Glass in buildings: Design and Application
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Lecture - 09
Structural Control and Design for Energy Efficiency

Let us see them.

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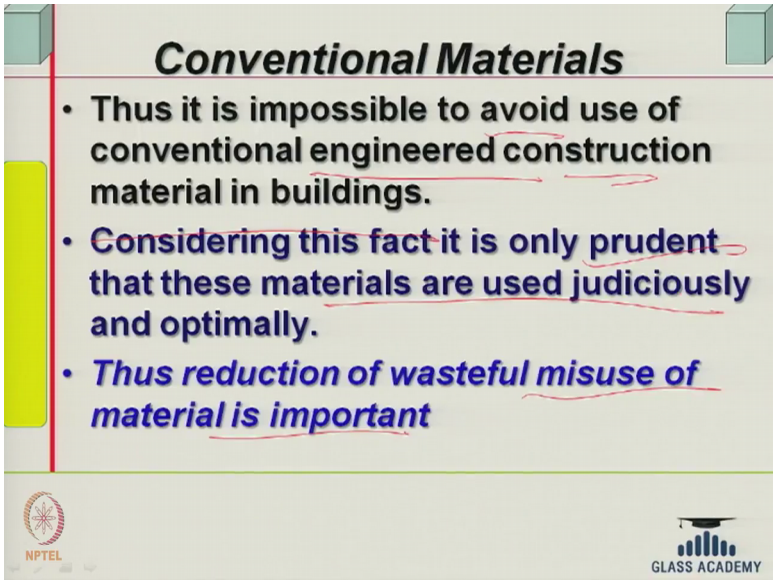

So, thus it is impossible to use conventional engineered construction material in building, you have to use them, you cannot avoid; you know you cannot build a large hospital with all bamboos mart or whatever is naturally available without much processing them you have to do some processing. So, it is only prudent therefore, that we use our engineered materials very judiciously and optimally from thermal design point of view. So, reduction of wasteful misuse of material is very very important, in the context of green, building or green construction and sustainable construction.

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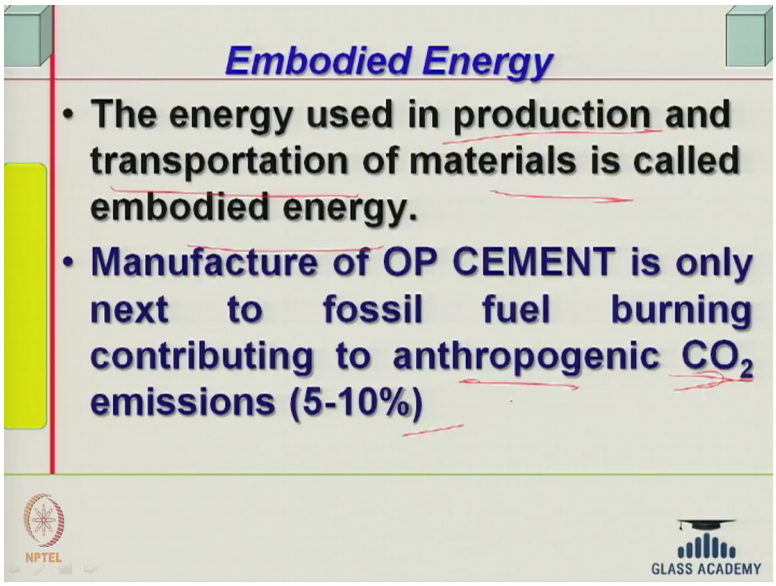

So, energy used in production, transportation of materials is called embodied energy right. So, embodied energy of the envelope material is very very important. Obviously, carbon dioxide is another issue right? You know that OP cement Ordinary Portent cement it produce a large quantity of carbon dioxide, next only fossil fuel, but I do not think I will go into that aspect; the point is important carbon dioxide emission and embodied energy is important.

