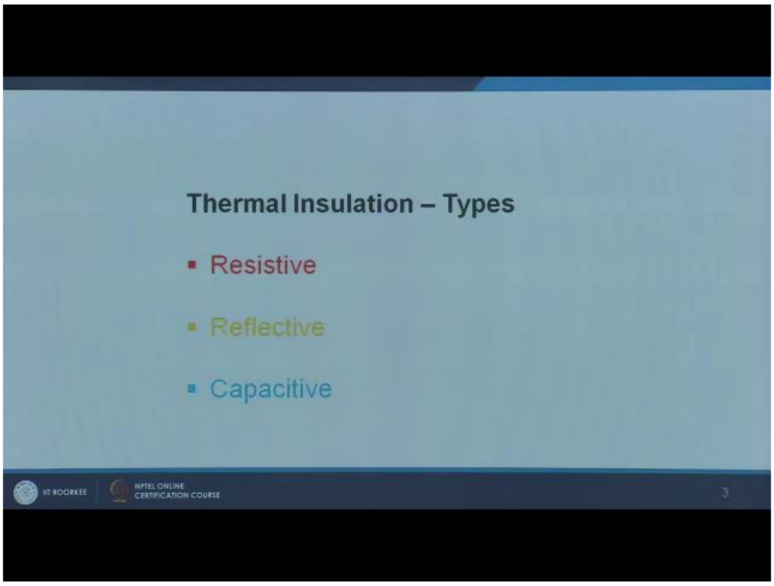
Principles and Applications of Building Science
Dr. E Rajasekar
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Lecture – 08
Thermal Performance of Building Envelop – Indices and Measures – 1

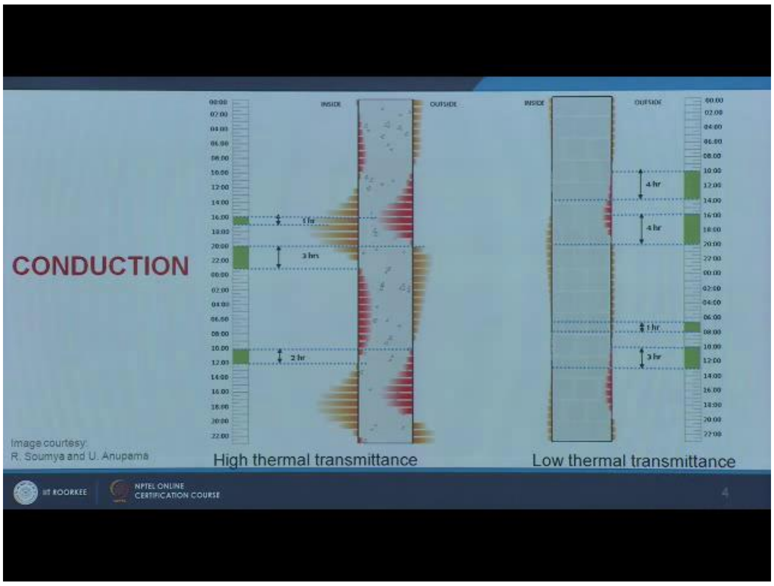
In the previous session, we looked at Thermal Performance of Building Envelopes. That was a section one where, we started with different modes of heat transfer. The principles and basics we looked at and some of the building application examples. That I was showing you in this particular module we will look at the indices and measures. That we primarily use to assess thermal performance of building envelope we will look at specific types of insulation and how to assess it is performance we will primarily focus on the Indian standards and codes and how we assess it using our national building code I will also show you some applied examples. So, to get a quick recap we looked at 3 types of insulation.

(Refer Slide Time: 01:04)



First was the resistive insulation the common index which we uses the ULU or thermal transmittance. Then are the r value of course, then we have a second type of insulation which is a reflective insulation and the third type which is capacitive insulation which goes on with the thermal capacity of a particular building envelope.

(Refer Slide Time: 01:28)



