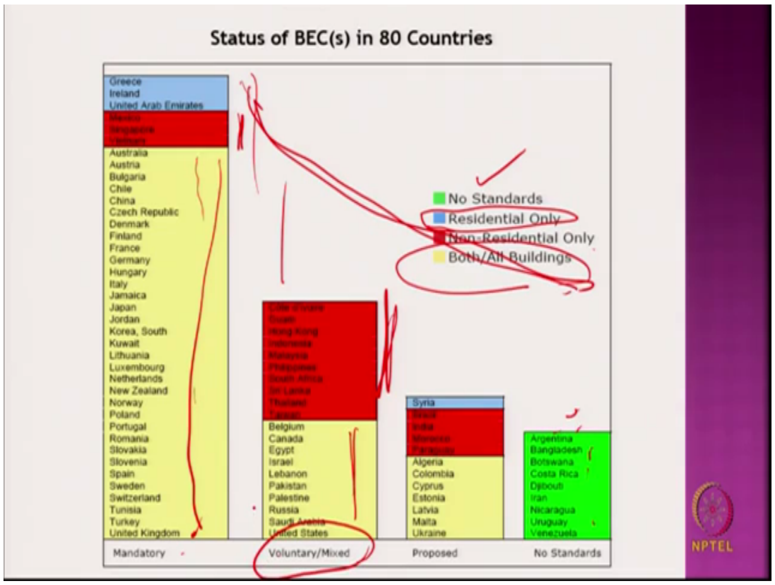
Sustainable Materials and Green Buildings
Professor B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology Delhi
Lecture -39
OTTV Methodology

(Refer Slide Time: 00:20)



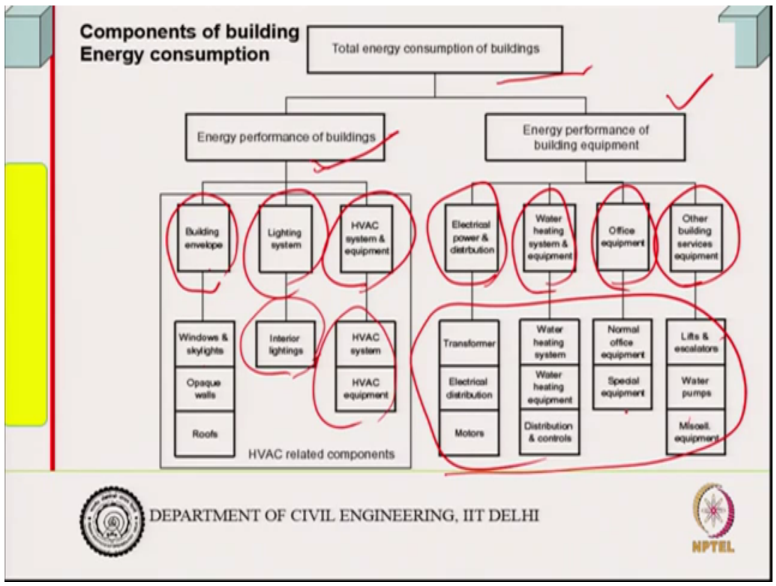
So, if you look at the status of building energy codes, now you will find this. This was I think 2007 around and maybe they have now some of them might have taken. Cognizance no standards are the green ones. For example, many of the African countries and Latin American countries Argentina, Bangladesh etc. they did not have. Some of might have might have actually brought in Djibouti etc.

Some have residential only. So, that is Greece, Ireland, United Arab Emirates but that might have gone to others as well. And then some have non-residential only. So, Mexico, Singapore and so on Vietnam. They have all types of buildings many of them for example Australia, China many countries.

So, some have made it mandatory. So, these countries are mandatory. These countries this is you know they have non-residential and these countries have both but not mandatory voluntary or mixed. And this is proposed this is proposed so at that point of time this proposed and this did not have. So, this actually this must have increased.

The curve must be going like this. The concern about the energy is there very much all over the world and therefore the curve must be now going like this. So, many countries do not have, but there are different approaches other than this prescriptive approach and so on. There are different approaches other than other than prescriptive approach, one of them that is been adopted in Hong Kong is you know Hong Kong and some of those some of those far Eastern countries.