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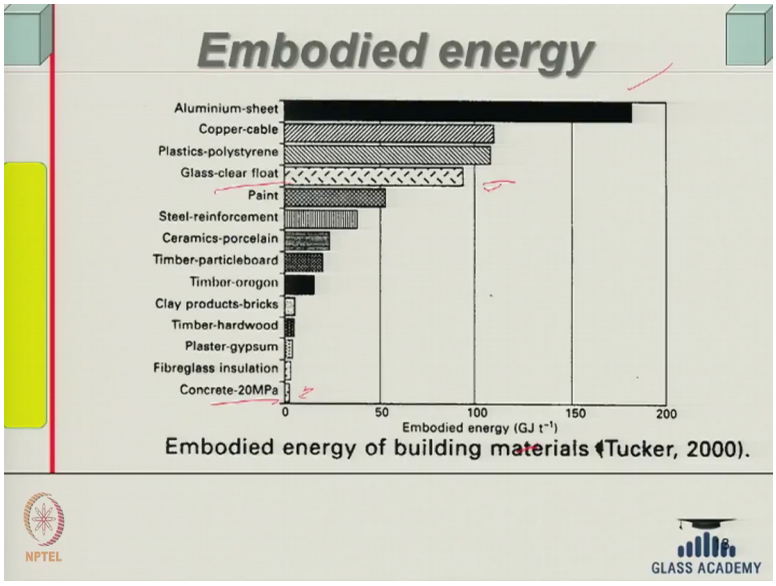

If you see embodied energy, this result is from Trucker's publication Trucker is an author. You will find that aluminum sheet has got a high embodied energy per ton, giga joules per ton, concrete has got pretty small amount, and if you see glass somewhere glass would be there, float glass is talking about and various other they have got high per ton. But the thing is that when you look at building typical building you know this is from Trucker's 2000 data.

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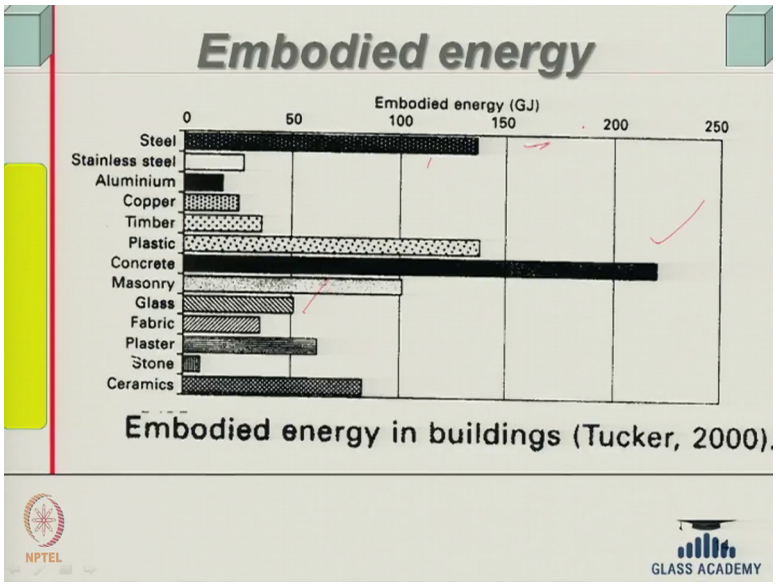

But, if you look at it for a typical building, you find this is the major component and if I look at a glass its somewhere there, you know steel is there. So, why? Because the quantum of concrete used in buildings typically you know in general over the wall all over the world in terms of giga joules in a typical building, in general many buildings large quantity of concrete. While, the other materials used are less although per ton embodied energy is more. Anyway this is one issue.

