Sustainable Materials and Green Buildings
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Lecture - 25
Types of Brick Kilns and Carbon Balance

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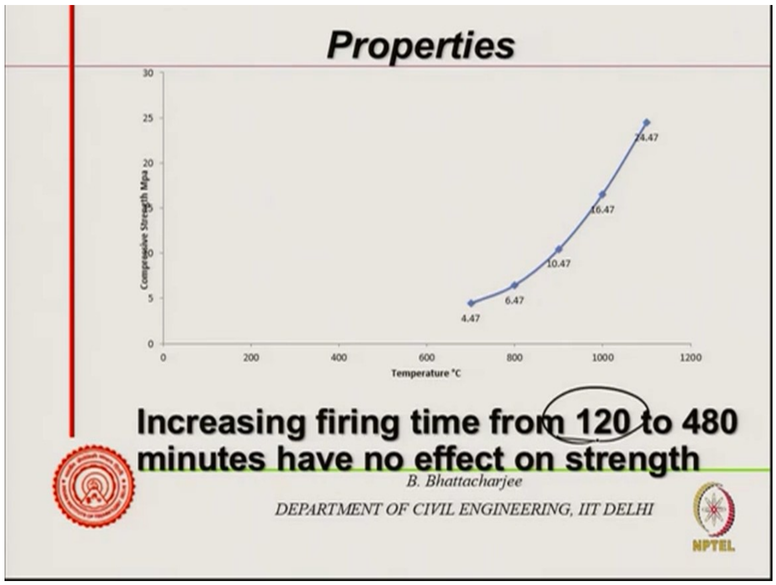

We will continue to look at clay bricks, right. And we are looking at the properties. I think related to burning condition, if you increase the temperature, compressive strength tend to increase. Normally if you see Indian bricks, most of most of them will be, some are there, it also depends upon the clay constituent, but for you know when the fire bricks, which actually formed, you know the, the vitrification occurs at higher temperature and you go to higher temperature. So you go to 1200 degrees centigrade, you might go to 25 or so, 25 MP, right. Which is, which you know normally that kind of bricks you do not get much in India but then higher the temperature. So is this is an observation.

Second thing is so increasing firing time of course does not have much of an effect, including firing times does not have much of an effect, but at least 2 hours, minimum 2 hours or more. That is what is the burning time keeping at the maximum temperature.

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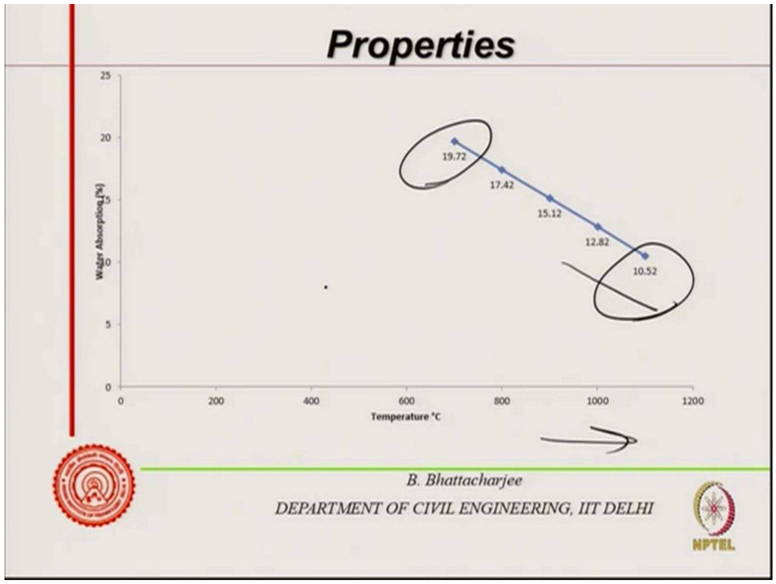

Properties, other properties of the water absorption, this is the most important. And as we can understand as the strength and you know this water absorption which actually relates to porosity, right. Total porosity, so a strength burning temperature increases, water absorption reduces and you can see the order of this is about 10 to 19 percent so porosity is corresponding to this would be even much higher, which would be around 30 percent or so, so much higher porosity for this one.

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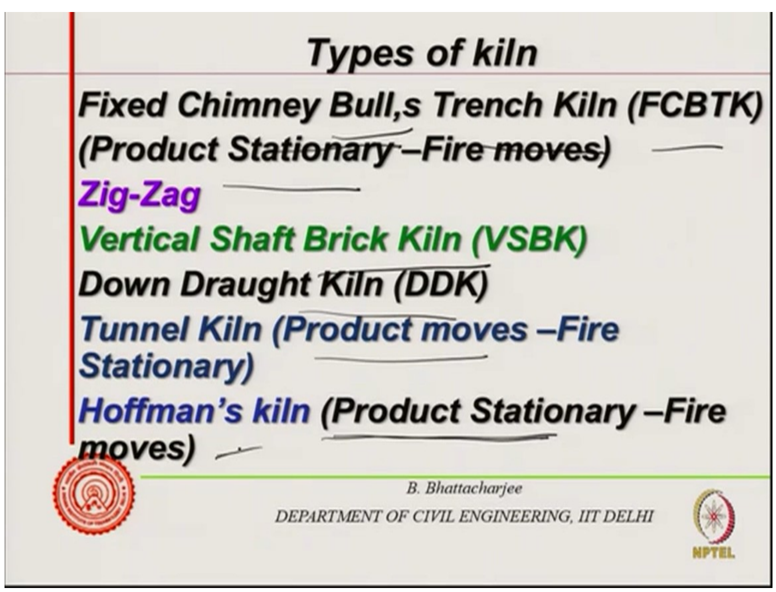

Now, where do you produce them? Produce in Indian scenario, Fixed Chimney Bulls Trench Kiln, Kiln is a most, you know one of them where we use, there is one type of Kiln. Here product is stationary, the fire moves, so the bricks are arranged in layer. We will see some photographs arrange in layers and the fire moves once and moves from place to place and then of course they are taken out.

We have seen before that actually it is made into plastics state, then molded and dried and then the causes will occur. Then there is something called Zig-Zag you know kiln, which is a variation of this one only, but now the fire will move in a Zig-Zag fashion rather not in a straight forward fashion.

Then of course, Vertical Shaft Brick Kiln, Down Draught Kiln and Tunnel Kiln, in Tunnel kiln of course product moves fire is stationary. So Hoffman’s kiln products stationary, fire moves. And this is actually after on Mr Bull's name. You know who, who actually introduced this in Indian scenario. So Hoffman's kiln is a product stationary fire moves. So these are the types of kiln you are so we can look into each one of them, one by one.

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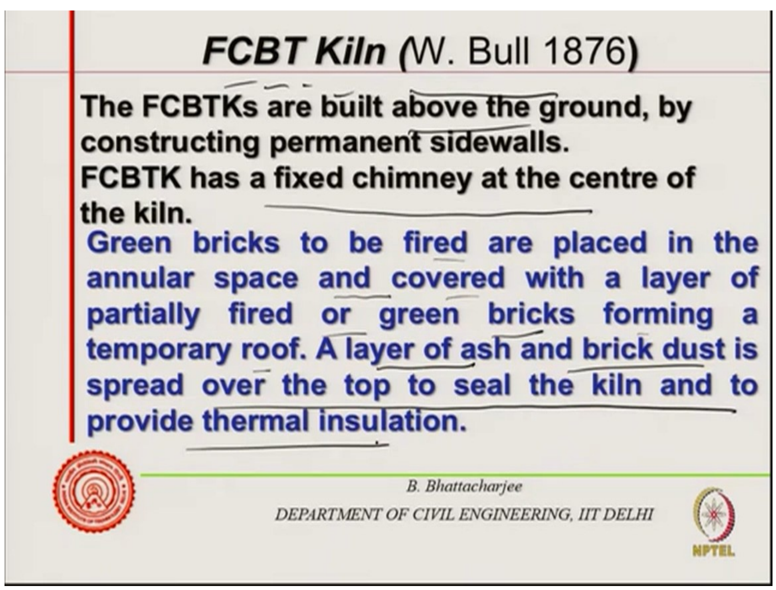

So Fixed Chimney Bull,s Trench Kiln this is by introduced by one W. Bull in 1876 these are built above the ground by constructing permanent sidewalls and as a fixed chimney near the center of the kiln, right. Green bricks to be fired are placed in the annular space and covered with a layer of partially fired green bricks as insulation, you know, forming a temporary roof. So temporary roofs are also partially fired green bricks and layer of ash and brick dust is spread over the top to seal the kiln and to provide thermal insulation. So essentially thermal insulation is provided by this by the roof.

