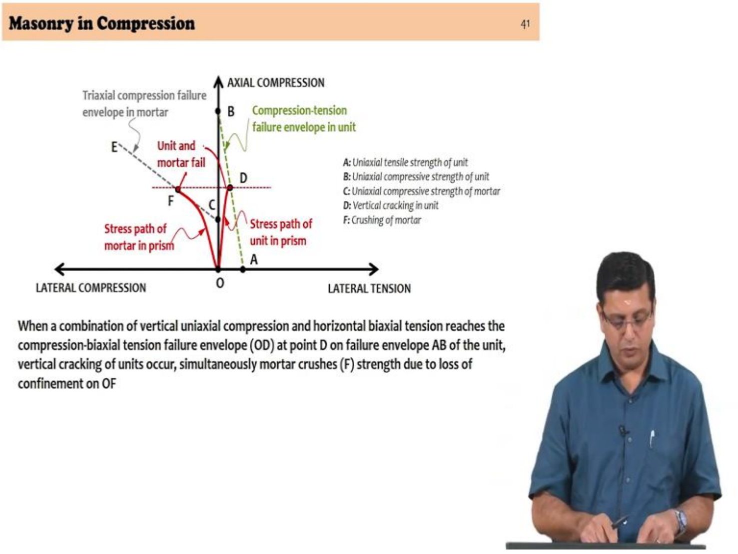

To be able to visualize this entire process it will be instructive to look at the behavior, the trend under lateral compression and tension versus the axial compression when you are loading a stack of bricks in compression. So, prism that is loaded in compression concentrically. Now this will actually form the basis of a set of formulations that arrive at the compressive strength of the assembly of masonry with an understanding of the roles played by individual strengths, particularly the unit and the mortar in compression and in tension ok.

So, if I were to look at the trend of the stresses in the masonry, the stresses in the unit and the stresses in the mortar depicted on a graph that has axial compression along the y axis and the lateral effects on the x axis- lateral tension on one side and lateral compression on the other. The two points A and B; the two points A and B would represent the uniaxial tensile strength of the brick and the uniaxial compressive strength of the brick unit right, you see that the point A is on the x axis on the lateral tension side. So, A is actually depicting the uniaxial tensile strength of the unit, B is sitting on the y axis on axial compression and is depicting the uniaxial compressive strength of the unit, these are the component properties unit properties.

The behavior of the unit is rather brittle. So, an idealization with a straight line of the tension-compression behavior is acceptable. So, that green dotted line there is actually the tension-compression failure surface or the envelope of the brick unit right. And on the sidelines, you can see that the tensile strength is roughly about 10 to 20 percent of the compressive strength of the unit and that is a typical value that you can go with. The point C again on compression, is actually the mortar compressive strength; the compressive strength of the material of the mortar right. So, A is the unit tensile strength, B is the uniaxial compressive strength of the unit, C is the uniaxial compressive strength of mortar.

Now, as we had discussed earlier the mortar tends to be in a state of triaxial compression. So, this envelope that you see here between axial compression and lateral compression is the line that defines the failure envelope of mortar in triaxial compression ok. If you were to examine the stress path of the unit in the prism itself; now you got the stack of bricks which has been subjected to uniaxial concentric loading in compression and we are examining the stresses formed in the unit, in the prism right.

These are now not the individual failure surfaces that we are looking at, but the stress path of the unit in the prism. As the axial compression increases we know that because of the co-action because of the bond with mortar the unit which is trying to confine the mortar itself experiences by axial tension. So, as the compression loading increases you have the mortar, the unit which is experiencing increase in stress that would go along this line O D right and then finally, reaches the failure surface we will come to that point in a moment.

So, the line O D is actually the stress path of the unit in the prism finally, coming and intersecting the line A B which is the failure envelope of the unit in compression-tension. Now, if you were to examine the stress path of the mortar in the prism, the stress path of the mortar in the prism it is no longer responding as a material that is in uniaxial compression. It is actually in triaxial compression; however, the mortar being more deformable is a material that is now behaving in a non-linear manner, the brick behavior can be idealized to an almost linear behavior.

So, as the loading progresses the mortar follows this red line that you see the stress path of mortar and in the prism O F right, you see that the stress levels in the mortar can exceed C which is the uniaxial compressive strength of mortar which is C it goes beyond that. But at a certain point; the stress levels in the unit reach the failure surface in compression-tension (the surface A B); cracks are formed in the unit and you have the initiation of failure in the unit itself.

The unit starts cracking and failing in tension. So, you get the units hitting the point D on the surface A B, but the moment the unit fails in tension it is capacity to restrain the mortar and cause a state of triaxial compression in the mortar is also lost and that is when there is a simultaneous failure the unit has failed almost the same time, the mortar can no longer resist the level of compression now higher than the uniaxial compressive strength of mortar, but it is suddenly fails because the confinement effect is lost. So, there is almost a simultaneous occurrence of these two phenomena which is the splitting failure in the brick and the loss of confinement and crushing failure of the mortar itself.