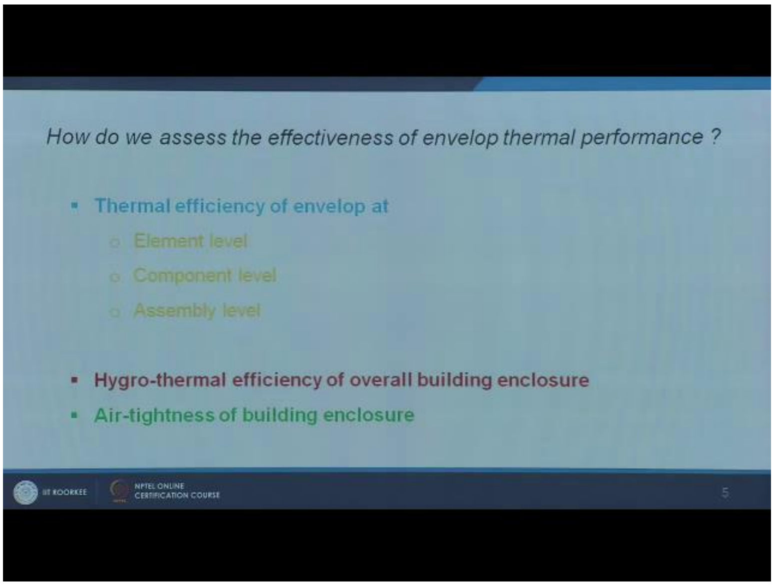
So, we looked at this picture we are talking about the intensities and the pattern of heat gains and losses through a particular wall. So, this is a wall cross section again this wall has a high thermal transmittance or highly conducting wall. This is a low thermal transmittance or probably an insulation you know insulated wall more closely an insulated wall. So, here we looked at what rate the heat gain happens during the day time this is a 48 hour that is 2 day cycle. Where the heat gain happens and then how it is transmitted indoor and then how it is reabsorbed and retransmitted outside, so few important things that we need to further note in order to evaluate the thermal performance this is again a conductive heat flow I showed you 2 other images, you know which correspond to convective as well as radiative heat flow in this particular thing, where 2 things are important; one is a magnitude where the bars indicate the magnitude the next important thing is the time which takes for the wall to conduct it inside.

So, between the ambient peak of the peak heat gain verses the indoor peak are to what extent a heat gain happens indoor this considerably varies from one wall section to the other wall section. It varies based on the orientation it varies based on the material properties it varies based on the ambient as well as indoor conditions.

So, we will look little more in detail about these things in the current module. So, how do we assess the effectiveness of thermal performance? So, you know as a designer we need to choose materials we need to choose wall system and we have to also ensure these materials or the systems or components are performing well. So, the common way people use is certain indicators or numbers. So, you are going to buy a product you are going to buy a material thermal insulation material or a wall system or a window component you know the company would be showing you a booklet, a technical data sheet, which as lot of number, how do we understand which number is essential, which is less essential? Which we have to look at and which is more representative or indicative. So, we will we will get little more understanding develop little more understanding on this side. So, the thermal efficiency of a building envelope can be looked at in 3 levels.

The first is the element level second is a component level and third is an assembly level. So, when I say you know element level it means the it starts from basically the micro structure it does like a inherent property of the material at the component level. Say for example, what is a performance of thermal efficiency of a brick; Para brick wall or a particular block you know aerated concrete block for an insulated system then the third level is the assembly level. So, when I have a whole system when I have the whole wall then the thermal efficiency can be looked at what are the merit's and demerit's we will look more closer today apart from this there are other things there is a hygro-thermal efficiency of overall building enclosure.

(Refer Slide Time: 04:26)

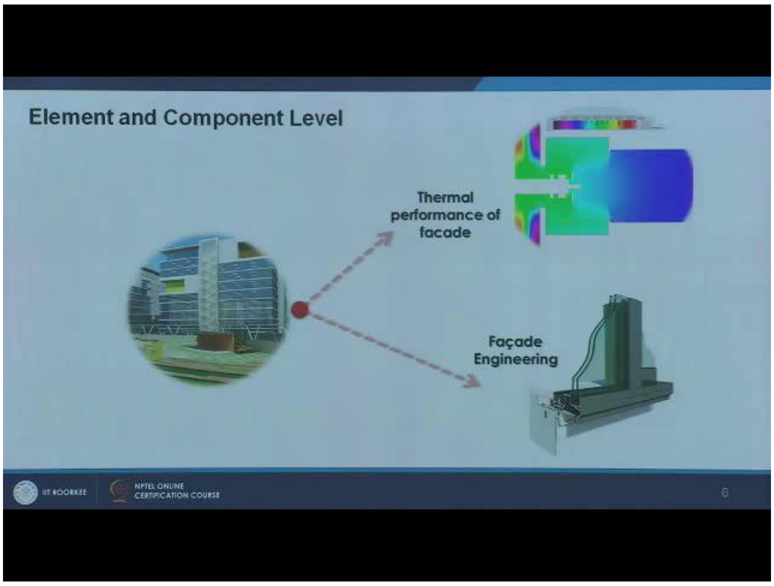


When I say hygro-thermal it is thermal as well as moisture more or less both are you know both of these are very closely related to each other when, I say moisture what happens when the you know wall system or a particular material gets wet the you know pores within the material absorbs water they get little more dense than their regular say you know material soaked in water is slightly higher in density than a dry material, then the you know type of heat transfer happening through that particular medium considerably varies.

