Sustainable Materials and Green Buildings
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Lecture No. 24
Thermal Diffusivity and Clay Bricks

So, having looked at thermal conductivity now we can look at thermal diffusivity which is a which is another other other property associated thermal you know energy efficiency and things like that.

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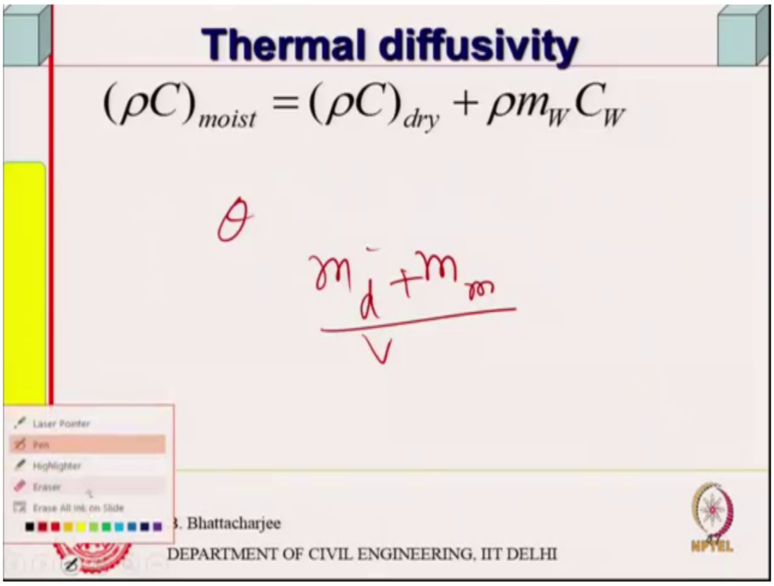

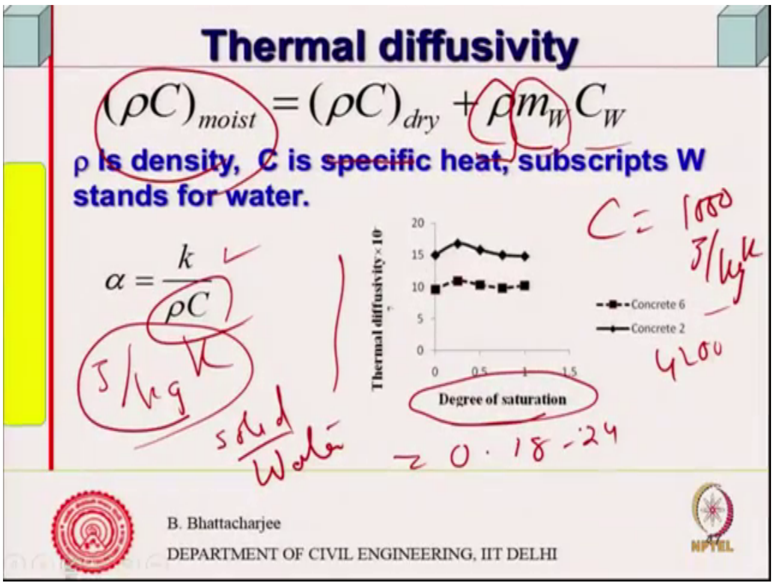

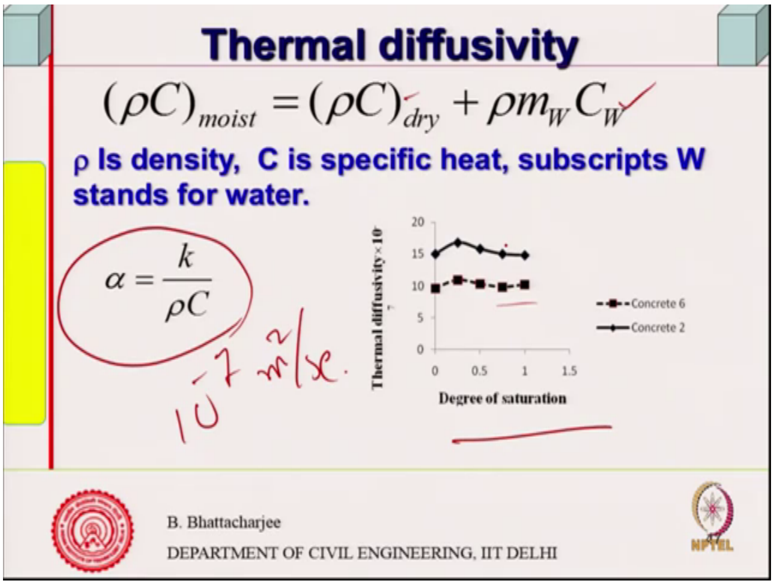

Now this one is thermal diffusivity of volumetric heat capacity. It is a simple additive property. For example, if I have (mois) if I have some moisture, some theta degree of saturation then it will cause increase in the moisture content and mass will increase by the amount of moisture, so supposing I am trying to find out the mass per unit volume, density.

Density is very simple, mass of the dry material part unit volume plus mass of the moisture simply per unit volume. So in the total volume what is a mass? Now in porous material I take the bulk volume, so bulk density we talk of. So it would be simply additive property simply additive property whatever moisture has gone in 1 meter cube that will add to the density. It was air, air density of air is neglected so just add it.

Similarly, specific heat is also as a additive property because it is the amount of heat required to raise the temperature to 1 degree, through unit unit mass raise the temperature of unit mass through 1 degree. And that if you add another material you will simply add that quantity, so these are additive properties. So row C is a volumetric heat capacity is simply an additive property. So row multiplied by mass of the water plus specific heat of water because air specific heat we neglect or density is also neglect.

So specific heat subscripts W stands for water. So thermal diffusivity is alpha divided by K by row C and if you see with degree of saturation, thermal diffusivity varies in this manner. Relative variation is small even for all the materials that we deal with their specific heat varies very little. The ratio of specific heat of these materials to water, you know that is the specific heat in CGS unit. Ratio of specific heat, ratio of specific heat if I take it could be written joules per kg per degree Kelvin (per) Kelvin .

So this this ratio of solid any solid to water for water, for concrete acetate varies only from about 0.18 to about 0.24 or even less 0.2 to 0.24. So the variation is not very large they are very less. While it would be slightly if you see the values of this row C, I mean C particularly. You will find that it is around 1000 joules per kg. For most some will have 1100-1200, some would have 800-900 so they do not vary much. But here also C does not vary much.

But water has got something like 4000 somewhere around 4200 somewhere around that level. So the ratio is around its variation is relatively small. While thermal conductivity can vary from material to material something for 888 concrete it can be 0.01 or 02 for some solid concrete it could be 2 or 2.5. So the variation is much higher and if it is moist the variation you have seen that it could be three, fourth times increase. While specific heat do not vary so much. But simply one can write is in this manner row C, one can write the row C simply in this manner.

So this model and you see degree of saturation thermal diffusivity do not vary that significantly not as much as row C into multiplied by 10 to the power minus 7. So it does not vary (vary) thermal diffusivity do not (())(4:30) it is a ratio. So row C not vary much.

Thermal diffusivity also in that sense varies only the conductivity. So for this (())(4:41). So one can simply model this very simple there is no complicacy involved in it one can just simply model this. Thermal conductivity and diffusivity you can find out in this manner. So they are of the order of 10 to the power minus 7 meter square per second meter square per second most problem. So that is what it is for concrete some concrete it would be something of this order and another concrete it would be of another.