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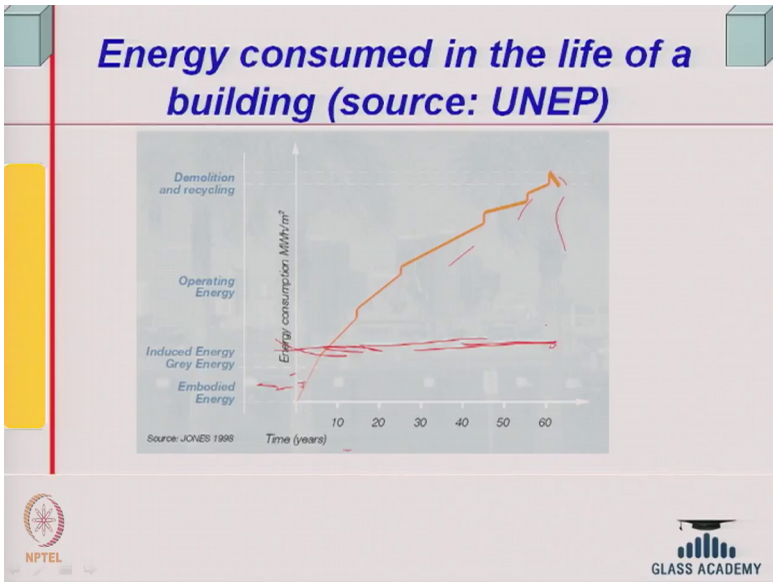

So, you have to see that, embodied energy of the envelope material if you are talking of envelop or whatever you are using its relatively low. But then we would be talking about something called operational energy right and that operational energy is yearly consists of yearly heating ventilation and air conditioning load cooling load heating load cooling load and all those kind of things. So, if you look at this, this is called operational energy and over the life cycle of the building if you look at it, let us say 60 years of lifecycle of the building right.

So, in time in years so, initially the embodied energy which is only a small component, then there are some gray energy which might be related to maintenance and thing over the years, but operational energy cumulative values it goes on increasing because every year you are using this operational energy. That is your energy cooling and heating load of the yearly heating and cooling loads. That is very high that cumulates this largely this quantity is relatively not more than 10-15 percent even less 7 percent or so, depending upon type of cooling.

So, operational energy is very very large, something you might recover even later on because after demolition during after finishing intended design life or service life of the building itself you know, life time period during which the buildings are usually typically in service you can talk in terms of intended life. So, you can see that some is some

amount is required also. So, operational energy is a major part because that is yearly every year that is recurring, while in embodied energy is only the initial part of it.

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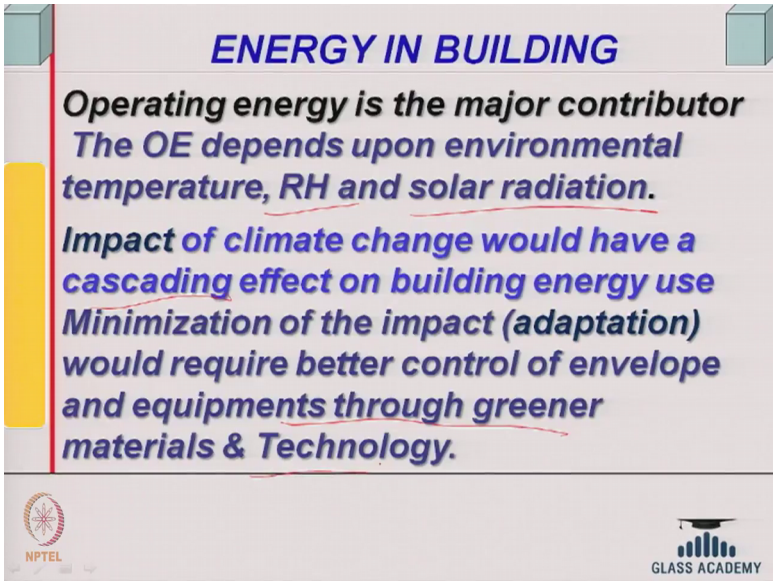

So, that is what it is. So, operating energy is a major contributor and therefore, depends upon environmental temperature, relative humidity, solar radiation that already we have discussed and impact of climate change you would have of course, if that is there, which is a lot of people are apprehensive of the climate change and if the temperature increases it will be actually having a cascading effect of building energy use.

So, minimization of this impact would require better control of envelop and equipment through better greener materials and technology and so on.

