Basic Construction Materials
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Lecture - 21
Stone, Brick and Mortar – part 4

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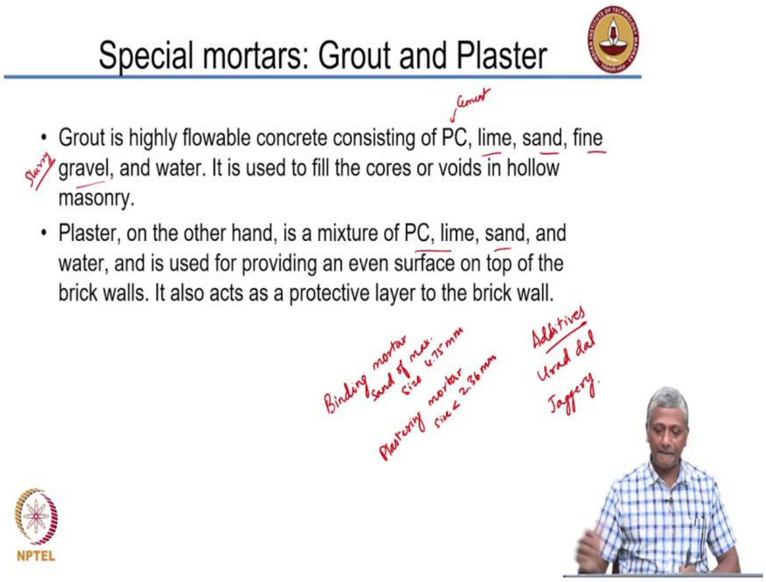

Mortars are not always used only for binding the blocks together, they are also sometimes used for other purposes. For example, a grout, which is nothing but a highly flowable concrete or mortar which consists of the binding material that is cement (PC is another name for Portland cement, which is your common general purpose cement), lime, sand and sometimes fine gravel (small pieces of rock) along with water. You make a slurry basically. A grout is nothing but a slurry made with all these materials.

Slurry made with a mixture of binding material like cement or lime and then you have sand and fine gravel along with water. The advantage with slurry is, if you have built up a wall and you realize that there are some portions of the wall that have lot of cavities and holes, you can fill up those holes with this slurry after the entire wall is constructed, so that's called a grout.

On the other hand, plaster is something that you put on the top surface, outer surface of your wall. Plaster is again a mixture of lime or cement and sand along with water. You don't put any larger aggregate in this case, even the sand which is used, you sieve it through a smaller size and use only the small size sand, for most binding applications. In binding mortars that means the mortars that are used to bind the blocks together, you typically use a sand of maximum size 4.75 millimeters. When we talk about concrete, you will learn that fine aggregate or sand typically as size less than 4.75 millimeters. For plastering mortar, we want to reduce that size even further. In plastering mortar, we typically use size less than 2.36 millimeter, because we want to get a nice smooth finish on the outer surface. That's why for plastering, you need to have a sand of lower sizes.

Now, very often if you go to different parts of the country, you will see interesting practices being done with lime. Now with lime, oftentimes you will find the use of different types of additives. For example, if you go to north India, you will see that additives for lime could include something like urad dal. In the old practices and heritage monuments, they used to grind the urad dal into a nice paste and mix it with lime. It basically improved the consistency of the mortar and made it easier to apply.

In south India, you will often find that jaggery is being mixed in the mixture of lime and water. They mix jaggery also in lime mortar and water. Jaggery imparts a nice water retentive quality to the structure. Depending upon the application and depending upon the geographical location, there are practices that have thrived or that have actually stuck on from age old times, which are still being followed, especially with the construction practices with lime.

You will see that depending upon the geography, depending upon the location, you may actually get very different practices as far as lime mortar preparation is concerned. There are even examples of people having used blood in lime mortars. It turned out that blood was a very good water retentive material, that ensured that the lime mortars were consistent and behaved nicely. But of course, you don't want to use blood anymore.