So, this is how the failure mechanism propagates between the mortar and the unit in a prism which is subjected to uniaxial compression, you must note here the linear envelope that is used to define the failure surface in the unit and the almost linear line O D because a material is quite brittle in comparison to mortar. Whereas, the stress path of the mortar itself O F is rather non-linear in comparison to the constituent and the constituent particularly brick and the behavior of brick itself in the prism right. So, this will form the basis of one or two formulations that we will look at in terms of defining the compressive strength of masonry knowing the strengths of the constituents.

So, to summarize when a combination of vertical uniaxial compression and horizontal biaxial tension reaches the compression biaxial tension envelope, O D reaches the line A B at D of the failure envelope A B, you have the cracking of the units and a simultaneous crushing of the mortar you reach point F now you see that it is at the same level of axial compression and this is due to the loss of confinement on the non-linear surface O F now.

So, this is your question is again dealing with whether D and F are simultaneous phenomena. Of course, we are looking at an instant in time you see that they are at the same axial compression level; that means, the prism has reached a level of axial compression, at that point the stress in the unit has reached a state where the biaxial tension is sufficient enough to hit the failure envelope A B right. So, that at that moment the unit is cracking, but the moment the unit cracks it has does not have the luxury of the confinement that it was providing to the mortar.

So, at that instant in time if you were to look at masonry compression test a prism test you would really not be able to distinguish between the formation of the final tension cracks in the unit. At that moment if you try to touch the mortar, the mortar is powdered. So, the crushing in the mortar has occurred at that stage. So, this is almost like a cause and effect that we are examining, but these are phenomena that are extremely close in succession and the reason why we are examining this is, closed form solution to arrive at the compressive strength of masonry that uses this concept of a simultaneous occurrence of the failure in the mortar and the unit is what is most probable as the real phenomena.

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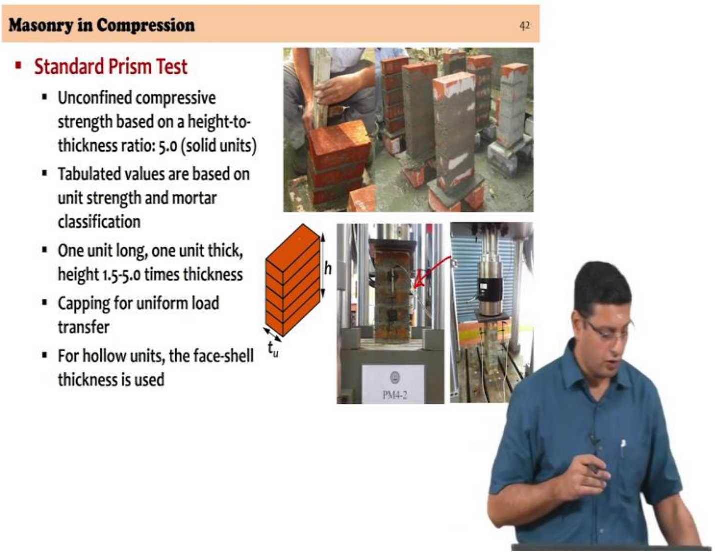

In terms of the test method itself, a standard prism test is what is conducted and now we are really looking at an unconfined compressive strength test. The unit is subjected to; the stack of bricks with the mortar subjected to uniaxial concentric loading.

So, it is an unconfined compressive strength. Recommendation when you are using solid units clay brick solid units is to go with a height to thickness ratio of 5 and this thickness here for the stack of bricks refers to the least lateral dimension. So, if you take a stack of bricks the length of the stack is going to be at least 190 millimeters whereas, the other dimension is 100 mm.

So, the height of about 5 times the least lateral dimension is what is required as far as the unconfined compressive strength of masonry. So, typical stack is seen here you might have for several reasons you might not necessarily be able to go with the height to thickness ratio of 5, several things can control the overall geometry you might not have a test setup that gives you the headroom that allows fitting all these 5 layers of bricks or the required height to thickness ratio in your system, you might have units that are of a dimension which again is different from the regular modular dimension.

So, you can have some deviations and it is interesting to examine if you were to use h/t ratios lower or h/ t ratios higher what effect do you typically get. So, most codes, in fact, all codes would actually then give you the compressive strength that you will be able to achieve for masonry based on typical unit strengths and typical mortar strengths defined again based on the classification of the mortar. So, for a given classification and proportion of mortar you can get a certain strength and so, if you look at a table of mortar strengths or mortar classification and unit strengths, you will know what is the expected compressive strength that you will get for the masonry itself.

