Building Materials and Construction
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Module - 10
Lecture - 1
Masonary: Materials

We shall start with module 10 today. That deals with masonry material. So, first we will discuss with the about the materials.

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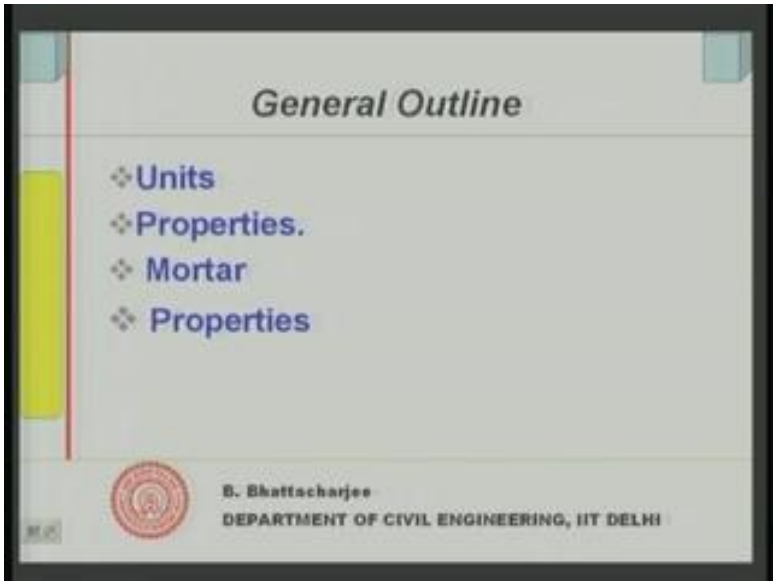

And as usual see the from basic definition of the masonry; it has got 2 things: 1 are the units, others are the mortars. So, we will look into first units, the properties of the units, mortar and their properties. And that is what we will do today. So let us see what is masonry?

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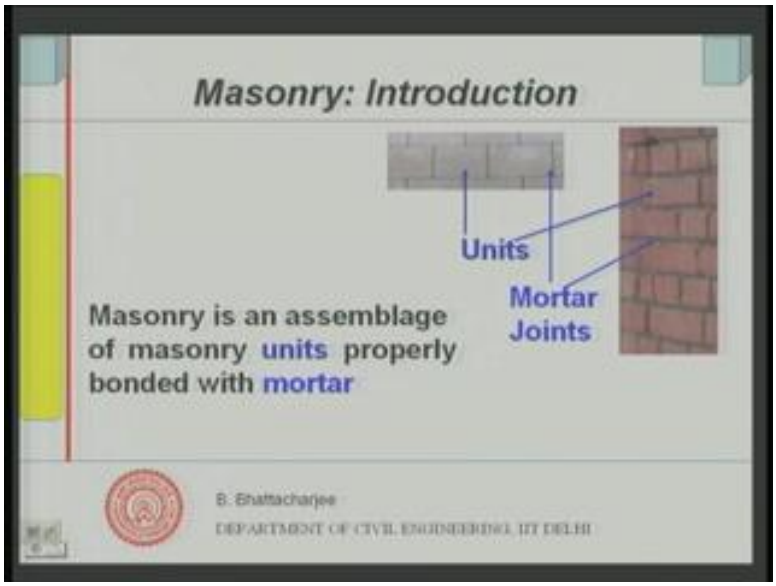

Let us look at the material itself. By definition: masonry is an assemblage of masonry units properly bonded with mortar. Let us repeat; masonry is a is an assemblage of masonry units properly bonded with mortar. So, that is what it is. So, it has got an assemblage of units and they are bonded with mortar. So, let us see how do they look like. Well, common masonry work, brick work you might have seen, because brick masonry brick is 1 of the units kind of units. So, brick masonry you would have heard of. So, you might have seen something like as you can see here.

Now, you can see the unit as shown. This is the units and the joints mortar joints. So, that is makes you see this the units. This is the units as I seen units and you know this is the units individual units. And the in between you have mortar joints. 1 thing you can notice here that this joints are not along same not along the same line, you see if you have 1 joint here, you have some joint here and joint here. They are not all parallel; they are naturally to avoid any weak planes. So, that is why definition as a … that is the definition of there a definition of masonry. So, now you can look into how this what this units are various types of units.

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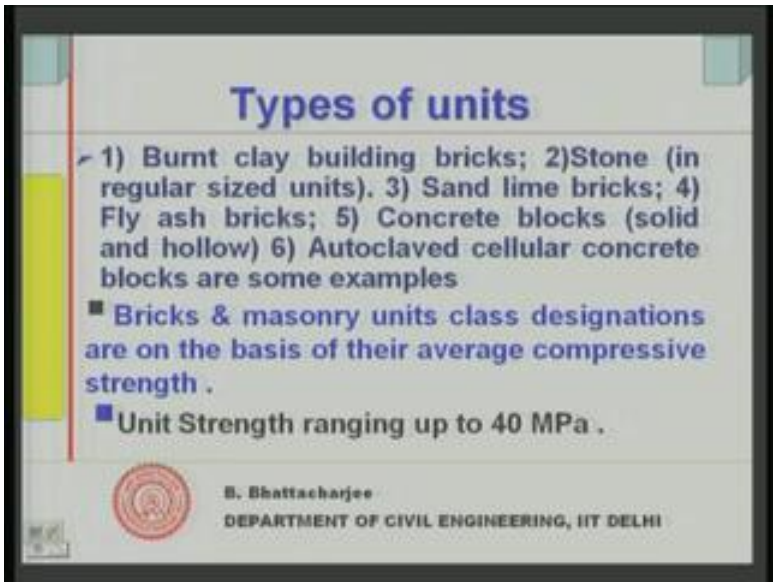

You can have several types units and it is a very, very traditional construction and in from life from peace to its states. All constructions are actually made of masonry; very early constructions are all stone masonries, because you can have stones of different kind of stones in regular size units, pressed up stones or even or even ramble masonry, which is not dressed up stones, but stones joined in mortar. So, that all and even district monuments, they are made up this kind of structure. So, that is very, very old you know are easiest things to make.

First you just have stones and then support the stones. I mean support some stones on other stones; that must have been the first kind of construction. And then in later on the-masonry came. You have pieces of stones, join them by some sort of joining material and you know said that volcanic acids with lime or some burned clay with lime; that was found out to be kind of material and the mortar could be made out of this mixing with sand. So, all your old monuments and structures have been made of those. So, you join stones with such kind of mortar and that is mix your masonry structures. So, that is the concept of masonry structures.

Now we will talk of regular masonries and for many years, burnt clay products have been used as masonry units. Even today commonly used burnt clay building cricks; they are the masonry units. Stones I have already mentioned in regular size dressed up, still they are use various very much in use particularly in places like Rajasthan. Particularly

in places like Rajasthan, where stones are available in plenty. You can have calcium silicate bricks sand lime bricks fly ash bricks. You see the 1 point I would like to make in the very beginning is burnt clay building bricks were they, they are lot of high energy intensive product, you burn them at high temperature as we shall later on and therefore, you consume a lot of energy.

So, also you use actually agricultural soil clay for making this material. So, your agricultural land the clay that was useful for agricultural purpose we use that. So, this is not a very, very sustainable option really. Although still we use burnt clay bricks and it is very, very popular, but it is not really very sustainable proposition, because we were first of all using agricultural lands and land and secondly, you are you are using lot of energy in production of those units.

So, although it is still there popular, but likely to come are fly ash bricks. So, were you can have fly ash together with sand lime is 1 kind, already use make use of fly ash concrete blocks, aerated fly ash concrete blocks and several combinations are possible. So, use of fly ash in large scale in brick production right is now going on. And fly ash bricks which mean that, they would come from fly ash lime bricks like concrete and similar sort of things.

Concrete blocks have been used as masonry both solid and hollow and you can have bricks also hollow and things like that right. Then you have got autoclaved cellular concrete blocks is that, example as I said autoclave cellular blocks are very low density concrete blocks. We will discuss about them how they are produced some of them a and cured at high temperature and pressure and this blocks are also used as masonry units. So, this is the other type and they have very low thermal conductivity.