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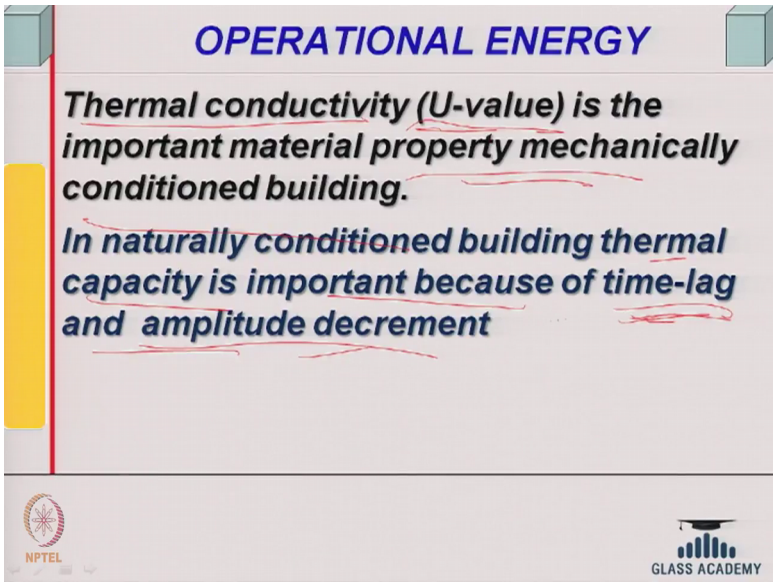

So, therefore, that is. Now the property of the envelop opaque material solid material as well as you know solid opaque material or transparent material let say even glass, one of the properties of the glass is also because glass other properties are important. We call it U-value I would not define the mathematics behind it or algebra behind it or you know equations of heat transfer and all that would be difficult to define in this short period of time. Now this is related to thermal conductivity of the material. You know it is a property of the material which is nothing, but the quantum of heat that you transfer would take you know the heat transfer quantum of heat that will be transferred in a solid material, and then you need steady unit temperature gradient for unit area in unit time.

So, its unit is thermal conductivity is that, and for a construction we know the we call it transmittance and its given a name of U-value because symbol is used is u. If you remember even in electrical engineering, we talk in terms of resistivity and resistance conductivity and conductance. So, conductance is of an element conductivity is the property of the material and when we take an element complete with some air layer on both the sides we call it transmittance and that is what we define as U-value.

So, is the important material property in mechanically conditioned building, you know in mechanically conditioned building. In natural building condition building thermal capacity is also important there is something called time lag and ability to decrement.

Now, let me just quickly explain this although again, the detail do not be will be available not will not be available in this course I mean this lecture. If you have a thick wall it will first store the heat. If there is a temperature change outside if the increase in temperature occurs outside right it will first store the heat, the wall or the roof solid you know material or element of the building external element of the building it will first get heated up itself so, it will store the heat you know getting heated up means sensible heat storage.

So, it will store that heat and then subsequently after getting heated up itself, it will radiate that heat you know conduction would occur and come to the it comes to the internal surface, then it transmits that heat by convection and radiation to the internal space or inside you know the space within the building within the building.

So, it takes some time, there is a time difference which because it can store and storage element holds the energy and then releases it, there is a time; time gap between its receiving the heat and transmitting to the outside and when you deal it mathematically for a periodic wave, you call it you can define something like time lag phase lag etcetera etcetera and if it is periodic heat flow, then you can it has got amplitude and there is something called decrement in amplitude. So, this is one aspect is important the amount of heat that is conducted. This is related to the amount of heat that is stored because thermal capacity is there and the amount of heat that can be stored and released later that governs just part of it.

So, in conditioned building it should not allow heat to come in straight away so, conduction part of it that is very important. But in naturally conditioned building you can think a around with envelope to control the heat coming in. We will have some example coming in you know time of heat that receive you know that that time of heat inclusion or heat entry into the inside of the room right.

Other thing is very important another thing is very important, long wave emissivity of surface is important, short wave emissivity of the surface external surface is important we will discuss about this somewhat later on because the solar radiation is absorbed by the surface. Now amount of radiation absorbed depends upon a property called you know it is or others quantified through a property called absorptive and it can emit back in the night, because external cosmos or sky is cool.

So, the terrestrial bodies actually radiates heat back to the outer space and that is long wave radiation well why long wave radiation? Because earth radiates at much lot temperature and the characteristics of that radiation is high wavelength right. While the one that is radiated from the sun because sun radiates a very high temperature is high energy radiations they are short wave radiations right. So, that is what it is ok.

