Building Materials and Composites
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Lecture - 02
Clay Products 1

Welcome students. After the introductory lecture, we will have to progress with one lecture after the other. We have a lot of items to cover. In this module (module 1), we will have this second lecture on clay products. Since we have a large number of topics in this section on clay products, I have named it "Clay Products-1", and the next lecture will be called "Clay Products-2".

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So, if we look into the concepts that will be covered today, they are- clay products and their composition, steps of manufacturing, brick as the most commonly used clay product, types of bricks, characteristics of bricks; and we will finally try to discuss brick masonry.

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Now, why did we choose clay, out of all these things available on earth? We must know the reason behind it and since when it is being used. Historically, since 8000 BC, we find the use of brick- that is the first simplest unit made out of clay, which is durable, having strength, is reliable (that means it does not fail), as we had discussed earlier. It is low in cost, readily available, and easy to handle.

So, when we talk of clay, it is actually "Kaolinite", with the chemical name of "hydrous aluminosilicate"- here, alumina and silica both are present. "Silica" is sand, which is the majority portion- 50 to 60%, and alumina constitutes 20 to 30%. Lime here is around 10% available. This proportion varies depending on the place (location) of availability. But you must remember that lime has a vital role to play- which is a 'stabilizer'.

Regarding color, the most common item made of clay is the brick, which appears a little reddish due to the presence of iron oxide (around 7%). Also, it has magnesia and lots of alkalis within it. Other than that, there are vegetative items, organic items, pebbles, stones inside the clay. So, we have to know how to remove the unwanted items, and then you can make the clay usable.

Now, what are the usual materials which we make out of clay? The most commonly used building material (in our country context) is brick. When we move to the countryside, we find the application of clay tiles as you can see in the next two

pictures. So, they are again of a different shape; as you can see, the two images differ. But more or less across the country, we see brick as a rectangular unit block.

Other forms of clay exist, like terracotta, which is again another kind of processed clay. We will enter into each of these items. In the image, you can see a pipe below a culvert passing; that is stoneware. Again, we have porcelain and also earthenware. Thus, we can look into the variety of available items one after the other. But before doing that, when we convert the clay to any of these items, we do need to know what is the role of each of them.

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So, silica prevents cracking, shrinkage, and warpage of brick (or any clay item). Silica gives durability, but remember, excess of it makes it brittle. Similarly, alumina gives plasticity to the item. It makes the moulding process easy. What is moulding? Every block of brick is moulded out by either hand or by a machine. Every tile is also moulded out. Thus, every clay item is moulded out.

Alumina gives plasticity to the item, and it helps in easy de-moulding, but an excess of it helps in shrinkage and warpage. “Warpage” is a kind of defect where the item becomes wavy. Hence, it warps. Lime helps the silica in the clay to melt and helps in binding all the ingredients. So, it acts as a stabilizer, but an excess of it makes it fluid (or more plastic), and it de-shapes the brick or the item.

Iron imparts color. It improves the impermeability and also gives strength or durability. What is impermeability? It is the property not to allow water through it. So, it reduces the absorption of a clay item, which is quite porous. Excess of iron will give it a dark blue or blackish color, and the item becomes yellowish if the iron is less in amount. So, using just your naked eyes, you can distinguish an iron-rich brick or a brick that is devoid or less in iron content.

So, it will be pale in color. Again, magnesia gives a yellowish tint to the brick, and excess of it helps in decaying or breaking of the brick. So, all these items together impart the properties to the clay product. Here there is another important part- the initial form of clay is not used directly. All these items have to be put into the furnace for burning (or baking), and then only the final clay product gets the characteristic.

So, clay in its original form does not appear red. Only after this processing, you will see its red coloration.

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Let us now discuss the preparation of clay. As already mentioned, you just cannot take some amount of earth and call it clay. The upper soil or the topsoil is full of organic material, pebbles, dirt and dust. We need to take out (remove), around 20 cm of the top layer of the earth until it is silt or riverbed.

So, you have to dig out the fresh soil (what you get after unsoiling) and collect the usable earth. Allow it to settle in one place where you remove all the vegetation if

any, pebbles, etc., by sorting. After doing this, you have to keep it open in the weather so that it gets exposed to the sunlight. Next comes the process of blending. When you get some amount of good earth, you can proceed with blending.

So, what is blending? You have to mix it or churn it inside a vessel (or a mill) so that it becomes uniform all through. The process is similar to kneading (akin to the kneading of flour). Ultimately, it becomes porous and hence ready for moulding. It is done in a pugmill, which is a V-shaped vessel which has a central axle and is rotated by means of a machine. There are tooth-like arms, inside which we have the earth which is being churned.

In the end, there is a spout from where the mixture is ejected and is thus ready for the moulding process.