In the past, they also used animal hair. Animal hair works like fibers inside the material. The mortar is held together nicely with the fibers. For those of you who are interested in heritage structures, there is a lot of interesting literature about lime and the use of organic additives in lime mortars. Anyway, that is not the point of discussion. In this chapter, we are primarily looking at lime and cement as binding materials inside mortars for putting together masonry.

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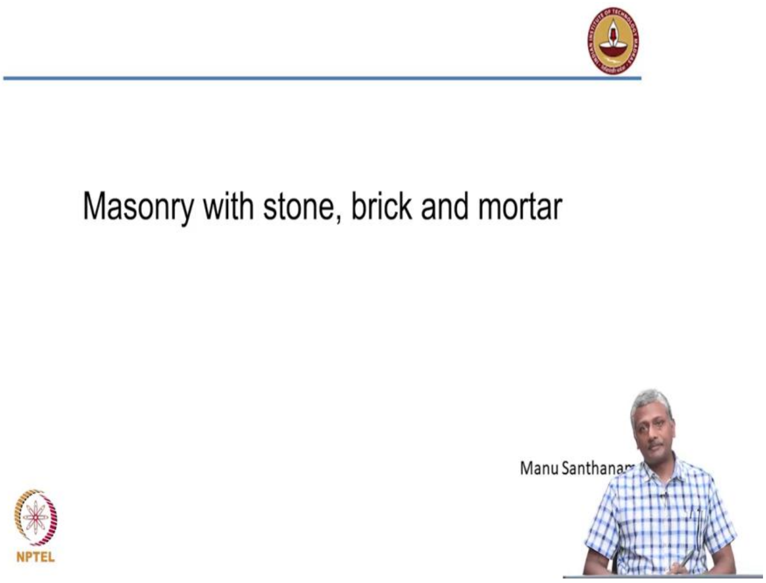

We have talked about masonry materials, but it's important for us to also understand how these materials are actually put together, to make the masonry structure possible. And these masonry structures with stone, brick and mortar are engineered to resist loads primarily in the axial direction. A lot of them are not engineered to resist loads in the lateral direction. So we'll talk about that aspect separately towards the end of the chapter.

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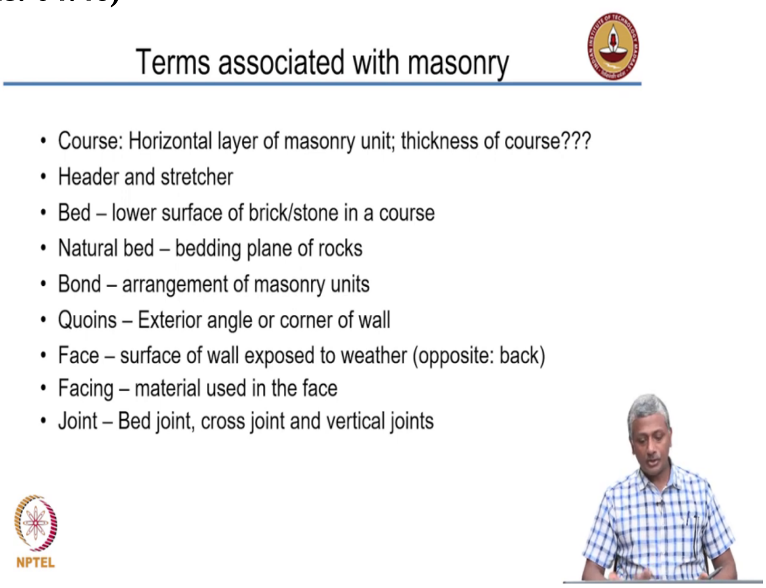

Before we go into looking at specific aspects of masonry construction with bricks or with stone, let's try and understand some terms that are associated with masonry. One of the common terms that we use in masonry is that of course. A course is nothing but a horizontal layer of masonry units, which have a thickness which is equal to the thickness of each individual masonry unit.