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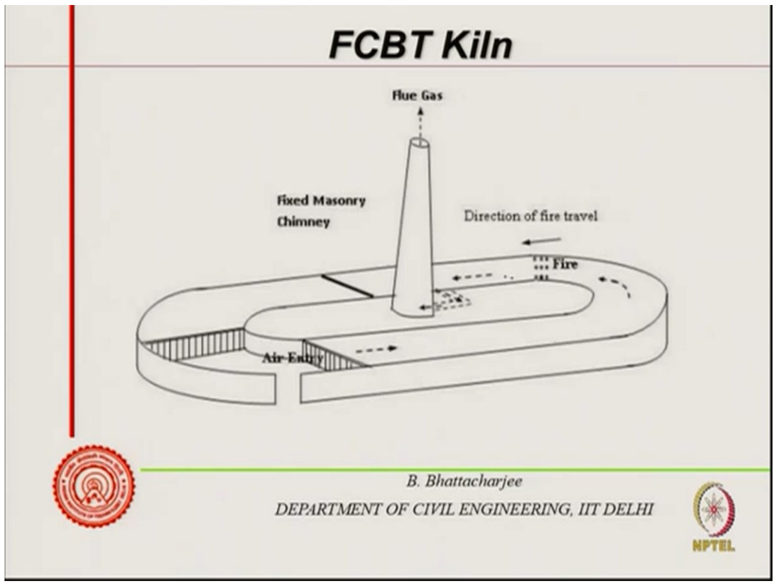

And this is how it looks like. So the bricks are arranged in this manner (())(4:36) from the side, the fire will move direction of the fire travels. So you actually will have the fuels together here. Fuel is also you know in the same arrangement because you have got bricklayers, layers of bricks here and the fuel is also there. So the fire will move and the smoke will move out through the chimney finally. So fire moves basically and as it is fired the bricks, you know, as it is, as it is, fires basically ones the firing is over and cool bricks can be taken away.

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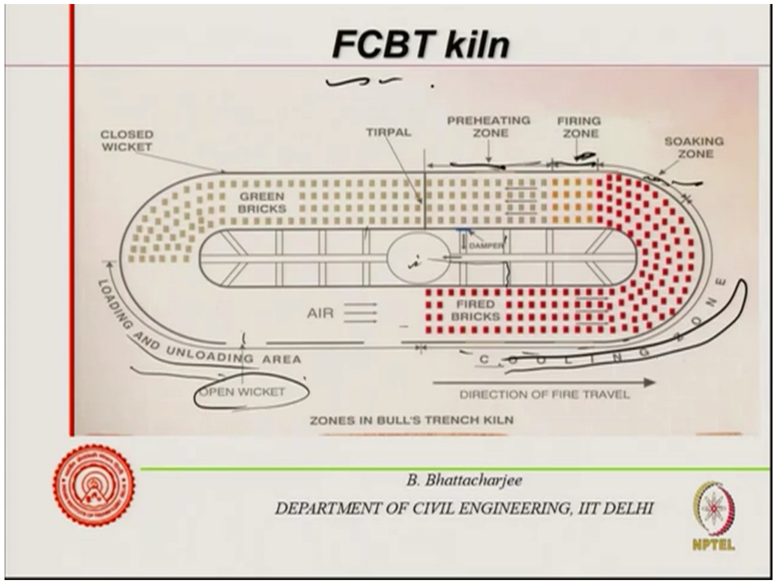

So this is how the diagram looks, it is something like this as you can see. So these are the fired bricks, right? This is a firing zone. So these are fired bricks. This is the firing zone, smoking zone where the firing is still going on and this actually at a higher temperature and this is pre heating zone, right? So first preheating, then after this is this is the green bricks, right. And there are entry point for the chimney. So smoke can for example, when it was burning here, the smoke would enter like this and reach there. Similarly, when it is burning here, the smoke will enter like this. So loading and unloading area is this.

So here, this will be actually, this is green bricks loaded in this manner and fire bricks are taken out for this manner fire bricks are taken out fire bricks are taken out from this manner, right. So this you have preheating zone, firing zone, smoking zone and there is a cooling zone here. So once cool, this can be taken out and loading and finding area. There is some open gates through which you can go. So they are arranged and the fuel is also there together. So as you burn, they heat up and that is how it goes, right? So this is that Fixed Chimney Bull,s Trench Kiln that was introduced in 1876 and possibly most, many, many places still it is used.

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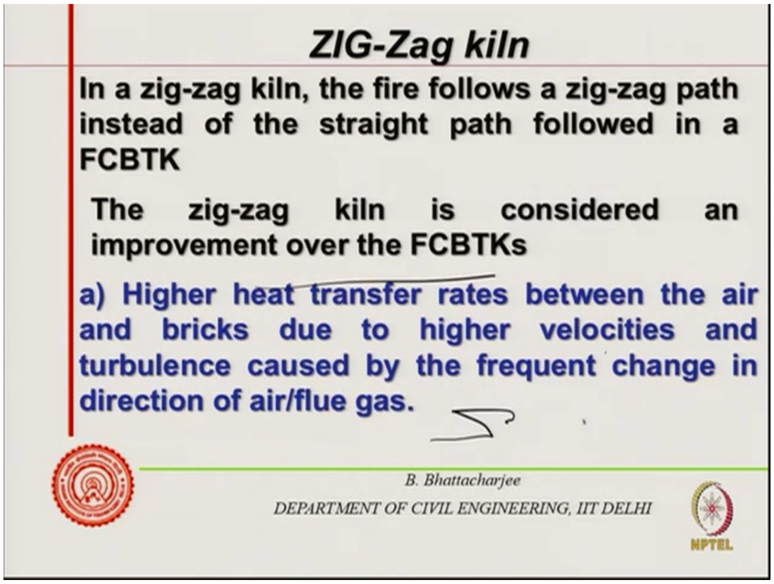

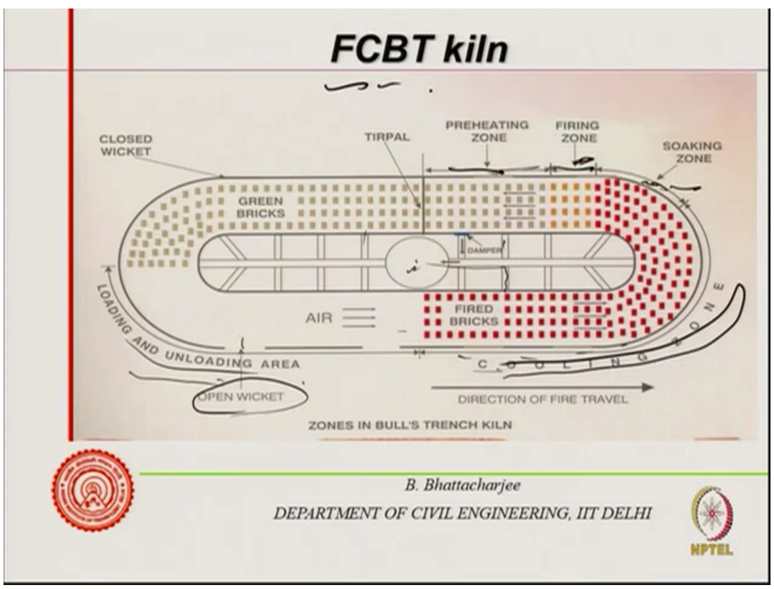

An improvement of what this is. Fire flows in a zig-zag path instead of the straight path that is followed here. So if you see in this one, this was fire was moving in a straight path. In this kiln the zig-zag kiln is considered an improvement of what this FCBTKs and higher heat transfer rates between air and the bricks due to higher velocities and turbulence caused by its zig-zag path, frequent change in direction. So since if you change in direction, obviously you know the turbulence will be created and the basically local velocities could be higher and that is how, that is what efficient burning.

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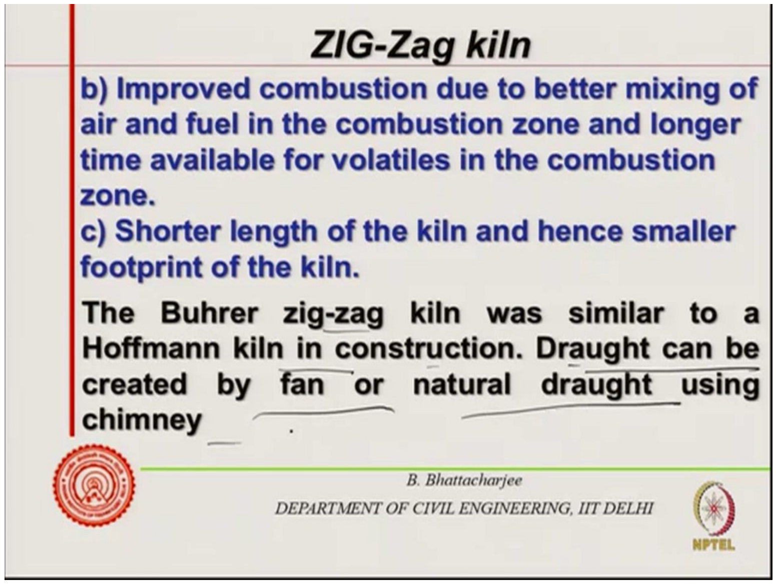

So this gives us improved combustion due to better mixing of the air and fuel in the combustion zone and longer time available for volatile in the combustion zone, right. Shorter length of the kiln and hence smaller footprint because the length now it is zig-zag. So you have, you know, you can, you can same length you can cover in a lesser area. So that is the idea. So it is an improvement over the previous one. It is an improvement over the previous one. The Buhrer zig-zag kiln was similar to Hoffmann kiln in construction. Draught can be created by fan or natural draught using chimney.