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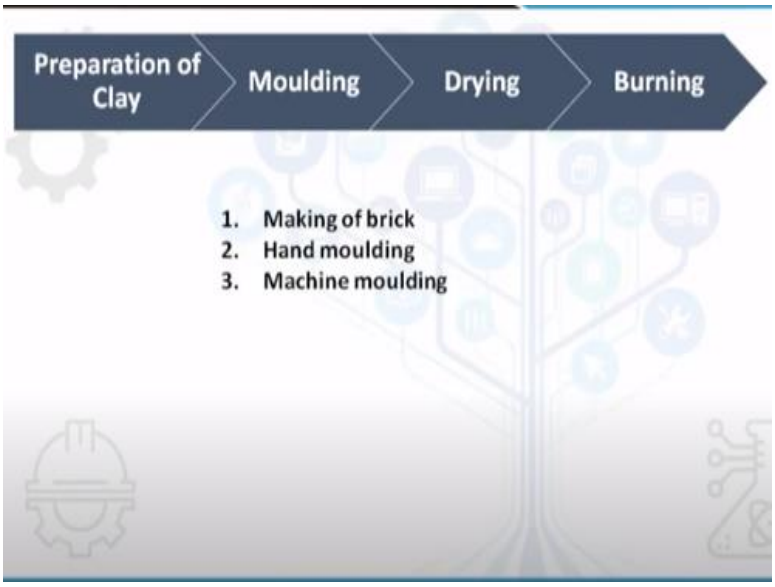

Moulding is the making of brick. There are two types of moulding: hand moulding and machine moulding. Obviously, machine moulding will be faster, but in our country, the process of hand moulding is still popular, where brick moulds are used- into which the clay is pushed in and then de-moulded.

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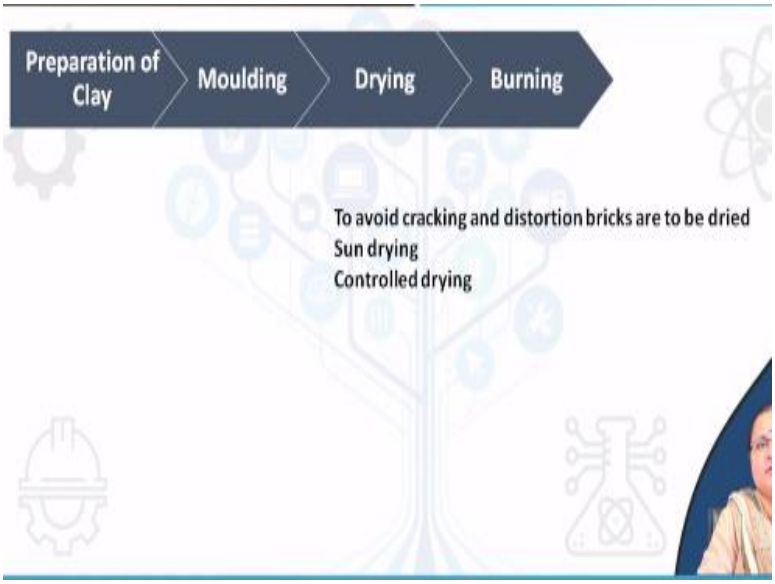

Next is the process of drying. To avoid cracking and distortion of the bricks, you cannot put these wet bricks (or moisture-contained bricks) inside the furnace. So, you have to wait or leave it for sun drying or controlled drying. When you leave it in the sun to dry, it will take some time (one or two days) when the furnace becomes ready for the next batch. You can arrange the bricks around the fire.

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After the drying process is the burning process, let us see what happens here. There are four stages. The furnace temperature can rise up to 1100 to 1200°C, but it increases gradually. The first part is the dehydration of these bricks. So, around 450° to 650°C, the water gets removed.

Next is the fusing process, where the oxidation of silica and lime with alumina happens to make it a consolidated whole. By 900°C, the brick is ready, but during the next 200°C, the process of vitrification (or solidification) or gaining of strength takes place. Finally, the furnace is allowed to cool, after which you take out the bricks ready to be supplied.

Now here again, what you see inside a furnace, the layers which will be very close to the heat may receive a higher temperature (or may get prepared early). But when you are baking, say ten thousand bricks together, it becomes very difficult to sort them out (or take them out early), giving you a wide range of bricks from a single burn (or processing). This situation gives you the opportunity to classify bricks into different types.

Even though we are referring to bricks here, the same happens for clay tiles and terracotta tiles too. Unless controlled heating is used, you will get different lots or different types.

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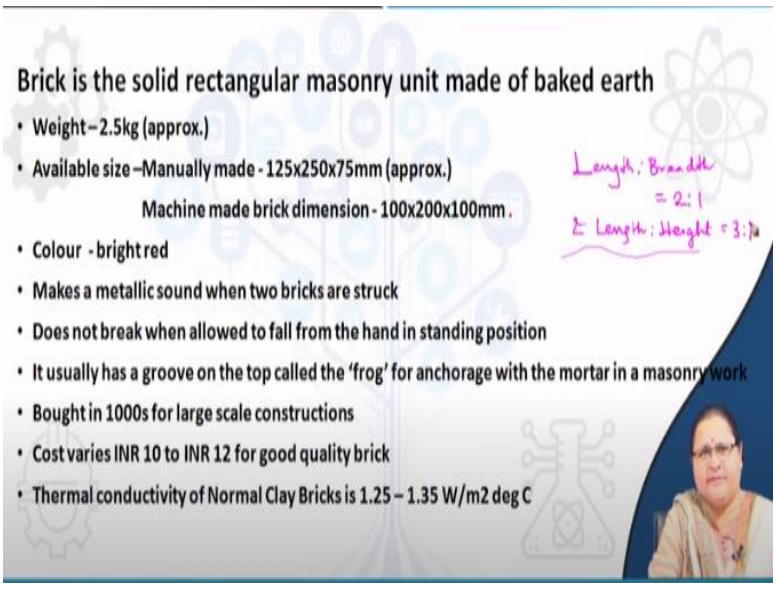

Let us look into more precisely what a brick is. A brick, as you already understand, is a clay product. It is a solid rectangular masonry unit made of baked earth. Its' weight is around 2.5 kg. The available size across our country varies between locations. However, the length to breadth (ratio) is equal to 2:1, and the length to height ratio is equal to 3:1. The mostly available sizes are 250 mm, 125 mm, and 75 mm.