So, that is typically height to least lateral dimension, not the other dimension. One unit long to stack test one unit long and one unit thick, you can go from about 1.5 times h/t ratio of 1.5 to 5, because if you were to deviate you have correction factors and that is for practical applications range is given to you. And when you are conducting the test now you really have to understand that it is no longer the component behavior, the constituent behavior it is an assembly. So, if you were to measure deformations you have to be careful that you are measuring overall deformations or are you measuring deformations in the constituent material.

Therefore, when you place the bricks as a stack in a universal testing machine as shown here. LVDTs or Linear Variable Differential Transducers are used to measure the deformations, you have to be careful whether you are measuring deformations of the unit or are you measuring deformations across the joints of the masonry assembly itself and that is the reason why we typically use a combination of strain gauges. The strain gauges will give us the strains and from which you can calculate deformations in the unit, but if you want them across the joints, we typically make use of LVDTs and measure the deformations in the masonry.

We also tend to have measuring devices on all 4 surfaces because you want to be sure you are applying uniaxial concentric compression, because due to any reason which could be due to the unevenness of the masonry units, you might have mortar joints that are thicker in one plane compared to another which basically alters the geometry.

And because of the difference in the composition, you might have flexural compression instead of uniaxial concentric compression. You want uniform compression, but you might not get it because if there are deviations in the mortar thickness it could lead to the sort of a situation. And hence to be sure that you are getting you concentric compression you would place 4 LVDTs, at least 4 LVDTs on the 4 sides and be sure that the deformations are comparable deformations.

Again, we have seen the effect of capping. Even here soft capping is adopted, but basically the capping is to ensure that the load transfer is uniform. If you are using molded bricks the brick at the top will have a frog, the frog is filled with mortar or plaster of Paris and then you use a plywood plank that is then serving as the capping for uniform load transfer. If you are using hollow blocks; then basically the loading is on the face shell, the loading is only on the face shell. You are not going to be filling the hollow blocks with any material you are testing the compressive strength of the hollow block itself so, face shell loading is what is happening.

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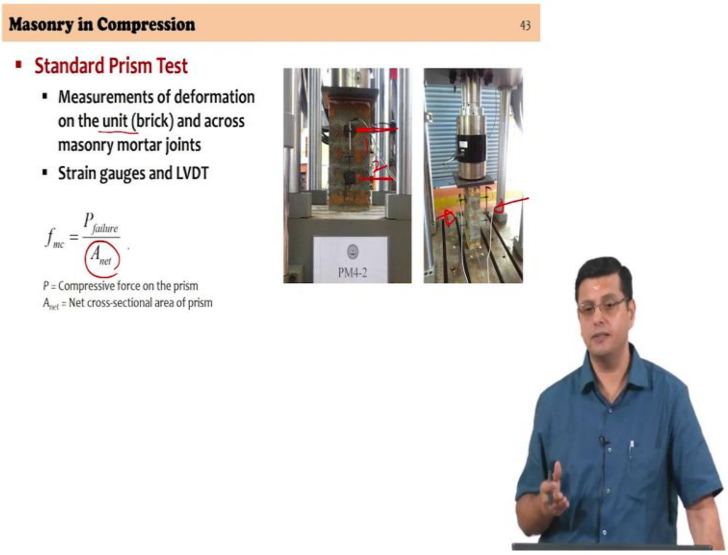

So, what is important is that you have measurements of what is the strain or deformation in the brick. So, you will have strain gauges fixed on to the brick unit itself, but if you want the deformation in the masonry you need to have measurement across at least one mortar joint and that is what you see here.

You can see that the LVDT here, this is a linear variable differential transducer that is running from the point here to point here, across two mortar joints 1 and 2. So, unit mortar joint unit mortar joint unit and so, you have got the deformation being captured over a gauge length in the masonry. This is what you will be using for estimating the stress-strain behavior of the masonry itself and you can see in the other figure, how on the other two sides you have the LVDTs. This is primarily for a check that the flexural compression, a strain gradient is not occurring in the test as you are conducting the test itself measuring instruments strain gauges and LVDTs are typically used.

And then you would basically calculate the compressive strength of masonry as the failure load to the net area and that is something that we discussed earlier that the compressive strength and the compressive stress is estimated based on Anet and here how much area of void is present matters to the strength of the masonry itself.