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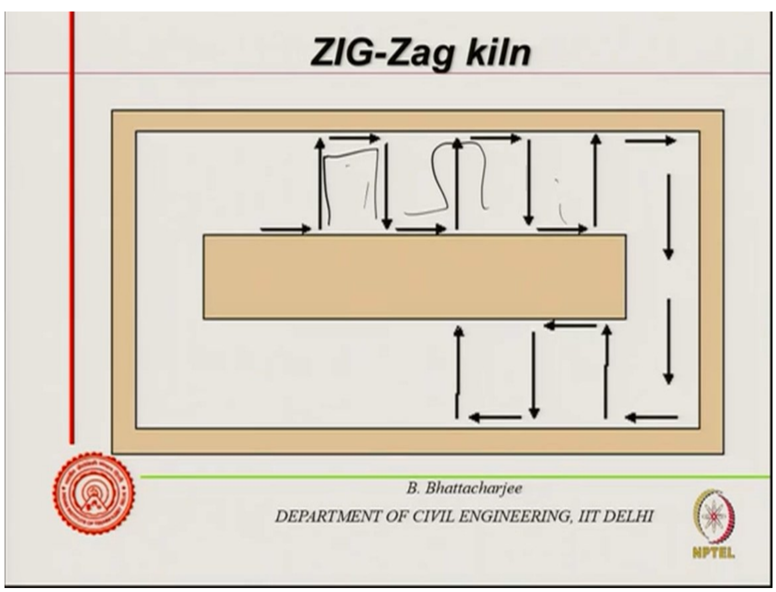

So basically chimney also creates natural draught. Hot Gases will tend to go, cool gases will come in. In this one, this is how the fire would move, right. So the path would be something like this. So bricks would be lagged in this manner so that the space here, it will move in this manner. So this is how the travel to the kilns I mean the hot air or by the fire moves in, you know, in, in this manner, right. So this is an improvement over the previous one.

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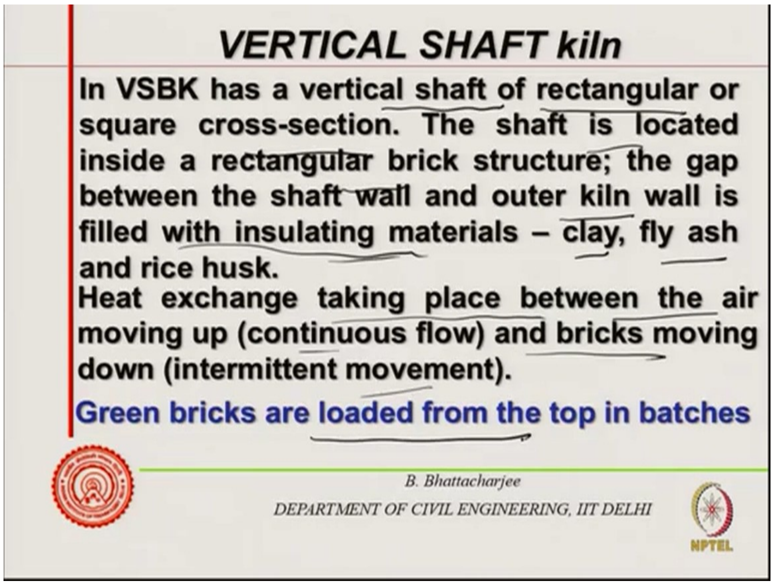

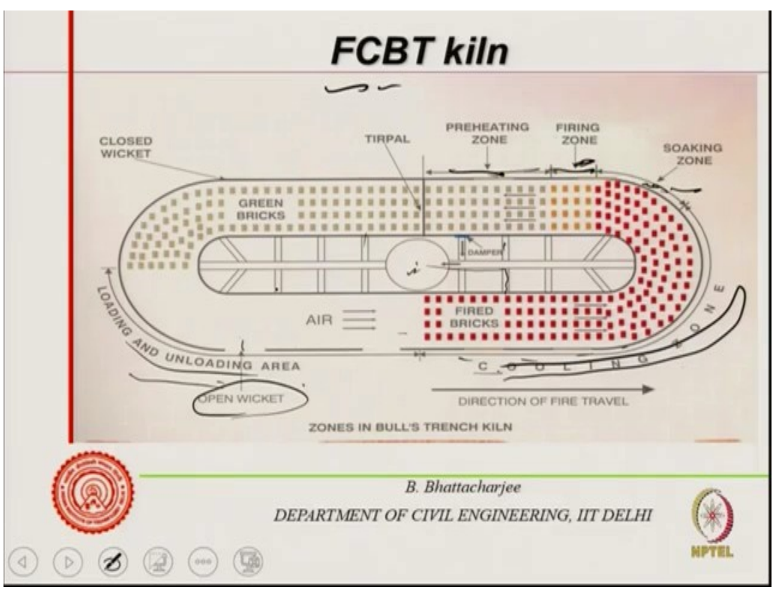

Then there is something called vertical shaft kiln. It has got a vertical shaft of rectangular or square cross section. The shaft is located inside a rectangular brick structure, right. So the brick structure itself and the shaft is there. The gap between the shaft and the wall and the outer kiln wall is fired with insulating material is filled with insulating material clay fly ash or rice husk or similar sort of thing.

So in the previous one you will have actually in both these cases you will have, you will have this roof covered with partially burned green bricks and then some ashes or something at the top to make a kind of insulation on top of it so both this one, here the same thing you can see, this is now vertical shaft that we are talking about is a vertical shaft kiln.

So heat exchange, you know, heat exchange taking place between takes space between the air, moving up continuous flow and the bricks moving down downward intermittent. So you actually feed the brick, they go downward. Hot air goes upward and this is not continuous obviously airflow is continuous, but the brick movement is not continuous. So let us see some diagram. Green bricks are loaded from top in batches.

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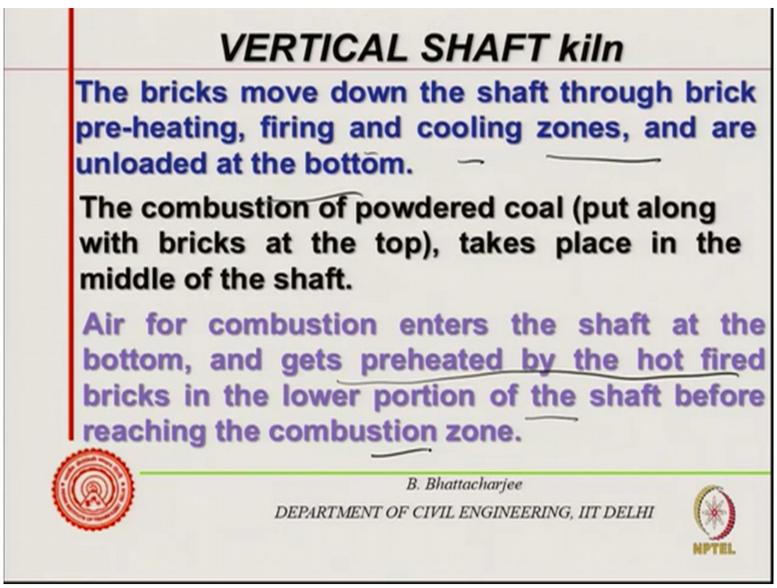

So bricks move down the shaft through brick preheating, firing and cooling zones and they are unloaded at the bottom. Now the combustion powered by coal put along the bricks at the top, right. So as the hot gases go up, they will actually ignite the coal themselves and a simultaneously you know firing will occur as as the, , you are loading, you know, (intermit) intermittent load is going downwards. So it takes place in the middle of the shaft. Air flow combustion enters the shaft at the bottom and gets preheated by hot fired bricks in the lower portion of the shaft before reaching the combustion zone.