These dimensions are roughly 10-inch, 5-inch, 3-inch, respectively. But these values actually denote “ready sizes”, already including the thickness of mortar. The actual sizes maybe 220, 110, and 70 mm (respectively). But machine-made bricks have a uniform dimension of 100× 200× 100 (mm)- referring to the length, breadth, and height, respectively. The height may be 75 mm too. Across our country, we have varying sizes; however, the dimensions are roughly 5-inch× 10-inch× 3-inch (height). The phrase “Ready height” implies dimensions, including mortar.

A bricks’ color is bright red- if it is a Class-I brick (or a very good quality brick). If you strike two bricks together, you will get a hard ringing metallic sound. That happens because of the right presence of iron. And if you allow it to fall freely, from around 1.5 m height, it will not break. So, you can test a brick on-site by just performing these two operations.

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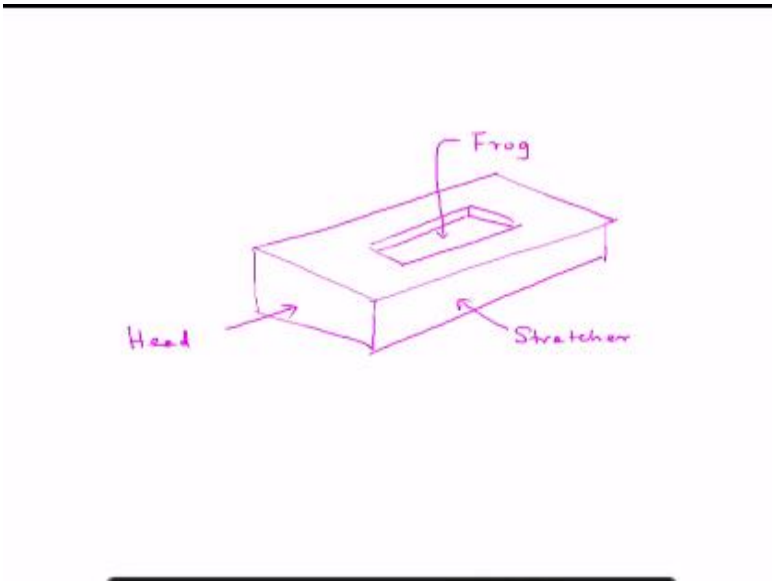

A brick usually has a groove on top, which helps in binding with the next adjacent unit (of the next layer). The shorter edge is called the “head”. The groove is called the “frog”. The side is called the “stretcher”. And usually, the brick sits on sits flat on its bed. The surface below the brick is called the “bed”. It is generally purchased in hundreds (quantity), but if it is a big project, it may be procured in thousands, and the cost changes accordingly.

But an individual brick costs around INR 10 to 12. The price may be higher in some places and generally varies across the country. This value should include

transportation costs. That is, the cost of transporting the bricks from the manufacturing location to the site, also adds to the price. So, if you remember these essential points, it will be helpful for you. Next, we come to the technical details. The thermal conductivity of brick is 1.25 to 1.35 W/m²/°C, implying a good resistance to heat.

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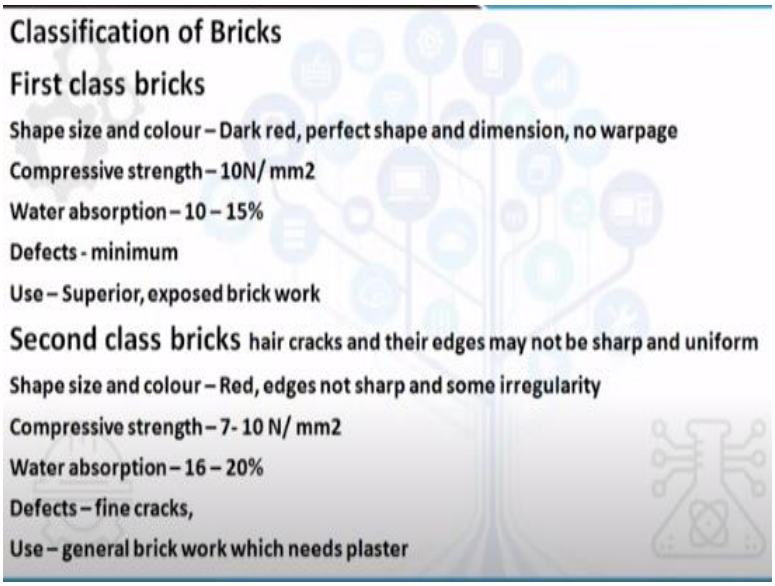

Regarding other properties, it varies between the different types of brick. So, I have classified them first for your easy understanding. And you see, we report the compressive strength, the water absorption, and also some defects. So, a first-class brick (which is the best of the lot from the furnace) has a perfect shape and size, having no warpage.