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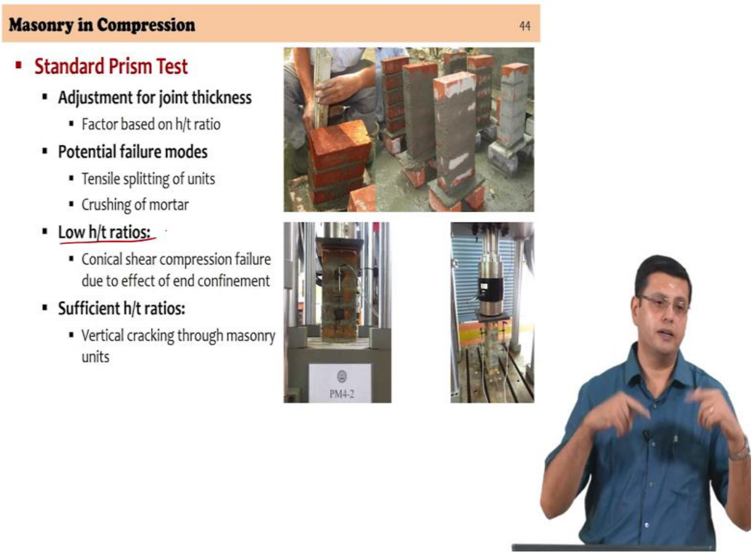

If you are unable to carry out a test with prescribed values of h/t adjustments for the joint thickness or the number of layers of bricks or units in the stack can be carried out by factors typically given to you in codes. So, we look at; we look at the differences that are there between codes, but there are factors that are based on the h/t ratio. Typical failure modes in the prism, you would see that the unit will split you can see the formation of several vertical or sub-vertical cracks and you will see that the mortar has crushed after the test. So, will be lateral bulging and the splitting of bricks along with the crushing of mortar.

But when you have very low values of h/t ratios that you are adopting for the prism, the problem is you will have confinement effect coming from your plates the loading platens of the top and the bottom and you will not get a range of uniform compression happening in the unit and you will not get the formation of these vertical cracks and lateral bulging, you will see the formation of the x crack the conical failure because of the confinement effect. The failure that you that we talked off earlier in the mortar cube or the brick unit or even in a concrete cube that you would see is the hourglass kind of failure is what will happen if you have values of h by t that are small.

Now, if you were to use h/t ratios that are more than what is prescribed, you would expect buckling failure in the prism that is why a cap of h/t ratio of 5 is prescribed, because if you go beyond that the failure mechanism would have second order effects and you will not get a compressive strength that is representative of the compressive strength of masonry. So, with sufficient h/t ratios you will get vertical cracking through the masonry units ok.

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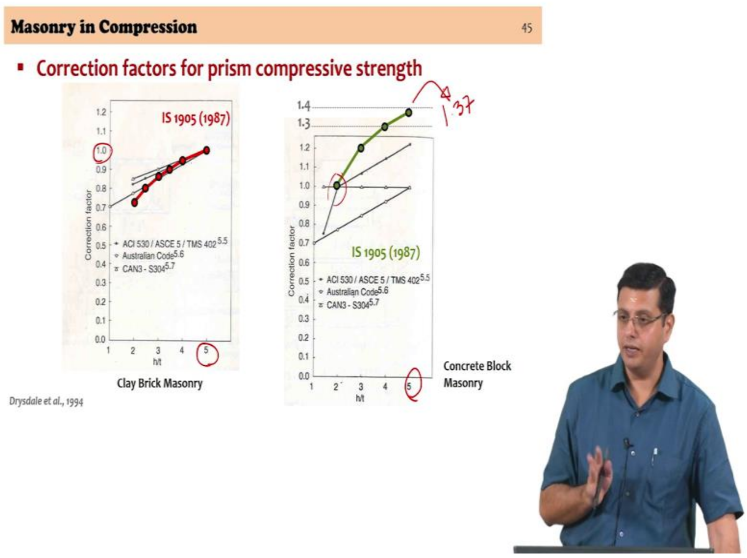

Just to examine what is the order of these correction factors that codes talk of, in terms of the prism compressive strength, in case you are working with prisms height to thickness ratios which are non standard or beyond the prescribed limits. So, this graph here shows you the correction factor for clay brick units and there is a comparison of the codes from the United States American Concrete Institute, the ASCE American Society of Civil Engineers and The Masonry Society TMS code, the Australian code and the Canadian code. So, here in this graph will actually examining clay brick masonry you will see that the correction factors converge to a value of 5 for a h by t ratio of 1.

So, the h by t ratio 5 is what is prescribed; with a h by t ratio of 5 you do not need to correct or if your h by t ratio is lower you see that codes can differ and that comes from variability in the manufacturing processes, variability in the materials available from country to country and that is clearly the reason why you cannot adopt codes from different countries particularly for factors such as these or any other empirically arrived at values.

So, you can see variability in the correction factors across codes in 3 countries here, if you were to look at IS code, the IS code gives values for 2, 2.5, 3, 3.5, 4 and 5; h/t ratios ranging from 2 to 5 and you can see that more or less we are in the same order probably lesser for h/t ratios of 2, but that is the typical trend you would get correction factors trend of correction factors for clay brick masonry prescribed by IS 1905 this information is available in appendix B of IS 1905.