For example, if you are using a modular brick, the thickness will be 10 centimetres in a course. If you are using a concrete block, the thickness in the course will be 20 centimetres. If you are using a traditional brick, which is 23 x 11 x 7, typically 23 x 11 is the top and bottom cross sectional area and the height is 7. So if you are using a traditional brick, the height will be 7 centimetres.

Depending on how you are placing these bricks in your wall, they are called headers or stretchers. For example, if you are placing the bricks in the direction of the wall, that means the length of the brick is facing the direction of the wall, that's called a stretcher. So, it is stretching along the wall. A brick that is placed perpendicular to the direction of the wall; the wall is running like this and the brick is placed perpendicular to it, we call it a header. We have to use different arrangements to satisfy the certain requirements of the bonding.

The bed is nothing but the lower surface of the brick or stone in a course. And sometimes when you go to stone quarries, you find that these stones are themselves deposited in certain layers and that's called a natural bed of the stone, or bedding plane of the rocks.

A bond is nothing but the arrangement of the masonry units. So how you put these blocks together to make the wall, that is called the bond. A quoin, as I said earlier, is the exterior angle or the corner of the wall. So if the wall comes like this and it turns like this, the point of the corner is called the quoin.

A face is the surface of the wall that is exposed to the weather. So you have an interior wall and an exterior wall, exterior wall is exposed to the weather and that is called the face of the wall. The backside is called the back of the wall. Now, on the front face of the wall, if you use a different material compared to your regular wall material. For example, as I told you about the facing brick, for instance. So, any material that is applied on the top surface without any structural reason, mostly for aesthetic, that's called a facing material. In many of your structures, you may have seen that the actual structure may be made with concrete, but they may have a brick or stone slab facing on the surface. These days increasingly, when you go to IT parks, you see that the facing materials or cladding materials are made with glass or aluminium. They use glass or aluminium cladding as the surface.

Now the joint is nothing but where the masonry blocks are coming together and where the mortar is available. So we have bed joints, cross joints and vertical joints.

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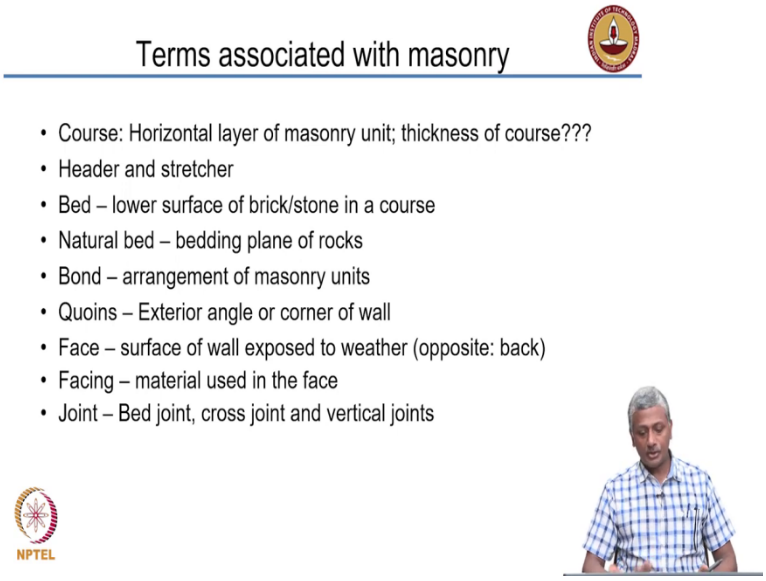

Let me just demonstrate this in a simple drawing. I will just draw a typical brick wall, let's say. So, that is the bottom of my brick wall and I have several layers of bricks and my bricks are arranged like this, for instance. Let us say I have a running wall length, which looks like this. So, I had several different definitions here. So this is one course of bricks, that is one full layer of bricks is called a course.