Apart from this though we do not look more in detail about the moisture related things or problems. In most part of the India it is a specific importance in places where, it is more moist as well as colder climates. For example, you know much of the countries in close to the pole polar region say lot of European countries, Canadian Northern parts of us. Moisture is a major problems they look at moisture movement hygro, you know hygric movement across the wall sections more critically it is as critical as the thermal itself for 2 reasons; one is the type of material they use by itself there is a lot of wooden construction, light weight construction, happening and number 2 there is snow outside it freezes out. So, the internal you know the internal areas the spaces are heated.

So, the kind of moisture transfer is very crucial there another important thing is air tightness of building enclosure this applies to a tightly sealed and condition buildings lot of people have presented. If you search online surf online you will find images on thermal imaging if you take a close look at it there is a lot of you know heat loss which happens through the you know improperly sealed windows or wall junctions when, the joints and seals are not proper there is a lot of air movement seepage outside on the other hand, it is infiltration heat gain inside which considerably increases both the heating and cooling load as far this module is concerned we will primarily focus on the thermal efficiency at 3 levels.

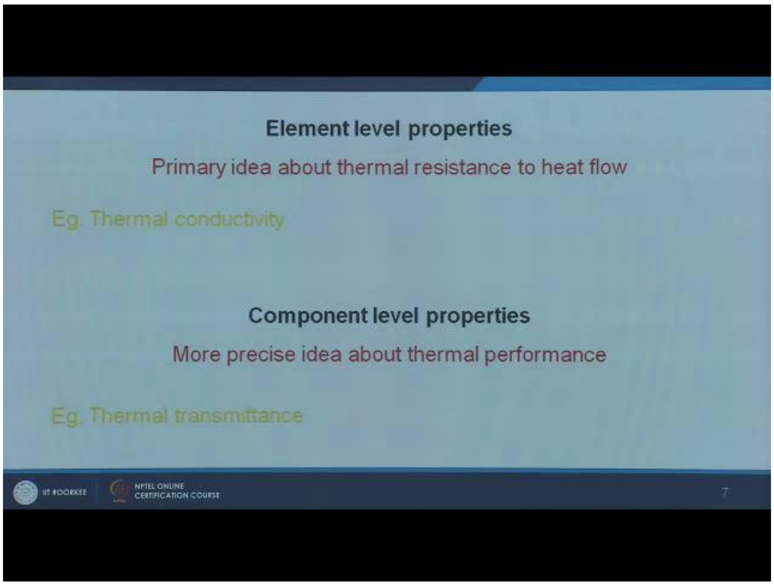
(Refer Slide Time: 06:36)



First when I said element level or next the component level this is the cross section of a frame, we did a thermal analysis of the frame, how heat moves through a frame this is a transformer. It can be anything in this case this is a transform where this is a glass this is a total frame surface outside versus inside the mode of heat transfer from one end to the other end it is get heated up and eventually the heat builds up and then it moves on to the other.

This can be a wall surface where you can assess one dimensional 2 dimensional or 3 dimensional heat transfers primarily we will talk about one and 2 dimensional heat transfer in terms of elemental performance. How one surface is heated up and eventually it passes on the heat or it flows to the other side in course of time most of the element level performance deal with the static level factors. Next is the component level performance what happens when you have a glazing assembly the next thing is when you have 2 glasses put together, or the whole thickness say there is a glass layer there is air layer and then there is a next level of glass. So, what happens with this performance we will look at as a component? So, element level properties primarily give an idea about the thermal resistance to the heat flowing from one side to the other.

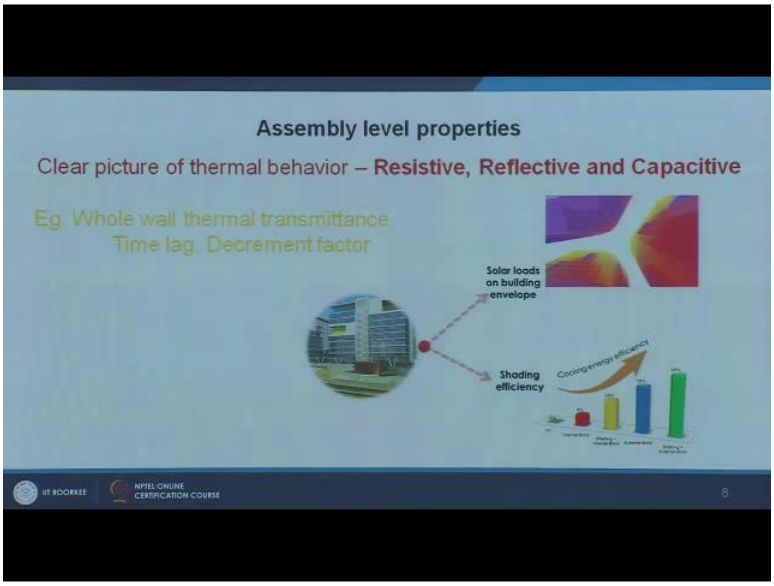
(Refer Slide Time: 07:58)



