Basic Construction Materials
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Lecture – 18
Stone, Brick and Mortar – Part 1

Hello everybody and welcome to the module on stone, brick and mortar in this course on basic construction materials. Of course, we have seen many different construction materials being applied for construction around the world. But if you look at the monuments which have been lasting for several centuries and even the recent designs that people come up with for the individual homes, most of these employ stone, brick and mortar.

Although in terms of true civil engineering, we don’t really do much with stone, brick and mortar, but it is important for us to understand the concepts involved with these kinds of materials, what governs their properties and how these materials should be worked up together to make successfully good masonry structures? So stone, brick and mortar are components of masonry.

Of course, the term masonry itself is something that is quite general. Masonry basically refers to any building or structure that is built by a mason. In most cases, masonry is dealt with in terms of understanding how to put different blocks of stone or brick together jointed with mortar to ensure that you get the necessary strength in the overall structure. So that is essentially the meaning of the term masonry. Masonry today means a wide variety of things. It is not just restricted to stone and brick. There are other masonry materials also, about which I will briefly discuss with you. However, for the most part, masonry around the world still consists of stone, brick and mortar. So, this chapter essentially deals with the properties of these materials and how they are put together to make the different types of masonry structures possible.

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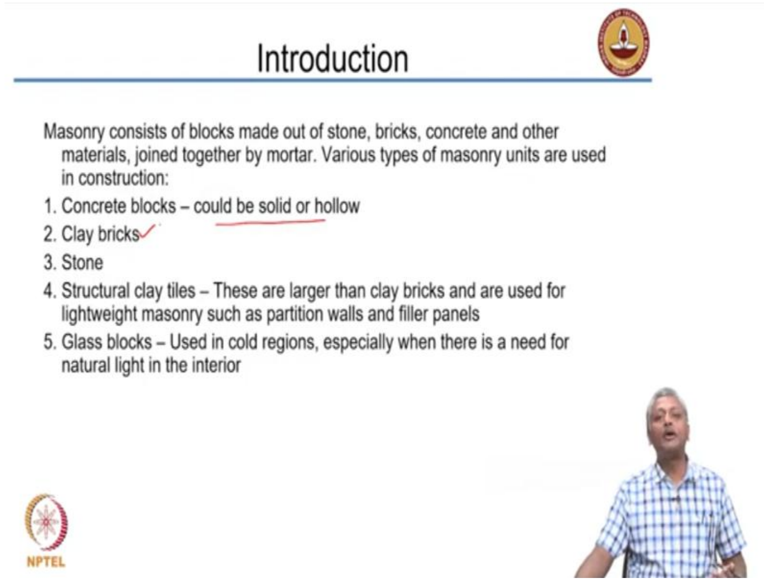

So moving on, as I was already saying, masonry basically consists of blocks that are made out of stone, bricks, concrete and other materials which are jointed together with the mortar. In some cases, they may not be jointed with a mortar also. They may simply be resting on one another, like in the construction of the old temples in the past where they have dry jointed masonry structures, where you did not have any jointing material like cement or lime inside. Or you could also have conditions where these blocks are manufactured in such a way that they are interlocking; they can simply fit into each other, just like your Lego blocks that you used to play with as kids. Essentially, your interlocking blocks are the same concept as Lego blocks, they basically fit in and then you form your entire structure without the need for any jointing material.

For the most part today, as I said we deal with stone and brick a lot. But of course, today we also deal increasingly with concrete blocks. Concrete blocks could be either solid or hollow. The advantage with concrete is because we can actually make it to a strength that is much higher than that of brick, because of which we can actually obtain the hollow concrete blocks also. And that reduces the weight significantly; we will come to that in due course within this chapter.

Clay bricks still remain the most popular form of masonry material around the world. There are obvious advantages because these are relatively cheap, easily available. And in some cases, when you don't want to cover it up with the plaster, it has certain aesthetic appeal also, because it has that nice reddish color which looks nice for an external rendering in a structure. Of course, in

India you don’t see examples of externally visible brick walls, because we don’t have good quality bricks that are easily available in our country. In most cases, the bricks are off a quality that is not good enough to leave exposed to the environment. There are several reasons why we don’t want to do that we will discuss that during this chapter.