So, the prescription for the compression test and correction factors is available in appendix B of 1905 the masonry code for unreinforced masonry as a structural system, but if you were to examine concrete block masonry. In concrete block masonry you already have units which are significantly different the blocks are significantly different in dimension in comparison to the clay brick units, you would have heights that are 150, blocks which are about 300.

So, these are typically very different in unit geometry, the block geometry in comparison to the clay brick units. And so, you must be careful about this the correction factors are; the correction factors are based on a completely different set of h/t ratios, here the threshold h/t ratio is 2 it is not 5 and that is because of (1) the material and (2) the geometry itself.

So, if you are using concrete block masonry you can see again how the three different codes give you different values, you can see that typically almost two codes look at h/t of one as the threshold value as the value for which no correction is required beyond that or less than that you have to have a correction factor for the h/t. So, if you have value is greater than 2, correction factor is greater than 1 according to the ACI or the TMS the masonry society and for the others you can see that there is a difference.

So, it is important that you are looking at these factors with reference to the specific code and the specific typology of blocks, geometry of blocks that are being used. The Indian code IS 1905 again gives you a set of correction factors which are with respect to the block geometry that is prescribed in the Indian standards and also the composition that is prescribed for the material of the blocks.

And you can see that the value at h/t of 2 commences at 1 and then you have values that are greater than 1 for the correction factor used for concrete block masonry if there is a deviation from h/t of 2 and beyond. So, given the block geometry given the block geometries it becomes cumbersome to do anything like h/t of 5; the UTMs will not be typically designed to have h/t of 5 sitting in the machine and also because of the material these values are significantly different, you can see the h/t at 5 for clay brick masonry and the concrete block masonry are different 1.0 it is 1.37 in this case for clay brick masonry at this at this point whereas, it is 1 for clay brick masonry. So, the geometry being hollow the material are what matter in terms of these values varying. So, you will be really careful what correction factors you are using ok.

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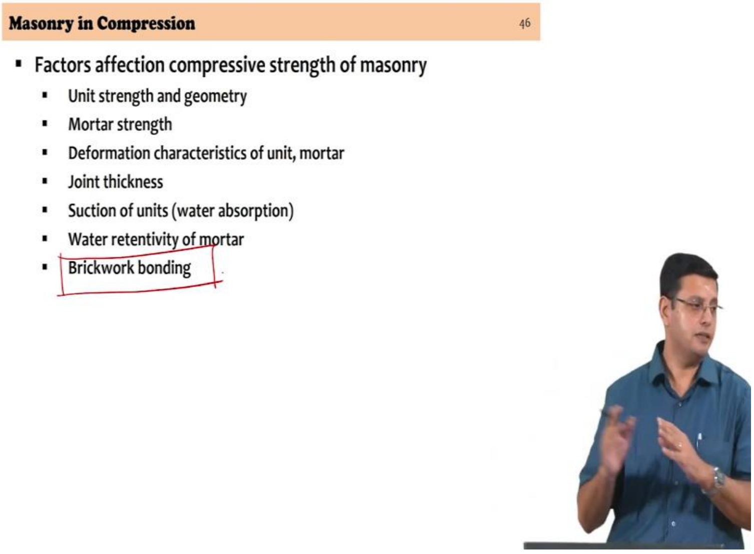

To examine what factors affect the compressive strength of masonry, all factors that you can think of at the constituent level has a significant role to play, but depending on whether you are looking at clay brick masonry, depending on the type of mortar and depending on whether you are looking at concrete block masonry, the importance of one factor or the other can change.

So, unit strength in geometry, the mortar strength so, we looking at geometry of the constituents, the strength of the constituents, deformation characteristics of the unit and the mortar, the thickness of the joint, water absorption characteristics of the unit and retentivity of moisture of the water of the mortar, because the mortar has to gain strength adequately and the type of brickwork bonding.

And at this stage I would like to point out one important aspect that you must consider- we are looking at compressive strength based on testing a stack of bricks right and you arriving at the compressive strength of masonry based on a standard prism test. However, you know that when you are constructing a wall you would never construct a stack of bricks right, you typically require thicker cross sections, stack of bricks is rarely used because you are going to get vertical joints.

So, you use bond patterns, now depending on the bond pattern adopted; let us say you are adopting a header bond, a stretcher bond, English bond or a Flemish bond, you can at and if you were to create small wallet us using different bond patterns the compressive strength of masonry will be different from the stack compressive strength.