Simple example, common example is the thermal conductivity it is a material level property it gives you the indicative idea about whether the material is resistive to the heat flow or not.

Next is the component level property it gives you slightly more you know much better idea about or more precise idea about the thermal performance of the component, say an example can be thermal transmittance when, I say thermal transmittance or thermal conductance resistance we talk about material in it is thickness, say thermal transmittance of a 230 mm brick wall thermal transmittance of a 200 mm thick solid concrete wall. So, these kind of things will give you slightly better idea than, the element level performance about the heat flow the next level is the assembly level properties. For example, you have a window frame and wall assembly what happens to the overall performance of this wall system in this set this is more critical and this gives you a very clear picture about 3 types of heat transfer.

(Refer Slide Time: 09:08)



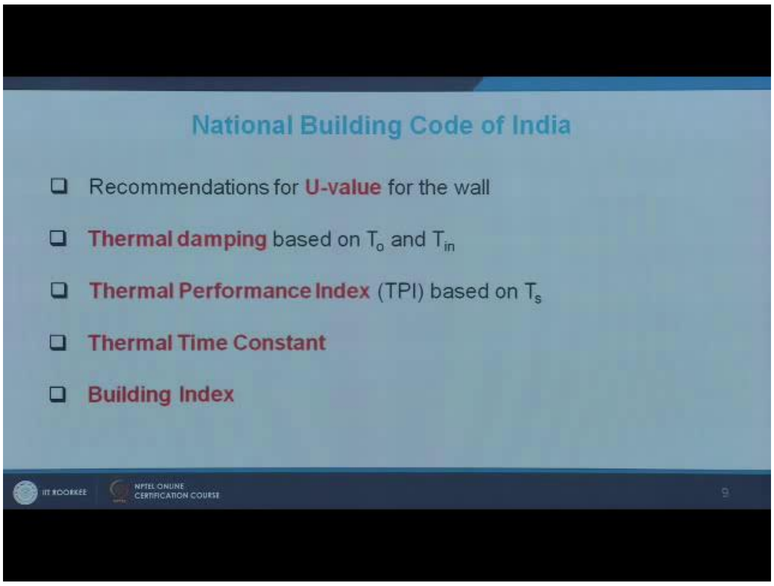
It gives you an idea about the resistive properties of the whole system it gives you reflective properties of the whole assembly and then it gives you the capacitive or the heat storing capacity of the whole assembly examples can be the whole wall thermal transmittance.

I am introducing 2 new terms time lag and decrement factor we will look at these 2 terms more in detail, but to have a clear understanding we should get much closer to the assembly level properties, but to take a practical note of what we actually get primarily we get inputs regarding the component level properties as well as element level properties. Element level properties are more easy to test their static tests done in laboratories people conduct you know thermal conductivity test hotplate, I was talking about you have hot and cold sheet you pass on heat and find out how isolative or resistive the material is this tests are commonly done you buy any material thermal conductivity values are spontaneously given the next property which is more commonly available in field is a component level property.

Where people can estimate it or compute it as well it involves 2, 3 or 3, 1, 2 or 3 dimensional heat transfers something are measured, but most of it is computed. For example, a particular seller may give you a component level property of an insulated wall system he will say my wall system, he will say my wall system has 100 mm thick blocker plus 50 mm thick insulation or 100 mm thick insulation the overall component level u value or thermal transmittance such and such.

So, this particular property might have been measured or he would have measured individual properties and computed it. So, component level properties are also increasingly available at least for more of the products used in building envelope, but what is less available is the whole assembly level property which is more or less and the moment you start computing them there is a lot of uncertainty, which happens in this values.