As I have already told, warpage is the bending of the brick's surface to become concave or convex (which actually needs to be flat). The maximum compressive strength of a first-class brick is 10 N/mm², and it has quite a low absorption of water (10 to 15%). They are used for superior work (or exposed brickwork) because it has no (or very low) water absorption. Hence, wherever there is no plastering required, you can use first-class bricks.

Wherever it is dry weather, you can use first-class bricks without any plastering. You have an elevation; the front part is crucial; you can use superior quality brick so that the facade looks better because the perfect edges are there. Coming to the second

class brick, you see they might have hair cracks, and their edges may not be sharp (or they may be ununiform). The color of the brick is red, and its' edges are not sharp.

The compressive strength for second-class bricks is a little low, around 7 N/mm². Any value between 7 to 10 N/mm² is classified as a second class brick, and water absorption is 16 to 20%. The brick has defects like fine cracks or fissures (gaps), and hence these are recommended for general brickwork. It is suitable for external walls, which will be plastered. Since water absorption has increased from 16 to 20%, we would need to protect it with a layer of plaster.

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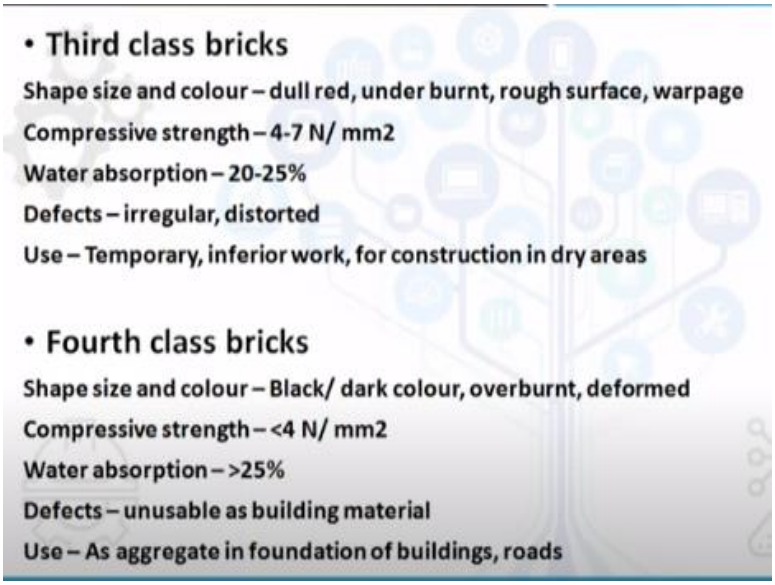

In the case of third-class brick, the color is dull red due to being underburnt. It may have a rough surface, may contain high quantities of alumina. It has become de-shaped (visible warpage). Its compressive strength has reduced. Water absorption has further increased. Being irregular, distorted- due to these defects, they are primarily used for temporary inferior work and for construction in dry areas.

Moving to the fourth-class brick- In these, the shape, size, and color has become black and dark, being overburnt. This type of brick has no use until it is broken down into big pieces (or large parts). The water absorption may be higher, or it may not, but it has become a hard block. It is unusable as a building material. However, it can be used as an aggregate.

We will come to aggregate later, but the fourth-class brick can be used in place of aggregates in concrete foundations, in road foundations and thus does not go waste. So, it also finds an application in the building industry.

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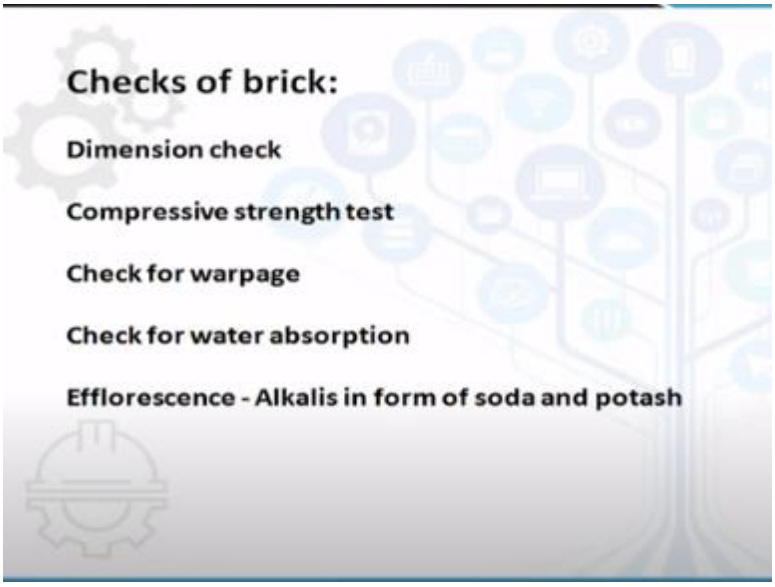

For checking of brick quality, as I have told you, on striking two bricks, you get a hard ringing sound. If you let it freely fall, you get to understand that it is a first-class (good quality) brick if it does not break. How to do the dimension checking?