We also saw that there were other things header and stretcher. So in this case, all the bricks are in their lengthwise direction. So they are all stretchers. The wall is running in this direction and the length of the bricks is also in the same direction. That's called a stretcher. Now if I come to the corner of the wall, where the wall ends and if I draw the plan of this wall, it will look like this. This is the end of the wall or quoin. If I am looking in plan, that's what it looks like. So this brick here, if I draw the second layer of or second course of bricks, that brick is actually in the other direction. So that's called a header. So when the brick is perpendicular to the main direction of the wall length, it's called a header.

A bed is nothing but a lower surface of brick or stone in the course. So in this course, that will be the bed or in this course, this will be the bed. Then we have the quoin, again as I said, the quoin is nothing but the exterior angle of the wall. So, this exterior angle is called the quoin. So, that's where we actually use the quoin closers or queen closers to close out the wall at the end. So that it can run in the other direction. I will come to that when we actually come to specific arrangements of the brick units.

Then we talked about the joints. The mortar that is in the bed is called the bed joint. The mortar that is in the vertical parts is called the vertical joint. And of course, if there are 2 layers of bricks like this, that is, if there are 2 layers of bricks in the wall, then apart from the vertical joints, you also have cross joints between the bricks. You have cross joins between 2 bricks. So, 2 bricks are stuck together like this, then along the length they are stuck together as the vertical joint and then under the bricks is the bed joint. So those are the different terms which are explained pictorially here.

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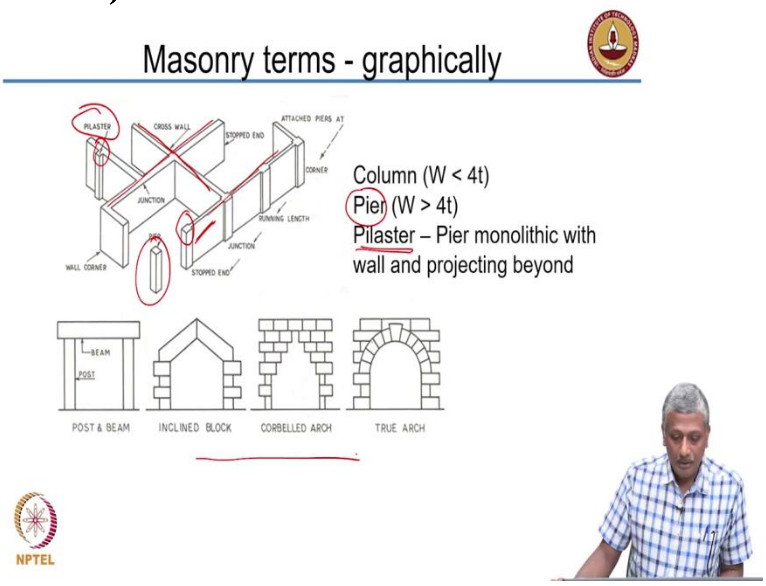

There are other terms also that we need to look in masonry construction. Very often, the terminology can be quite different as compared to regular concrete structures. So it's important that we understand this.

Now, in bricks when we have a column, we typically call it as a pier. A brick pier is a freestanding column. A brick pilaster is a pier that is attached to the wall. A Freestanding column is called a pier, whereas a pier which is attached to the wall and which projects beyond the wall is called pilaster. So that's a pilaster and that's a pier.

Now, in a regular masonry construction, you have the main walls, which are running like this and you have the cross walls, these are cross walls. So we have main walls and cross walls. And here, the wall and piers are actually attached at different locations. There are also examples of the use of lintels or arches for door openings and window openings. There are several types of arches, we will talk about arches again separately later, but then you can have different arrangements of window openings and door openings. They are basically making your arches.