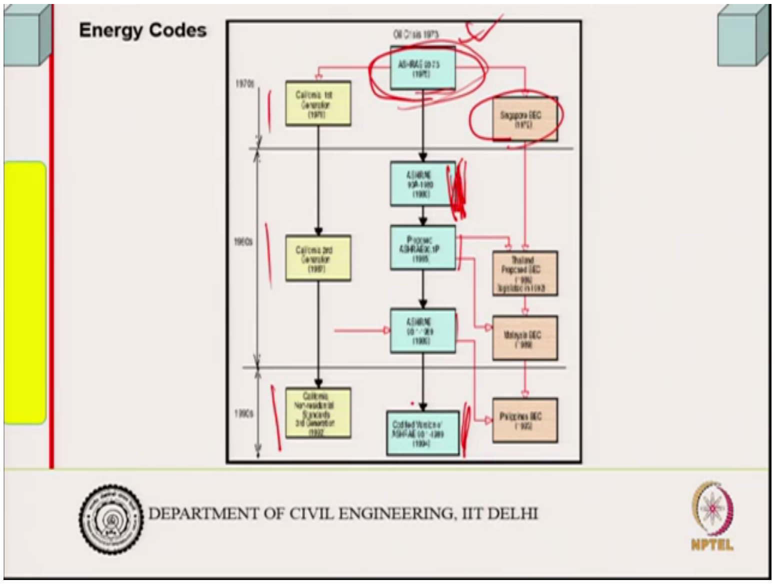
(Refer Slide Time: 03:12)



So, some of the countries they have adopted for the envelope something called Overall Thermal Transmittance value. We will look into this. Specific to envelope basically, right. So, total energy consumption of the building if you look at it. One side is the equipment, other is the you know envelope and other parts. So, this will have Building envelope, Lighting system, HVAC system & equipment and this way Electrical power, Water heating, Office equipment, Other building services equipment.

So, envelope when it comes to it is windows, skylights etc. etc. which I think I might have shown you sometime. Lighting related to this and HVAC equipment. Well this will have electrical system, Lifts escalators and so on. So, overall thermal transmittance value is a kind of a value suggested in this part.

(Refer Slide Time: 04:19)



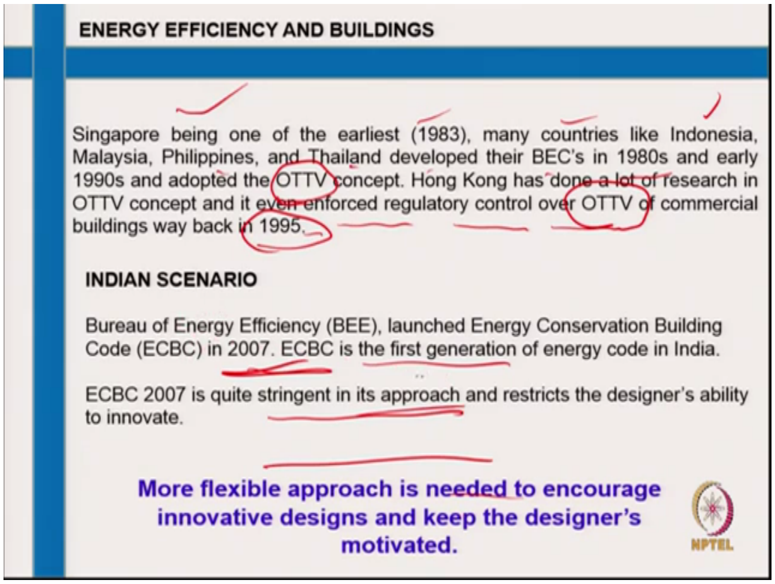
You know eastern many of these countries what they did was this was mainly for envelope part, other part of course is separate. Same course they will have other parts. But we will discuss only the envelope aspect. So, if you see historically 1970s, 80s and 1990s now you know As-Rae. Before going to that, people started realizing about the energy problem although (())(04:56).

You see some of the books written by philosophers or in literature things like hydrogen energy forever. There are an articles on that kind of thing. Because can a scientific society be stable by Bertrand Russell. So, this this you know because the seeing that you are continuously increasing the energy use. Where is it going to come from?