Stone has been part and parcel of our heritage monuments. Even today, some of the modern structures that are coming up, which are not made with concrete or reinforced concrete are being made with stone. There are a lot of stone structures still being constructed. The difficulty again is obviously getting good quality stone. Because for stone structures, you need stones which are a fairly large size without any defects and sometimes that becomes very difficult, because these are naturally mined. And in many cases, there may not be enough good quality stone available.

Apart from these, there are also structural clay tiles. You can actually make structural clay tiles to bear load. So in masonry, basically the components are bearing load. A typical tile which you put on the floor is not bearing so much load as a block that is supporting a wall. So, structural clay tiles are designed to be larger than clay bricks and can be used for lightweight masonry such as partition walls or filler panels. We are not going to talk about that in much detail here.

Just to give you another example of masonry block, glass blocks could also be used as masonry, especially in locations where we have very little daylight available. Especially in the winter seasons, if you go up to the northern Arctic regions, people cannot really afford to spend a lot of energy on electricity, so they have to maximize the input of the daylight as much as they can. Glass blocks basically can help you get maximum amount of daylight inside.

So a lot of these designs are obviously, the domain of architects. Civil engineers typically don’t really design or engineer masonry structures. That is sometimes could be a problem, because especially when you talk about earthquakes. If you don’t engineer masonry structures well enough, in earthquake, there can be very severe damages. In many of the earthquakes, the structures that completely collapsed were the ones which were built with masonry. That is because they were not engineered, they were simply constructed.

Again, many of you would have had this experience when your parents are building a house or when you yourself are building a house. You may find that at the job site or even during the construction process, you will hardly meet a civil engineer. You will probably entrust the responsibility of construction to an architect and that architect will come up with his or her team to do the construction process. Architects understand very well the functional needs of the house. They also understand very well the aesthetic design of the house. However, to really engineer the house to last for a long time in a given environment, especially environment where earthquakes may be quite prevalent, that requires a lot of civil engineering expertise.

Today increasingly, people are realizing that in masonry also there are components that can be made in such a way that the structure can be earthquake resistant to a large extent. Generally, when we think about earthquake resistance, we talk only about reinforced concrete only, with a lot of steel reinforcement inside. But indeed, if you engineer the masonry structures properly, they can be made to perform satisfactorily during extreme events such as earthquakes. But again, I am just diverging here, we are not here to talk about the design of structures, we are talking mainly about the material characteristics, as to how that affects the overall performance of the entire structure.

In this chapter, we will primarily talk about stone and brick. I will also touch upon concrete blocks, because increasingly, they are replacing stone and brick to a large extent because of the advantages that you have with concrete blocks. So, I will also touch upon concrete blocks. Of course, I will also talk about mortar, which is the essential binding component that keeps the masonry together.

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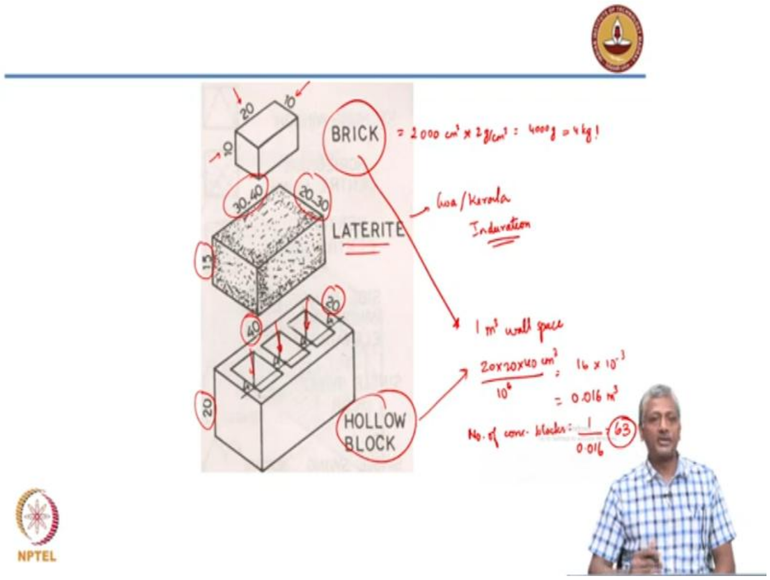

Now, just to give you some example of typical sizes, you may have seen these stones and bricks lying around a job sites. Some of you may have lifted these also. But if I asked you the weight of a block, let's say, if I ask you the weight of a brick, many of you would probably think that it is about a few 100 grams. But if you look at the typical modular size of the brick, that is 10 cm x 20 cm x 10 cm, this is what we use for design and drawing purposes. But the true size is quite different. I will talk about that a little bit later. If you think about this, the volume of the brick itself is about 2000 cubic centimeter. And if you multiply that by the density of the brick which is 2 grams per centimeter, you get a mass of 4000 grams or 4 kilograms.