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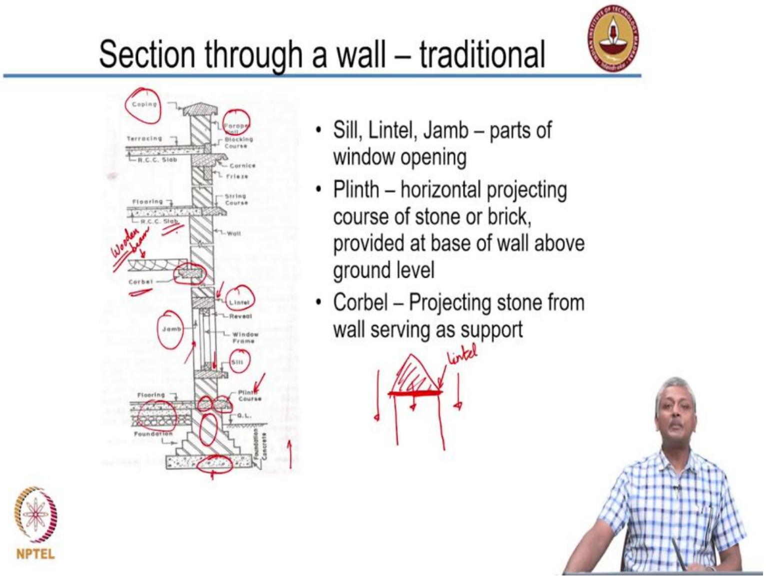

If you look at a section taken through a wall in a traditional building, which typically combines brick and stone; most of the traditional houses, for example, in the southern parts of the country, like Kerala, for instance, if you go there and take a section through the wall, this is what it would look like. So coming from the bottom, let's say from the foundation, this is your ground level. Under the ground level, you have your foundation, which is basically a layer of plain cement concrete and then you have a step, step footing of brick. You build up the step footing of brick all the way up to the plinth level. Now, many of you recognize that the plinth level is nothing but the inner floor level and that's typically raised above the ground level on the outside. The plinth level describes the inner floor level.

In the old structures, this inner floor level was actually marked by a string or plinth course on the outside. So this, what is shown here, the plinth course is nothing but a stone masonry layer, which is projecting out of the wall, just to mark the location of the plinth. Then, when you have window openings and door openings, you have different parts of these openings, the lower part of the opening is called the sill, window sill, we commonly use that term, the sides of opening are called jamb and the top of the opening is called a lintel.

Now, that’s a very important function, that the top of the opening has to form because if you have an opening like this, the load of the wall on the side is obviously coming down without any problem. But this load here, there is nothing to bear that load. That load has to be born directly by the opening and obviously the opening does not have a material, so it cannot bear that load. So we need to form something which is strong here, which can bear that load. It is like a beam or a lintel. We call that beam as a lintel beam and which is typically made with either stone or with reinforced concrete. In most modern construction with masonry, we will do lintels alone with reinforced concrete.

So here, this is a stone lintel and you also see that the structure goes all the way to the top. This is a parapet wall on the terrace and then you have the covering of the parapet walls, which is otherwise called coping.

Here is an example of a traditional house, which actually mixes up different materials together. In fact, on the interior, there is also a projecting stone coming out of the wall. That’s called a corbel. It’s a projecting stone that serves as a support. For instance, this corbel is actually having this wooden beam resting on top of it. So, if you want to support something internally, you project out stones from the wall and those are called corbels and you are protecting them, you are using that for supporting something internally.

So, your entire wall is now broken up into several different materials. So, you have concrete here, this is concrete, this is brick, that stone and of course in the flooring, it depends on what layers you have, sometimes you have fills of earth and granular materials and so on. You again have wood here; you have flooring made with concrete RCC slab. So you have a combination of different things that make up your wall construction in traditional households.