Because already we have seen that the total energy that was available you know by I mean even now largely is from the sun. So, but people started realizing this even more when oil producing countries they started controlling the prices of oil. So, 1970 around that time and around that time I think or just before that YC is came into (())(06:00).

And then they started looking at it can we reduce down the energy consumption. So, American society of heating refrigeration engineers 1975 they started looking and then they changed Singapore then of course As-Rae then developed you know further advanced their code to 19 you know 1980s and so on. In 1990s you know they started further developing their codes itself. So, historically this is how the codes have actually gone.

(Refer Slide Time: 06:40)

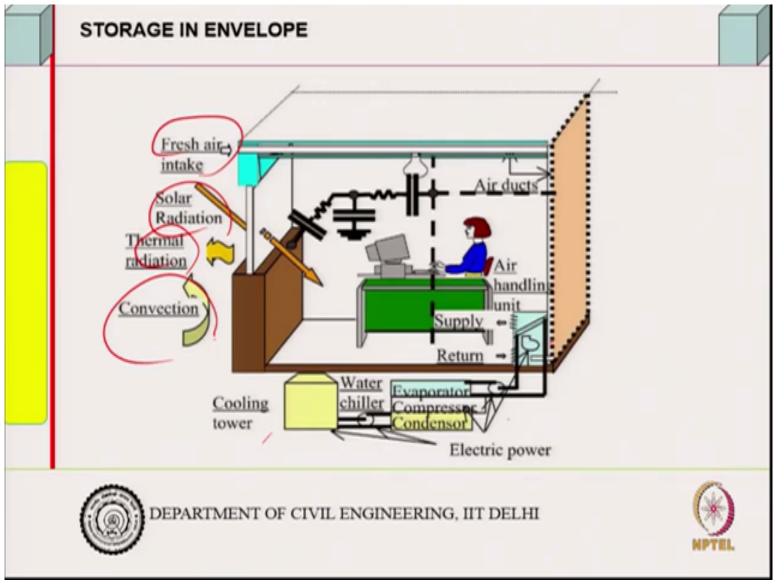


Singapore being one of the earliest 1983 they started. Then Indonesia, Malaysia, Philippines, Thailand developed building energy codes in 1980s and 1990s and some of them adopted this concept called OTTV. Hong Kong has done a lot of research in OTTV concepts and even enforced regulatory control by OTTV. So, I will define this what is OTTV and then how it can be used to control the envelope performance? That is what I will talk about. So, this was you know they did it in 1990s and so on. India first code came in 2007.

And it is quite stringent in the approach at that point of time because it was absolutely prescriptive than whole building purpose. Now, given to the people who are involved in design not having very great background in building physics having somewhat superficial knowledge of building physics. There is always always tend to use the prescriptive guideline. If somebody is knowledgeable then they would like to use something else. And of course whole building performance can one can use them mechanically if one knows how to handle the software.

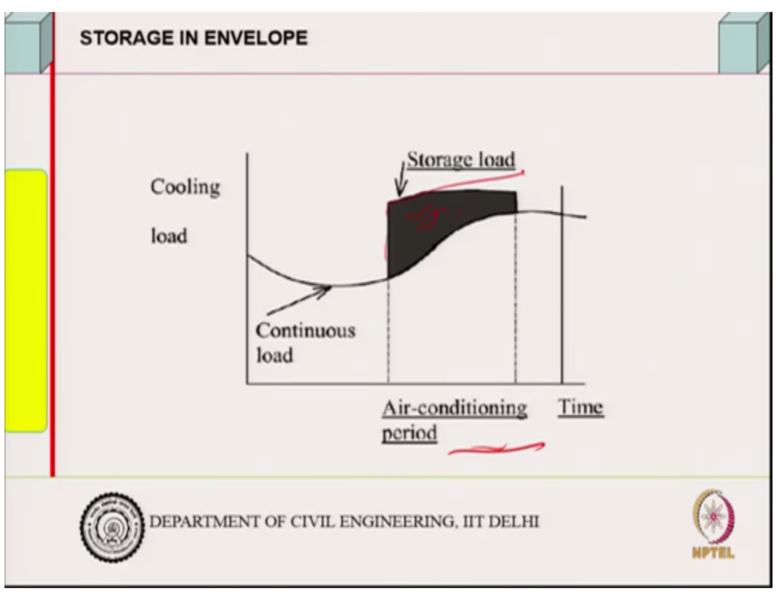
But before that if you want to generate your own several design you know the, you go to have the knowledge base. But quite often the building designers may not have the knowledge base, the scientific knowledge base you know required background, required for that. So, often if given an option that I have a prescriptive option, I have whole building performance option, tendency would be to go to the prescriptive which is likely to be conservative and stringent in terms of stringent in terms of you know design. You cannot change much because flexibility is not available. So, this is quite stringent approach. So, more flexible approach is essentially something like this or whole building performance is definitely flexible.