Each brick actually weighs close to 4 kilograms. Of course, depending upon the size and the type of textures that the brick may have, and the speciality purposes for which the brick is being used, its weight may vary. They may have bricks which are less than 4 kilograms also.

So why am I telling you this 4 kilograms for a brick, you might have seen the people working on job sites carrying a lot of bricks on their head or they put it in a container and carry it on top of their head. The next time you see them, you will be able to appreciate the amount of effort that they are actually putting in. 4 kilograms per brick multiplied by let's say 10 to 15 bricks at one time, so they are carrying a load of nearly 50 kgs on their heads, just to make sure that they are able to construct your house. So the next time you are on the jobsite where your house is being constructed, stop for a moment and appreciate the fact that these people are really doing a lot of hard work.

Anyway, that’s just the sense of point, but one needs to appreciate construction processes in order to really understand what is involved in actually getting these things together. When you deal with stone blocks, here an example is given of Laterite blocks. Now, laterite is quite common for construction in Goa, Kerala and most of the Malabar Coast. You will see a lot of structures that are built with laterite in these locations. These lateritic blocks are basically hardened soil blocks.

So the soil itself, over a process of 1000s of years hardens into almost a stone like texture. So we can actually cut out the soil from under the ground and shape that into a block size. The typical block size is nearly double of the brick with the thickness being 15 centimeters and width of about 20 to 30 centimeters and the length of about 30 to 40 centimeters. So approximately double the size of a brick not exactly double, but each dimension being nearly double that of a brick.

Most stone blocks would be in this kind of a size. So laterite as I said, is a popular material in the Malabar Coast and many of the structures that you see; residences, compound walls, sometimes forts and palaces, they are also built up with laterite. It has a very nice reddish colour. The advantage with laterite is, as it gets exposed to the atmosphere, it gets stronger and stronger. It’s a very different type of a stone.

As compared to granite or limestone or quartzite, which are extracted from quarries and those typically do not change their structure very much in the long term except when they are getting weathered and that is when adverse reactions actually happen. With laterite on exposure to a benign atmosphere, they will slowly gain strength and indurate. This process of the slow strength gain with age of laterite blocks is known as induration.

A typical concrete hollow block is shown here, you can see the dimensions. Each one of them are exactly double the dimensions of a brick. Brick is 10 x 10 x 20, concrete blocks are typically about 20 x 20 x 40. Now, if you think about solid concrete of that size, it will be quite heavy but the fact that you can engineer concrete to different levels of strength makes it possible to create these cavities inside. You see these 3 huge cavities that are inside. These can be created and you can still have the block capable of withstanding very high levels of load. Think about it, there is a major advantage here. What is the advantage when you have a brick? Let us say you want to fill up a total of 1 cubic meter of space for the wall using bricks and then same thing you want to attempt with concrete hollow blocks also. So, let’s see how many bricks we actually need.

So, each brick is having a volume of about 2000 cubic centimeter (cm^3) and if you convert that to cubic meter (m^3), how much will that be? You have 2000, you need to divide it by 10^6, because each meter is 100 centimeters. So, if you divide this by 10^6, you get 0.002 cubic meters. So, each brick is 0.002 cubic meter. That means, how many bricks do you need? you need 1 divided by 0.002, that is 500 bricks. You need 500 bricks to fill up a wall volume of 1 cubic meter.

At the same time, instead of bricks if you try to use a concrete block, what will happen? The same 1 cubic meter wall space can now be filled up with much less concrete blocks. How much lesser? Let’s see. So, in hollow block, the volume occupied is 20 x 20 x 40 cubic centimeters. Let’s divide that by the conversion factor for cubic centimeters to cubic meter, that is 10^6. Now, this becomes $2x2x4x10^{-3}$, that is 0.016 cubic meter. So how many concrete blocks do you need? Number of concrete blocks is 1 divided by 0.016, that is nearly about 63. So, you only need about 63 concrete blocks, where you actually needed 500 bricks. Approximately you have reduced the requirement by 8 times.