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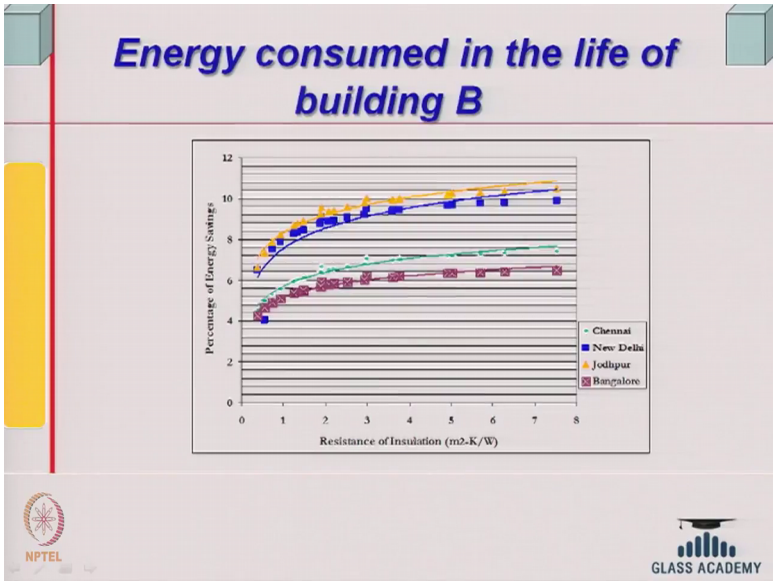

So, we have seen actually if you if somebody does looks calculates out one would see that insulation which is nothing, but 1 over U right 1 over U U-value is transmittance one by transmittance as it increases the cooling load actually you know percentage of energy saving increases. But then does not increase continuously monotonically there is a point beyond which increases is relatively less this from an actual simulation scenario in some building in you know building actual building in Chennai, but assuming that they are in four different climates of the country this is what we did ok.

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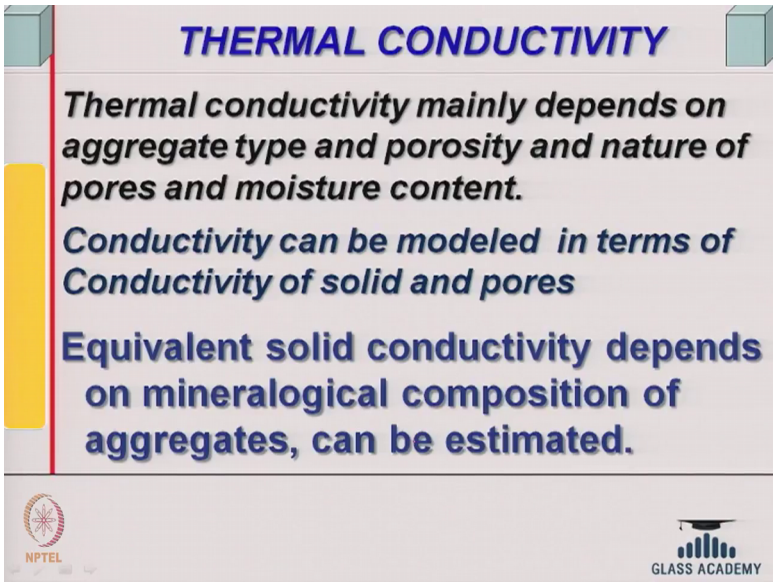

So, in case of concrete or similar materials thermal conductivity of brick, thermal conductivity largely depends on porosity of the material and conductivity you can model them in terms of conductivity of solid and pores. I do not think I will go too much into it, and equivalent solid conductivity you can find out it depends upon mineralogical composition of the aggregate etcetera etcetera and one can estimate.