(Refer Slide Time: 09:00)



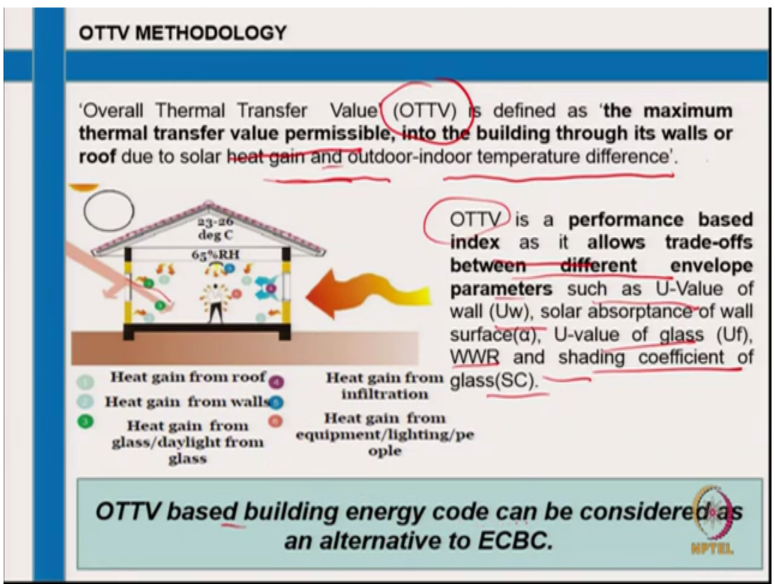
So, anyway this is the component which we talked about several times fresh air, solar radiation, thermal insulation etc. And you know this typically a building shows air duct which been seen cool air and so on. Air handling unit and heater and so on.

(Refer Slide Time: 09:20)



So, it is usually air conditioning period is intermittent except for buildings like hospitals. Which will have 24 hours only. So, you know cooling load if I look at it, continuous load would be something like this. So, load is actual load would be during the air conditioning period. This is the this is the air conditioning period. This is the continuous cooling requirement but it may not be really required cooling required cooling may not be necessary or the building may not be operating at that point of time. So, there has to be some amount of you know air conditioning period. The actual load might go somewhere there.

(Refer Slide Time: 10:07)



So, overall thermal transfer value this is what is the OTTV stands for is defined as the maximum thermal transfer value possible into the building through walls roof due to solar heat gain and outdoor-indoor temperature difference.

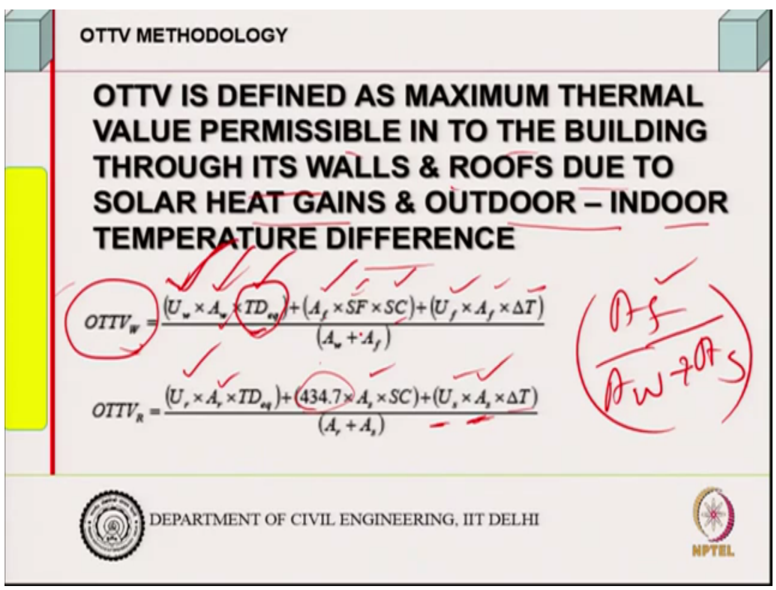
So, basically two issues you have got outdoor and indoor temperature difference. So, it is the maximum thermal transfer value possible into the building through its walls and roof due to solar heat gain sun's radiation direct and temperature difference. So, this is this is a figure simply an equation is there, we will look into that. So, it is a performance based index that means it is quantified.