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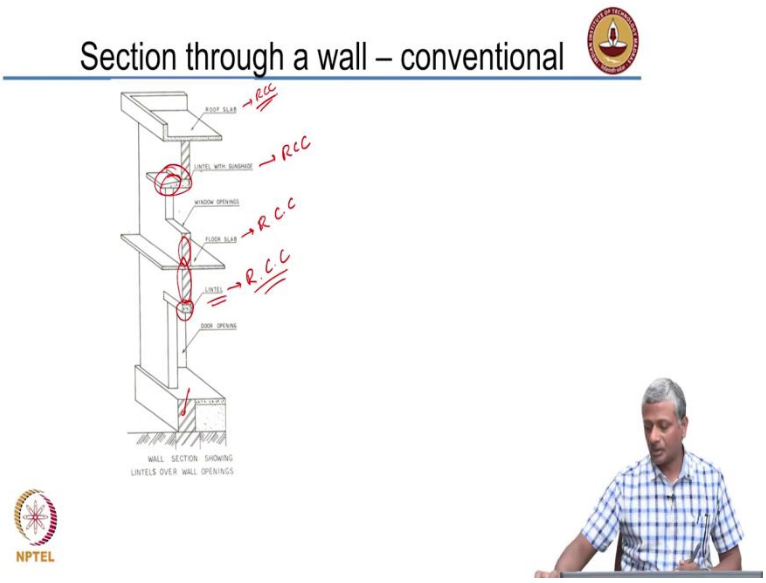

In more recent construction, obviously, you would not see such elaborate features, you will probably see a very simple cross section of the wall. Nevertheless, it still combines different materials together. So in the foundation, you have brick and concrete. Again, you have brick here, you have a door opening here, at the top is a lintel typically made with reinforced cement concrete. The floor slab is also made with reinforced cement concrete. You have a lintel along with sunshade. You may have seen that these projecting shades that come out of your window to ensure that the sun does not directly get in. So you are protecting your house against the direct entry of the Sun. It reduces the heat to a large extent. So that's called the lintel and it has a sunshade attached to it. That's also made typically with reinforced cement concrete.

So, you have brick, you have the brick walls, you have the reinforced cement concrete features like lintels and sunshades. And of course, the roof slab is also made with reinforced cement concrete in most typical residential households. So, this is a typical residential wall that you will find. But in more modern buildings, we start utilizing the benefits of multiple materials together in a different way and how do we do that?

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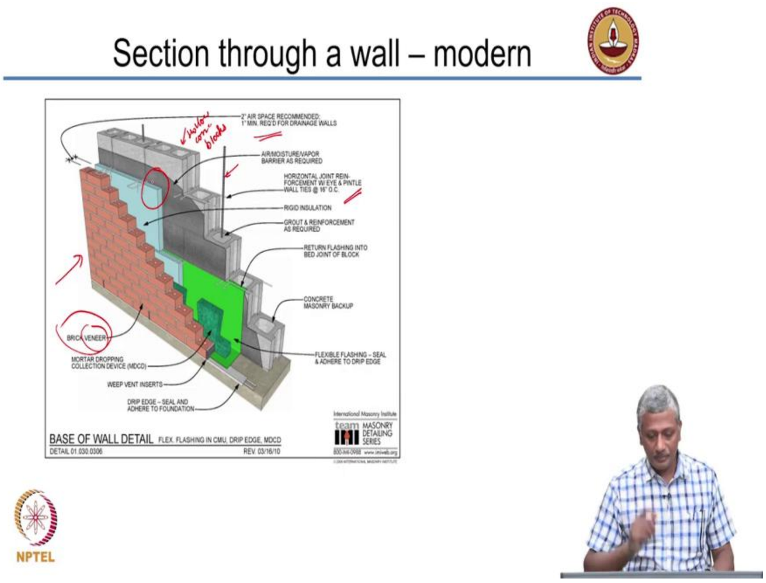

In a modern building, we utilize the engineering concepts optimally. So, what are these engineering concepts that we are trying to utilize? One aspect is aesthetics. in this wall, the outer surface looks like a brick wall and we call it a brick veneer or a brick facing. Essentially, it's the outer surface which is simply giving it a nice aesthetic brick like appearance, but the actual wall itself is made with concrete blocks. These are hollow concrete blocks.