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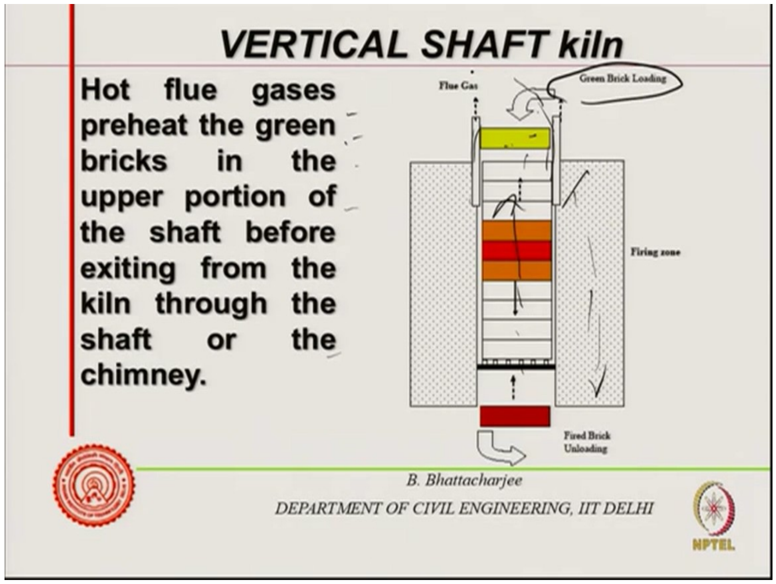

So this is how it looks like. Green Bricks are loaded from here. You know in, in some sort of a supporting system tray or something of that kind. And this, this is, this is itself is a firing zone, together with this I load also the fuel so fuel is also loaded and the binding is continual continuing as the binding is continuing hot gases hot air would move through this, hot air would move through this, this air will ignite this fuel and burning will take place here.

So once, this is intermittent, so you hold it for a certain period of time, but they are during the burning time and then this whole thing comes out. So flue gases will go out from the site and then it is unloaded from the bottom. So hot flue gases preheat the green brick so naturally if it is, you know this is going through this. So this can also preheat the green bricks in the upper portion of the shaft before exciting from the before exiting from the kiln through the shaft of the chimney. So this is a shaft of the chimney through that, you know, it will like just go out.

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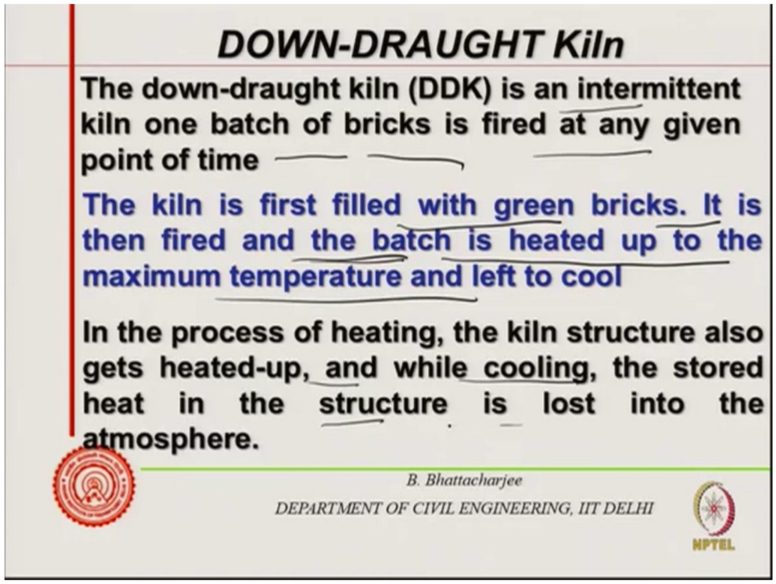

So the draught, this was, this was vertical shaft kiln, then you have Down Draught Kiln is an intermittent kiln. One batch of bricks is fired at any given point of time. So this, you know, every. The kiln is first filled with green bricks. It is then filled, fired, and this is then fired and batch is heated up to the maximum temperature and left to cool. So in the process of heating, the kiln structure also gets heated up. And while cooling the stored heat in the structure is lost due to atmosphere. So this, as we shall see, the energy part of it.

So these are the processes, but then we will look into the energy part of it. We will see that actually the efficiency of this system, because a lot of heat is lost. You first burn them and then you go to cool it with it before you load it. So cooling means the heat, whatever was there is actually wasted.

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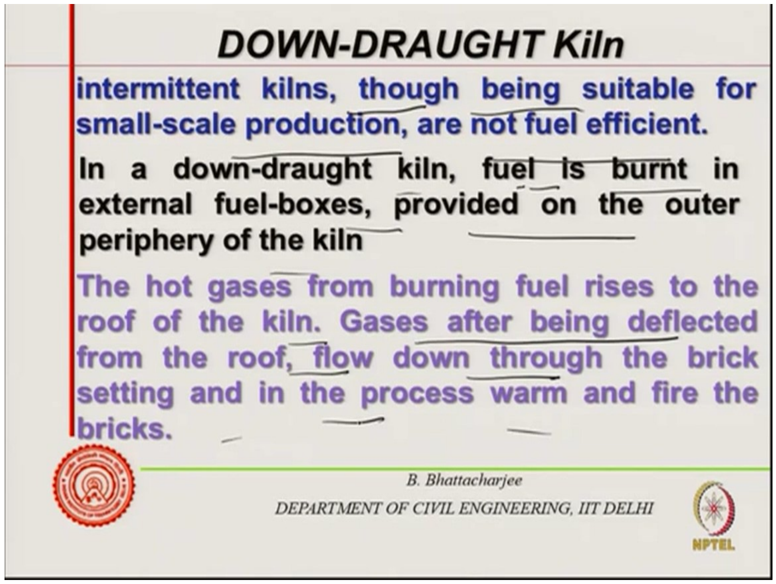

So intermittent kilns, you know this, this one Down Draught in which is intermittent though being suitable for small scale production is not fuel efficient. In Down Draught Kiln fuel is burnt in external fuel-boxes provided on the outer periphery of the kiln. The hot gases from the burning fuel rises to the roof of the kiln. Gases after being deflected from the roof, flow down through the brick setting in the process warm and fire the bricks.

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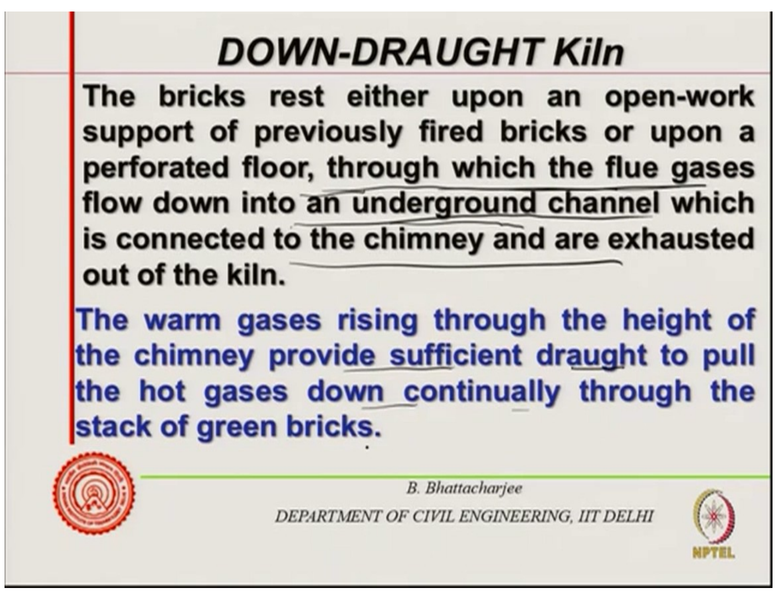

So the bricks rest either upon open-work support or previously fired bricks. That means you might have a, you know, kind of a, some sort of a support system built in there which will remain there and suppose the bricks on top of it or upon some perforated floor so that hot gases can go. Hot gases can move upward and flue gases through you know perforated floor, through which the flue gasses flow down into the underground channel, which is connected to a chimney and are exhausted through that kiln itself.

So the warm gases rising through the height of a chimney provide sufficient draught to pull the hot gases down continuously through stack of the green bricks.