That’s the power of using a concrete block. First of all, you have reduced its weight by making it hollow, so that it’s easy to handle by 1 person. And then you can actually place much less number of blocks to build up the same level of wall space that you would have needed for 500 bricks. So, there are major advantages in productivity, because in a day’s work, a mason can lay many more bricks or many more concrete blocks as opposed to bricks.

With stone, the difficulty is, you have to work with solid blocks. So stone blocks could be quite heavy. And again, productivity is going to be affected by the fact that stone blocks are heavy. I will come back to this when we discuss concrete later on, in the class also.

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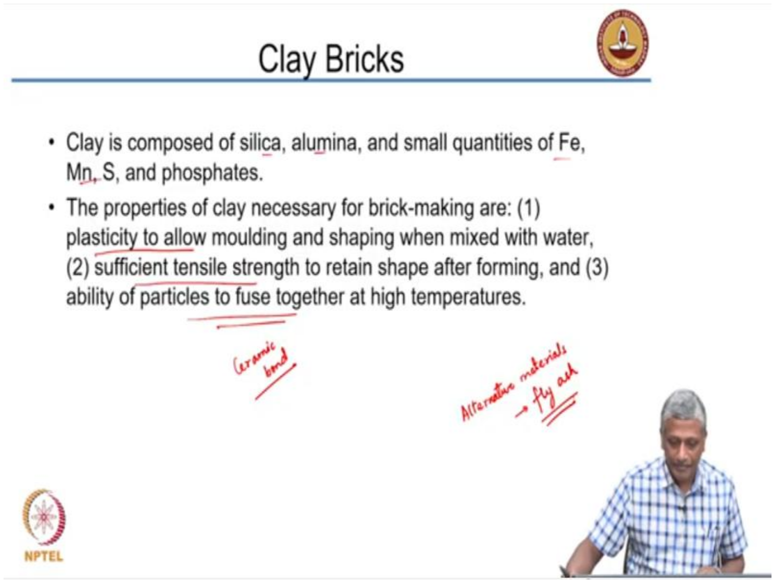

So moving on, let's first talk about brick and how bricks are actually manufactured. This is something that you are clearly aware of, you would have seen it in numerous locations and you may have even had the chance to see some kilns where bricks are actually manufactured. Bricks typically are taken from the clay that is found in the topsoil. Clay is composed of silica, alumina and small quantities of other elements such as iron, manganese, sulfur and sometimes phosphates. But mostly clay is composed of silica and alumina in certain ratios. Depending upon the type of clay you get a different ratio of silica and alumina. Now, what do we do with this clay? As you all know, you played with clay as children, when you mix it with water, it has a nice pliability or plasticity. So, you can actually start forming shapes when you mix the dry clay with water.

So, what you need to do is, you need to have the plasticity that allows molding and you need to have the retention capacity of a shape. So, supposing you are molded a particular shape, the clay should retain that shape after mixing with the water. The water content should be just enough so that the clay is able to retain its shape. You learn more about the geotechnical concepts behind all these such as requirement of water by the soil and so on, when you actually get exposed to basic geotechnical engineering.

But here, essentially, we are almost like going back to our childhood days where we are mixing clay with water just to form a desirable shape. Now, after the shape has been created, the material needs to have sufficient tensile strength to retain the shape after forming. After forming, there is a chance that the material may collapse. So it needs to have sufficient strength, we call it green strength, because it is not yet hardened. In such cases, it is called Green strength and it needs to have sufficient green strength to retain its shape without collapsing.

And secondly, over time, because there is water inside, there will be drying of water from the clay. So, if this water dries out too fast, it will lead to desiccation, that is drying cracking of the clay. You don't want that to happen obviously even before you form the brick. So, the tensile strength should be capable of resisting any cracking tendencies of the brick.

And finally, after the brick shape has been formed and you have dried the brick, you then need to subject it to a very high temperature firing operation. And in that firing operation, the particles fuse together and form what is called a ceramic bond at high temperature. This ceramic bond will not form with any odd material, it needs a certain composition that is present in your clay. Essentially it needs to silica and alumina, which undergo a process called sintering, where they form complex bonds that lead to the hardening of the clay to form the brick.