Interestingly, the hollow concrete blocks are also filled up with reinforcement. So, hollow joint reinforcement is present in every 4 cavities that is there. So, what does the reinforcement do? I told you that the walls are designed to take axial load that means the loads that come in the plane of the wall. What if the loads are coming along this direction? The wall has to bend like this and if it does not have reinforcement, it will simply collapse.

The lateral resistance of the wall is increased or enhanced by the presence of reinforcement, so that it can respond to the lateral loads also. So, that is a nice structural wall but on the outside it's got a brick veneer. But interestingly, if you look at what's inside, it has got an airspace. So there is a cavity inside, which reduces the transmission of heat and sound. You also have barrier layers for moisture and for heat and sound, like foam barriers for instance and then you have a waterproofing membrane.

So, overall you have a nice composite wall which is made up of many different materials, which are functionally different, which are different in terms of the mechanical characteristics. In this way you are able to maximize the potential of how that wall will work to protect the interior from the exterior alignment. We will come back to that a little bit later.

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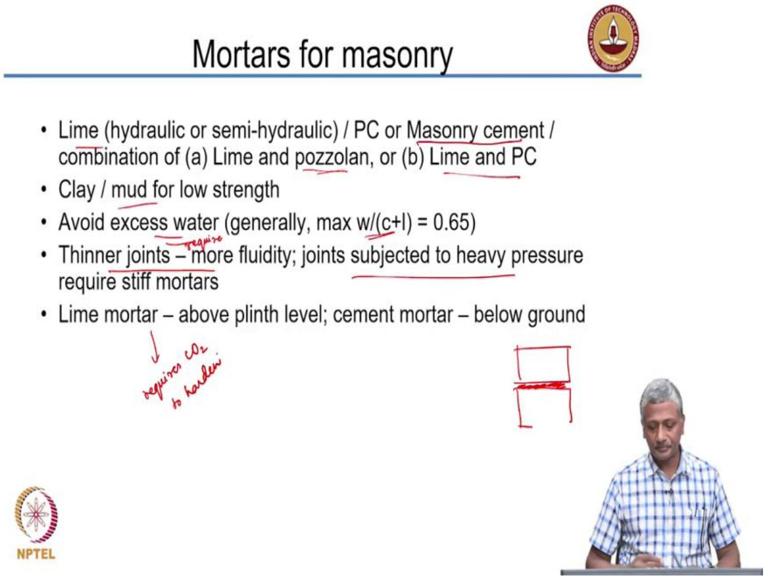

Coming back to the use of different types of materials for mortar, what type of mortars are typically designed for masonry and how should we actually use this? As I said, the materials typically are lime, Portland cement. Sometimes in some countries, we may also have special cements called masonry cements. In India also masonry cement was available in the past. Today it is not available. Today only plain cement is available, which has to be mixed with sand.

Masonry cement in the past was a special blend of cement, which was much more suited for masonry purposes. Sometimes limes are used in combination with materials called pozzolans like fly ash or volcanic ash and then in some instances you may find that lime and Portland cement also are mixed together.

In certain cases, as I said in rural areas, they use clay or mud mortar, but those actually end up making low strength masonry. The principle of designing the mortar for masonry is to avoid excess water. What will happen when you press the masonry blocks together with the mortar in between? If there's excess water, it starts coming out. Usually this is defined in terms of the water to cement plus lime ratio and it should be around 0.65. If you have too much more water beyond that, this water will start coming out when you press the mortar joint together.

The thinner joints result in more fluidity or thinner joints require more fluidity. For example, if you have blocks sitting on top of each other and if you want to have a very thin joint, you need to have a mortar that is quite fluid, so that it's getting pressed properly. At the same time, you should not press it so much that the mortar completely squeezes out; It should not be that wet.

Joints that are subjected to heavy pressure require stiff mortars. For example, if very heavy loads are coming, the mortar itself should be designed in such a way that, even if the joint itself is thin, the mortar should become stiff to ensure that it does not deform out too much.