So, from that point of view they are good, they can they have very good insulation properties. So, as usual see this masonry is mostly we use them in wall. And in walls some cases we need good thermal like sticks properties and so on and we discuss will properties somewhat. And autoclave cellular concrete blocks are those kind of purpose for such mason masonry structures. So, that is what other types of units. There can be cellular other types and then how do we design designate especially the load bearing masonries. There can be several types of class designation, but for structural purpose, particularly the 1 use load bearing masonry.

We shall define what is load bearing masonry obviously, when I say something like load bearing masonry exist, there must be non load bearing masonry also. We will look into those later on, but they are classified according to their designation. You know class designations are based on their average compressive strength. So, we look into the compressive strength of the unit mostly we test the bricks flat on. You know blocks or bricks test flat on that means, the largest surface area is placed onto the testing machine, same composition testing machine which we used actually for concrete cube testing and they are designated according to the standard test procedure, whatever compressive strength you get.

So, that can vary from possibly when 3.5 to you know up to 40 MPa. So, in India of course, it is not very common to get clear bricks 40 MPa, you get 10 MPa and may be 12 MPa. But 40 MPa bricks are available or concrete blocks you can make of that kind of you know that kind of strength. So, your masonry strength can go as high as 40 MPa right. That is the masonry masonry right. So, let us look at some more things of the clay bricks, let us say.

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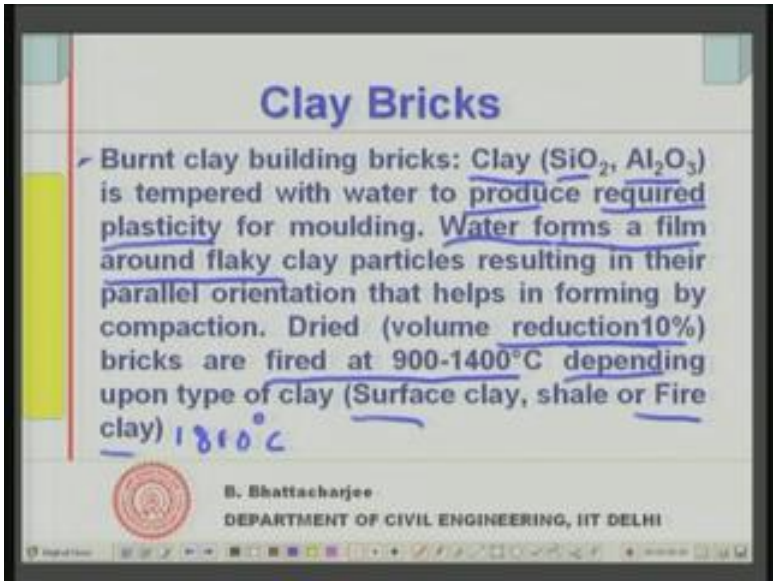

Burnt clay building blocks bricks you know, so that is that is what is the thing and how do we produce it. These ones we produce this one we produce from clay and you know what is clay. Clay is nothing but silica and alumina Si O 2 and Al 2 O 3. This is first mixed with water tempered with water to produce required plastic plasticity. So, you add

sufficient water with the clay and so that it becomes plastic right. It just becomes plastic and so that you can mould it. So, it is first made plastic.

Then in this process, actually water forms a film around a flaky clay particles, clay particles are flaky. So, they can absorb water at the surface and forms a film of water around its particles. And this results in their parallel orientation. The particles are now parallel oriented; they will be oriented in parallel direction. And which helps in forming you know in making or molding and compactions. Since they are parallel, they can easily be shared of sort of workability will be mould, the plastic material it can be easily worked on and it helps in forming.

So, the adding of water to clay mix is easy to handle and you know workable as you have understood and we can then compact them. Once you have compacted then we dry them, say there the volume reduction 10 goes about by 10 percent. So, we dry them and, because there will be shrinkage when you dry. Now, this drying is required because if you do not dry it, the shrinkage will be excessive, during the next process that we will discuss. So, first we dry them right another process that is some amount of shrinkage, because some of the moisture will go out, some of the moisture will go out. And the structures of the clay structures will collapse somewhat, because the moisture has gone out then the volume reduction there is a shrinkage. And then they are fired.

So, they are fired bricks using fired at 900 to 1400 degree centigrade of course, depending upon type of clay. Fire bricks of course, are burnt at much higher temperature may be around 1800 degree centigrade. You see the surface clay is first what you do is you remove the top portion of the clay. The organic matter should not be present in the clay. So, if you remove few meters or 1 or 2 meters from the top of the top surface soil, what you get is surface clay. And this surface clay is formed at relatively low temperature whereas, the 1 you go further down below the clay that you go get it low-depth, they are found you know they actually found at high temperature.

Fire clay for example, is obtained which contains more alumina. So, you obtain it from depart. So, surface clay and then the fire clay. Now, all those can used for brick making. Fire clays are usually used for burnt at much higher temperature 1800 to even 22 centigrade and then they are basically used for refectories. So, what we are talking of mostly is the surface clay or the sale bricks, you know prepared from sale or surface

clay. These are burnt at about 900 to 1400 centigrade. And in the process of burning what will be happen; initially of course, there will be of water smoking.

The water will go away followed by actually what is known as nitrification. So, there are solid solutions formed and the new material, material is no longer clay, you have new phases formed in the solid solution and that is relatively strong with sufficient certain amount of pores in the material, because the solid would have formed solid solution would have formed, the volume has been formed right in the beginning. There could be some shrinkages; but the structure has formed. So, during the process of nitrification, some you know the volume changes takes place and the space originally occupied by water and which has actually got evaporated or left from that place, usually would there will be voids remaining.

So, micro structure of concrete will have lot of inter connected porosity force coming, because you know the water that would go out would leave some connected porosity system and the solids. The solids is actually product of solid solution, which is formed during the high temperature and when you cool the solid solution solidified faintly, you know, it has got solidified, so is the product. Of course we are not much interested in the details of big manufacture, because civil engineers are likely to be really involved in big manufacturing process, practically not nobody but we will be using and 1 civil engineers are expected to use it. So, we look into more of the properties rather than manufacture, but some idea I try to give you that how clay bricks are manufactured. Then you have got calcium silicate bricks.

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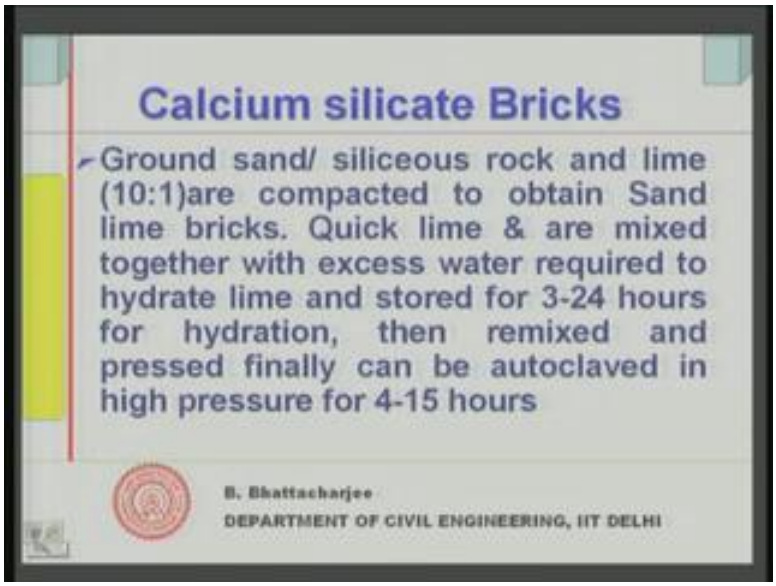

And this is basically you see this is basically; you might have siliceous material basically ground sand, grain the sand or siliceous rock to get a kind of siliceous material to get siliceous material. And then use lime, usually could be 10 is to 1 or some and these are compacted together to obtain sand lime bricks. So, you can calcium silicate bricks, these are compacted together. Quick lime and water, actually there should be water, water these are mixed together, you know I mean sand, quick lime and sand are mixed together in excess water required to make hydrate lime. So, the lime is expected to hydrate. Quick lime is calcium oxide which gets hydrated forms slacked lime and you know it gets hydrated lime. And this is stored for 3 to 24 hours for hydration.