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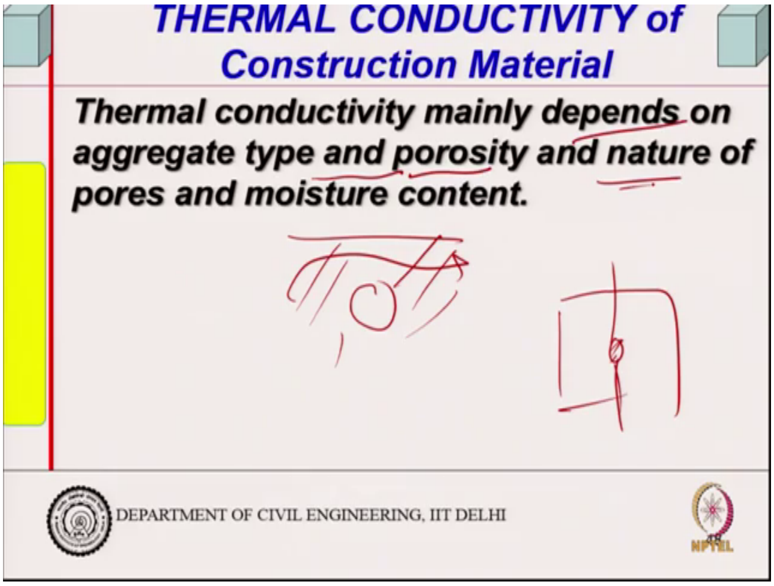

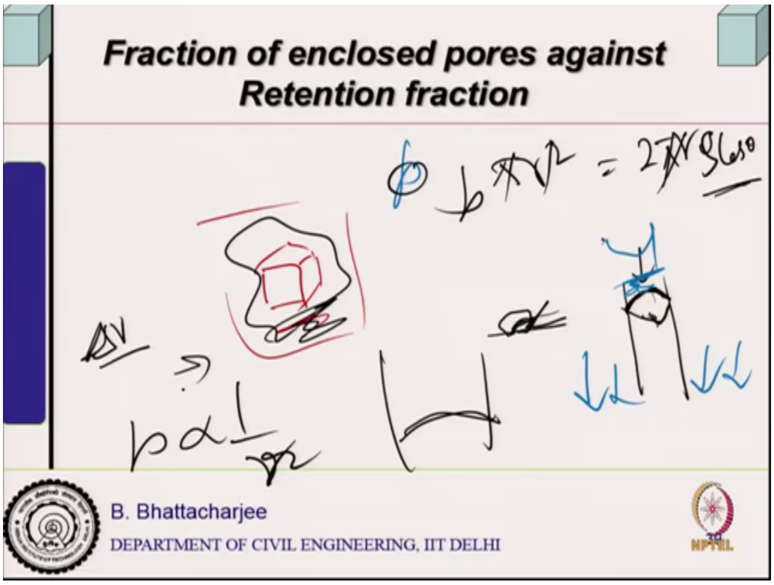

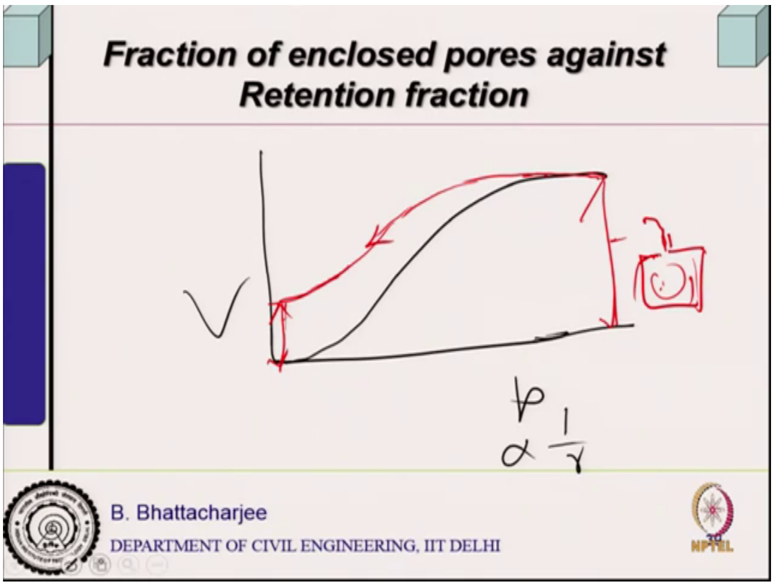

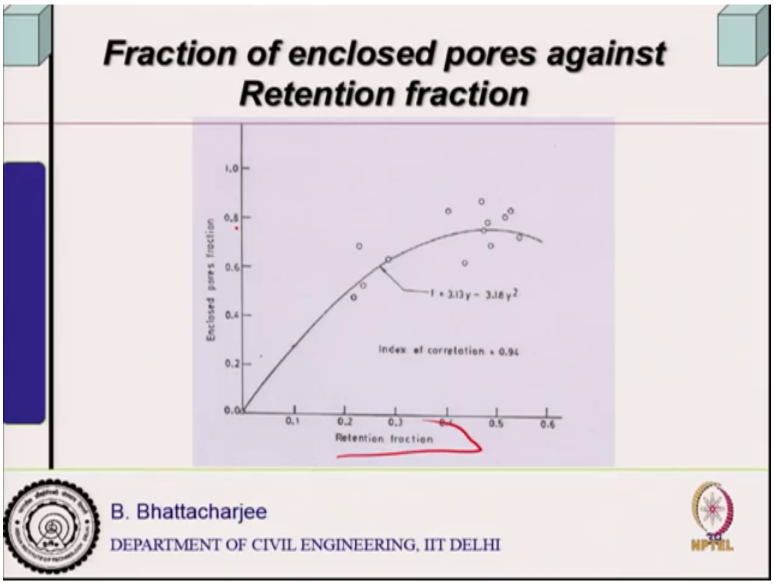

So by then then all all putting it summing it up all together for this kind of material, thermal conductivity mainly depends on, for concrete it depends upon aggregate type. For bricks it will depend upon the solid because firebricks will have different, ordinary bricks will have different, fly ash bricks will have different and so on. And then largely depends on porosity, nature of pores and moisture content.

Now what is nature of pores? Nature of pores means how much how much how much proportional of heat is actually closed and how much proportional of heat is relatively open, relatively close and relatively open. So it depends upon that because if there is a pores which is closed inside solid it will allow for the heat to pass around it. And if the pores are larger pores with solid which surrounds the solid it will block the path and the conduction path will be only through the connecting part of the solid itself.

Therefore, the nature of proportion of this porosity is important porosity is important. And these such thing can be related Mercury intrusion porosimetry last class I was mentioning you. Because through Mercury intrusion porosimetry you can find out what is called the volume of pores versus the radius of pore how? Essentially you have a sample which is first evacuated, small sample which is first evacuated. Let us say evacuated and then you know put it, submerge it into, submerge it into Mercury, submerge into Mercury at atmospheric pressure, at atmospheric pressure.

So evacuated to let us say 1-micron level or such level of evacuation then allow it to submerge it into water I mean Mercury. Mercury will penetrate at atmospheric pressure then applying more pressure because Mercury is a non-wetting liquid. As you recollect it will form something like this on solid. So you want to spread you will have to pressure. They do not go into the pore on their own where water is wetting liquid, so in case of water you get something like this. In case of Mercury will get something like this because of the contact angles, surface tension property.

So you want to bring it to this level you have to actually push. So in fact in a capillary there will be a depression, capillary depression I mean no to the water will be somewhere, water will be somewhere up, water will be somewhere up there forming a meniscus, if it is a mercury, it will not penetrate, it will have capillary depression in fact in a capillary. So you want to, you want to bring it to the same level you will have to actually exert pressure all around. You have to exert pressure all around so then Mercury will go up. So as the pressure increases and it is a function pore size because it is given by you know surface I can actually equate and find out. It will be related to pressure pie r square very simple of course, let us do it quickly.

Pie r square into p, the pressure I am applying must be equals to twice pie r you know twice pie r twice pie r into twice yeah you see I means. I might denote it by Sigma or I do not know what did I used s s, twice pie r s. And there will be an contact angle theta cos theta, so this would be their cos theta contact angle will be involved. So basically r will cancel out, pie cancels out, pie r will cancel out so it is basically p is inversely proportional to r. Rest all is, rest all is okay for you so twice pie r you know rest of these things.

And it depends upon the contact angle, so Mercury has a contact angle for most of the solids more than you know it is 90 degree, plus 90 degree plus for glass it would be something like 140 degree. So Mercury as a contacting even much higher therefore this this angle I am talking of angle this angle this angle, this is angle which is more than 90 therefore it forms a kind of (()) (9:23) globule rather than wetting. So if you apply higher pressure it goes into the pores and I can actually monitor the volume of pores. So I can find out delta V into that as a function of r.

So at each r how much it is gone in I can find out but what happens is when you actually do a test results, test you will find that this is a kind of curve. This is your P versus V, P versus V, P versus V or I can write this would be actually proportional to 1 by r. That I can find out with respect to r but for this class I am not really interested in that. So P versus P and when you actually when you actually release the pressure the Mercury comes out but it does not follow the same path. So this is my return path and it comes out and some Mercury is retained. This is called retention this is called retention.