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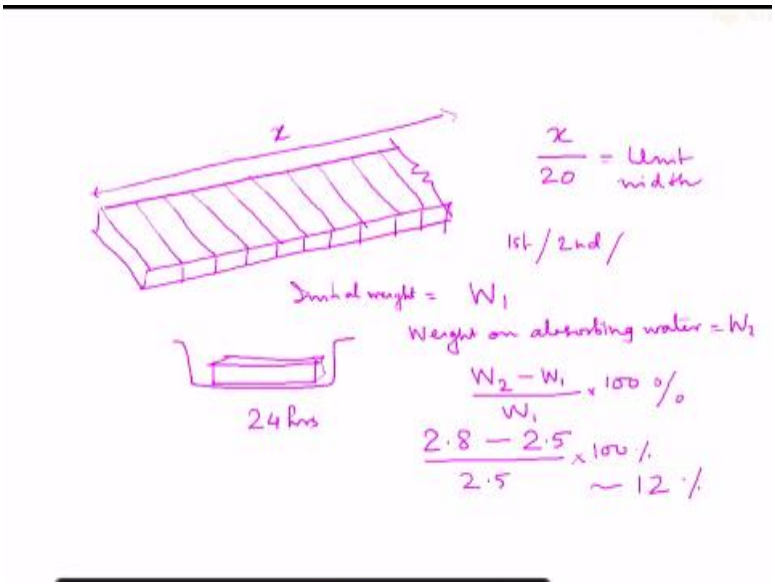

If you lay, say 20 bricks, if you lay 20 bricks one after the other, and you measure it, you will get some dimension. And if you divide it by 20, you get the unit width, which needs to be checked with a first-class brick. Similarly, you have to immerse six

such specimens of the brick type in six tubs for 24 hours. You measure the initial weight (sum of weights of six items) and note it as W_1.

After 24 hours, you get the weight on absorbing water, and let that be W_2. Now doing, $\frac{W_2 - W_1}{W_1} \times 100\%$ will give you the percentage of water absorbed by the brick. Find the average. This result will decide whether the lot is from the first-class or second-class, or third-class category. So, say, if the new weight is 2.8 kg and the initial weight is 2.5 kg, as I had told earlier, it will be something around 12%. So, it will be a first-class brick.

So, this has to be done across all the six specimens you have picked up from the brick lot which has been supplied to you. So, from the value, you can understand what kind of brick has been provided. For the compressive strength test, it is the universal testing machine, on which you can check the test strength (or the compressive strength). Next is to check for warpage.

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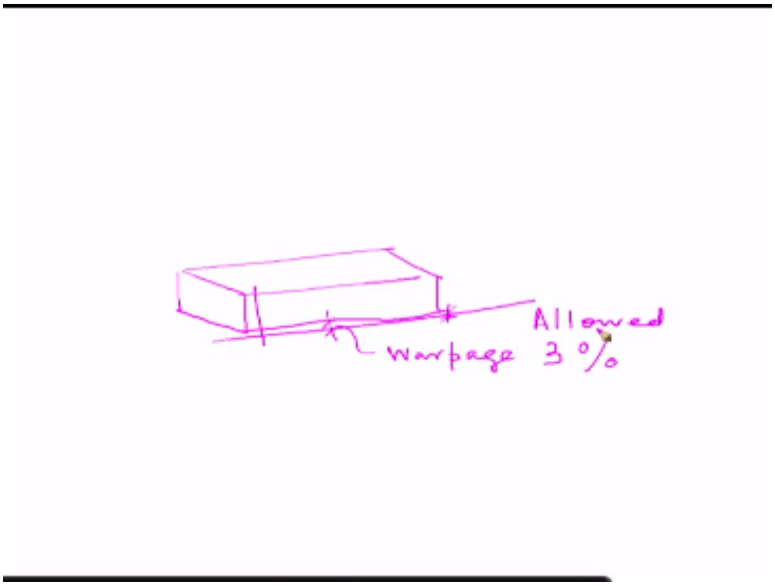

For warpage, you can place a brick on a table and check if the bottom does not align with the table. Measure the height from both ends; the percentage difference will give the warpage value. You can allow up to 3% warpage (with respect to the height). But a first-class brick does not have any warpage. The warpage may happen in the upper direction also. So, it may be convex or concave. The diagram shows what the warpage is.

Next, we come to efflorescence. Some alkalis may remain in the form of soda or potash inside the brick. Now, since brick is an absorber, you need to do this check because when it is subjected to rainfall, these alkalis will react and become salt and will deposit as white salt patches on top of the brick. You can perform these visual checks by randomly picking bricks from the lot.