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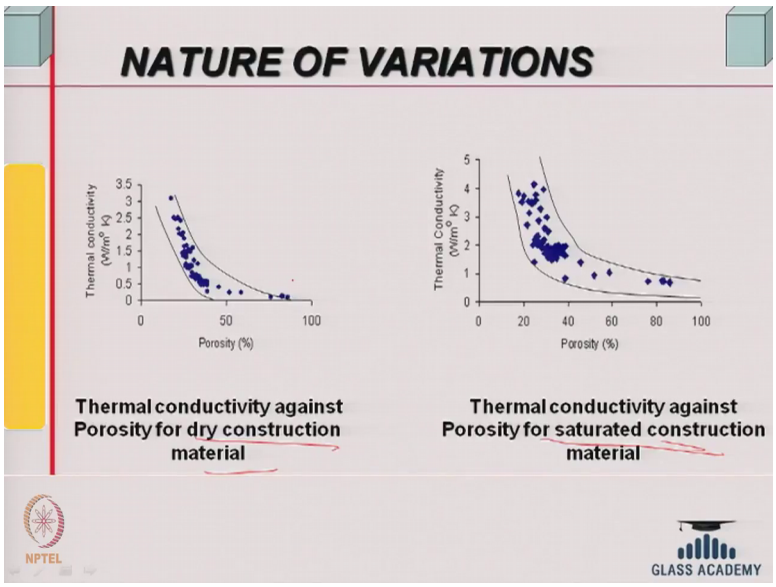

Concrete is of course, the roof usually or various even modern industrialized construction you might have a wall, made up of concrete or precast elements of concrete

which are being used. So, brick concrete; concrete is significantly use and its conductivity properties are important that is what we are talking.

So, thermal conductivity or similar material varies with porosity. Higher the porosity conductivity is less right as you can see in dry state as well as in saturated state. So, when moisture actually conducts 6 times I mean 25 times more than that of air. So, a saturated material transmits more heat than dry material and that what you can see this in saturated condition this is in saturated condition. So, typically in dry construction material it is a function of porosity it is a function of porosity, and as porosity increases conductivity reduces right.

So, if you want an insulation material of this kind granular material bonded together or sintered or you know vitrified material. If the low porosity they will have lower conductivity as well you know higher porosity is higher sorry higher porosity they will have lower conductivity. So, porosity high porosity low conductivity low porosity high conductivity; obviously, there are other properties one is to look into. So, insulation material usually porous many of them are and of course, there are varieties of other materials that will be there.

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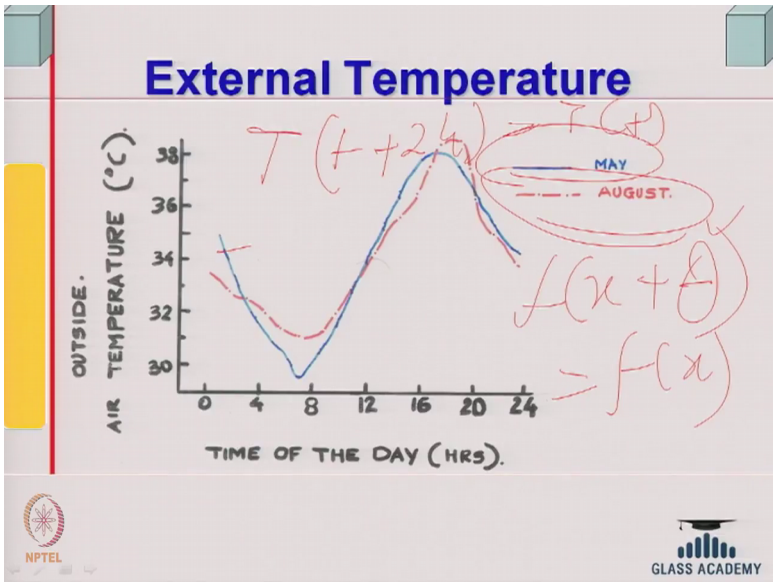

So, this is one issue that I wanted to talk about u value for external roof wall etcetera etcetera that is important. Typically if you look at it external temperature variation for example, this is a case of Delhi measurement, outside temperature real measurement in

IIT Delhi campus somewhere in 1980's may month of May and month of August. Now you can see that you can assume that the temperature repeats itself after 24 hours and mathematically we call it periodic. So, when a funcs you know when a function or a variable or you know when an quantity or something for example, here temperature, which varies or which becomes same after certain period of time here 24 hours period of time. For example, a function of you know the temperature, temperature function of x plus let me call it theta is equals to fx then it is periodic, theta is what is called time period right.