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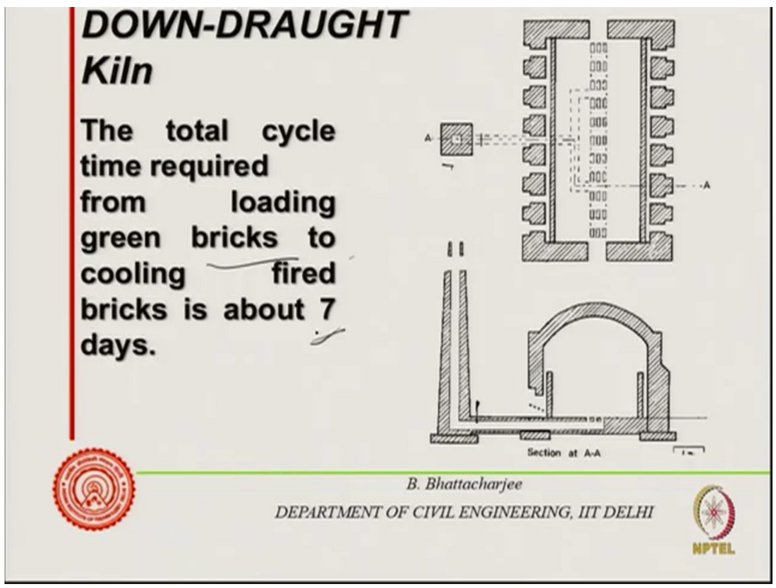

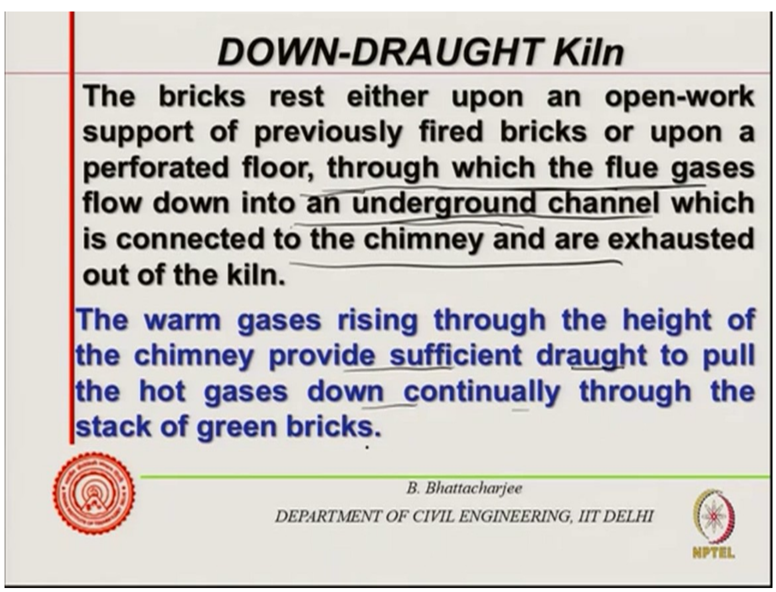

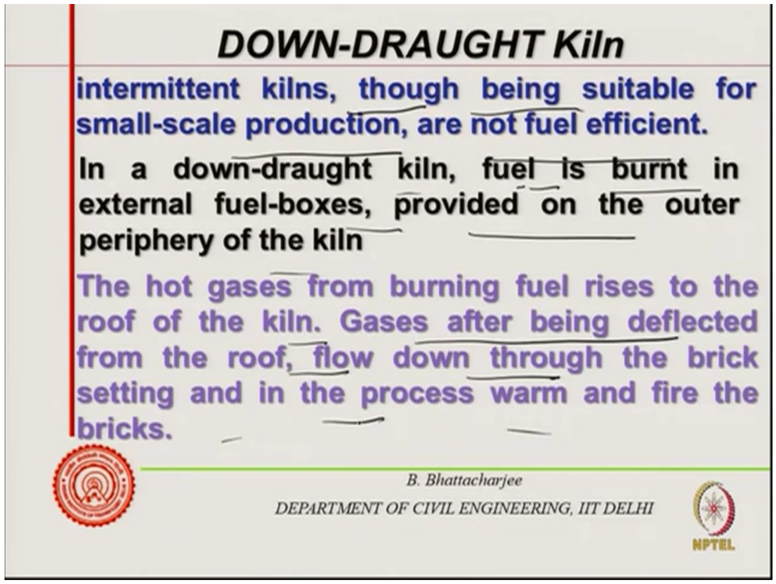

So this is how it looks like. You know, this is, this is the chimney somewhere outside, here are the bricks, right this is the chimney. So every, you know, there is this kind of perforated floor. So basically, , as, as you have seen earlier, the total cycle require, okay, this is separate. , this is what we have said is the bricks, the rest of course in some sort of perforated floor and the you know the hot gases flow down into an underground channel. So what you are doing is, you have basically fuel is burned in the external fuel-boxes provided with the outer periphery of the kiln that means if we will have something here some places here the boxes were a little burn.

I mean the heat will be supplied through this, they will burn and the flue gases will go out like this. So cycle time the cycle time because it is intermittent, not continuous, so it is around 7 to 5 bricks or 7 to 7 you know cooling loading to green from loading green bricks to cooling. It takes about 7 days or so. This is most common. You find them very commonly in many places with a small Kiln (())(15:07) of this kind, but not so efficient.

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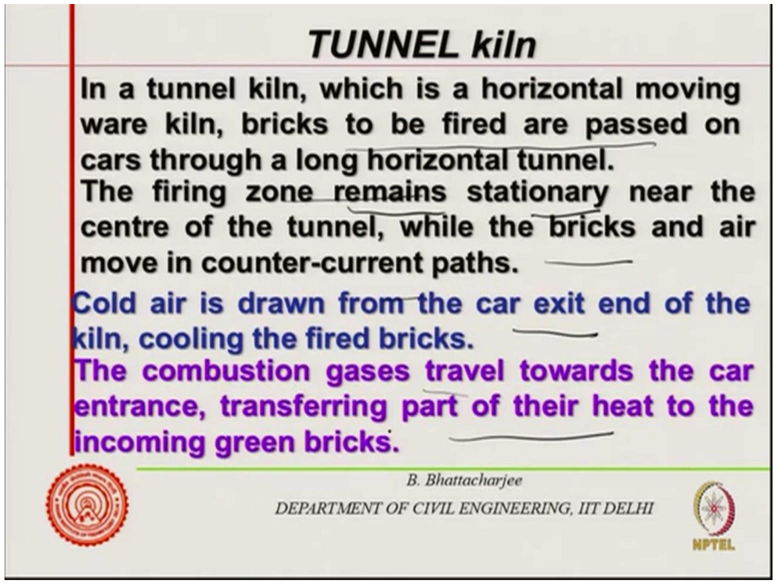

In tunnel kiln, which is horizontal moving ware kiln, bricks to be fired are passed on cars through a long horizontal tunnel. The firing zone remains stationary so that this cars will move holding to the firing zone, held into the firing zone. Once the firing is over, it is taken away and then the next plot will come in where the bricks and air move in counter direction because where will cool air will move in one direction, hot air move in the other direction so that green bricks gets little bit of preheated. So cold, cold air is drawn from the exit of the car and, and cooling they will, they will, they will cool the fire, fire bricks and preheat the you know previous bricks. Combustion gases travel towards the car entrance transferring part of the heat to the incoming green bricks.

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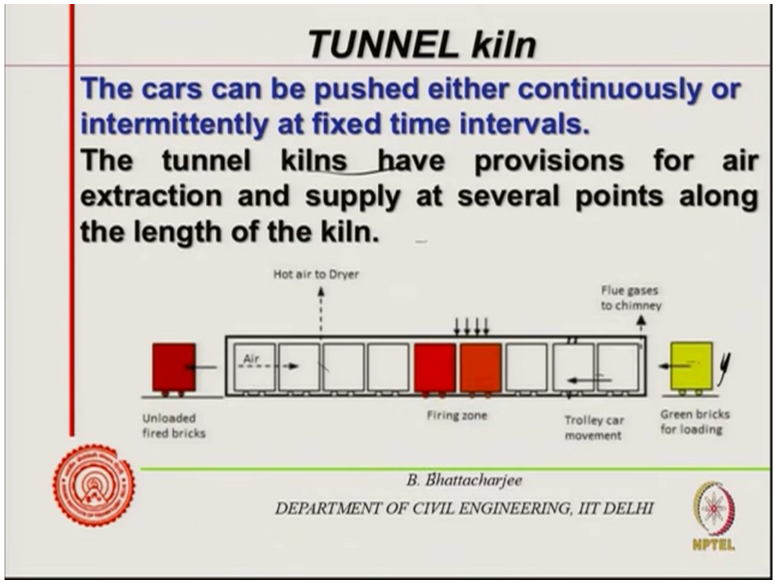

So the cars can be pushed either continuously or intermittently at fixed time of intervals. That is what is done. And the Tunnel kilns have provisions for air extraction and supply at several points along the length of the kiln. So this is how they look like there is a car, right? This is green bricks. So this is loaded here. This is his position. Okay this is the, this is the position. So flue gases, comes from, you know, the firing is occurring here and the air comes from this side, right. So this, this air, the air gets in the , I mean this, this, sorry area. This is the trolley car, the air I mean hot air, cool air comes from this side. Some of the hot air go to dry air. And then this, this follows and flue gases will actually preheat the green bricks. So this is this so this movable basically. So that is the types of bricks.