And fraction of retention you can find out because this divided by this is a retention fraction. Now retention fraction depends upon the nature of the pore. For example, they are something called D- module pores which has got narrow neck but wide inside something like this you know wide inside. So at at when you release the pressure at higher pressure some Mercury comes out through this but there will be large amount of Mercury still entrapped till you will remain entrapped.

So therefore this is a measure of the kind of enclosed pore, pores which are surrounded by solid on all directions roughly. So this retention fraction can be related to fraction of enclosed pores, fraction of enclosed pores something like this so retention fraction. So experimentally you can get some idea related to related to some idea related to how much is a pores which has been which are enclosed pores, so this also can be determined. So this is I think deals with the thermal conductivity part of it most of it for porous materials.

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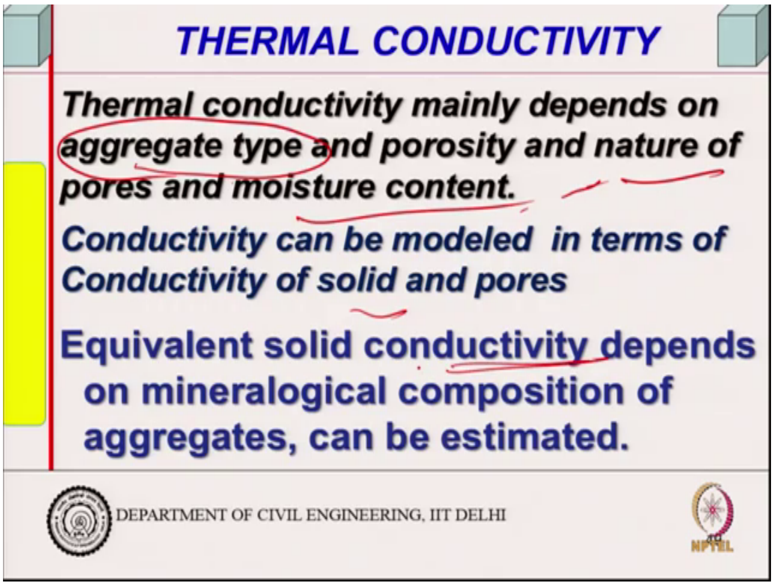
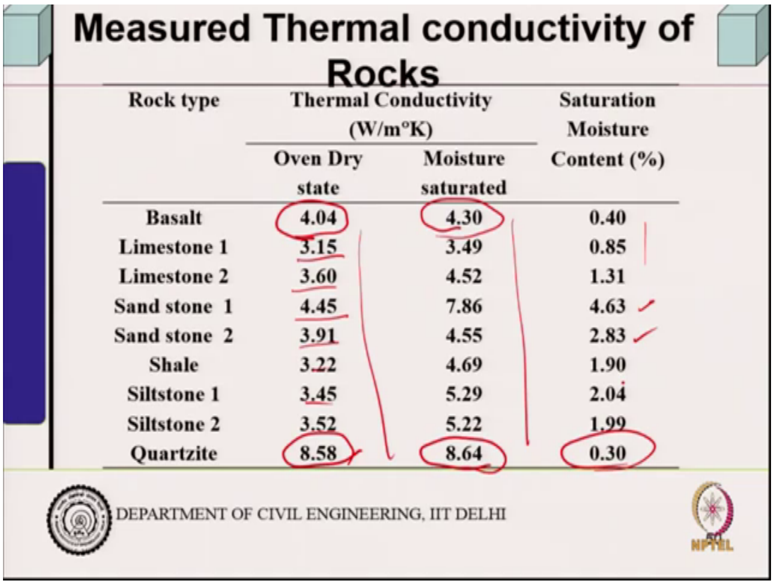
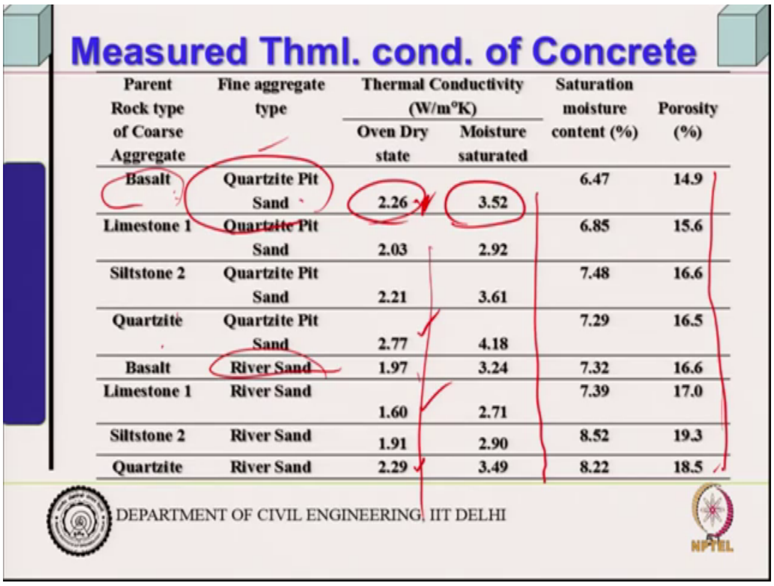




Measured Thermal conductivity of Rocks

Rock type	Thermal Conductivity (W/m°K) Oven Dry state	Thermal Conductivity (W/m°K) Moisture saturated	Saturation Moisture Content (%)
Basalt	4.04	4.30	0.40
Limestone 1	3.15	3.49	0.85
Limestone 2	3.60	4.52	1.31
Sand stone 1	4.45	7.86	4.63
Sand stone 2	3.91	4.55	2.83
Shale	3.22	4.69	1.90
Siltstone 1	3.45	5.29	2.04
Siltstone 2	3.52	5.22	1.99
Quartzite	8.58	8.64	0.30



Measured Thml. cond. of Concrete

Parent Rock type of Coarse Aggregate	Fine aggregate type	Thermal Conductivity (W/m°K) Oven Dry state	Thermal Conductivity (W/m°K) Moisture saturated	Saturation moisture content (%)	Porosity (%)
Basalt	Quartzite Pit Sand	2.26	3.52	6.47	14.9
Limestone 1	Quartzite Pit Sand	2.03	2.92	6.85	15.6
Siltstone 2	Quartzite Pit Sand	2.21	3.61	7.48	16.6
Quartzite	Quartzite Pit Sand	2.77	4.18	7.29	16.5
Basalt	River Sand	1.97	3.24	7.32	16.6
Limestone 1	River Sand	1.60	2.71	7.39	17.0
Siltstone 2	River Sand	1.91	2.90	8.52	19.3
Quartzite	River Sand	2.29	3.49	8.22	18.5

So we said that we were saying that it depends upon the volume of pores, nature of solids, volume of pores and nature of solids, volume of pores and nature of solids, it depends upon volume of pores and nature of the volume of the pores..

So as we said depends upon nature of (pores) porosity and nature of pores, so this is the nature of pores part that just mentioned and moisture content. So it will depend upon for concrete it will depend upon aggregate type because that forms the bulk 70 percent of the volume of concrete is actually aggregate volume. And this you have done already equivalent conductivity we have seen that. So this conductivity of the solid would depend upon mineralogical composition.

For example, pores conducts more compared to many other minerals, so it has the highest so because crystalline structure of it. So if you look at rocks, oven dry state you will find basalt rock will show a conductivity of 4.40. And in a saturated state something like this. Then if you will look at Quartzite that is what I saying which origin is quartz 8.64, 8.58 to 8.64 not much of an increase actually because saturation moisture content is small they are not as porous as bricks they are not as porous as bricks, limestone, sandstone. So it depends upon the nature, the rock type and their degree of saturation is relatively small.

So moisture content finally accept this let us say sandstone it has got 4 percent moisture content, the saturation 2.83 etcetera etcetera. So for rocks thermal conductivity varies with the rocks and if you are using them in concrete they will dominate the solid conductivity, they will dominate the solid conductivity. But then one cannot use them unless one is trying to specifically generates a somewhat lightweight aggregate concrete or somewhat a concrete because aggregate normal structural concrete we will use locally.