(Refer Slide Time: 11:04)



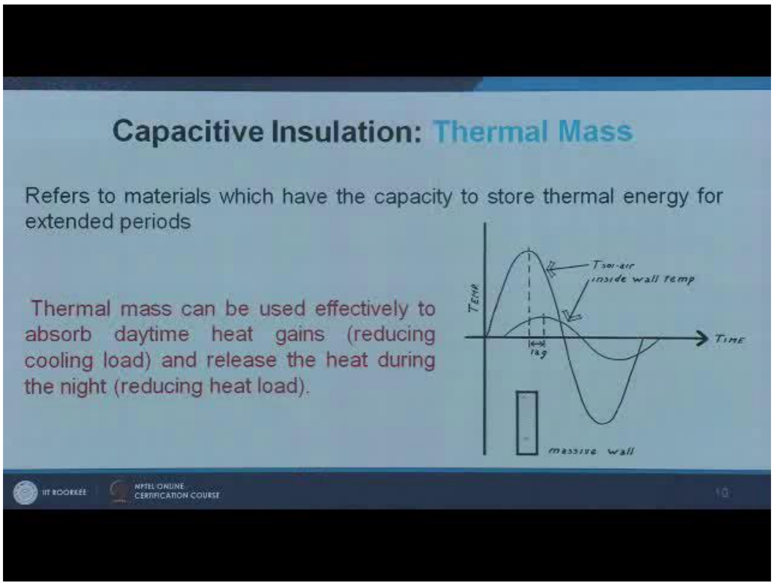
We look at why they are happening and what actually the difference are before that national building code of India n b c prescribes, some of these things in detail it has recommendations for u value that is thermal transmittance. It tells you which climate zone you are with respect to that what is a recommended u value what is a maximum u value you can go for your wall or any system that you use should have values less than what n b c is prescribing.

The next important thing it talks about is something called thermal damping. We will define and look at some examples more closely thermal damping depends on outdoor as well as indoor temperatures the next property is thermal performance index, T p I it is based on T s or the surface temperature inside surface temperature of walls are taken into account when, thermal performance index is calculated next is thermal time constant T t c it is also a material property. We look more in detail about this then, the last thing is building index it is a overall heat gain through the enclosure which is which ever wall window area fenestration area is exposed you calculate the heat gains and cumulate them call it building index. So, we will take a look at May capacitive isolation.

So, we looked at resistance isolation and reflective isolation before getting into what these index is mean first let us take closer look at what happens with the capacitive isolation as I said we have been traditionally using this type of isolation much commonly most of our old buildings especially palaces bigger. Occupying the residential places even had adobe walls you are you know thick granite slabs they had a high thermal capacity what is a thermal capacity all about.

It refers to the material which can store thermal energy and then, you know for an extended period of course, and then give it back outside release it outside. So, what happens is a consequence.

(Refer Slide Time: 13:07)



It can absorbs a lot of daytime heat it can be due to temperature as well as solar radiation it absorbs and then it release or re release it during the night time to the ambient itself. Rather than passing it on inside it is by virtue of the materials density specific heat capacity as well as the thickness of the whole system as a consequence. It reduces the daytime cooling load as well as it reduces the night time heating load.

So, here one thing we have to understand imagine this is a case with a hard and dry climates the ambient temperature may go as highest say 45 or 46 degree and the night time temperatures drops to 25 degrees, one thing we need to understand as a effect of thermal capacity this is a outside temperature, as I said this is a inside temperature. So, this much amount of thermal energy is dampened this is absorbed and the inside temperature fluctuates here. So, you are saved this much amount of cooling energy rather than cooling, they are from 45 degrees to 24 degrees. Effectively you are only cooling it from this particular temperature say it may be around 30 degrees or 32 degrees then, other side of it what happens when the ambient temperature drops well below the inside is also kept more or less warm.

So, the inside temperature fluctuation is much lesser always we look at time lag the major parameter that we look at based on capacity isolation is how much time it takes for the maximum to occur compare to the outside maximum. So, if this is a outside maximum this is a inside maximum this. For example, happens at 2 o clock in the afternoon this is a ambient maximum on a particular surfaces you know, remember this is a solar temperature which is a cumulate value including air temperature it includes the absorptive of the wall surface and it includes the solar radiation this is a solar temperature maximum and this is a inside wall surface temperature.