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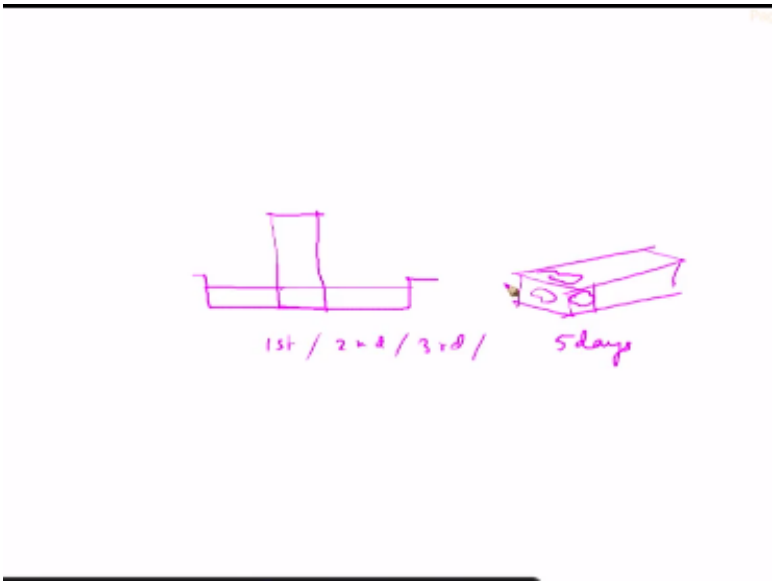

You can keep on dipping the brick in a vessel in this way so that a part of it remains in the water. Repeat the task for four or five days. You dip it and then take it out. After some time, when kept for drying, you might see white patches in these areas that were previously submerged. This shows that the brick has alkalis within it and is showing efflorescence.

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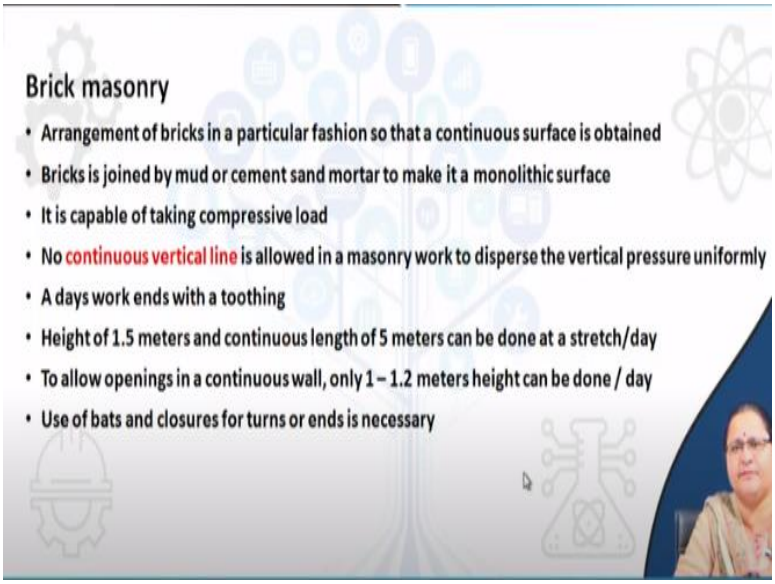

Now let us come to the other part, which is the brick masonry (the arrangement of these bricks). We have seen brick as a very small unit, and if you look into the dimension of the brick, what do you find? It is around 5-inches, which an adult person can hold in one hand. It weighs about 2.5 kgs, which any adult person can usually lift. The person can pick these blocks, unit by unit, and make the construction.

So, the brickwork can be done by a single person. So, what is brick masonry? The arrangement of the brick in the fashion makes a continuous surface (because you are using bricks to fill up) or a load-bearing wall that will surround or define your space. Now you can keep on putting brick after bricks and build a wall.

But if you have observed, you must have seen that there is no continuous vertical line (joint) on a wall. I will show you pictures- the wall is taking pressure of its own and of whatever load is put on top of it. So, the lower part is taking the maximum load (vertical pressure). And for that to be uniformly distributed, you are not allowing any continuous vertical line to exist.

So, when a day's work ends (it may not be possible to complete the entire structure.in one day), you need to have a 'toothing'.

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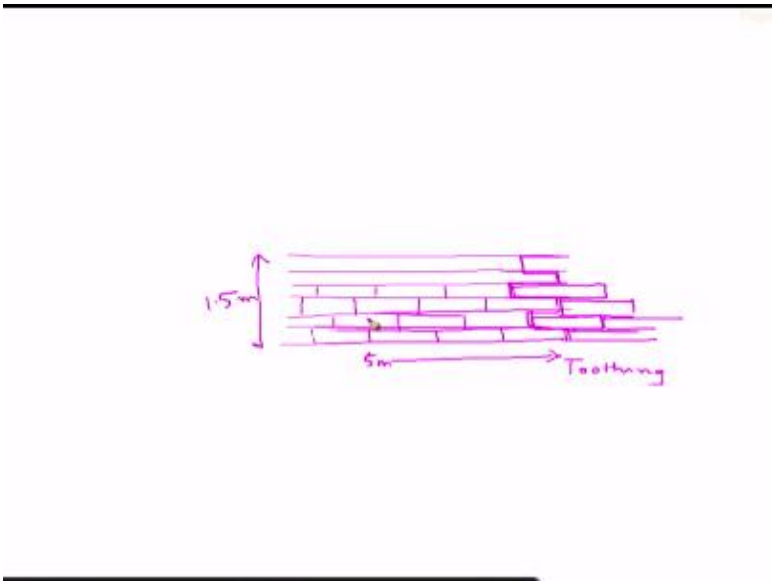

So, if this is your wall, you will never see a continuous vertical line. Rather, you will see it is disconnected. When a mason finishes his work, he ends the profile (at the end of the day), appearing like this (see image). This is called 'toothing'. So, when the next day's work starts, he starts by pushing brick here. So, now there are several ways of doing this which I will not elaborate on.