So, the particles need to be able to fuse together at high temperature. So you need to select the clays appropriately to make bricks. For the most part, these clays are available in the topsoil. Now there obviously you have an environmental problem. The top soil is fertile for agriculture, should we be removing the soil for making bricks? That is a major question that many engineers face today and they need to make decisions for sustainability. And obviously, allowing agriculture on the land is a much more sustainable practice, as opposed to removing the soil to make your brick. So what happens today is that many more alternative materials are coming up to help in brick making. You need to select materials carefully from alternative sources to make bricks.

One of such materials alternative materials is fly ash. I will talk about that again later. So we need more and more replacement of clay with alternative materials like fly ash to make your brick, because you can't be using too much topsoil. You can't be denuding fertile land where people can actually practice agriculture. India happens to be a nation where majority of the workers are in the realm of agriculture. So we can't deny them their good quality soil by removing it from making bricks. So we need to replace the clay more and more with alternative materials.

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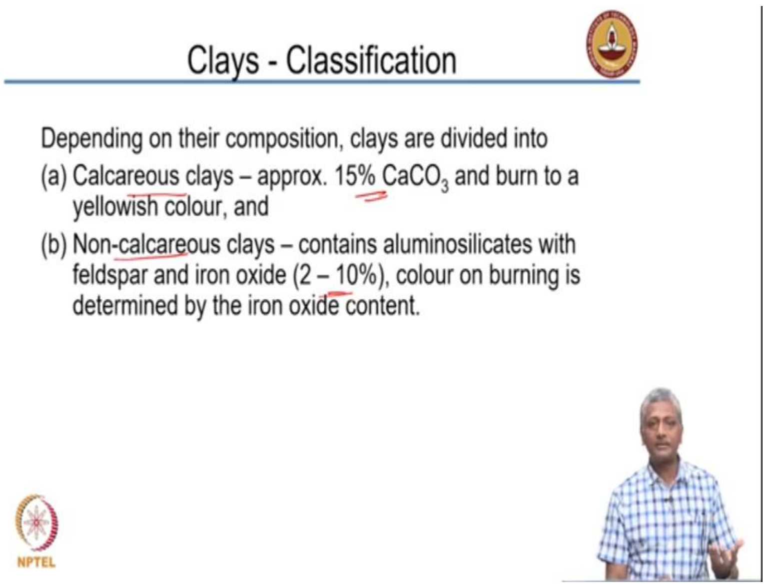

So, how do we classify clays, which are going to be making bricks? Depending upon the color of the brick that we get, we have an idea that the original clay may have been having a very high level of calcium or less level of calcium. So depending upon the composition, the clays are divided into either the calcareous clays, that means the ones that have calcium typically about 15% calcium carbonate. And when you burn these bricks in the kiln, when you fire them at a high temperature, they will impart a yellowish sort of a colour.

Now in the case of non-calcareous clays, which have very little calcium in them, these will have a lot of feldspars and iron oxide. This iron oxide will tend to impart this reddish brown colour after the firing. So, the extent of iron oxide that is present in the system will govern the extent of the color that you get, that is the reddishness or the brown or blackishness depending upon the type of iron oxide that is actually present. Mostly hematitic materials which tend to give you the reddish and reddish brown colors. If you have magnetite, you will get more darker varieties of brown or close to black.

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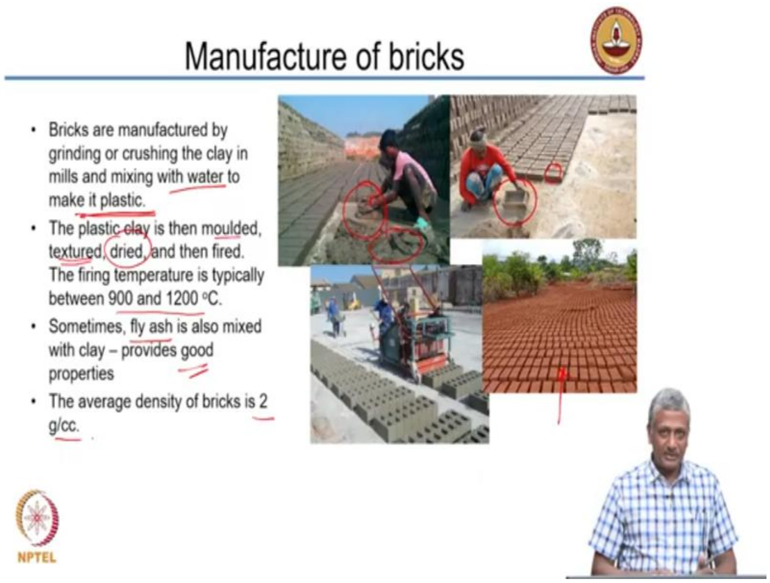