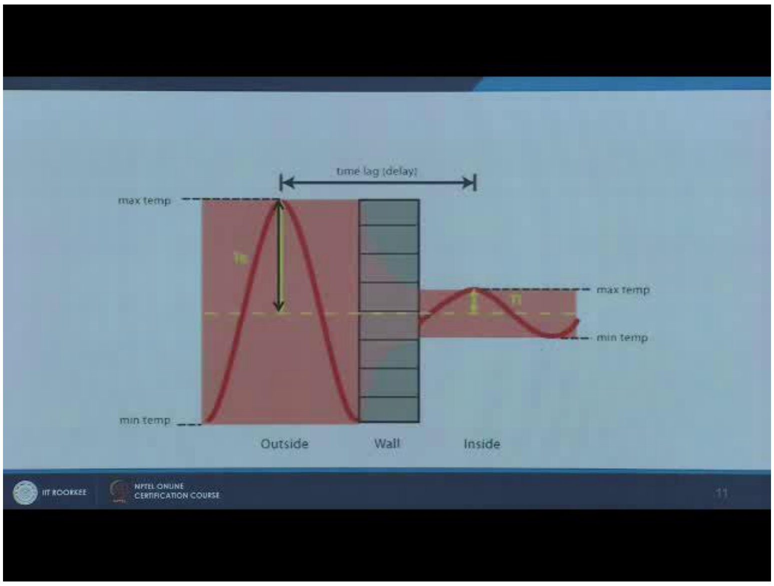
So, the outside surface temperature versus the inside surface temperature say around one and half to 2 hours are as the thermal capacity increases say thick adobe wall. It can go as far as 4 to 5 hours in terms of thermal lag, there are wall systems which are even more you know which have a larger thermal lag also, but the other side of it we should not be missing what happens the same effect happens in the night time also it may be advantages in some cases, it may be disadvantages in some cases as I said imagine this is 45 degrees this is coming down to 35 degrees instead of rising up to 45 there is a 10 degree reduction in the daytime maxima. So, this is now 35 degrees.

The minimum temperature drops to say 25 degrees. So, the diurnal variation is somewhere around 20 degrees the inside here drops say 30 degrees. So, what happens when, you are comfort are the prefer temperature we were looking at thermal comfort in the previous sections our comfort and prefer temperature. Somewhere lie between near 26, 29 degrees depends on season age gender etcetera. So, imagine it is somewhere, around 26, 28 degrees daytime you are saved it is getting as close to 35 degrees.

Further you can enhance it with air movement or you can have some passive as well as active cooling. So, here you are saving energy and you are being comfortable, but night time it is also not dissipating the heat it is still holding this much amount of heat. So, the temperatures are higher this particular place traditionally what people did they were coupling it with night ventilation. So, they use to open the windows they use to ventilate the houses. So, that the ambient temperature the indoor temperature gets as close as possible to the ambient temperature. So, in this case the night time performance will not be as cyclic as this, but it will get closer to the ambient temperature.

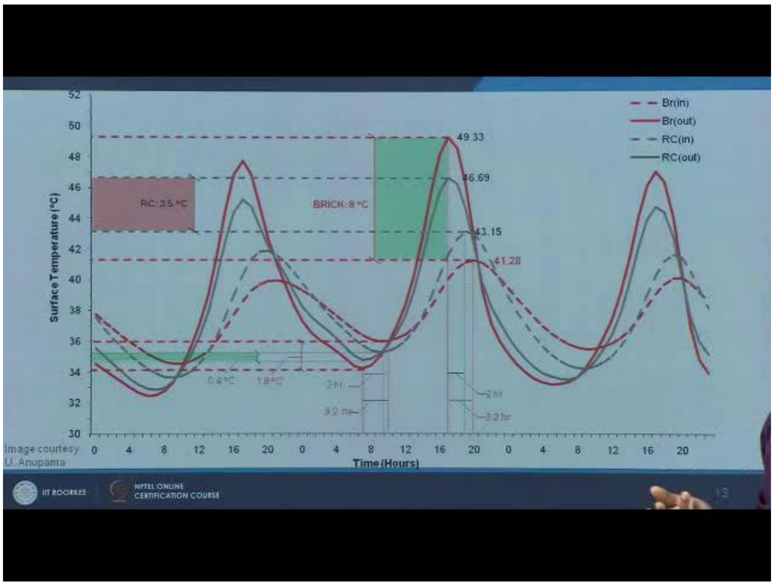
So, primarily when, we have to learn about capacitive isolation the first thing we look at it the time lag and the second important thing is the amplitude reduction.

(Refer Slide Time: 17:09)



As I said time lag this is a ambient variation from minimum to maximum and the indoor there is a reduction in amplitude as well as the difference in time this is recorded in terms of time lag and the amplitude reduction. So, we have lot of traditional examples, I have put this Egyptian storage areas, but we do not have to go all the far you know to Egypt we had a lot of individual example starting from you know poor man's mud house to palatial spaces where thermal mass are the capacitive isolation as been all the more effectively implied some measurements that we took.

(Refer Slide Time: 17:47)



There are 2 types of wall systems we are not getting into what wall they are, but typically the grey line represents a wall system and the red represents another wall system recording for 2 days again like last time it goes from zero and one day sorry this is 3 days this is the first day second day and third day we will look at the second days data more closely.