But if you know you can know if you know that type of aggregate you know how much will be the conductivity and how much insulation you really want to put to make it up. So if you look at fine aggregates if it is quartzite pit sand, this will be of this kind thermal conductivity. And you can combine them parent rock also you can have river sand which may not have as much you know like quartzite origin may be of some other origin. So one can find out thermal conductivities of various combinations of concrete using this solid conductivity of will vary on the aggregate type that is what this shows. So for basalt aggregate for example in dry state this 2.6 while you come to limestone it is 1.60 it can go to 1.60.

And quartzite with river sand is something like this, quartzite with quartzite is the maximum. So depending upon type of your fine and coarse aggregate the original mineralogical composition we will find the (moist conduct) dry conductivity varies in this manner and saturated conductivity might vary in this manner and porosities concrete porosities are relatively less. While bricks will have 30 percent clay bricks this will be the order of maximum 20 percent.

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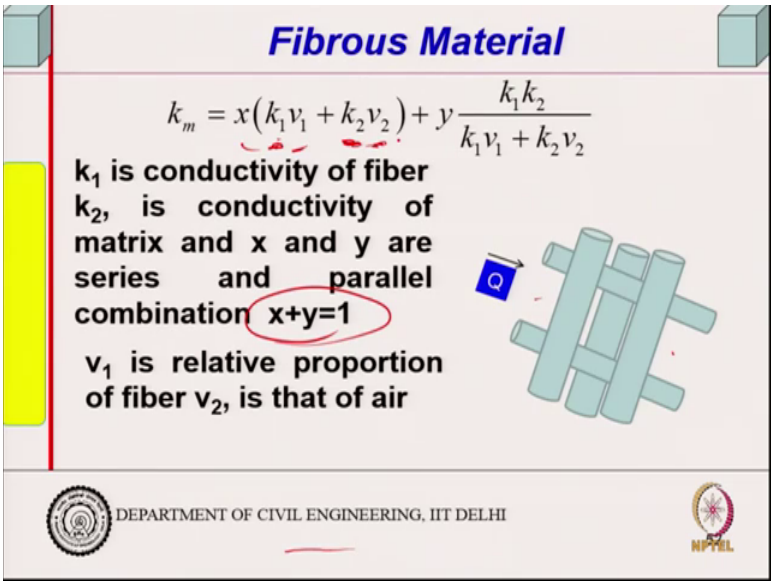

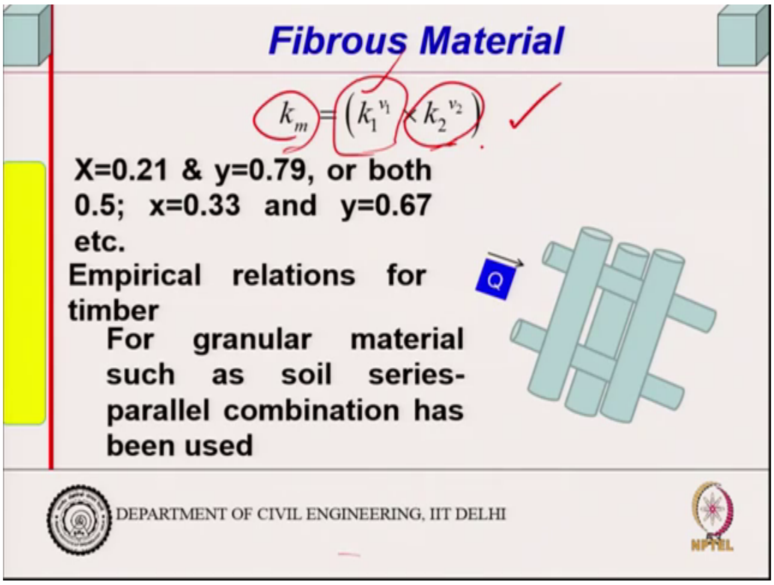

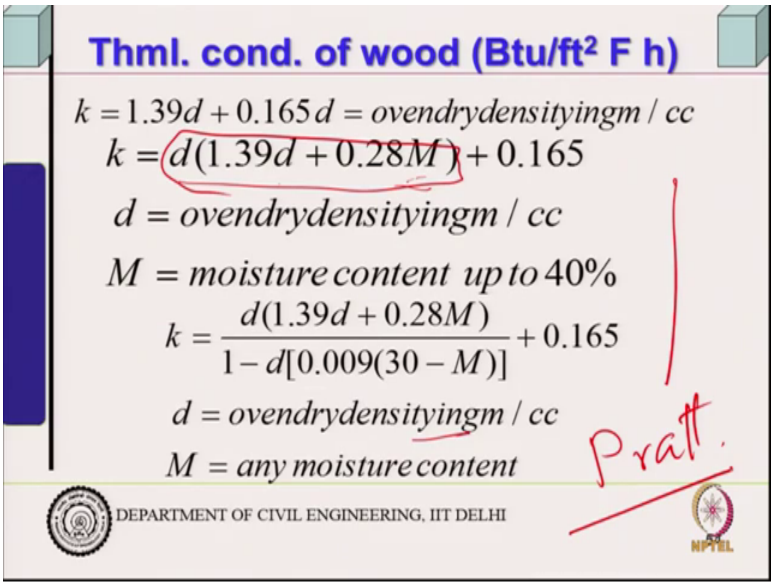

So these are related to such kind of porous material which forms large class of a construction material. And if you are trying to use let us say precast concrete system, the wall is precast, the roof is also, ceiling ceiling and the floor system is also precast, the roof is also precast. Then everything is a precast unit and they are structurally connected monolithic that would save a lot of your money. But then you got to look into this sort of aspect also if you are looking into issues of energy load and things like that.

So when you have a multifunctional system which serves like like a precast box system, precast box system let us say. Something like hollow claw coarse slab here wall panel, precast wall panels, precast wall panels are on all sides. Then you got to look at there, these properties as well. You can ignore these properties because they would either require cost they would either lead to use of higher insulation material in order to satisfy the requirement of energy efficiency and things like that. Or may require less insulation, so additional insulation will finish that will depend upon up on those.

So fibrous material are the other kind of (con con con) construction materials. So generally the fibers are whipped in this manner. And this material heat chroma might take place like this. Essentially you know this is a solid fiber will conduct the heat, the air will not. So you can talk in terms of you can actually again talk in terms of conductivity of the fiber, volume proportion of the fiber and you know K2 is a (propo) proportion of the matrix if it is in a matrix.

So in a fibrous material let us say timber which is natural fibrous material you have cellulose embedded in lignin matrix. And if you have an insulation you might have something like let us say some you know some matrix like epoxy or something of that kind some matrix and then you will have some nylon fibers or something in it. So if it is insulation material one is to choose accordingly.

So this is the thermal conductivity of the matrix. This is a volume proportion of the matrix. This is the fiber conductivity of matrix and x and y are the proportion of series in parallel combination. That is what one can model as because this is as this is you know this how much is as one can think matrix is parallel to the fiber and matrix in series with the fiber or matrix is in parallel to the fiber the way we looked into. So fiber and that could be relative proportion of fiber that could be if it is simply fiber and air than one can think in terms of that should be air also, x plus y is again equals to 1 because x is parallel proportion like we discussed earlier.

So fibrous material one can think in terms of these, so people have also tried to put in geometric proportion of the same, series parallel model combination. So for example this is one model this is the this is one model the to the power v1 geometric mean of the proportions. If it is both 0.5 x equal to point y is equal to 0.67 etcetera. So one have tried lot of empirical relationship with these. For granular material such as soil, series parallel combination so one people have used this for similar combinations of series parallel what we have said earlier has been used or geometric proportion as we have used in the previous model model.

This is a geometric mean where K1 is the one form of conductivity, series conductivity K2 is a parallel conductivity or if there are 2 materials even their people air. For example, air and solid one can knew geometric mean.

So fibrous materials of something of this kind, now wood if you look at it there are some empirical models. For example, K this is in Btu feet because the empirical model so units are important. So thus in fps unit British thermal unit fit square Fahrenheit and hour, that is are old experimental work they did and d stands for oven dry density.

So some of this empirical relationships are of this form, moisture content for moisture content yeah this is another kind another relationship with moisture content. So linear relationship as moisture content increases, oven dry density so this is another relationship for moist conductivity of wood. There are some more empirical relationships of this form oven dried and at any moisture content. So there are some empirical relationships of the kind people have tried for timber.