So, you have mix the quick lime and sand together in excess of water. Quick lime and sand, this is sand, this will be sand. Sand together and mixed with excess of water and then you leave it for the lime to hydrate. You leave it for the lime to hydrate to 3 to 24 hours. Then it is remixed again and finally, it pressed remixed and pressed and finally, can be autoclaved depending upon what you want at high temper high pressure and temperature high pressure and temperature for 4 to 15 hours and that is what results in formation of this variety of bricks. There is another kind of bricks used quite often.

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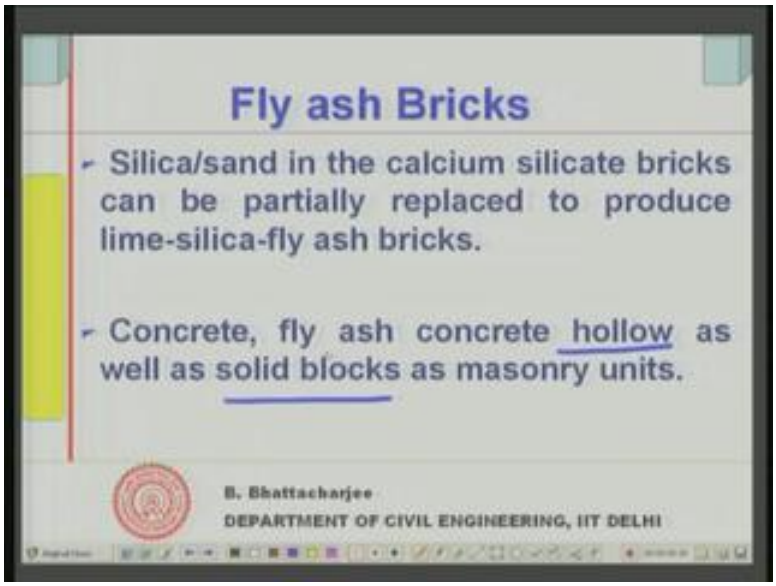

Then of course, I mentioned that fly ash can be used in brick manufacture and that is definitely sustainable. Now, the moment of autoclave and autoclave at high temperature and pressure again you are using large amount of energy. So, that is also a little bit energy -intensive. So, you have to grind it, clear bricks were also energy intensive. So, you can reduce this down somewhat, of course alright you can use fly ash in the calcium silicate bricks, instead of using the silica you can use fly ash right. And partially replaced to produce lime silica fly ash bricks also you can use partially.

So, lime and silica lime and fly ash they would some similar purpose. The reactions will be available and that would make fly ash lime fly ash bricks of course the strength etcetera that would be. You can you can make concrete using fly ash, large quantity of fly ash and make blocks out of them. Concrete blocks has such are used for masonry purposes. You know concrete bricks has such are used as masonries and they can be hollow or solid, because hollow would mean that we will have better thermal conductivity.

So, they can be hollow or solid as you wish depending upon the purpose and the masonries. They can used as masonries units. So, concrete and fly ash concrete bricks or blocks can be used very easily for masonry purposes. Now, I mentioned that you can do autoclave product; aerated autoclave, aerated concrete blocks.

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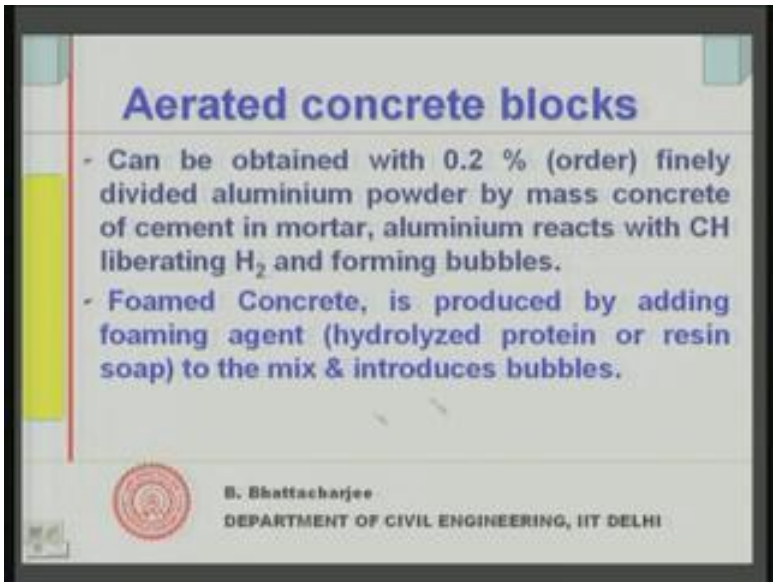

These are produced by 2 methods or 2 types of basically, like with like you see you have a forming kind of what you do gas generating. In such products what you do; you actually you had add particular ingredients into the concrete making process which will form bubbles. Close you know close pore system, close pore system of small diameter not very large diameter, but small diameter. And thereby you can control the density of the concrete itself. You can get from aerated concrete block; you can get from 200 to possibly 2000 kg per meter cube density of concrete.

So, can we obtain from using 0.2 percent finely divided aluminum powder, finely divided aluminum powder by mass of concrete, mass by mass of cement in mortar, aluminum reacts with calcium hydroxide hydrating generating actually hydrogen and this forms a bubble. So, basically mass of cement in mortar and aluminum reacts with calcium hydroxide the concrete generating liberating hydrogen and thus forming bubbles.

So, this bubbles remains as close pro system. And they essentially brings down the density of the concrete or mortar as you can call it, density of the mortar. And essentially this would be good common resolution, see that density is the common resolution become the lower density, higher density means more thermal conductivity less resolution. So, therefore, this is used this can be used you know, they can be used for both structural as well as thermal and similar used. This is 1 way of making aerated blocks.

The foamed concrete are made to some foaming agent, like you know you can for an example, foam concrete is produced by adding foaming agent, like usually they hydrolyzed protein or resin soap to the mix and they again introduce bubble. This forms the soap solution resin soap for an example they introduce bubble formation, because the surface call it is and that it forms bubbles concrete during the high speed mixing, during the process high speed mixing and this foam concrete has got again low density. So, you can get densities from 200 kg to 2000 kg depending upon the situation. And you can make use of fly ash in this particular one and replies the part of the cement. So, that is that would be useful situation. What are the properties which are important for the units?

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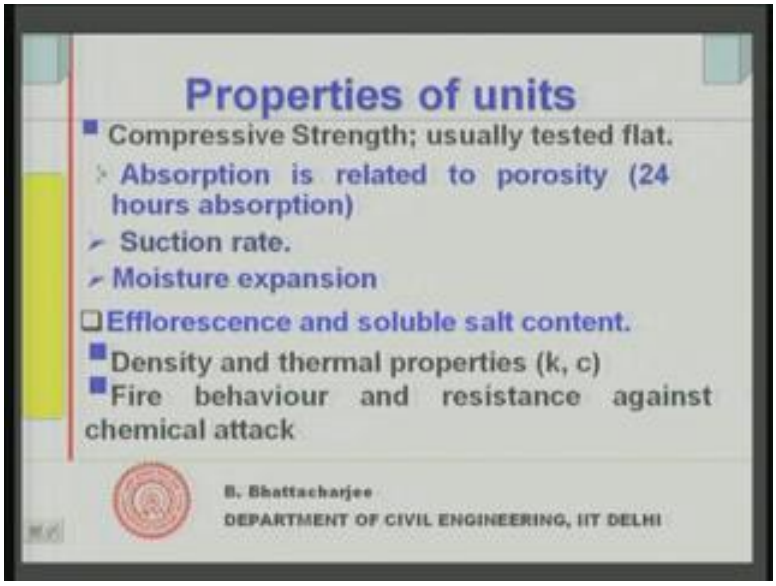

First is the compressive strength and they said usually tested flat. Then water absorption is another property which is actually related to porosity, because again porosity dictates the strength of the units. Porosity also dictates the water in gas. You know the penetration, resistance against moisture in this that is depending upon porosity. So, many properties most of the properties this could be a function of the porosity, useful properties in the bricks, all masonry units will function of porosity. So, it comes to stone of course, they have very little porosity, but stone is a necessary available material, you cannot get everywhere. Other places wherever whatever the masonry units we are using, their porosity is very, very important, because lower porosity means higher strength, higher porosity means lower strength, but at the same time higher porosity means better

insulation. Close pore system of course, got the strength reduces the I mean do not increase the resistance against moisture ingress.