It is quantified allows trade-offs between different envelope parameters. So it is you know it is looking for envelope. Now, you might you might use one parameter in better form better you know better values for one parameter. Somewhat worse for worst value for some of the parameters. And yet you can achieve OTTV.

So, it allows for certain amount of flexibility as you will see from the equation. So, U value of wall or U value of roof so you might have higher U value of roof or higher U value of glass. But finally OTTV value is the controlling value it is a performance index. So, your OTTV value should be you know according to the prescribed value. U value of glass, window to wall ratio, shading coefficient and so on.

So, this is again the diagram shows you the the direct solar radiation coming in, some getting reflected, air flow inside and 60 percent 26 degree centigrade because 3 degree centigrade we say is our you know operating differential and so on. So, OTTV based building energy code can be okay.

(Refer Slide Time: 12:04)



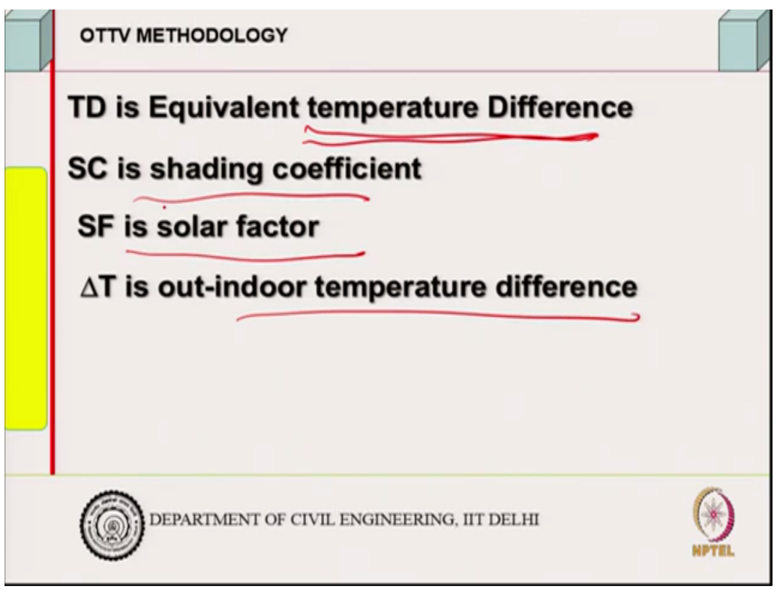
So, this defines the maximum thermal value permissible in the building through its walls, roofs due to solar heat gains and outdoor indoor temperature difference. So, overall thermal transfer value, overall thermal transfer value for wall you define as Uw, U value of the wall, area of the wall, of the walls and equivalent temperature difference.

Now, this equivalent temperature difference is what the code gives you or you might estimate them also. But codes gives you four different conditions. Then this is for the wall, this is for the fenestration area that is the solid portion of the wall. Then shading coefficient, solar factor and U of the glass or fenestration, area of the fenestration and delta t is again the design temperature difference.

So, equivalent temperature difference this is given for given location and given season. You know given location actually it is given for the given climatic condition. So, you have choice of putting your own U values, area ratios Af to Aw or Af by Aw plus Af. This is this you can choose how much wall area but there is an upper limit of course as you increase it, it will tend to bring in more heat. So, this is for the wall.

For the roof the same thing, U value of the roof, solid portion roof if there is some sort of you know skylight or something and same thing it will have you know it gives you some value and this is for the skylight U values one for the solar gain of the skylight. This is solar coefficient, shading factor this is what is so taken into account.