So basic difference between granular porous material or this is that they are here due a fibers. Again the complete modeling based on fundamentals is not available this is given in book by A W Pratt. So large number of data they have generated from earlier work. A W Pratt transmission of heat in solids, so you get some empirical model. So that is about thermal conductivities, thermal conductivity of varieties of materials that is generally used in construction that is generally used in construction.

So after that you will look into so far so what we have done is we have tried to look into some materials like concrete the issues related to concrete, so we tried to look into (carb) carbon dioxide issues of concrete then we looked into also recycled aggregate aggregate system how do we make it more sustainable with recycled aggregate then we looked into the operational energy side of all this kinds of materials. Now next we will look into bricks now next we will look into bricks we will look into bricks because we still (till) even today we use large amount of clay bricks.

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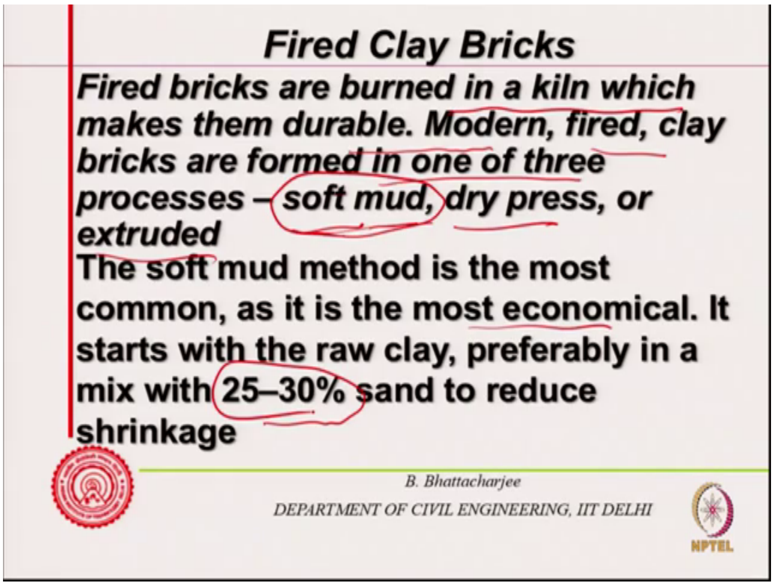

We use large amount of clay bricks even today so it is important to look into them although their thermal performance point to be thermal conductivity etcetera we looked into. But let us how these are produced fired clay bricks.

So generally these are burned in kiln, these are generally burned in kiln and modern fired clay bricks are formed in (one) 3 processes. You know first is dry press you can have dry press even in an extruded process can be used and soft mud process. This is the most common that is used in Indian scenario. It is economical also, it starts with the raw material what is the raw material for brick? Clay and sometimes with 25 to 30 percent of sand to reduce down the shrinkage when you vitrify them.

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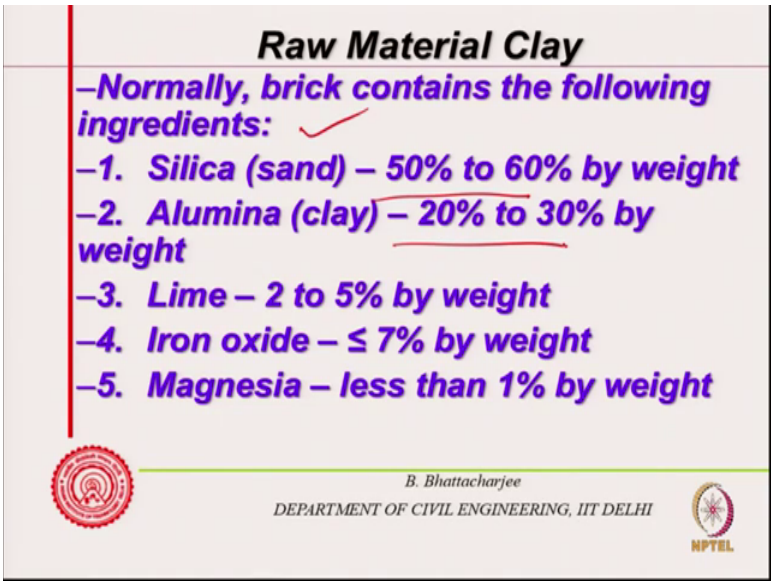

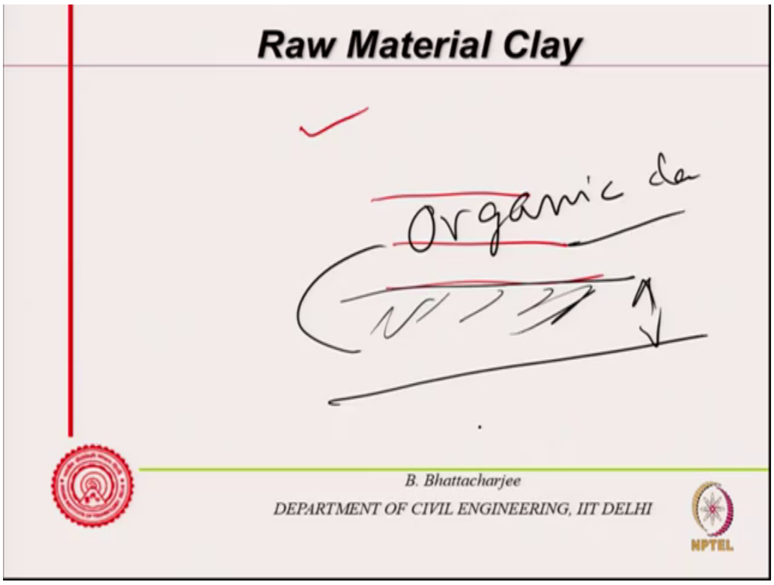

These are the ingredients generally of bricks. Silica, alumina this is for surface clay bricks as I said you know this is this can be my this can be my ground so what I do is. I remove a part of the organic, soil is removed organic clay is any organic material etcetera. So top layer is removed and get into the surface clay if you go further down below you get shell which is another form of clay. And they are you know they are compressed naturally compressed over a longer period of time into that level. And if you go further down then only in certain places you get fire clay which has got more Al2 O3 component.

And that is more dense and requires much higher temperature to bring it to a fuse state. So fire clay bricks are produced at higher temperature and therefore it can sustain higher temperature. If we produce them at 1800 degree centigrade, so till you go to 1800 degree centigrade nothing will happen to it so they are used as refractory materials.

So let us look at the ordinary surface clay bricks that is what we are looking at which is used mostly in building. So you will have silica present in them alumina, lime, iron oxide and magnesia so this is what is present normally in the clay. Majority is 50 to 60 percent even in sand you will get similar sort of thing.

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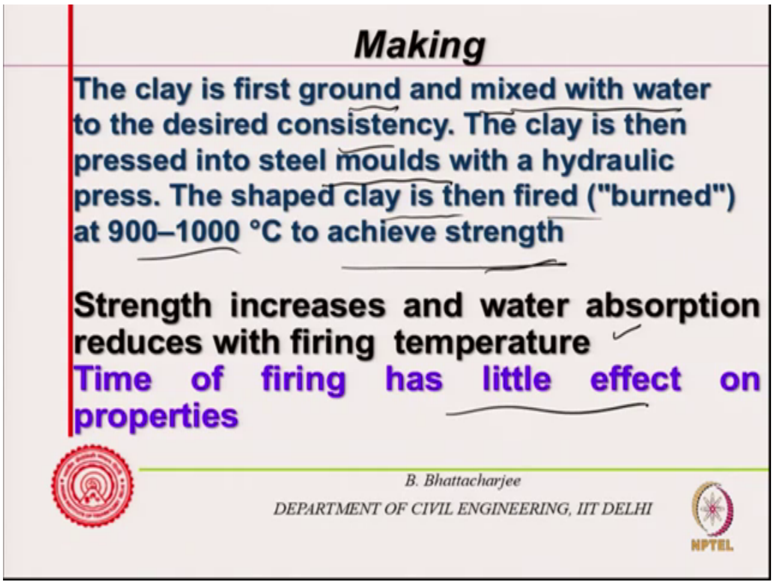