So, the stack compressive strength really does not account for the interactions of the masonry from the pattern of joint and the lateral effects that come from the units that are sitting around bonded to it in the masonry wallet itself. So, brickwork bonding has a role to play, but since you can have several types of bonds you do not have compressive strength defined based on the bond, you have compressive strength defined as the compressive strength of a stack of bricks ok.

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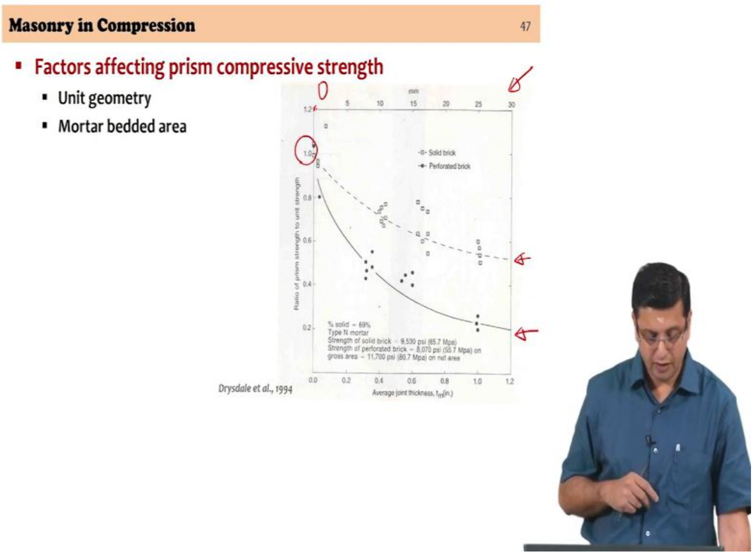

Let us examine a few factors that affect the compressive strength. You are looking at the unit geometry and the mortar bedded area. So, primarily what is the kind of role the unit geometry has or the mortar bedded area has if you are looking at solid blocks versus perforated blocks right. The gross area versus the net area effect as far as the strength is concerned.

So, on the x axis you are looking at the joint thickness in millimeter at the top, on the y axis it is the ratio of the prism strength to the unit strength; taking the ratio of the prism strength to the unit strength right. And this is clearly what we were talking about earlier that if you take a stack of bricks with no mortar you should be able to reach the unit strength; you will be able to reach the unit strength.

So, if the ratio of the prism strength to the unit strength is 1 you can be sure that the joint thickness is 0, which means introduction of a mortar joint of any thickness is going to reduce the compressive strength of the masonry. So, you can see how the ratio of the prism strength to the unit strength keeps dropping both for solid blocks and for perforated blocks as the mortar joint thickness increases.

But what is instructive to note here is the geometry between the 2 types if you have solid blocks versus perforated blocks the effect of the joint thickness is much more pronounced in the perforated blocks the reason being you are really looking at a smaller area in the perforated block that is carrying the stresses as against the solid block right.

The geometry matters in the solid block you have larger area that is getting affected by the joint thickness whereas, in the perforated blocks it is a smaller area that is actually resisting and the role of the joint thickness is much more pronounced in the perforated blocks. So, between the solid blocks and the perforated blocks this difference is primarily due to the available bedded area; available mortar bedded area that changes the behavior under compression itself.

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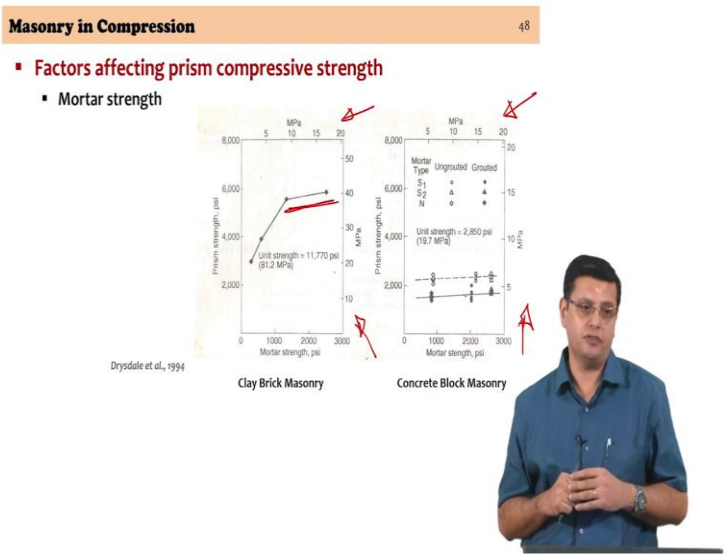

If you are looking at the role that the mortar strength will play on the compressive strength of the masonry assembly what comes out as an important message is beyond a certain mortar compressive strength you cannot increase the prism compressive strength. There is a saturation; it does not mean that you keep increasing the strength of the mortar you going to get stronger and stronger unit stronger and stronger masonry, there is a saturation that happens.