So, in our case it is temperature at you know temperature at any time t say 8 am or something plus 24 is equals to T into t. So, today 8 am and tomorrow 8 am it would be similar there are some variations not exact, but usually it is periodic. So, one can assume it to be periodic and these are typical measurements and it will have some sort of a mean it can be described by a mean and mean and a amplitude as we call it or variation above the mean.

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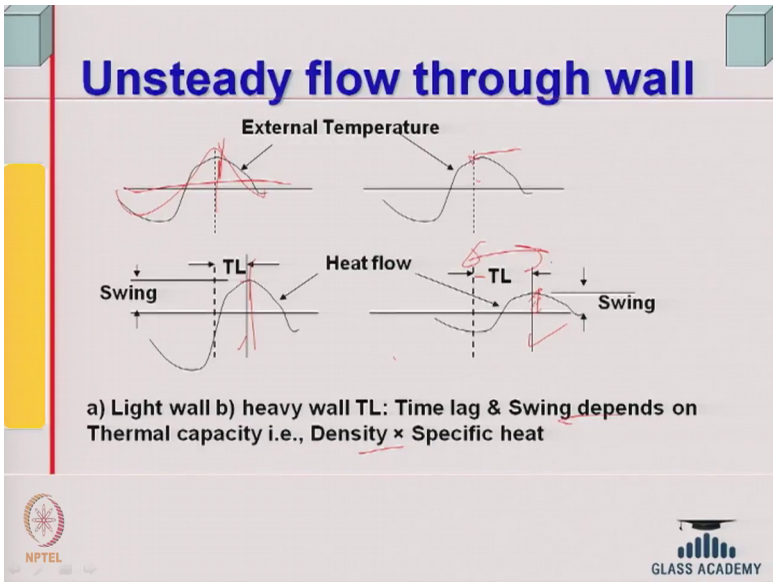

So, if you look at it, this is the external temperature, this is the external temperature right. This is the external temperature which is periodic it's mean is here right it's mean is here. Internal temperature will have this peak shifted by some time depending upon the thickness of the wall or its heaviness I will say not thickness alone thickness plus density specific heat and all that depending upon that.

So, heavy wall plus there is a reduction in the swing, this value this amplitude reduction will be there right and this is what we call as time lag; this is what we will call it time lag the swing has reduced, this peak has you know its value is now somewhat lower amplitude is somewhat lower and the shift inside temperature, this inside temperature these are external temperature these are internal temperature. This is a shift in the peak of the internal temperature and its amplitude is also less compared to the compared to you know mean.

So, light wall this is a case of light wall, this is the case of a heavy wall. So, in case of a heavy wall time lag and swing depends on thermal capacity density into specific heat and all that L into length into density into specific heat that's precisely would control. So, therefore, we can choose the wall element or roof element in such a manner that I might like some cases I might like to do that, I will just give you an example I would like to keep this high. Some cases I may not like to keep that high, I mean it's not necessary to keep it high right I might like to keep them high and in that case or appropriate I will say. So, I can I can choose envelope accordingly so, effect of this is one aspect.

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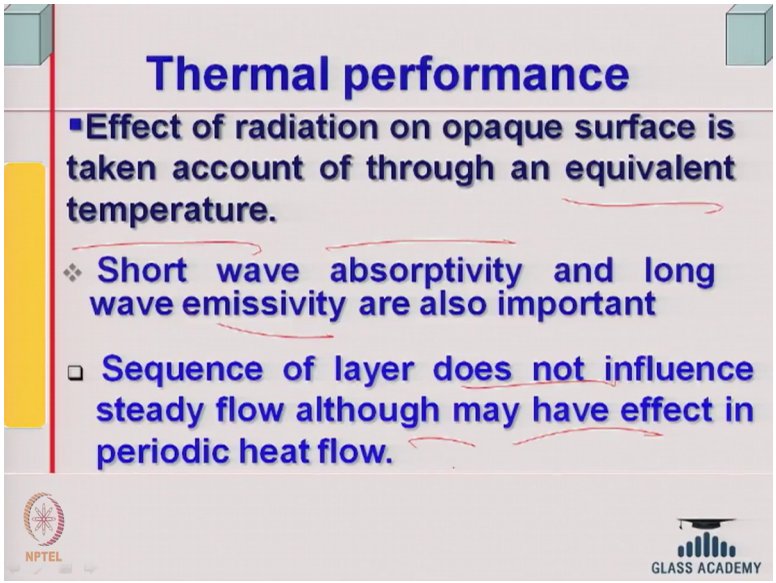