So, what happens? This dark you know thick line this represents the outside surfaces temperature it goes as highest 47 degrees and this is inside surfaces temperature claims up to 43 degrees and this are test measurements. So, we do not have to worry about what intensity actually they are it may go up or it may be lesser than this in this case, it went up to 47 degrees inside is 43. So, the difference what we see here is 3 and half degrees this is like a thin wall system then again we take a 110mm thin brick wall system in this case sorry this is a 230 mm thick you know slightly thicker sections, where the ambient temperature maxima are the outside surface temperature solar temperature went up to 49 degrees and the inside amplitude was 41 close to 41. So, there was more or less an 8 degree reduction in the maximum temperature this is a peak temperature apart from what we need to know and the other side of this we also notice a similar difference.

So, the ambient temperatures this was night ventilator. So, the ambient temperature goes as close to where one 35 degrees, 34 and half degrees precisely, but the indoor temperature also gets closer it is around 35 and half 35 and half degrees here, but in this case the ambient temperature surfaces temperature drops to 34, where as the inside surfaces temperature is 36 there is a 2 degrees temperature difference. So, there is a reduction in amplitude if you take the time lag calculation or the reduction in amplitude calculation first there is a considerable difference between what happens in the daytime and what happens in the night time another important things here is the time difference. So, if you look at what is the shift that is a face shift this is a maximum peak temperature occurring at somewhere, around 16-30 or 17 then for the inside peak to happen I am talking about this grey line here it happens 2 hours, after the outside surface peak has occurred.

On the other hand here it is more than 3 hours, similar thing happens in the night time also. So, what we need to understand this wall system one heats up faster which is not really good. So, we have to do something, but in the process of doing something say you want to increase the thickness you want to change the material insulate it in this process we should also not forget by doing that the heat loss or the dissipation also increases imagine this is a living room or an office space, which is occupied from 9 o'clock in the morning 6 o'clock it is closed air conditioner is running.

So, at case insulating or increasing the thickness or doing some material change might be beneficial in this case where as for residential buildings mainly you where you would get into the room to sleep say around 9 o'clock, you turn on air conditioner you go to bed at ten o clock. Then if you still have a longer time lag you know your heat is not getting dissipated much faster as you know increase the thickness insulate, it more this is going to go up instead of 2 it becomes 3. It may become 5 in that case the wall will still be holding lot of heat and getting back to the interiors in that sense this is going to consume slightly more energy compare to the other wall system.

Here another important thing that we need to understand, we have to always look at time lag and decrement factor more closely with respect to each other this is, not independent it is the face shift as well as the amplitude shift which is important here it is not just the factor of wall system itself.

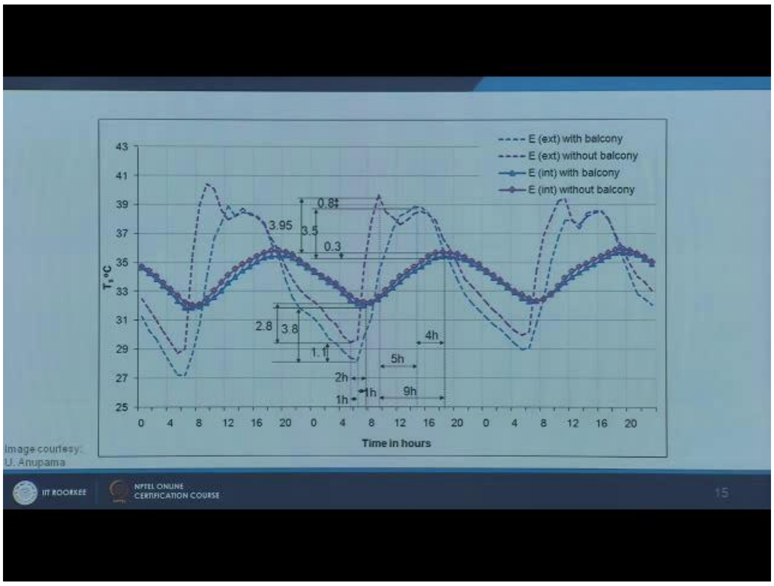
(Refer Slide Time: 21:51)

Here it is also assist you know varying based on the type of insulation where you put the insulation if you have internal insulation the time lag and decrement factor considerably varies. If you have an external insulation it considerably varies now let us for the moment omit the you know grey lines again the grey line is an uninsulated wall system the one you see here this line this is a outside insulation. This is external insulation outside versus inside temperature the orange one is inside or internal insulation outside versus inside surfaces temperature. So, what we see closely here when the wall as an external insulation the solar temperature outside goes really high, but the inside surface temperature is damped it is more or less flat where as in the case of internal insulation the ambient temperature is you know solar temperature is slightly lesser. Whereas the internal temperature also fluctuates little bit more this graph and the previous one, one crucial thing we should not forget the effect of ventilation your windows and the ventilation efficiency really play crucial role in determining. How effective your insulation or the capacitive insulation precisely functions.