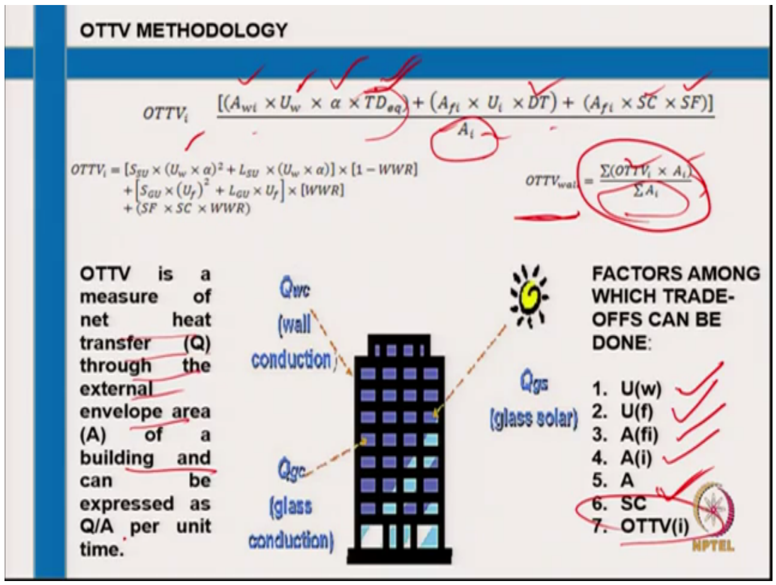
(Refer Slide Time: 14:11)

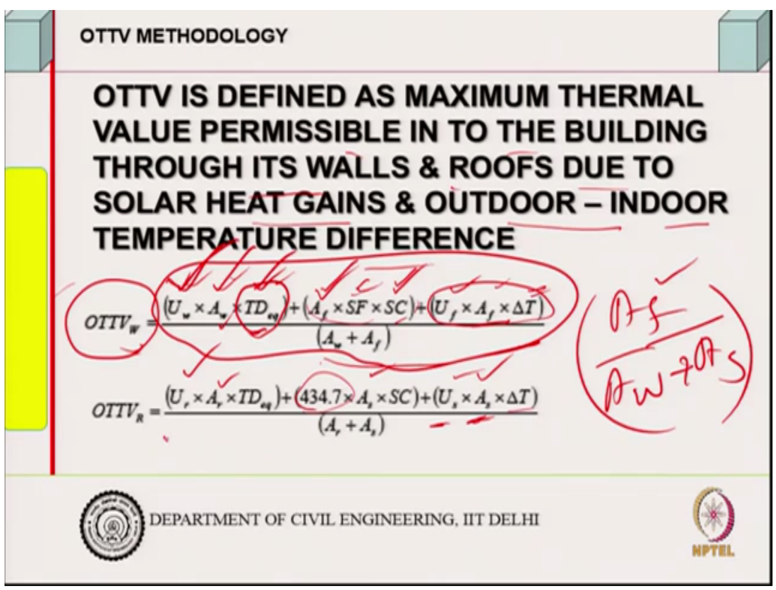


So, this the formula. TD is equivalent temperature difference, that is given calculated over the years obtained through regression one can obtain them and these are given in the code actually. So, further location for example in a small country like Hong Kong it is not very difficult. They can have temperature difference specified or Singapore they can specified the temperature difference. But is if it is to be done for Indian scenario then it is to be done for number of cities and different climatic zones.

So, equivalent temperature difference. SC is the shading coefficient. This is solar factor and it is the outdoor temperature difference. So, this this values are given. one can generate them of course.

(Refer Slide Time: 14:57)





So, overall you know so overall OTTV will be for the whole window would be I mean basically you know this is a measure of net heat transfer. So, what does it give actually? If I look at this, this gives you ua delta t, area of the fenestration, shading factor and solar coefficient. So, that is the amount of energy that is coming through the glass.

This is the energy that is transferred due to the heat transfer or U value of the insulation value of the glass. So, it is per unit area amount of energy transfer on a gross or average value for the whole year. Because this is an equivalent value which will be found or given in the code. And similarly this is for the roof. So, for each individual component for i-th component i-th wall you can find out you know U as you have chosen this is absorptivity td equivalent temperature difference equivalent and area.