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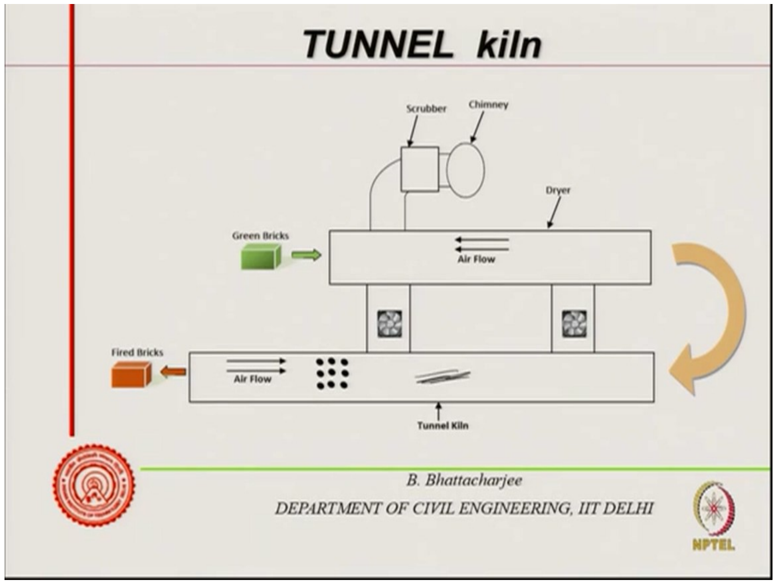

So this is, this is what it could look like. You can have a chimney here. The scrubber green bricks comes like this, the hot air flow, right, and this is a kiln so just, you know, I mean basically ia a hot, hot flue gases and all that. There is a fan here, there is a fan here which can drive it out and airflow through this, right. So the firing occurs in the tunnel kiln in here and the fire bricks comes out like this.

So this is the kind of bricks you have processes and first, first of all the clay bricks. We use a lot of alluvial soil, clay you have to take from, so therefore, land is also you are occupying certain amount of land. Otherwise, if it is let say blocks of some form I mean if it is from waste material like Fly ash then of course this is most advantageous. But however, this is still there very much they in practice in some parts definitely in India this (())(18:02) is there.

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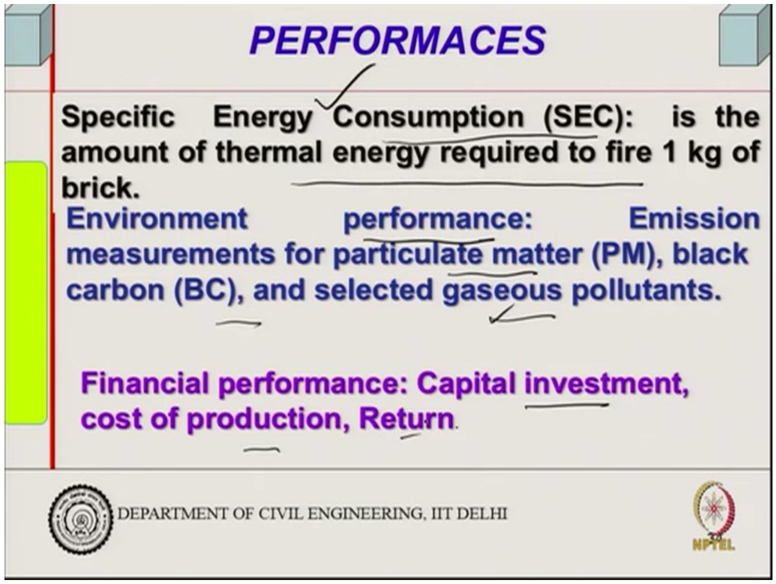

So we talk in terms of what is called specific energy consumption. It is a thermal energy required to fire 1 kg of brick per kg per units of specific energy consumption we are talking of. Then we talk of environmental performance, so this is one issue is this the energy consumption issue, other issue is environmental performance. So emission measurement for particulate matter, black carbon and selected gaseous pollutants. Then obviously the financial performance in terms of capital investment, cost of production, and you know how we get the return. So these are few performers one looks at.

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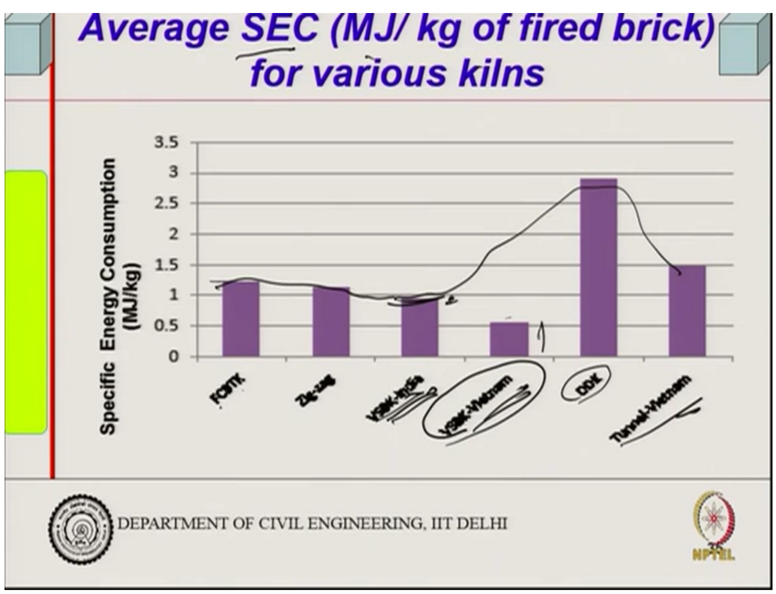

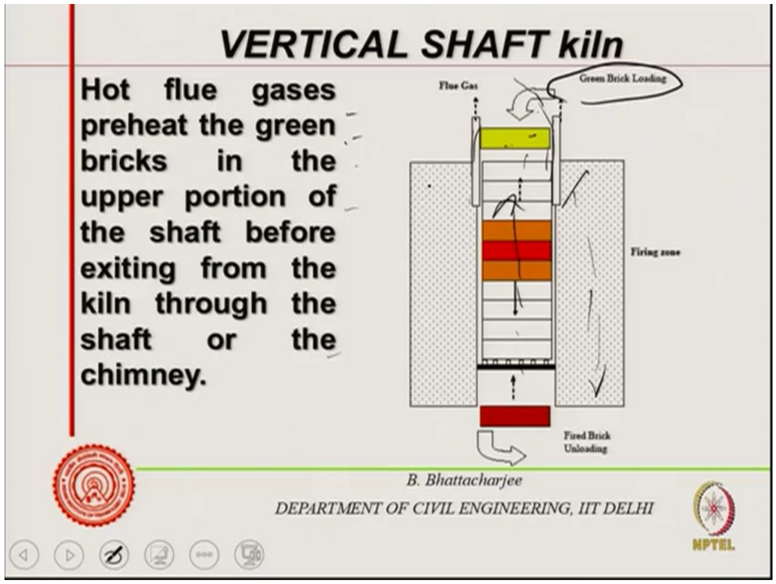

So, if one looks at the average specific energy consumption in mega joules per kg of fire brick for various kilns. The fixed chimney bools trench kiln it is of the order of around 1.2 mega joules per kg. Whereas, Zig-zag (())(19:11) have slightly less because you have an efficient system relatively. And then vertical shaft kiln is somewhere there, and this is the downward draught kiln and this is the tunnel kiln and this is the most efficient. You can see vertical shaft kiln you know which one we discussed earlier if you remember vertical shaft kiln.

Now this down draught kiln is one of those worst type, vertical shaft kiln you know, not this down-draught, not this, not this, vertical shaft kiln, this is what we talked about and this is the, this is the most efficient sort of from energy point of energy performance point of view. So vertical you know shaft, they are the, they are the one most efficient, they are the most, most efficient.

So vertical shaft kiln this is in Vietnam this is in India. This is in Vietnam, so the, you know, people, some people collected the data on those kinds. So in Indians in Vietnam also it is quite popular and apparently they have some sort of relatively more efficient system. But however, amongst all this vertical shaft kiln means the better one, or you know it uses (())(20:37) energy. So of the order of around 1 less than 1 mega joules per.

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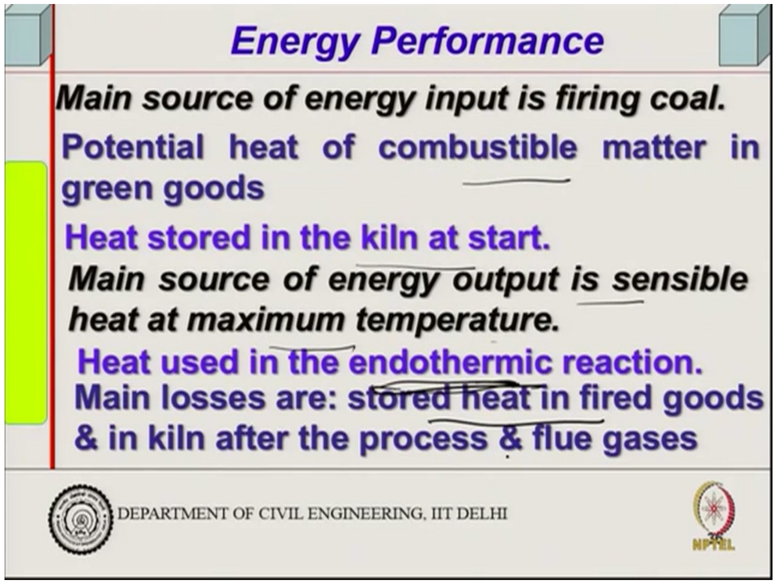

Main source of energy input is a firing coal. Earlier people were using timber also, potential heat of combustion, you know combustible matter in green goods, obviously that would be there. Heat stored in the kiln at start and main source of energy output is sensible heat at maximum temperature, right. So heat used in the endothermic reaction that so occurs, you know, the vitrification where it forms solid solutions there, the chemicals reaction I told you about earlier in the last class.