So, if you are looking at mortar strengths on the x axis for clay brick masonry first and the prism strength on the y axis, then you can see that beyond a certain mortar strength you have a saturation of these values right. Of course, these pictures are given for a specific unit strength and the trend would be similar keeping in mind what the ratios are between the unit strength and the mortar strength.

If you come to the concrete block masonry again with the mortar strength on the x axis and the unit strength on the y axis what you start seeing is that really the mortar joint is not playing a significant role, any idea why that is so? The masonry compressive strength, the prism strength is almost insensitive to the variation of the mortar strengths. If you look at clay brick masonry and the mortar the unit and the mortar are significantly different materials with different values of Poisson's ratio whereas, in the concrete block masonry the mortar cement mortar and the concrete block made in almost the same manner probably with aggregates which are of a slightly higher size than the mortar.

So, you are looking at almost a uniform material in the concrete block masonry; there is no significant difference in the constituent behavior in the concrete block masonry as against the clay brick masonry with a clay unit has a very different compressibility very different deformability in comparison to the mortar. That is why there is an insensitivity to the mortar strength in concrete block masonry whereas, in clay brick masonry it is quite significant which also saturates after certain point.

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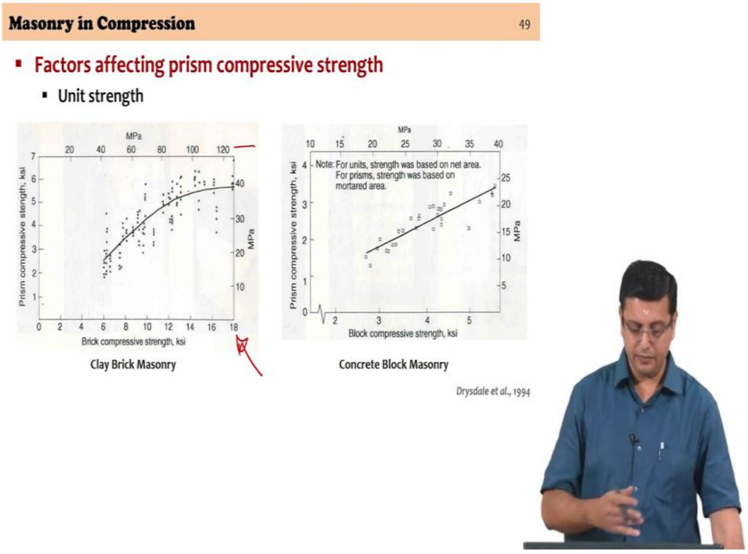

The unit strength how about the unit strength you are again looking at clay brick unit compressive strength on the x axis (MPa) on the top and the prism compressive strength on the y axis you can see that it definitely has a very significant role in the compressive strength of masonry, again significant or steep increase and then saturation beyond certain level.

Those high values that you see at the top is also because you can get very good quality bricks particularly used for refractory purposes as lining for kilns where you fire materials. So, high compressive strength is useful in such situations even in our country, if you look at you do not have to look at refractive bricks, but if you were to look at bricks coming from the Indo Gangetic plain the clay is of such quality that you would get bricks easily of a compressive strength of 30 to 40 MPa.

So, the variability is because of the variability of clay in South India and Tamil Nadu for example, it is difficult to get brick units which are more than 10 MPa or 12 MPa. So, that is the kind of variability that you will have, but the unit has the unit strength has an important role in the masonry compressive strength.

Again, with the block you see a similar trend here it is more uniform that is because it is a manufactured, I mean it is a material that is manufactured with more quality control cement and aggregates in a factory sort of situation. Whereas, clay brick masonry you see that this slightly non-linear is the kind of trend between prism unit compressive strength and the prism compressive strength.

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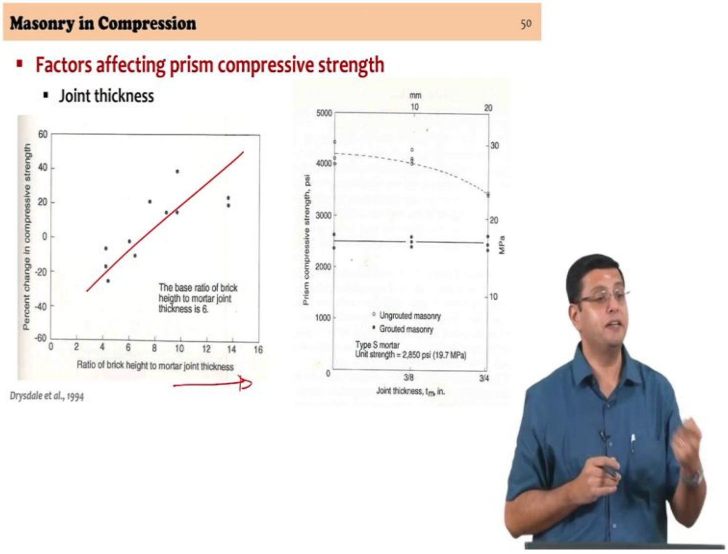


Joint thickness, it is very clear that thinner the joint better is going to be the masonry compressive strength you can see the; you can see the trend here, it is the best that you can ask for, you see on the y axis the percentage change in the compressive strength to the ratio of brick height to mortar joint thickness and it is normalized; and normalized to a height to joint thickness of 6.