So, if you close pore system moisture ingress will be there, but higher porosity is beneficial from thermal properties point of view higher porosity if, it is interconnected, not advantageous from auto penetration and; obviously, porosity of any form. Now, quick measure of the porosity is 24 hours absorption. So, what will be done; you oven the brick, put in water distilled water preferably, keep it for 24 hours if not ordinary water also put it in water for 24 hours and then take its mass. The difference in mass will be the percentage water, the mass of the water that has been. And that can be converted into percentage etcetera. Of course if you want to determine the total porosity, then you can put it for another 48 and may be for another consecutive 24 hours weights when it is not define by 0.5 percentage of the original initial weight. Then you can say it is fully saturated.

Then boil it for about 6 hours 5 to 6 hours to get the complete moisture absorb anyway. That is another way of finding out total measure of the porosity of the bricks and blocks. Now, absorption is the measure of the porosity therefore, it can be related to property. So, this is a very important property. Earlier crude way of looking at the properties of 1 clay brick is to find out what is the sound it makes. Supposing you drop it from hand it should not break. Drop it sudden from some height it should not break. Very cool way of looking at the strength of it. Sort of whether it is a good quality brick or not. 2 bricks you hit it should make metallic sound. Those are the very empirical way of looking at the properties of brick, but these are the methodical way of absorption.

Then another test is suction rate or another property suction rate. First is sucks water, because moisture in gas could be related to this. Suction rate means you have you have you actually keep the brick vertical. Keep the brick vertical you know vertical in a tray, you keep the brick vertical in a tray with say about 1 or 2 inch dipped into chilled water and go on measuring its mass with time. So, then we find out the suction rate of this 1. Suction rate of this particular 1 rate. This should be again relatively low.

Then you have moisture expansion is the swelling does the swelling takes place with bricks, normally it does not most of them do not. So, you have to see units of measure units, whether there is a moisture expansion. Should not have swelling in contact with

moisture. Efflorescence and soluble salt; you see in the clay there can be some soluble salt. This is burnt clay brick particularly can show some sort of efflorescence. It can have some soluble salt present in the clay, say sodium sulphate or similar other salts.

Now, that has gone into the solid solution alright, but will you subject it to water then you know you keep it in water and then dry it what will happen, you will see white marks of white marks over the surface of the brick. And these white marks are nothing, the soluble salt that was there that has got dissolved in the water and come out to the surface, reached out to the surface. And as the water evaporated, this actually left the marks right onto the surface. This is typically very, very unpleasant. So, this is not desirable. Although: it does not really matter much to the strength of the brick masonry units, because you know this efflorescence really create much problem towards strength of the brick masonry or its performance in that direction. You know stability and strength related properties, but it is ecstatically very unpleasant

Normally it takes place once. If, it takes really you know time and again there can be problem. But when it takes once an acid wash where actually these salts will dissolve is a good solution you know that you just give acid wash, very dilute acid wash and that takes away the scales that is formed. So, efflorescence is related to that soluble salt content and efflorescence that is related. The test of- efflorescence is again put into the brick part of the you know small portion dipped in water vertically up and absorb it for couple of …

If you see salt mark of the surface, you know there is a criteria where significant efflorescence, based on the visual observation 1 can determine whether significance efflorescence is there or not. Now, as we shall later on bricks, today are used mostly for mostly as wall material. Masonry construction is mostly limited to wall materials. So, when it is used as wall material, the property that is very important is thermal properties, because you see thermal comfort is 1 of the issues, which we discussed right in the beginning of this course; functional properties of various construction.

Now, 1 of the thing is that the space should, if it is building the space should remain comfortable. So, the temperature should be within controllable limit which may be may not be possible without any active means we said, but if you are trying to first you must try to you know control it as much as possible through passive means. Now, while want

to you want do not want to hit to come into the building or space from outside, the thermal properties are very important. In tropical countries we do not want heat to come from outside, of course in colder regions they would like no heat from inside to go, because you know. So, that there is a situation when outside temperature is very, very low. And in summer in tropical countries we do not want heat to come inside.

Now, the properties of the material for the construction that is wall or roof is dictates is the thermal properties. Thermal properties are the materials that is you want to look into. Therefore, thermal conductivity of the bricks all masonry units are very very important. Density is important and specification is also important, because they are all relate to thermal properties right. So, these are important properties, we shall see that. And of course, the fire behavior is very important.

Now, fire behavior, because if there in buildings and this will be important but fortunately 1 in much about the fire behavior of brick units, because most of them are actually burnt at very relatively high temperature. You know the temperature fire this material is been produced at such temperature. So, normally nothing happened, but something happened to mortar that is the joint in material. Resistance against chemical attack that is very very important, but usually the bricks most of the types of bricks are actually resistant clay bricks. Burnt clay bricks are resistant against chemical attack anything of that kind, generally that will be strong.

But you see if you look at other masonry units, then both fire behavior and resistance against chemical attack 1 has look into, because if it is blocks of the kind of concrete or cement, you know not fired ceramics, but it is chemically combined chemically bonded ceramic like concrete, where you actually have bonding as chemical or aerated system and so on, where it is actually chemically bonded.

Then normally it will behave how similarly as the cement hydrate behaves. So, also the mortar joints behave in the same manner. So, other units may be susceptible to fire affects. Now, let us see how cement system is affected by fire. When you subjects cement or cement hydrates to fire upto 200 degree centigrade 300 degree centigrade there is no affect, because first the water free water will actually evaporate out. This water you know which is just absorbed from the atmosphere or because the contact of the liquid this goes out by 100 and 10 degree centigrade. So, that is not a problem.

Now, beyond upto 200 150 to 200 degree centigrade all such water will go away. Beyond 200 or 300 degree centigrade, then absorbed water from the surface of the gel structure starts faintly going away, because you know that you would require more energy to remove them. So, at 200 300 degree centigrade this goes away, 400 degree centigrade onwards this dehydration process continues and it is still about 600 degree centigrade, whereby most of the gel waters will actually evaporate out. But at 800 degree centigrade, calcium hydroxide just broken to calcium oxide.

So, therefore, by that time the cement hydrate would lose all its bounding property and this is irreversible process; that means, if you put back water reduce down the temperature and put water back, it is does not come back to the cement hydrate state again. So, it is the irreversible process and therefore, all cement material which are used in masonry units will behave in the same manner. So, up to 200 300 degree centigrade are fine, but after that the strength reduction starts and its strength gets reduced and at 800 degree centigrade practically no strength will be left.

But 1 advantageous situation is that, this materials are all insulating relatively insulating the their thermal conductivities quite low. They are low conductivity material compared to say steel. So, therefore, heat get inside, although surface may be affected heat may not go inside socially. So, masonry units which are made of cement based material; they will have similar sort of behavior as I just now mentioned. But chemical attack same durability issues which are there with respect to cement. So, all cement based masonry units have similar properties. So, let us look into some details of these properties again.

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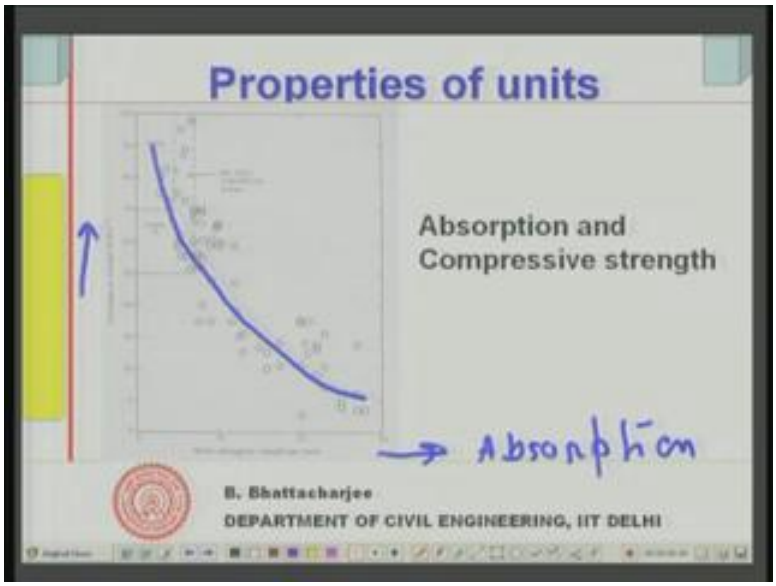

So, let us say how absorption, because also the absorption is 1 of the ways of measuring the quality of brick and, because it is related to compressive strength. So, data shows data of compressive strength versus you know compressive strength versus absorption. In this axis I have absorption and this axis I have compressive strength. And as I can see as my absorption increases compressive strength decreases down. You know this points represents. So, it in fact, I have a curve of something of this kind.