It is this toothing that keeps the structure together, makes it monolithic. At the same time, in one day, you are neither supposed to make more than five meters in this (horizontal) direction nor more than 1.5 meters in the vertical direction. This is to make the whole wall structure stable. Otherwise, the mortars will come out from these joints. So, what is mortar? It is the item which is allowing two bricks to get joined.

So, this frog is where the mortar gets in and allows it to get affixed to the next brick. So, how do we end a wall if you want a straight wall? You have to break the brick or make it half. You can break it into two parts, each of which is called a"bat". It may be half bat; if required, you may use a three-fourth bat. It depends on the type of bonding you are selecting.

So, the beauty of brick is that you can cut it into hales in the transverse direction, or in the longitudinal direction. And when you are trying to achieve any kind of shape, you can use a "beveled bat".

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So, this is one-fourth here and full brick here. These are called ‘closures’ when a brick is cut longitudinally and ‘bats’ when cut equally in the transverse direction. There are half bats, three-fourth bat, and one-fourth bat, depending upon the extent of the remaining brick. The ‘frog’ is the indentation where the mortar goes into and helps the next brick to get supported. So, these bats and closures help for turning or ending a wall.

And you must remember the key points which are to be followed when we are doing brick masonry.

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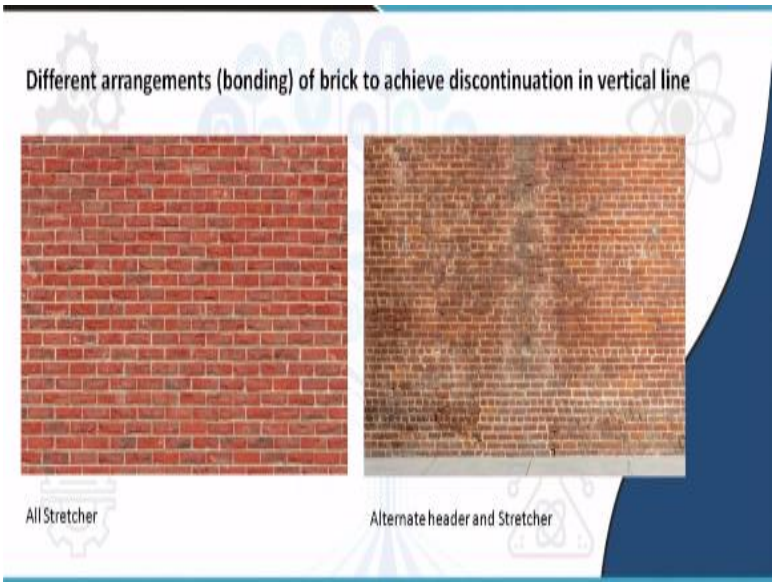

So, you can see in one of these pictures; it is the longer face that is being seen (stretcher courses). In this other picture, you can see, some are stretcher courses, and

some are the headers. That is, the head side or width of the brick (the wider/ longer part) is seen. The overall style is a mixture of header and stretcher.

This (see image) has only stretcher. But as you see, as it had been mentioned, there is no continuous vertical line. If there is even one continuous vertical line, it separates the two masses. So, any kind of lateral force incoming towards the wall face will isolate the masses of the wall. So, the wall may fail; but when it is toothed in (inside the other adjacent mass), it will behave as a monolithic (single) entity.

So, if you remember these points, you are done with bricks and the brick masonry. There are various kinds of bonds- English bond, Flemish bond, double English bond, because different types of widths of walls are required. Walls can hold their weight from even 3-inches thick. So, brick can be sitting even on its wider (thickness) side. But, usually, bricks are to laid to rest on their beds.

So, brick thicknesses become higher if it is a load-bearing structure at the base or the lower floors, and it gradually tapers up, because the load it has to withstand is maximum at the base. Let me demonstrate the making of a brick masonry wall.

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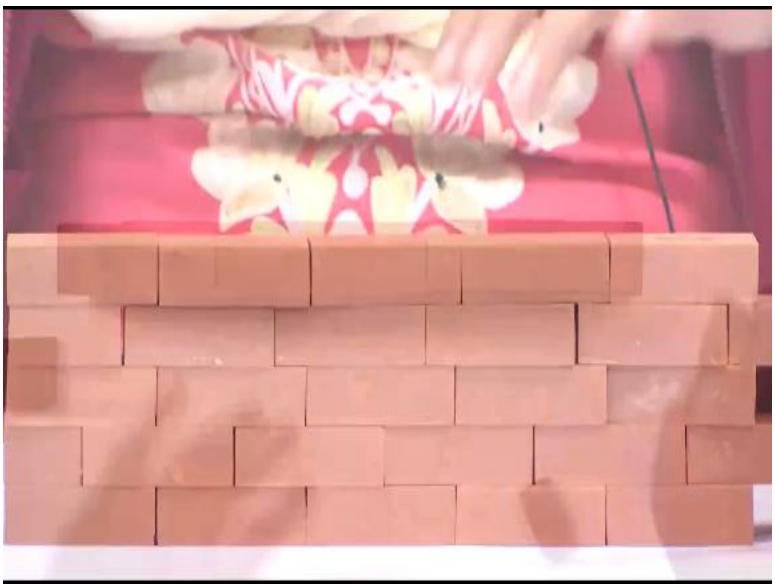

So, this is a 5-inch thick wall. This is the first layer, and I want this end to be flat. So, as per principle, we have to start with a full brick such that this joint (line) does not appear. If I would have started like this (see video), then this part would have

separated out (as another mass). So, we start from here, and thus we need to start with a bat at the beginning and then continue laying the bricks one after the other.