In the manufacturing process of bricks, first and foremost, you need to take the clay and crush it and grind it so that you have very uniform particle sizes. Because typically when you collect clay from the ground, it will be quite lumpy. It might have dried and the particles may have got together and flocculated. So, what you need to do is break these lumps down so that you have a nice and uniform powder which can mix intimately with water.

So you need to mix with water and make the clay plastic. Plastic means mouldable. So, the plastic clay can then be moulded into the shape that you want. In most cases, we have bricks that are cuboidal, that is you mold it into a cuboid shape like you see this person doing here in this picture. You can see that the person has mixed some clay and is moulding in this kind of a cuboidal mould.

The next process is drying. Before drying, you can also do texturing. For instance, if you have to put in some imprints on top of the brick indicating the manufacturer of the brick, texturing is done. I will touch upon that later. Texturing basically is done right after molding it.

Following texturing, you need to dry it, it has to lose all the free water that is there in the system. If it is quite wet, it needs to dry out so that it has sufficient strength that you can pick it up and handle it. Otherwise, what will happen if it is wet? when you try to pick it up, it will collapse. So you don't want that to happen. So, when it's dried, you are able to pick it up and handle it, put it in the furnace quite easily. Again, this is a process of drying. All the bricks are lying out in the open and drying.

Now, after drying what do you do? You need to fire it at a high temperature typically between 900 and 1200 degrees Celsius. So, at that temperature, the fusion of the particles which is called sintering actually happens. And then you have your bricks available for use in building.

Now, sometimes as I said, you need to look for replacement materials because the top soil is too valuable to lose for making bricks. So, a number of times you have fly ash as an additive that can be used to reduce the quantity of the clay that is required to make the brick.

Now what is fly ash? Fly ash is the ash that flies out when coal is burnt in thermal power plants. Many of you are aware that in most parts of the country, in India, we use thermal power to generate our electricity. Thermal power generation involves burning of coal in boilers. Now, the gas that flies out with the small particles of impurities that are there in the coal is collected through precipitators called electrostatic precipitators. These particles have a nice inorganic content of silica in it. It has got a lot of silica content in it. This silica could substitute to a large extent the silica required for brick making. So we can actually fire the fly ash together with the clay to make a clay fly ash brick. I will touch upon fly ash again when we talk about cement and concrete. So, the silica and fly ash is quite interesting to look at from the perspective of even cement replacement in concrete.

So, the fly ash provides good properties to the brick and secondly, it helps in making it a lot more sustainable, because fly ash is getting generated as long as you are burning coal and nearly 60% of India's electricity comes from coal burning. So as long as coal is getting burned, you will get a lot of fly ash and because fly ash is available, it can also be used to improve the properties of the brick.

So, the average density of a set of bricks that you get out of this process is about 2 grams per cubic centimeter. Now, what is the need to know the density? Material properties like density are very important for engineers to get some feel of, so that you're able to do some calculations on the back of your hand. You do not always have the luxury of looking at books or internet sources to answer simple questions. So some target figures you need to sort of remember and keep be aware of all the time, like density of brick, density of stone, concrete, sand. These are very important characteristics to remember. So again, I will touch upon many of these numbers as we go along in this course.

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We have looked at the process of manufacturing bricks. And again, as I said, the firing is done inside a kiln. So typically, the kiln is located here. And that's a stack which removes all the gases, because obviously, to fire it at that high temperature, you will be putting in some fuel, igniting some fuel and this fuel will let off some gases and these gases could be quite harmful also. So because of that, you need to leave out the gases at a very high level.

You can't leave out the gases at the lower level, because then they will start mingling with the air and people will have difficulty in breathing. So you need to actually have the stack which is high enough to put the gases into the upper atmosphere. But of course, not all stacks are that high. Brick industries can cause a significant bit of pollution, if you do not have a control on the stack height. So again, this is another picture. The entry to the kiln is shown here and the kiln is right underneath. And that’s the stack which carries out the gases that are generated from the burning.