So, my as my absorption increases something like 30 I have 10 MPa strength. Well, this may not be an universal, but how about this we can understand as absorption increases compressive strength will definitely reduce. As absorption increases compressive strength will definitely reduce, compressive strength will reduce. That is because more pores and also sizes becomes larger interconnected pore system pore sizes also. So, related to that same idea as absorption increases. Therefore absorption can be a good test to find out how bricks will behaveas far as compressive strength or all other mechanical properties are concerned.

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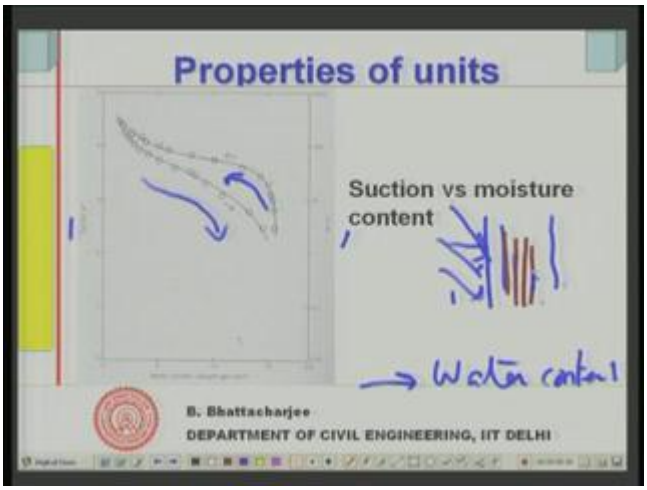

Now, you can look into the suction. The properties of concrete it will indicate moisture ingress into bricks, how much water they will suck in. This axis is actually water content. This axis is water content, this axis is water content. You water content along this direction water content. And on this axis is suction pressure, you know suction pressure or suction hand. And when it is waiting, moisture content is increasing it follows this path, when drying it follows path. There is a, if you try to increase the moisture content of bricks or similar other materials. This is also true for all other similar ceramic or inorganic porous materials. When there are absorbing water the path followed moisture content and suction pressure.

Now, suction pressure is a function of capillary size. The whole idea is that, the capillaries which are filled in and while this is drying exactly the process would not reverse, path followed are different and therefore, you have a hysteris. Therefore you have a right while wetting and while drying you do not follow the same path. So, there is a and suction rate is important, because that would tell us how much water can penetrate into it. You see basic idea of moisture protection is of course if you have a barrier, it is fine, but if it is not a barrier. You have massive material massive thickness of the wall.

The moisture penetrates into it, but before it is you know does not penetrate to its full length, before the drying period starts. That means if this is a wall, if this is the moisture you know the water rain water let us say, rain water is hitting it like this. So, this is gradually it will move the wet front. You know the wet front will move like this. But it should not move to the inside surface, because the rain will stop eventually and the

drying period will start. So, it should start actually after the drying period. You know the wetting period, during the wetting period the moisture should penetrate, but should not penetrate up to the inner face. Before that the drying period should start so that, this place there is no you know there is no moisture penetration right onto the surface.

So, the moisture can penetrate alright, but the rain must stop and drying period must start before it has penetrated right up to the inside surfaces. Now, this property will be function of the suction property. And you know moisture ingress property will be function of the suction. So, that is what is the idea, 1 can do more exercise onto this, but we are not interested in our class to do that.

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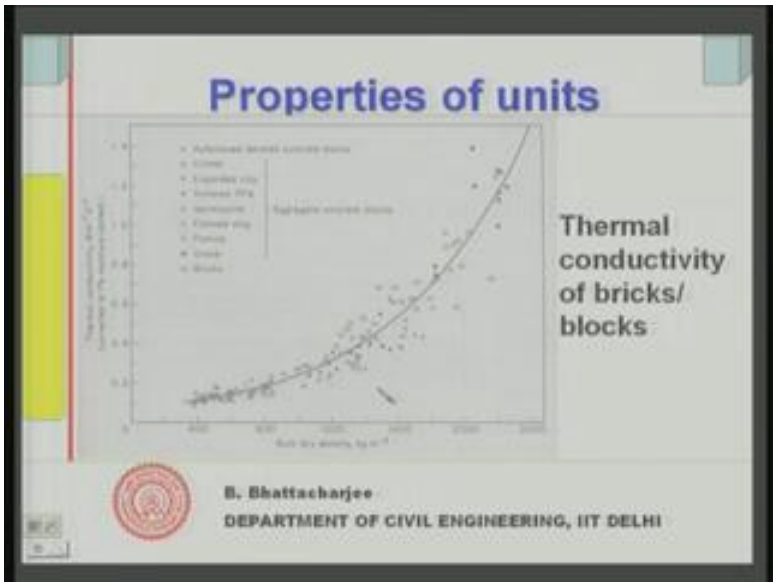

Now, let us look at the property thermal conductivity of the bricks and blocks. Generally traditionally many people have related thermal conductivity to density. Many people have related thermal conductivity to density right. So, we can relate thermal conductivity to density. First results people have related thermal conductivity to density. And as the density increases thermal conductivity also increases. The unit of thermal conductivity as you can see is what meter per degree centigrade. We might look into this a little bit more some later on in connection the wall. But at the moment this is the property and you would have seen this. I mean learnt this in basic school physics.

So, thermal conductivity increases as the density increases. This is the amount of heat that would be transferred under sturdy condition, so temperature gradient, so unit area

the wall. This is the heat rate of heat flow. The unit area of the material not wall here the material for unit temperature gradient. So, higher the thermal conductivity more is the heat conduction, higher the density more is the heat conduction. And you can see several materials here; autoclave aerated concrete blocks expanded clay and then you know pulverized fuel ash, this aggregate concrete block.

So, you can have synthetic aggregate as I mentioned earlier, pulverized fuel ash you know making from fly ash actually. Then is another 1 is the other 1 from the slag plus 1 slag, cubic and so on so forth gravels and bricks. So, if you use all those as aggregate and then bricks are also there, gravel aggregate and this sort of relationship is known to us. So, this is thermal conductivity 1 way.

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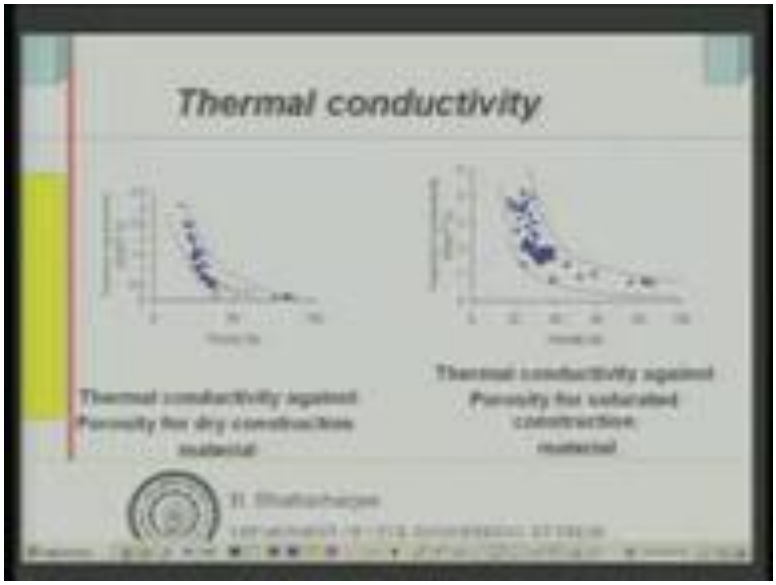

But fundamentally thermal conductivity is actually related to porosity. 1 thing is the I mean of course, the conductivity of the solid and porosity. And this is actually results for Indian bricks. Most of the Indian bricks or rather north Indian bricks mostly and some of the east Indian bricks. Some from eastern part of the country Calcutta and so on. And the most from north Indian bricks including some fire brick. So, 1 can measure the porosity and also measure the thermal conductivity. It has been observed as the porosity increases thermal conductivity decreases

One point I would like to mention here is that, you see it you can see the value orders are about 2.5 3 not more than that, even concrete would be which should be somewhere

there. So, this concrete also some concrete, these are all concrete you know made with soap solution, aerated concrete blocks autoclave aerated concrete blocks. So, this is also for bricks blocks everything, bricks of course, some where here. We can see the values they range up to concrete up to 3 meter centigrade, but steel it is 50. So, this is really a insulation material compared to steel. So, that is what I say this is got an advantage to from that point of view in the contacts of fire in normal temperature of course, in high temperature the thermal conductivity will change however.