In choice of materials, we generally use lime mortar above the plinth level and cement mortar below plinth level. Why do we not use lime mortar below plinth? As I said lime requires carbon dioxide for hardening, that is, lime requires CO_2 to harden. Under the plinth level or under the ground level, you will not have enough CO_2 available for hardening the lime itself. So, you don't want to use lime in the lower levels of the building.

In the superstructure, you can use lime mortar. But today, people use cement mortar all through. If they are going to be doing block construction for the foundation as well as for the building, they typically tend to do it just with cement mortar.

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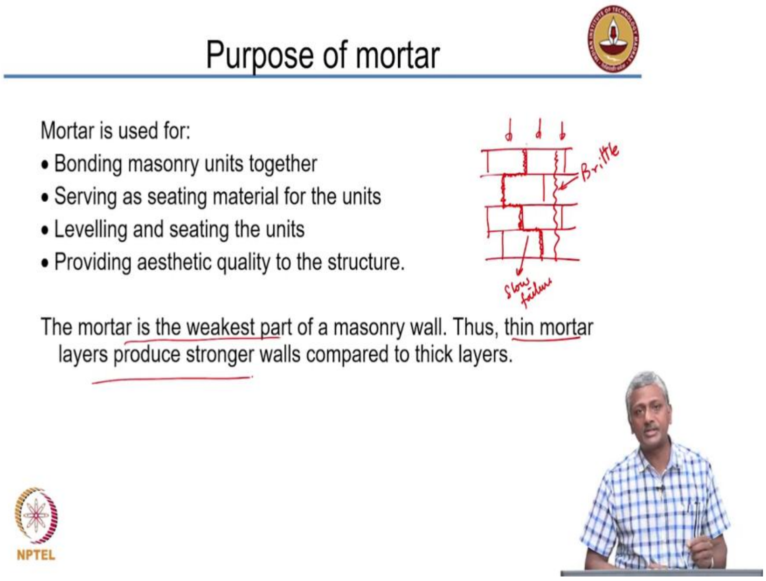

Why is mortar needed? Of course mortar is needed to bond the masonry units together because it keeps everything in place. It serves as a seating material for the units. Units sit on it and make a level surface for the course. Mortar is also nice to break the monotony of the masonry blocks and provide an aesthetic quality to the structure. Please remember that the mortar is designed to be the weakest part of the masonry wall. Why is this so? Again, let me just draw a simple masonry wall and draw the joints like this.

So, masonry wall has been drawn with the mortar joints and if the arrangement is like this, what will happen now is when you are having a load on this wall, the wall will tend to fail. Now, if the mortar is weaker than the block, the failure will come like this. The crack will probably go like that, along the masonry joints are along the mortar joints. So, the building will fail because of failure of the mortar joints. And that will be a slow and steady failure because the crack has to travel a longer path. It needs to come like this and come like this and like this and so on.

On the other hand, if the mortar was strong and the masonry material was weak, the failure would be completely different. You may have a cracking right through like this. The entire building may just split into half because the masonry material (that is a brick or the stone) is weaker than the mortar. This is because you have used a mortar which is very strong and it does not fail at all. So, you will get what is called a brittle failure.

In such cases, in a brittle failure, your structural collapse will be sudden. And in engineering buildings, you always want to ensure that you have a slow and steady failure, that's what you get when the mortar is weaker. You get a slow failure. It may not be a ductile failure, but you will get a slow failure, not like metals. Ductility in metals is a completely different order. Here we are talking about slow failure, which gives signs of damage so that people can be evacuated from the building.

But a brittle failure will be a sudden failure. You don't want to create mortars that are stronger, you want to have mortar designed weaker than the masonry unit. The other part is, even if failure does occur, the masonry units are still intact and can be reused. You don't have wastage, for example.

Thin mortar joints produce stronger walls as compared to thick joints. Obviously because the mortar is the weak plane, you are reducing the overall area of the mortar, so that means you are getting a stronger wall from thinner mortar joints as opposed to thicker joints.