That is essentially the silica, you know, first the, first one obviously the mortar smoking would occur, free water would go away. Then in the water bound in the silicate and aluminate system that goes away forming the new product, if you remember we talked about the chemical decomposition of the clay product forming into a new fused solid solution, right. A new kind of compounds and that in the process actually initial process was endothermic it will take a lot of it. There is an exothermic component also, but , you know, main is the heat is used in endothermic part of the reaction like breaking the , this composition of the clay themselves the composition of the clay themselves. So main losses are stored heat in fire bricks itself, right after the process and also flue gases goes at higher temperature so there is some losses from there also.

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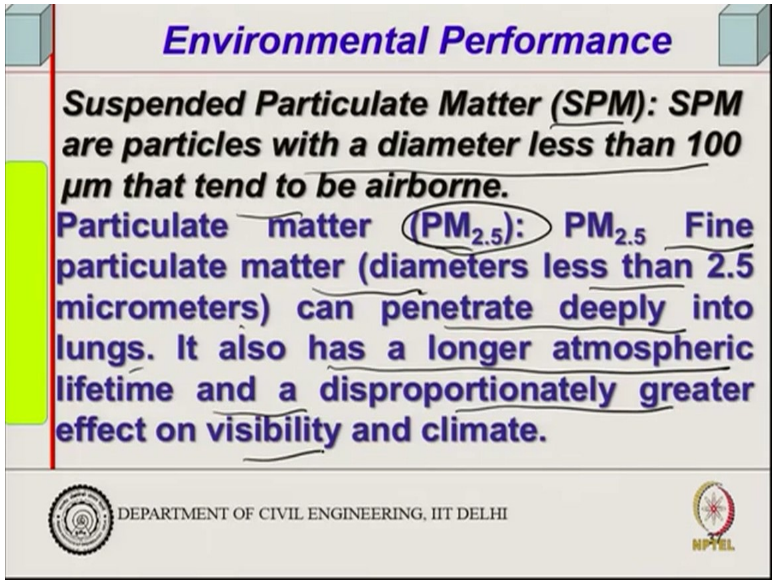

Environmental performances are measured in terms of suspended particulate matters, right. Suspended particulate matters that is particle with diameter less than 100 micron and that tend to be airborne, airborne. So particulate matter 2.5 is a basically the fine particulate matter diameter less than 2.5 micrometers can penetrate deeply into lungs. And it also has a longer atmospheric lifetime and disproportionately greater effect on visibility and climate. You know, that is what, that is what they say that because this particulate matters, they will come from burning, right. Burning of the fuel that you use in kilns.

And since the particle size is very small, they remain suspended for a much longer period of time and they can, you know, they can actually, that they can penetrate through your respiration process into lungs and they are dangerous.

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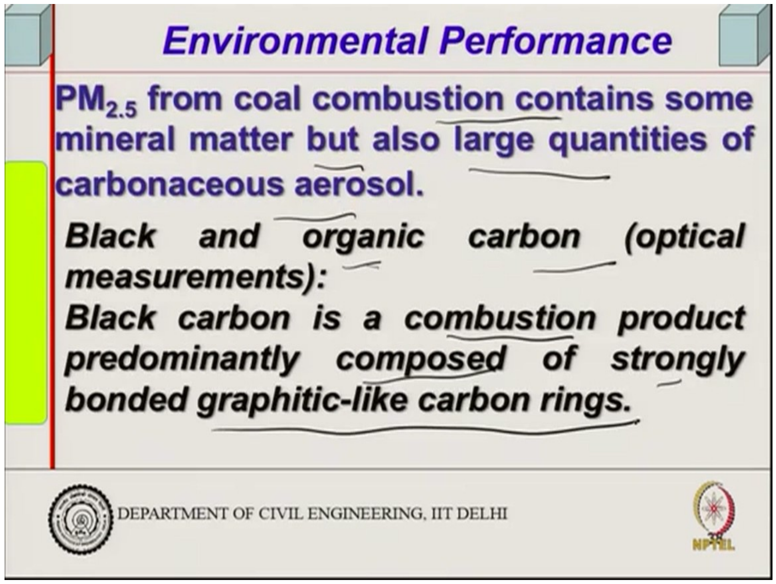

So PM 2 from coal combustion contain some mineral, but also large quantities of carbonaceous aerosol right. So aerosol are the fine particles that can remain suspended in the air. So that is what it is. So also, you know, like black and organic carbon, which you can measure through optical measurements. Black carbon is a combustion product, predominantly composed of strongly bonded graphite-like carbon rings. They are very fine material, aerosol formation, aerosol form.

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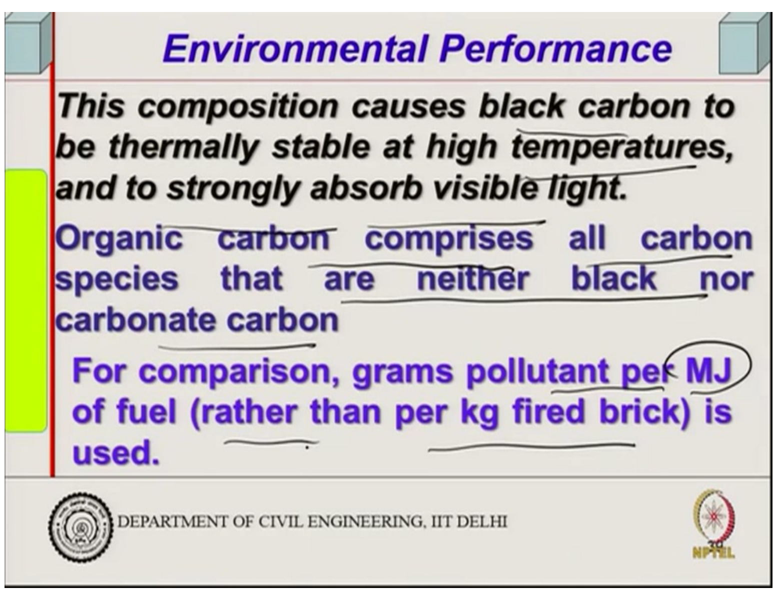

And this composition causes black carbon to be thermally stable at high temperature and strongly absorbed. They can strongly absorb visible light. So when you are heating black carbon, you know it can absorb light and it is stable at higher temperatures. So that remains while your vitrification occurs. Organic carbon of course comprises of all carbon species that are neither black nor carbonated carbonate carbon. So there are all carbons that is what you call it organic carbon.

So they are not necessarily all will be suspended in air, but black carbon is the ones which can be. For comparison, grams pollutant per mega joules of fuel rather than per kg fire brick is used. So we have used specific energy in terms of per kg of brick. But when it comes to, when it comes to, when it comes to pollution, right, we look into per mega joules of fuel because it comes from the pollutant comes from the fuel, not from the coal. So if you are using more fuel and more specific energy consumption is more, obviously the pollution also will be more.

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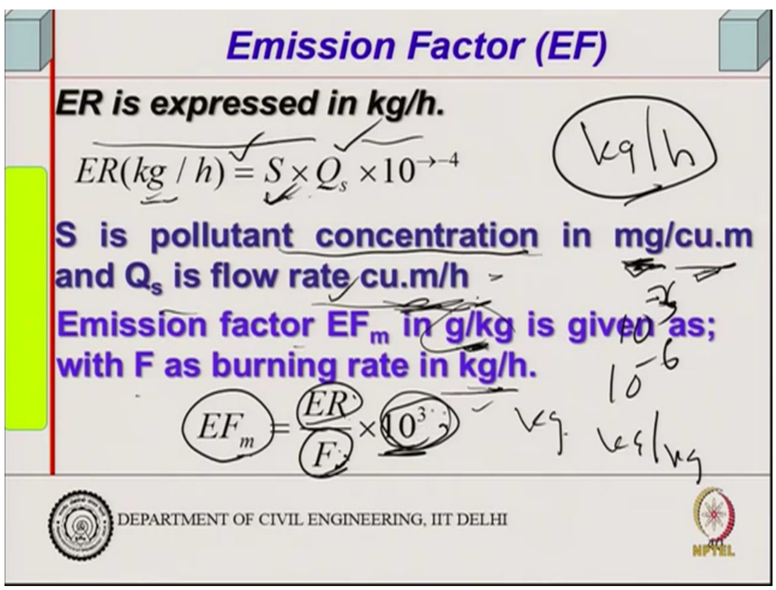

Then there is something called emission factor. Emission rate is expressed in, kg per hour, emission rate is expressed in kg per hour. So kg per hour, which is S is the pollutant concentration, right. So emission rate, you talk in terms of pollutant emission actually in milligrams per cubic meter and Qs is the flow rate. So if Qs is the flow rate from the chimney and S is the pollutant, pollutant concentration, then this would be S into Qs 10 to the power minus 4 because this is, this is in kg per hour and this is in milligram per cubic meter. And this cubic meter per hour, so milligram, you got to convert into kg, milligram you want to convert into kg, right.