In this case the indoor temperature is more or less damped and it is flat revolving around 34 and half degrees and 35 degrees it goes to 35 and half in the third day. So, in this case if you consider around 35 as an average indoor temperature, even in the night time the temperature are going to be much higher you will set your air conditioner probably at 22 or 23 degrees. So, you will have to still be cooling it down much more than, what you will do for an uninsulated wall system sometimes that would perform much better than a insulated wall system especially in the night time.

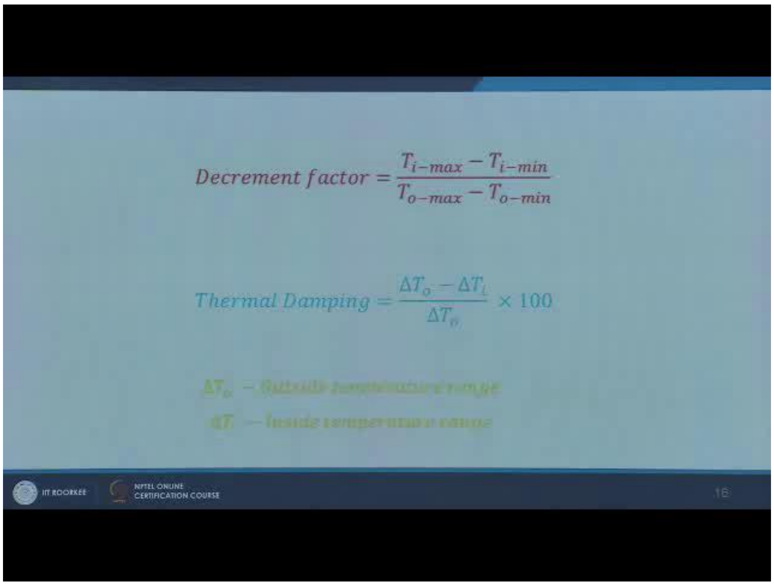
So, keeping this in mind, if you ventilate your building properly if your windows are, so oriented and if you are ventilation effectiveness is much higher than you can have benefit of this insulation system during daytime and ventilation will play it is role convective cooling will happen during evenings and the night time before you know before turning on the air conditioner more details about the amplitude reduction and the time reduction apart from insulation another important factor which affects. This time lag and decrement factor could be your shading especially the presence or absence of balconies they not only effect the magnitude see here this is without balcony this is with balcony. You know magnitude of solar temperature the peak solar temperature reduces which affects the indoor surfaces temperature apart from this it also in facts here ventilation efficiency.

(Refer Slide Time: 24:15)



The time lag you know and the amplitude reduction is considerable here, now I am going introduce you to an important factor which is called Decrement Factor. So, far we have been talking about time lag straight forward. So, you have outside peak and the time associated.

(Refer Slide Time: 24:34)



And the inside peak and the time associated. So, the next thing I was talking about is a amplitude reduction we saw 3 degree reduction, 8 degree reduction, 14 degree reduction in some cases now, how do you quantify this number there is an indicator called decrement factor which is very simple delta T in are the T i maximum this is indoor temperature maximum surfaces temperature here then, indoor surfaces temperature minimum by delta T o which is a outside surfaces temperature maximum and surfaces temperature minimum. So, if you take this ratio you get a number between 0 and one which gives you the decrement factor as far national code or national building code is concerned we refer to a one minus factor that is thermal damping which is almost the same it is a reverse of it. Where you have the delta T o minus delta T I this is the outside temperature range minus inside temperature range by the outside temperature this actually takes into account the varying amplitude this is not surface temperature based, but this is the ambient air temperature and the indoor air temperature based.

So, what happens here you take the outside peak say 45 degrees maximum 25 degrees is minimum. So, you have a delta T of 20 inside you have a delta T similarly, 10 degrees for examples say it is fluctuating somewhere between you know say 40 degrees to 30 degrees. So, you have a delta T of 10 degrees. So, you will get if you substitute you will get a thermal damping of about 50 percentage. So, it is 50 percent damped. So, out national building code prescribes certain damping values for, which as to minimum damping this is. So, you are to be higher than what is prescribed in the national code will look at the numbers more in detail, in the following sessions.

I will wrap up the sessions at this point in the following session we will look you know more in detail about how this indices impact.