So, you can see that with the ratio of the brick height to the mortar joint thickness increasing, which means you are getting thinner and thinner joints as you go along the x axis, thinner joints means improvement in the compressive strength of the masonry. If the ratio is falling, you are getting thicker joints and then you see that the compressive strength is actually going below; it is going to the negative range that is the role joint thickness will have.

If you are looking at block masonry concrete blocks- grouted and un grouted, the role is again not as significant as in clay brick masonry right. And you will appreciate the kind of complexity now, in concrete block masonry, in hollow block masonry you have space to put the reinforcement.

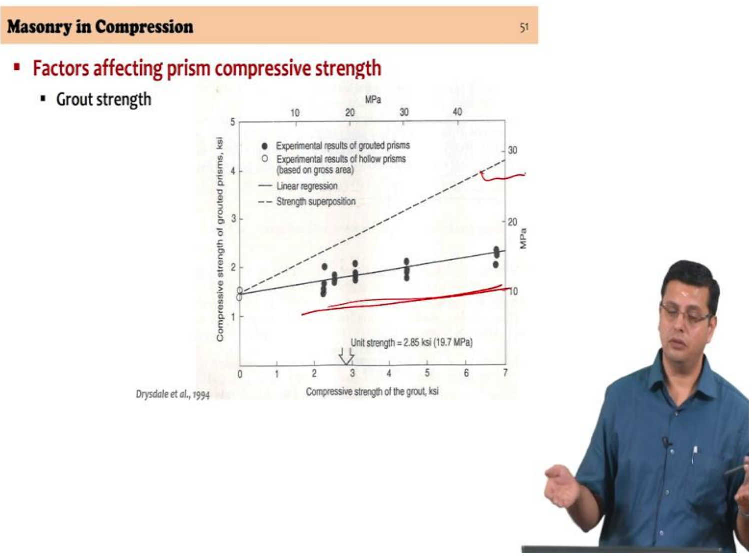
And the compressive strength of the masonry is not affected so much by the joint thickness, but in solid clay brick masonry where compressive strength is affected by the joint thickness you have this issue of how can you place the reinforcement without changing the or increasing the joint thickness. So, it is easily demonstrated by this trend between joint thickness and the compressive strength of the unit itself, what is on the x axis here, is the height of the brick unit.

Student: Ok.

Height of the brick unit divided by the joint thickness. So, if you keep increasing the joint thickness, then the height to joint thickness is coming closer to 0 whereas, thinner joint you getting a higher ratio, with respect to optimum thickness levels typically it is expected that the mortar joint is not more than 10 millimeters.

But you can get see that depends on the kind of tolerance you have on the brick unit itself if the brick unit is undulatedd which is very often the case when you use country bricks the tendency by the mason is to use a thicker joint which is then going to give stability to the entire wall. Because, if he is going to use thin joints then you will you will have out of plain deformations while manufacturing the wall itself, that is the reason why the mason puts a thicker joint, but the effect is significant on the strength of the masonry and that is why there is dimensional control on the unit which is required.

(Refer Slide Time: 44:03)



And finally, examining the grout strength; so, if you looking at hollow grouted masonry and if you were to again grout the void we are not looking at reinforced in this case it is just the hollow block with grout, what you see is that the effect of the grout is it is there it is weak right.

If you were to use the strength of the block superpose it with the strength of the grout it is this line that you should be getting right, you are actually you are actually getting a more resistant cross section you have the block geometry, block has a certain strength you have the grout you test the grout; the grout has a certain compressive strength you put these together superposition does not work right.

And you see that as you keep increasing the grout strength you do not have significant increase in the strength of the masonry. That is the reason why it is prescribed that keep the grout strength close to the block strength properties and you should be; you should be able to get desirable performance in compression of the masonry itself.

Student: Design (Refer time: 45:23).

Yes of course, if you are using; if you are using the grout strength has a role to play when you are looking at design of a hollow block of partially grouted masonry construction you will have to account for how many of those voids in a cross section are filled, how many are unfilled and the net area matters as far as the axial load carrying capacity of the wall is concerned ok. I think I will stop here and we will examine the remaining properties of the masonry assembly in the final lecture in this module.

Thank you.