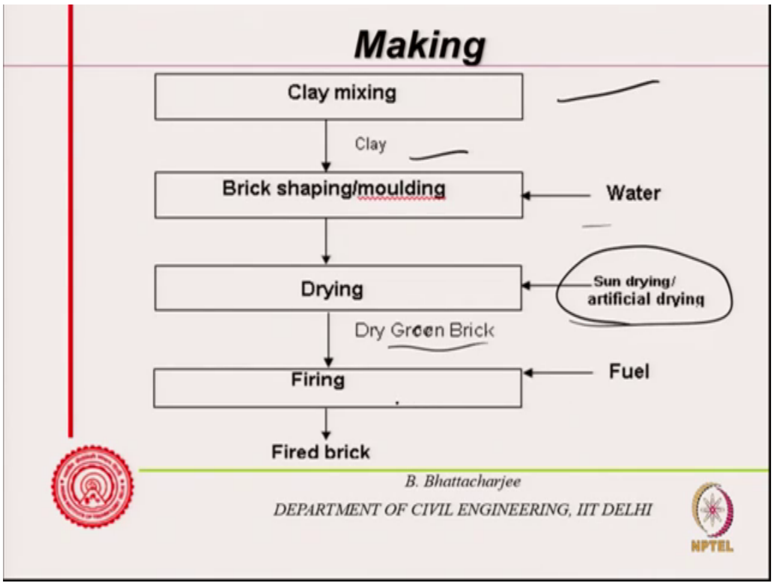

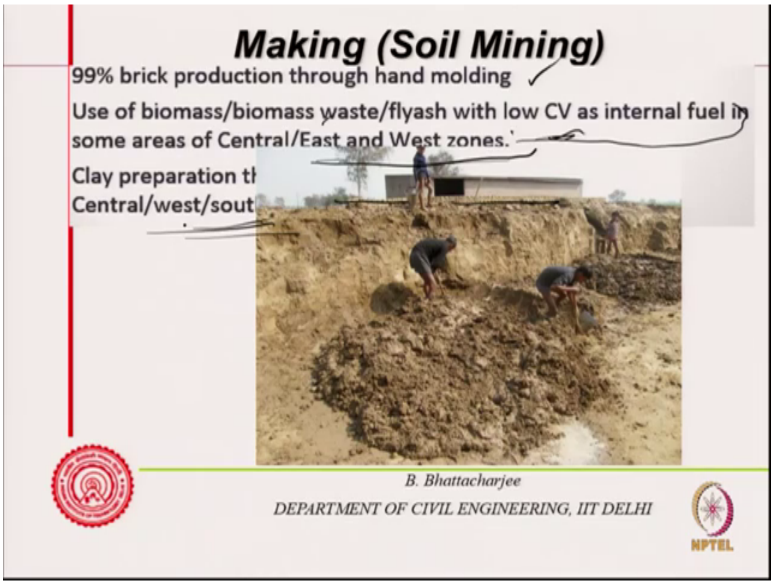

So first what you do, the clay is first grounded, mixed with water to desired consistency. Same concept you want to make it plastic otherwise you cannot mould it, so you go to evade water to sufficient level to get the desired consistency and then pressed into steel mould with hydraulic press that is the better one press and the shape the the shaped clay is then fired to about this to achieve basic strength. So in the process what happens this clay all from solid solutions. They at that temperature they form a kind of solid solution.

First level of course the water smoking will be there, the water that you have added that will smoke out. And then at high one can look even at the phase diagram I am not sure whether I have it or not I will see that. But at higher as you go at a higher temperature the they come to a fuse state and form into a almost as a one single uniform mass with a lot of pores because the water would have gone. And water would have gone through the surface only.

So therefore large amount of interconnected porosity remains, whether you chemically filled in this, if you see the similar other material like concrete exactly is chemically combined this is vitrified. Now when you chemically combine also the originally water filled space in the plastic system is filled in by adhesion product, chemical reaction product. Here the water will go away and the solid even might shrinked, so leave the pores.

So therefore these that is why these materials are all porous and if you put them in water obviously water will be absorbed because interconnected pores. Water would come have come out through the surface only, so left pores which are exposed to surface and inter connected system and so on, so that is what it is.

So basically this is what you do to achieve the strength, strength increases and water absorption reduces with firing temperature. If we increase the temperature for the fusion you require higher temperature, strength will increase and type of firing has got little effect because type of firing that has got little effect on the properties.

So the first step is clay mixing then shaping or moulding, use water and get it to the mould then you do a lot little bit of drying sun drying or some sort of artificial drying. So these are called dry green bricks. You know dry green bricks and then fuel firing so fired clay bricks, so that is what you get.

Good lot of it in Indians scenario is hand molding. For burning you might use biomass, biomass waste. Some fly ash with low calorific value as internal (fol) fuel you can also use because they will have some carbon, in some various you know that is the Indians scenario. Some zones people also use little bit of fly ash because that is also clay and it will have some low calorific value because internal fuel will be there. You know loss of ignition higher fly ash you can use in brick.

Because loss in you know fly ash one of the characteristics is burned to heat it up to 1000 degree centigrade. Find out what is a loss of mass? That is we call it loss of ignition, so more carbon means higher loss of ignition. So you can use them in brick production actually. Clay preparation through pug mills, tractors with mixtures you know so just mix them and mixtures in different part of the country that is what it would look like that is what it would look like. So they will you know dig out the clay, top clay has gone top clay is gone from there, they are trying to collect the clay.

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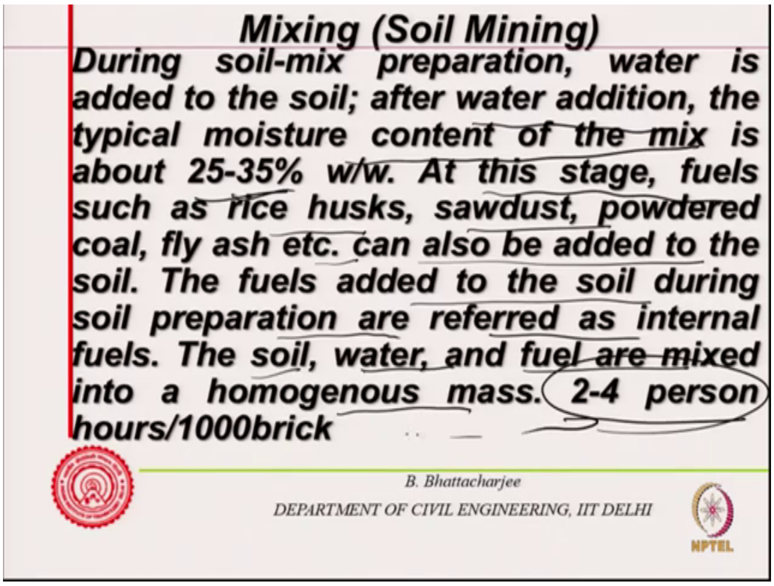

Then during soil mix preparation water is added to the soil after water addition the typical moisture content of the mixture is around 25 to 30 percent this is consistency. So you got to get a consistence plastic means but not to much of water again. So order would be something of this kind which you have seen in cement also of the similar kind it will be slightly higher here. At this stage fuels such as rice husks, sawdust, powdered coal can also be added which will burn themselves out.

This fuels added to the soil during soil preparation are referred as internal fuels. So you can add some internal fuels. The soil, water and fuel are mixed into a homogeneous mass. So the rate of production is 2 to 4 persons per hour person hour person hour to produce 1000 bricks. 2 to 4 person hour to producing or if you on an average basis one can find out.

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Then this is moulded. So simply hand hand molded . As I said 99 percent of the Indian scenario is hand molded so this is hand molded that is what they are doing preparing a hand mold. This is the Indian scenario not the best thing to do but then this is the scenario right now.

And typical typical energy requirement for hand molding is estimated 15 to 25 persons hours for molding 1000 bricks. So this was this this time this is for mixing you need 2 to 4 person hour for 1000 bricks just for mixing 2 to, so here is the energy is per person because all manual but if you combine it into mechanized system so things will be different in it.