So, as for as thermal conductivity porosity and density are inversely related; higher the porosity density will be lower. Basically the mineral materials will have similar thermal conductivity, but it will vary it will vary depending, got thermal conductivity 10 volt meter degree centigrade when many other much faller. So, thermal conductivity also function of porosity. But most importantly it is also function of moisture content you know, because water has also got thermal conductivity about 25 times more than that of the that of the air.

So, if you are air now filled with moisture and is saturated the bricks and blocks, then the thermal conductivity be significantly and you can see the values changes. Values changes you can see for example, this is the porosity of the whole rain and now this starting with 0.15 and very small value is 3, this is now going to 4 or 5. So, some amount of increase in thermal conductivity, when moisture comes in. This is saturated condition the moisture causes increase in thermal conductivity. So, moisture is the other factor which controls the thermal conductivity, but any way it is natural you cannot do much with it.

So, first one, if it is interconnected porosity, then moisture comes in the thermal conductivity insulation property may be loss, but in case of close pore system, thermal conductivity will be intact totally it will remain intact.

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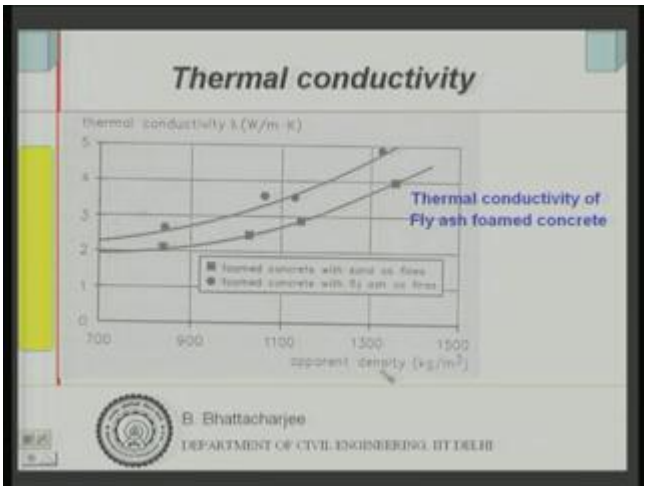

Now when you have fly ash bricks the thermal conductivity will be something like this, you know foam concrete will send as fines and foam concrete will send fly ash as fine. So, you would made fly ash, this is 1 this is the fly ash once and this is the foam concrete send as fine. So, thermal conductivity changes it shows, fly ash actually increases the thermal conductivity with the density again it is brought at. So, does not matter. So, fly ash also it can increase little bit, but does it relocate it forms sufficiently forms, that part take care of it.

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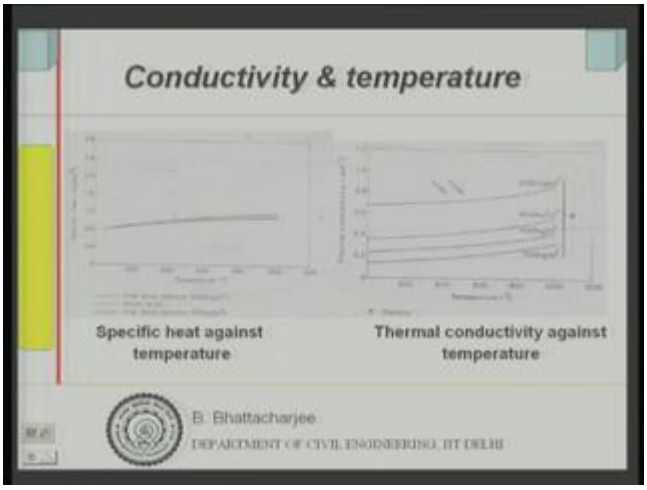

Now, when you deal with fire the, situates fire the temperature of fire can go up to 1200 degree centigrade, you know standard degree temperature fire of course, it was on monotamically increasing, but real fires can go up to 1100 1200 1000 degree centigrade's, fire temperature can go higher this. So, whenever time to determine the fire

resistance, which will define subsequently sometimes which will define in terms of time interested in estimating the fire resistance, 1 will like to know how the thermal conductivity thermal property changes its temperature. Also specific heat how does it changes temperature.

So, that is what it is; specific heat against temperature this is how it varies. It specific heat of normally such heat do not vary very much. Normal condition at ordinary temperature it varies from about around 900 joules per kg per degree centigrade or around 0.2 kilo calorie per kg degree centigrade. In this case this is temperature this excess is you know this excess is temperature exits and this exits is specific heat temperature exists and this excess is specific heat. So, this excess is specific heat.

We can see the specific heat is actually in kilo calorie or kilo juice per kg degree centigrade and values around 0.8 you know I said that around 900 800 900 joules per kg. So, about 0.8 0.9 joules per kg is normal temperature, with temperature higher temperature increases go up to about 1.1also 1100 juice per kg degree centigrade not a big variation, but slightly increases with the temperature, but not normal increase in all types of bricks using. The thermal conductivity varies quiet significantly for varieties of bricks and blocks and so on, it varies from about 0.015 0.01 extra in that low thermal conductivity for aerated concrete to about 2 to 3 in case of concrete blocks whereas, specific heat does not varies so much, it will varies about I mean somewhere around 800 juice per kg degree centigrade, it will about 900 or it will near about 1000 not more than this. So, this variation is relatively less.

So, let us see what will happened to thermal conductivity with temperature. This also increases little bit, this shows with the density. For each density for 700 density you see the thermal conductivity it was about 0.16 also 0.16 and then it increased and as the density increases this was the this for bricks this only for bricks this for bricks 0.7 it increased about 2100 and it increased about 0.8 or 0.9. So, thermal conductivity also increases the temperature increase of thermal property expenditure temperature when it exposed to fire. So, these are the other kind of properties that 1 who look into. Now, let me just put it in this way; the concrete should have shown a thermal conductivity to ordinary temperature 1 2 about 2.5 or 3 depending upon aggregate use. So, concrete blocks would. So, higher thermal conductivity, bricks normally shows around 0.2, 0.3 to about 0.7 fire bricks show around 0.7 0.8, fly ash bricks will show around 0.3 0.4 meter

degree centigrade in the aerated blocks shows much less you know 0.1 less than 0.1. So, they were the range of thermal properties of masonry units.

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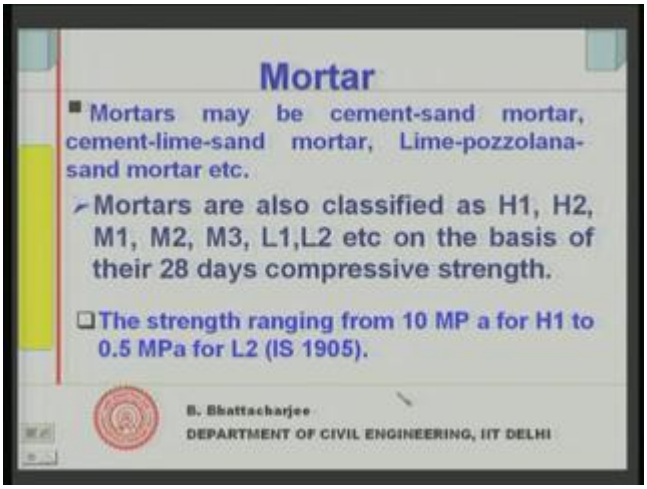

So, let us look into mortar and their properties. Now, mortar traditional air vention that it is actually pozzolana lime-pozzolana mortar, lime- pozzolana sand mortar. So, today you can have cement, sand mortar, cement lime sand mortar or lime-pozzolana sand mortar. So, all these varieties are possible. And we classify them as heavy H1,H2a, M1,M2,M3,L1,L2, on the basis of their 28 days compressive strength. And the compressive strength maximum for each 1 is for 10 MPa. And for you know to 0.5 MPa for last 1. And the Indian standard code which deals with masonry design load bearing masonry design is 1905. So, H1, H2, M1, M2, M3, etcetera. And the combination the first 1 would have more amount of in fact, cement and the go down lesser amount of cement and the strength. Let us see how these are…