We will look into it second thing is radiation falls on to opaque surface for example, over the roof element external element or many other external element. Direct solar radiation suns radiation will fall into and through them and we must be able to take them into account in some manner. One of the simplest way of doing it through an equivalent

temperature, through an equivalent temperature we will call it sol air temperature you know. So, this is dependent on what is called short wave absorptive and long wave emissivity also somewhat contributes to it not very significantly relatively less. Because amount of long wave radiation is usually much less compared to the amount of suns radiation, that is received on any external surface ok

What we know is from all mathematical descriptions and quantification of that, sequence of layer does not increase the steady flow or U-value as I mentioned, but it has got an effect when you have an alternating flow because first it will store then release. So, if you put a heavy material in the beginning it will store for a longer period of time, but if you put a light material at the external facade it will absorb.

Store it for less period of time then transmit. So, the sequence of material whether outside material is heavy, lot of mass lot of thermal mass I am talking of that is the specific heat and density heat capacity or less heat capacity that will dictate. But while conduction part of it is independent of independent of sequence of material.

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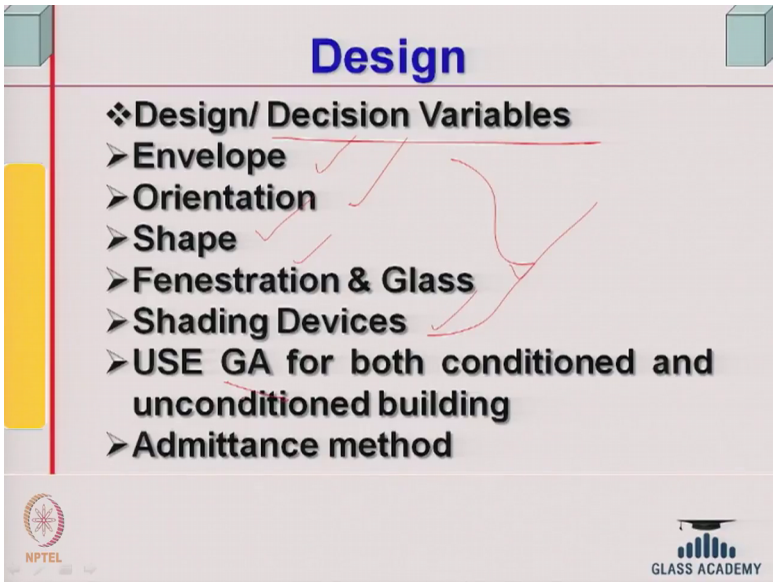

So, this is some aspects. Now we will look into some aspects then some more we will look into when as in when it comes. Now in thermal design of building or energy efficient building design of building, the decision variables are envelope parameters which I have discussed so far. Orientation is the other one shape type of glass and the fenestration location, setting devices I will discuss some of them, these are the decision

variables. And you want to find out the best combination, you can use some sort of optimization process for example, evolutionally algorithm of the kind of genetic algorithm etcetera. But then you must have a method for estimating the quantity of quantum of heat coming in one such method is what we call admittance method, I am not obviously, going to go into the mathematics of it.

There are other methods like there are numerical methods one can use for calculating the heat transfer finite element, finite difference and there are some other kind of solutions many software might be using them like you know time domain, solution of heat transfer equation, for a periodic wave outside. So, etcetera etcetera. So, this is you know this there are methods. So, one can use them.

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