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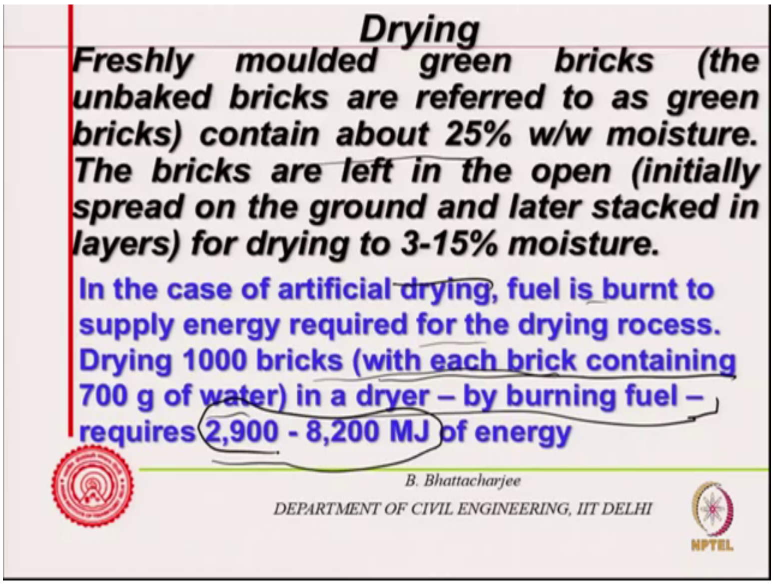

Then this is drying freshly molded green bricks they have you know the unbaked bricks are referred as green bricks. So they are not anything greener but in the terminology, similar terminology we are using also for concrete green concrete, plastic concrete earlier we were using. Not the green today we understand, so referred as green bricks contain about 25 percent moisture roughly than they are left in open for drying. And stacked to reduce it down to 3 to 15 percent moisture content.

In case of an artificial drying, fuel burnt is to supply energy required for the drying process. You can have for example hot air blowing or some kind of artificial drying. So drying of 1000 bricks by in a dryer by burning fuel requires this much mega joules, 2900 to 8200 Mega Joules of energy so this is this is what it is. So per 1000 bricks because 1000 bricks you know every brick has got around 25 percent of moisture. And you want to cut it down 3 to 15 whatever it is so this is a kind of energy required.

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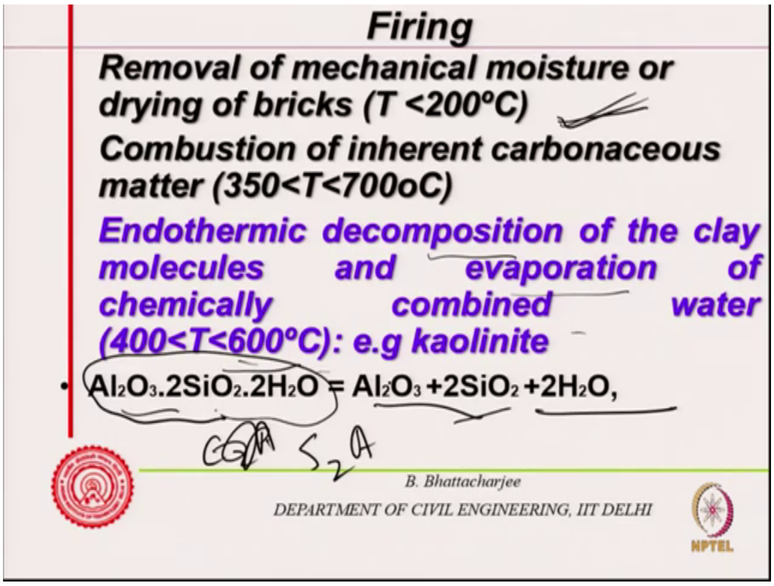

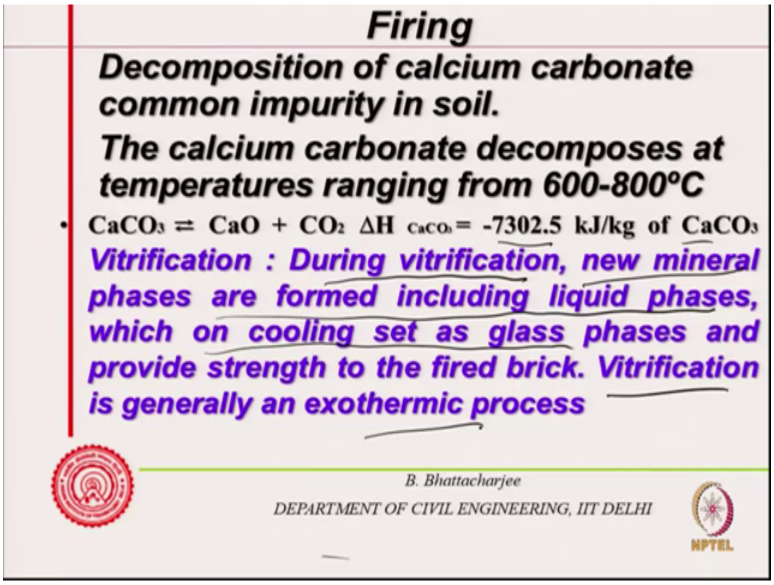

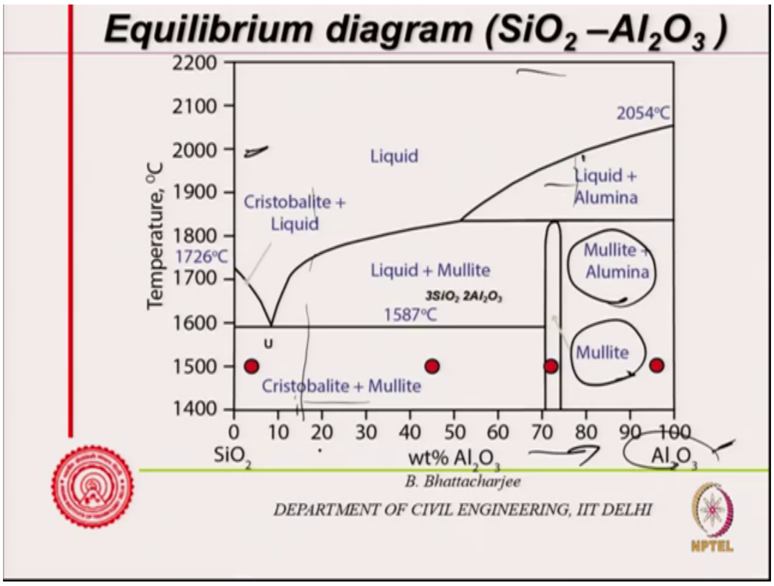

Removal of mechanical moisture or drying of bricks below 200 degree centigrade. First step of firing so obviously the free moisture will go away free moisture will go away here. So while moisture will be removed below 200 degree centigrade then of course if there are carbonaceous matter inside like you have added fuel, internal fuel they will burn. And endothermic decomposition of the clay, clay will decompose absorb heat and decompose. And evaporation of chemically combined water that is what I say.

So same thing something similar happens because some of the them are water of crystallization type, chemically combined water, silica, alumina system. And that would go out when you heat to about 600 degree upto about 600 degree, so similar up to 200 degree centigrade few water goes away which are not chemically combined. 400 to 600 degree centigrade any chemically combined water will go away. And decomposition of clay out takes place, something of this kind you know Al2 this is the structure let us say Al2 O3 2H2 O.

So say actually in our cement C2 A you know it is a kind of structure of C2 A not C2 sorry S2 sorry S2 A S2 A S2 A no C2 so there is so much. So this will this will go out now and this will this will decompose into oxides this will decompose into oxides. This will break into oxides so this this is what happens. And enthalpy change is 501.6 kilo Joules per kg of kaolinite. So if you take kaolinite clay this is the kind of energy you require per kg of kaolinite. Calcium carbonate which is an impurity in soil that will also break down into carbon dioxide and calcium. But usually this is not much, so 600 to 800degree centigrade it will be complete and its delta you know its its delta h is this this much (700) 7302 kilo Joules per kg of calcium carbonate then there is the vitrification.

During vitrification so first stage is what? Water smoking, water goes out then clay minerals, they decompose taking heat,. break down into aluminum oxides, silicon oxides and any combined water that will go away. And then or calcium carbonate if it is there, if magnesium carbonate is there then they will actually decompose. So oxides are now left, this during vitrification process new mineral phases are formed included liquid phases which on cooling set as glass phases and provide strength to the fired brick. Vitrification is generally an exothermic process, so it gives out heat.

So after that you start you know as the temperature increases then they all get combined into new kind of solid solution form and some different phases are formed on cooling and thats gives you this the strength. So this is a phase diagram this is a phase diagram depending upon the percentage of aluminum. So if you have high percentage of aluminum you can see that heating required is you know temperature at which actually you will get the liquid to solid phase.