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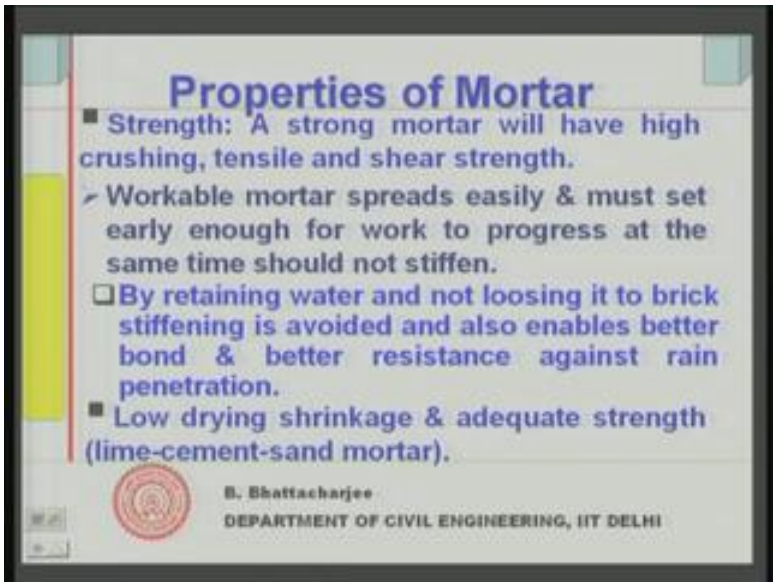

Now, first thing what properties are; strength is very important parameter as for as mortar is concerned. A strong mortar will have high crushing tensile and shear strength, of course all these properties you mean a strong mortar. So, strength is 1 property. Now, I to apply the mortar onto the bricks, therefore it should be you know normally if travel, 1 applies the mortar onto the brick. So, should hang onto the towel like if you scope it up, it should remain there and should not really flow away, but it should still be I should be able to spread it easily with towel.

So, therefore, the workable workability is the mortar is important. So, it should be able to you know it should be able the 1 which should, I should be able to spread it easily. And it should set also not too late. If it sets too late, then there is a problem, then I have to wait for constructing the another layer, because the brick work construction goes on or the masonry work construction goes on from 1 layer and then possibly the length of the wall or length of the structural section, come back again and just lay another layer right.

So, while you are trying to do that it must set quite early. If it sets very late maybe 1 2 hours late, then you have to wait. Come back and you cannot put new masonry onto it. So, it should set reasonably early enough for work to progress at faintly you know. Progress at a relatively comfortable rate or relatively first rate, but at the same time it should not stiffen while applying.

So, this is important you should be able to retain the water, so it should not stiffen. And this should is done by retaining water. So, it should retain the water. It should not totally quickly consume the water in the reaction process. Should be able to retain the water for slightly longer period of time, at the same time should not have … So, all this all this you know all this properties are desirable.

Now, again another problem is; if there are too much of water should be held together with the particulate system as a cohesive unit in mortar and should not have lot of you know segregation of water or something. So, when it comes in contact with the brick, brick being porous although we saturate them before laying down. Brick being porous it should not absorb this water and stiffen my mortar before application. So, that is why the water retention property of the mortar is important. You know water retention property of the mortar is important, because it should not stiffen and better bond.

If it does not stiffen then it will allow for better bond and better resistance against rain penetration. If you have poor bond through the bond rain can penetrate. So, you should have a you should have a good bond and that is water intention properties are important that point. Then low drying shrinkage, it should not shrink and it should have of course, adequate strength. Now, if you have too much of cement in the mortar, then it will give you good strength alright, but it will have high shrinkage also.

On other hand, lime has got good retent less shrinkage, but low strength also. So, if you see this properties that we are looking at, the properties like strength comes higher cement gives you higher strength. But lime gives you better water retention, better workability as well and less lime shrinkage. So, a combination of lime cement sand mortar that is good and of course, helps in the direction as well because; would retain the water for longer period of time. And you have something called masonry cements also which are made out.

So, well, in India of course, they were not much available, but earlier P P C were produced which were used only for masonry works. Some of the P P C you can 1 can easily work using masonry world, if you do not mistake the setting time strength is sufficient for the mortar and of course the shrinkage is less and it can retain the water also. So, this is the properties of the mortar which are desirable properties of the mortar right.

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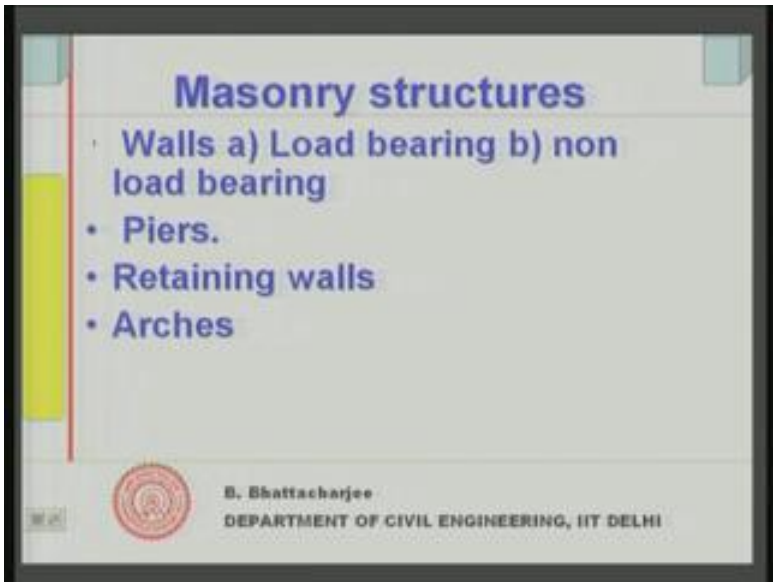

So, we conclude masonry structures, what are the types of masonry structures. But some more issues related to mortar, you see mortar is after all cement based material. So, this properties will be like cement based materials and when it comes to its although it comes to it is relatively small proportion in the brick work. It does not constitute a very long large proportion of the brick work, but its joints are very important, because they should not allow with moisture to go in, also the mechanical properties are important in the sense that, you see the load is transferred through the joints. Load is transferred through the joints and the differential movement traverse movement between brick and mortar that could be a source of stress internal stress generation into the brick work itself.

So, ratios are important, strength is important and shrinkage is if it shrinks, then it will actually kind of introduce or kind of sort of you know induce a kind of tensile stresses into the brick itself. So, that is why it is important that, it has all those properties that we mentioned. The material can be sent; obviously, its common lime send lime cement or sand cement or lime sand. So, usually lime sand is- also another combination which is used and can be used effectively for making masonry mortar.

So, first thing is cement, sand mortar, cement sand and lime, cement lime and sand mortar, lime and sand mortar they are also there and then lime, sand mortar. So, these are the kind of mortars that 1 can have. Now, where do we use these masonries? You know masonry structures those are there; wall is the most commonly used. You see earlier

historically speaking people did not know use know how to use tension carrying material. Sometime earlier I might have mentioned this right in the beginning. So, therefore, also some materials which could take only compressions arches, arches where the load is you know mostly the stresses are compressive right. It is by the shape, by shear shape it can carry the load and the material there is no tension in the arch.

So, there is compression in the arch, it will depend upon of course, the bottom fixity or what kind of bottom you know fixity is there at the bottom. So, whatever it is arches are usually compression taking materials. So, brick masonry was useful there. Then if you want brick masonry to take also some sort of tension, then you must reinforce it. So, you have reinforced brick masonry, not very popular in this country, but they are there elsewhere, it is actually used.

Ordinarily we use brick masonry earlier where used for bridge piers arches and similar other many other structures, but now it is most commonly used for walls. And the walls can be of 2 kind; load bearing and non load bearing. When we have load bearing wall, you can it will carry the load from the slab and transfer it. We will look into this somewhat. Now, you can construct about fore storey building. I mean conventionally up to fore storey buildings in many parts of the country are made of load bearing brick work. Non load bearing works are walls are the 1 which does not carry the load except the self load, but it provides envelope in a let us say R C C frame structure. So, the in the field between in the frame would be the brick.