So a cubic meter hour this is in cubic meter hour straightaway. So milligram would mean how much? 10 to the power minus yeah but, minus, you know, these cubic meters will cancel out, milligram per, milligrams in 10 to the power minus 3 and 10 to the power minus 6 kg. This is why this is 10 to the power minus 4. It is not definitely not per meter square. So this kg per hour, S is pollutant concentration in milligram per cubic meter, if we simply multiply S by Qs I will get milligram per hour which (())(26:47) minus 6 actually, so anyway we will come across this again.

Emission factor in grounds per kg is given as with F as a burning rate in kg per hour. So if my burning rate is FKG per hour, emission factor is emission rate divided by F into 10 to the power 3, emission rate, emission rate divided by F into 10 to the power 3, right. So emission rate is in kg per hour, emission rate is in kg per hour and this is in kg per hour. So this simply a dimension less quantity, right. But, is given in terms of multiplied by 10 to the power 3 because this term will be relatively small, so this is, this is sorry this is grams per kg, one of them is in grams per kg so 10 to the power 3, so emission this in grams per kg so this will be in kg per kg multiplied by 10 to the power 3.

So this, you know, this emission rate is in emission rate is in kg per hour. This is also in kg per hour. But this is this. So this is multiplied by 10 to the power 3 because this is expressed in grams per kg, this is expressed in grams per kg. So this would have been, this would have been what? This would have been kg per hour divided by the burning rate kg per hour, again, kg per hour. So this is expressing grams per kg. This is emission performance is expressed in grams per kg, kg burning rate of fuel and this was pollutant concentration kg per or the flue gases. So there is a multiplying factor 10 to the power minus 3 coming here because I think it is converting into kg to gram somewhere we will see that, we will see that actually it will come out through.

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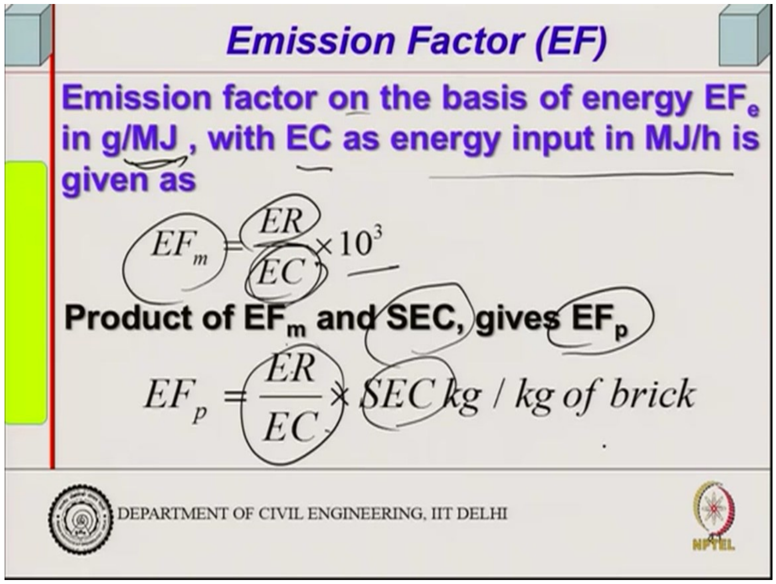

So emission factor on the basis of energy is grams per mega joules. So EC is the energy input mega joules power, which is given like this EFm ER over EC into 10 to the power 3. So you can talk in terms of per grams per mega joule rather than grams per kg. But in that case, this will be, you know, EC is that energy input mega joules per hour. So product of EFm and SEC gives performance emission factor performance product of this ER by EC SEC per kg, per kg of brick. Because this is expressed in terms of mega joules per kg and this is in terms of mega joules per kg, now, and therefore you can express in this manner.

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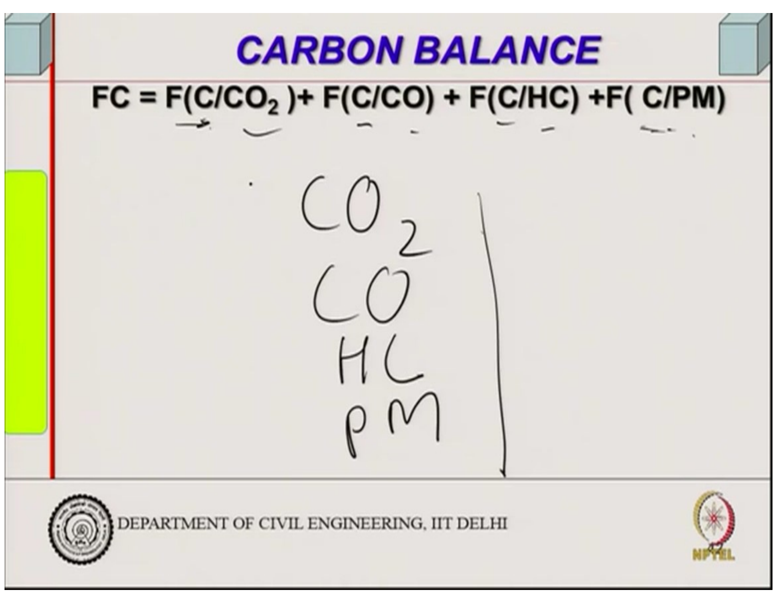

Then the other issue is carbon balance. F of course is from the fuel because burning of fuel will produce carbon dioxide. It will also produce carbon monoxide. Some hydrocarbons might be left and some carbon in some particulate form like carbon black, et cetera, et cetera. So if you know, you know, if you know the carbon in carbon dioxide that is known, carbon in carbon monoxide and known and carbon in type of hydrocarbon it is known and in particulate metal, metal (()) (30:21) of carbon if it is known then you can find out how much is the, how much is the carbon in unit fuel, unit, you know we are talking in terms of cubic meter per hour. So that is what we can find out.

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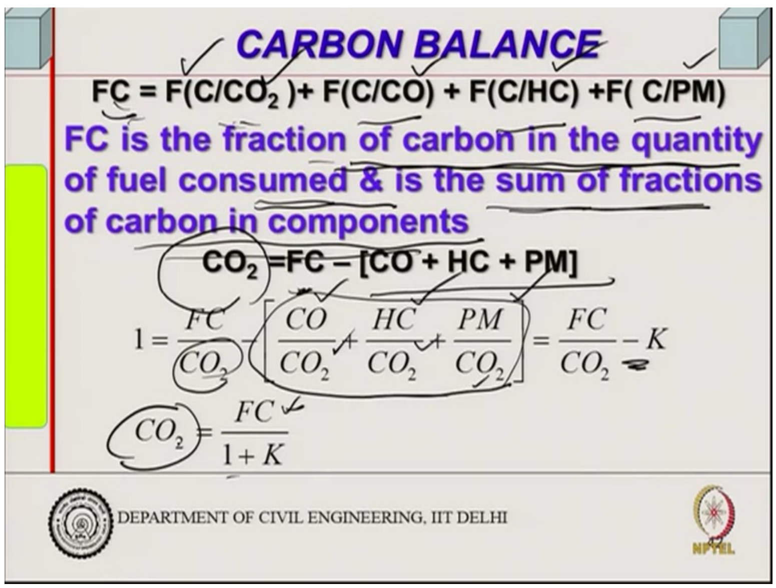

FC is the fraction of carbon in the quantity of fuel consumed and is a sum of fraction of carbon in components, right. So carbon dioxide is totally, if I am looking at carbon dioxide alone, then FC is a fraction of carbon in the quantity of fuel consumed and, and is a sum of fractions of carbon in all the components which are carbon. So there are four components. That is carbon dioxide, carbon monoxide and hydrocarbons and particulate matter, which can have carbon. So FC is the fractional carbon the quantity of fuel consume, right.

And only in this four components I have got carbon. So this is the fraction of carbon as per as carbon dioxide is concerned. This is in carbon monoxide, this is in hydrocarbon. So carbon dioxide therefore, would be FC minus all this because we are interested in the Carbon Dioxide. So FC divided by quantity of carbon dioxide is written something like this. FC, you know, this is written in terms of a term K. So one can find out the carbon dioxide, FC plus 1 by K where K stands for proportion of carbon monoxide to carbon dioxide, proportion of hydrocarbon to carbon dioxide and proportion of carbon in the particulate matter with respect to carbon dioxide. So this gives us, you know, if so, if you know this FC, FC one can obtain how much carbon dioxide is produced. Okay.