I mean it remains liquid so this is at higher temperature percentage of alumina higher generally this will be lesser as we have seen in our case. And the phases formula are mulite as a crystal plus alumina is mulite at higher temperature this is what you know higher percentage of alumina, this is what you get. Whereas at lower percentage of you know alumina, liquid is here than it solidifies into this kind of stage. So this is the kind of phase diagram for (Si) Si O2, Al2 O3 system.

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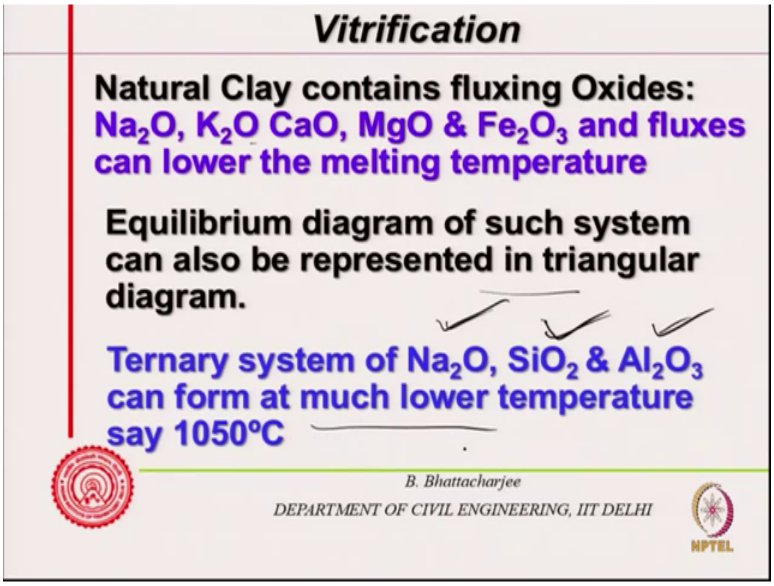

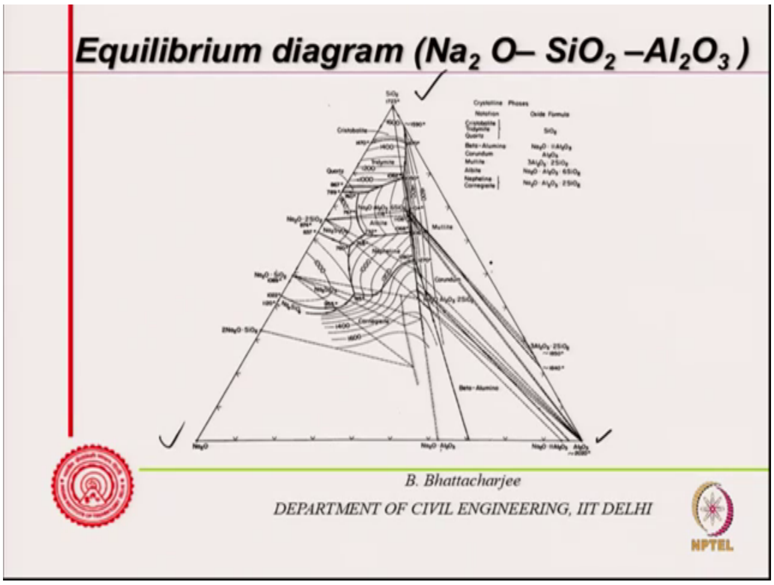

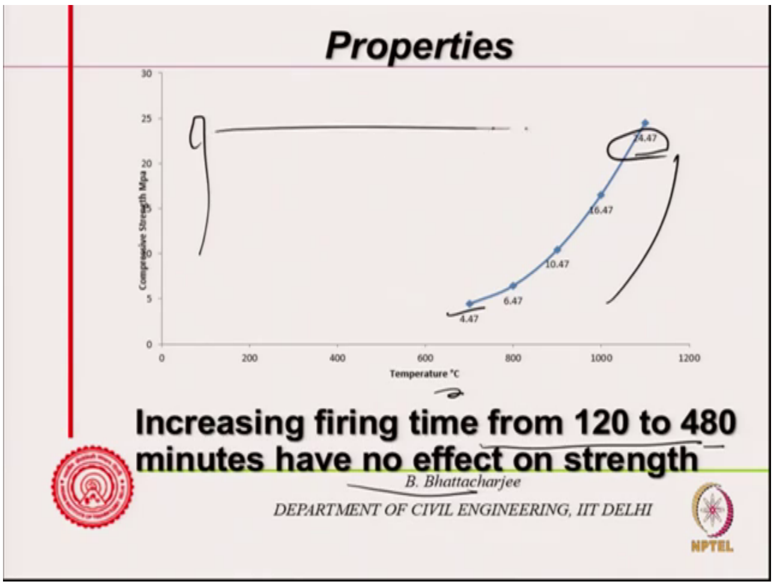

So natural clay we have fluxes like sodium oxide, potassium oxide calcium oxide just one point if it is all alumina obviously melting is it will remain you know solid, liquid till this. Then liquid plus alumina it remains liquid for higher temperature but if you add silica together with its so as you come along this direction, the temperature this liquid level temperature up to which it is liquid level actually it reduces down. And at this portion it is you know if you heat up to this 1600 degree centigrade you will get in a liquid stage if you heat it up and then cool of course. Cool then this is solid solid level.

So anyway this is not really that important for us but this fluxes are usually are there sodium, potassium, calcium, magnesium and they lower the melting point, melting temperature. One can represent this equilibrium diagram in triangular phase. Ternary system of sodium, silica, alumina can form much lower temperature so at 1050. So if you have a (turn) ternary system of sodium oxide I mean silicon oxide, silica and alumina they can form the you know actually you can heat it up to much lower temperature to melt them.

So this is a kind of equilibrium diagram. This is Al2 O3, this Si O2, this sodium and the such combinations are available whether I do not think I am going to that discussion but generally temperature would be around 1050 (2000) you know around around 1050 plus 1200 degree centigrade you heat them up to. So as you are increasing firing firing temperature and time generally increasing firing time from 120 to 480 minutes have no strength in change. So temperature here compressive strength but temperature has got a role. Higher the temperature you find the strength increases.

So your energy required would be higher as you go higher but time does not have much of a meaning. Once everything is molten you cool it and you get this type. So these are the values 4.47 to 24.47 is the brick strength Mpa. And water absorption will obviously reduced. Higher strength water absorption reduces.

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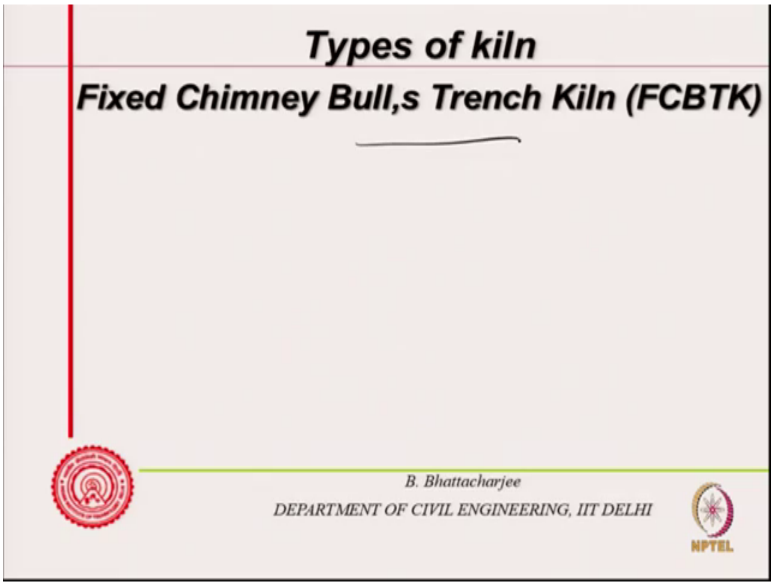

So this is what we will discuss in the next class. Types of kiln where we produce India, the ports are actually available but this is actually this you know as you should see this is highly energy intensive. And also we have say labour intensive so that way you are not really using the other kind of you know like (mecha) energy from other sources.

But highly even clay bricks are quite energy (inte) intensive also you are using surface clay which might be used for agriculture or other purposes. And since you are using a lot of fuel you might be using generating a lot of carbon dioxide. Although the production process may not generate carbon dioxide as long as you will use waste material it is all right. But if you are not waste using waste material than the carbon dioxide issue will come. So we will look into the types of trench in the next class.