So, this brick works although may contribute to the structure stability somewhat, but basically we consider that they are not bearing the load. They have to only take the horizontal load traverse load come from and their self weight. So, these are the walls other than that piers where it has been used very few now, retaining walls and arches. There are many other similar structures where brick works have been used. So, brick masonry has been used, brick masonry or even stone masonries dams. Dams are there very much, the arch dams or dams stone masonry right.

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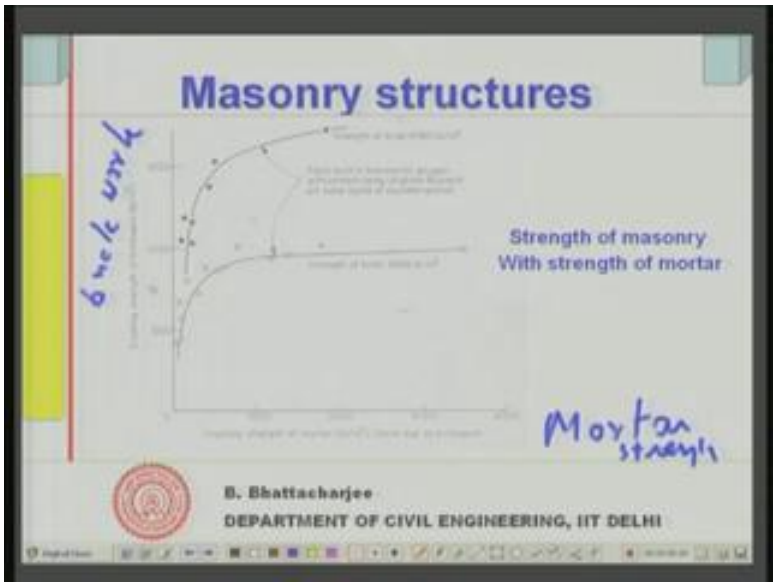

So, masonry structures we will see in the next class. But let us just introduce it; we will see that you know we will go back to this again, may be look into that. If you see the strength of, this axis is the strength of the compressive strength of the brick work or the masonry. And this axis is the compressive strength of the mortar. So, compressive strength of the mortar, this is mortar strength. And this is the brick work strength the masonry strength brick work strength.

Now, orders if you see; this is about this is in pounds. You know does not matter the units of this is 3000, this is only 1500. So, strength of mortar increases, the brick masonry brick work strength is much lower much lower than the mortar strength. And by increasing the strength of the masonry beyond a point you do not get any, I mean the strength of the mortar you do not get any advantage. This is a lower strength bridge, this is a higher strength bridge.

So, as you increase the strength of the bricks somewhere there is an increase, but you see mortar very strong mortar using strong mortar do not give you improvement in strength. We will look into this issue a little bit more in details in, you know in more in details in the next lecture.

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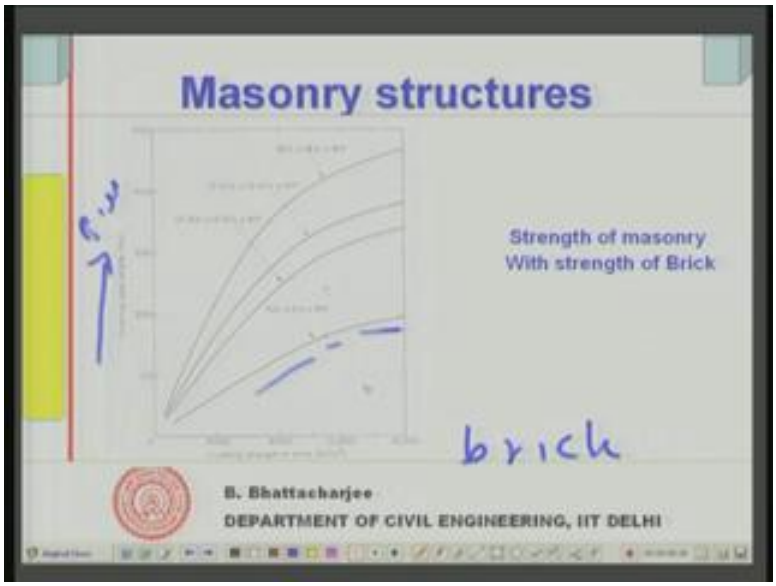

Similarly, just introduction to the masonry structures again. If you have, if you this is again this axis is strength of the brick work. Brick strength of the brick units, this is the strength of the units and are the strength of the piers, different piers actually sizes are different. And what the point I am trying to make is, you will increase the strength of the brick work, it increases initially, but beyond a point it does not increase the strength very much. The mortars used are same, so there is a point beyond which it does not strength does not increase right.

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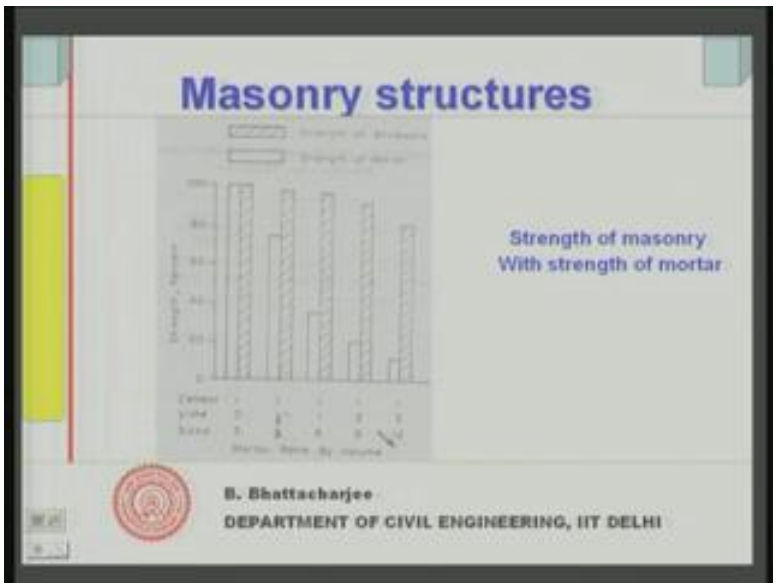

And some idea regarding this and we will into this in the next class as I said in more details. You see this is for the same strength of the brick. Now, mortar strength this is the strength of the mortar. This, this line shows the strength of the mortar. This line shows the strength of the mortar. This show strength of the mortar, you know this mortar and this is the strength of the brick.

So, as I go on increasing different mortars I use weak mortar brick work strengths for the same, brick work strength do not change. I can reduce the mortar strength, but brick works strength does not increase. Same thing different mortars have been shown here. We will repeat this again in the next class when we look into brick work more. So, I think this is we can summarize.

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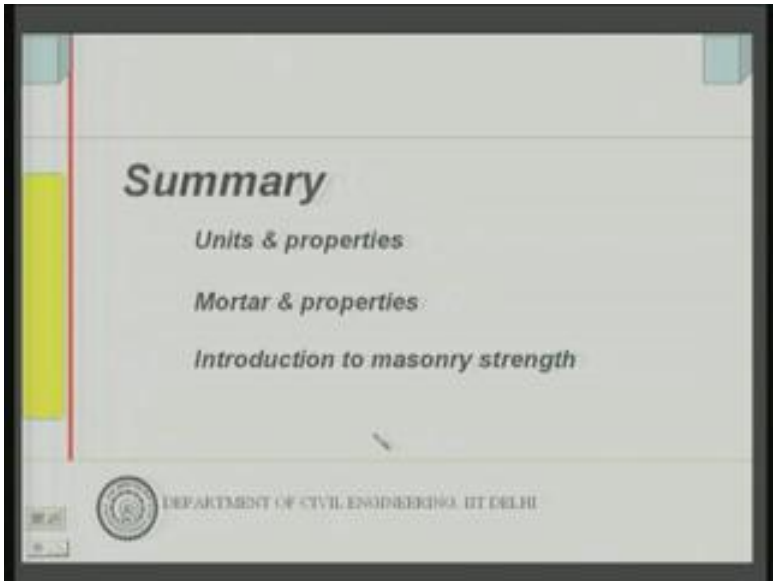

We have looked into units and properties. We have looked into mortars and properties. And then just I have introduced you the strength of the masonry. We will look into the strength of the masonry and behavior of the masonry in the next lecture.

Thank you.