And then again, we have to put one bat to either finish construction, or if it is to be continued on the next day, we can leave it just like that. So, on top of it again, we follow the lower course (that is the lower layer). We see the lines will appear just on top of it. In this (see video) case, it is a continuing line whereas in the other case (see video), this has broken the line to make it discontinuous. So, again we can arrange it like this. And we would stop here.

We could have gone the other way also; we could have started with a one-fourth bat or a three-fourth bat. And then we could have again continued with the bricks one after the other, ending with another notch which is one-fourth thick. So, we could have repeated the same thing using bricks after brick. And finally, we get a notch of one-fourth.

Here we get a notch of half-brick. So, this is the toothing. The next day, if the construction starts, it will begin with a full brick to be inserted from here (see video). So, the next day when it is added, the binding takes place at that point. Similarly, when it is starting from here, we can actually place another brick, which will allow the binding process, and eventually, what you see in the elevation is that none of the lines are continuous.

So, no vertical line is continuous all through. The lower two lines are set half brick apart. They have started with a one-half bat, and then it has continued. In the other course, we have started with a three-fourth bat, which you can see here, and we have continued. So, this is how we can lay the brick without getting any continuous vertical joint. This helps to make it a continuous wall surface.

Now, this is the case when we are doing with the half brick thick wall or 5-inch thick wall. Let us dismantle it and see what would have happened in case of a full brick thick wall.

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So, in a full brick thick wall, if you keep on arranging like this and follow the same principle, like having bricks in this direction and then again having bricks in a staggered way (as you had seen), you are obviously complying elevation-wise. But if you look the other way, this (see video) entire block can be shifted. Similarly, this entire block can be shifted (separated as a mass). This happened because these two walls are not bound together.

So, it has become a separate wall. So, in the vertical direction, and also in the transverse direction, you have to remember that there should not be any continuous surface that may detach the two masses which, together, forms a full brick thick wall. In that case, you need to orient them in such a way so that the header course and the stretcher course form just one after the other, and also, there should not be the formation of any vertical line.

And then again, on top of it, you can set your bricks in this fashion. In the elevation, there is a header course, followed by a stretcher course, and again on top of it, there is a header course. Now how to end this? You have the ‘closure’ brick. Here also, if you want to end it you have to use the closure.

The next day when you start, you have to start here with a closure. So, when you have a full-brick thick wall, you will see that the arrangement is having a stretcher course as well as a header course. The stretcher course is the continuous longer face. And the

header course is the shorter face. And this helps in binding the whole structure both ways.

So, there is no continuous vertical line formed here and has been closed by this layer. So, the bricks here, which were capable of moving in this direction, are locked by this layer on top of it. So, in any kind of bonding, the basic principle is to have no continuous vertical line and the use of bats and closures to achieve it.

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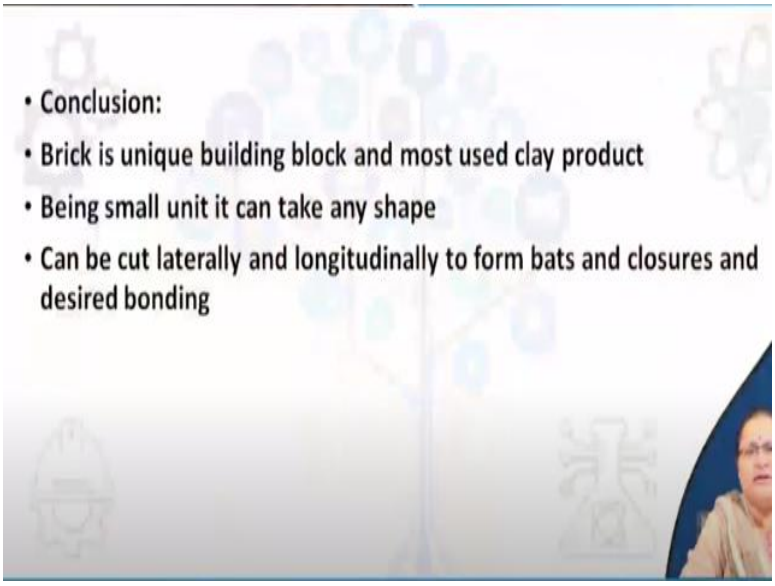

With all these, I finish this lecture, and I would conclude that brick is a unique building block and it is the most used clay product. Being a small unit, it can take any shape or form which is desired. You can change the rectangular block to any other shape if you require. That is desired by the architect, but that has to be separately ordered. Bricks can be cut into the lateral or longitudinal directions to form bats and closures for getting the desired bonding. So, with this, I end today's lecture.