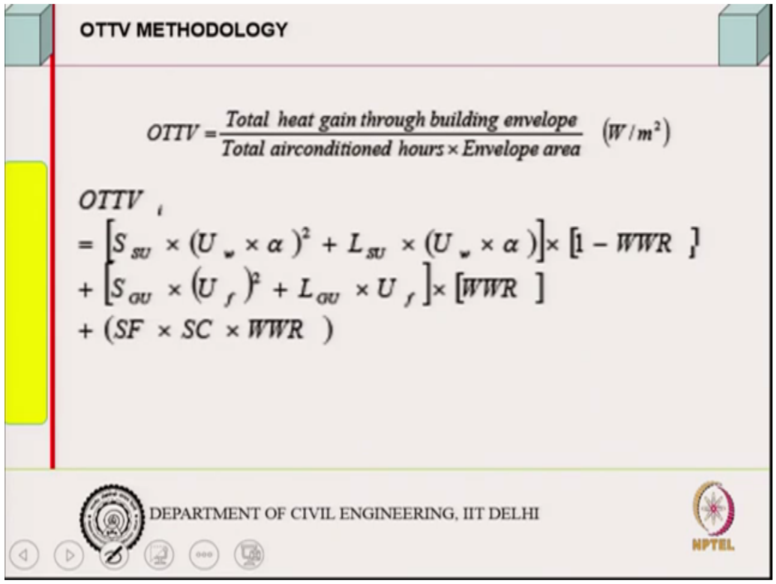
That is for a solid portion of the wall. This is for the fenestration etc. So, this is the total thing divided by the area. So, for each wall or each roof you can find out because it might be different depending upon the orientation. And then for the you know for overall wall for all the total for all the walls OTTV for each wall is known to you.

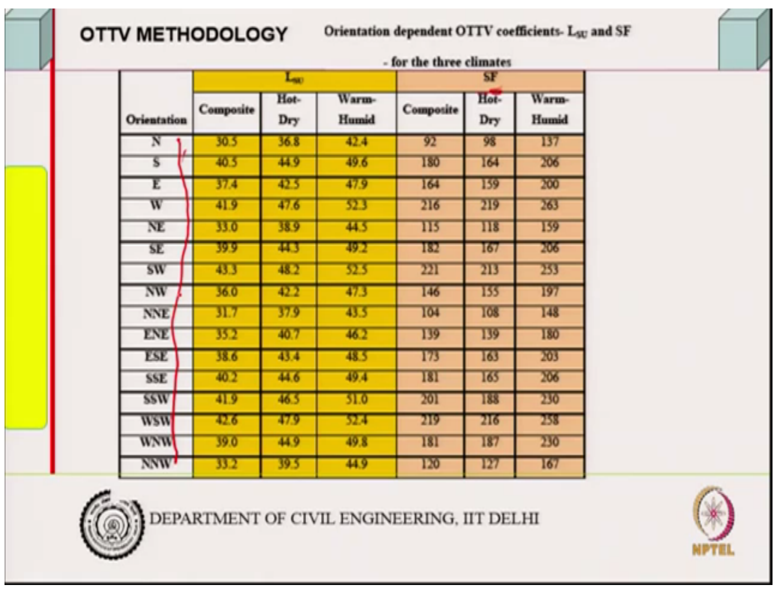
OTTV for each wall is known to you. Multiplied by the area of the wall divided by sum total of the wall. So, overall OTTV for the building also you can find out by taking OTTV values of each individual wall and roof multiplied by the area divided by the total area. So, finally it gives you what, it gives you an equivalent average heat transfer. That will occur over the whole year which you can estimate based on the values which are given in codes.

So, these values are given in the code for different climatic condition and then multiplied by the area simply and you calculate it out. So, it can be little bit simplified in a way direct solar radiation of course will include alpha value, so for that also separately you may have to calculate out td equivalent. So, U of the wall is important, U of the fenestration is important, area of the fenestration is important, overall area of the important. Hence shading you know the solar coefficient area and this for each one, one can find out OTTV value. So that is what it is.

It is a measure of net heat transfer through the external envelope area of the building and can be expressed as q by a per unit area. So, that means what you have done? You have sum of four each component in the envelope multiplied by their area that is the summed up divided by the total area of the envelope. Total area of the envelope. That will give you in terms of quantity kilo watt per meter square or whatever it is.

(Refer Slide Time: 18:31)

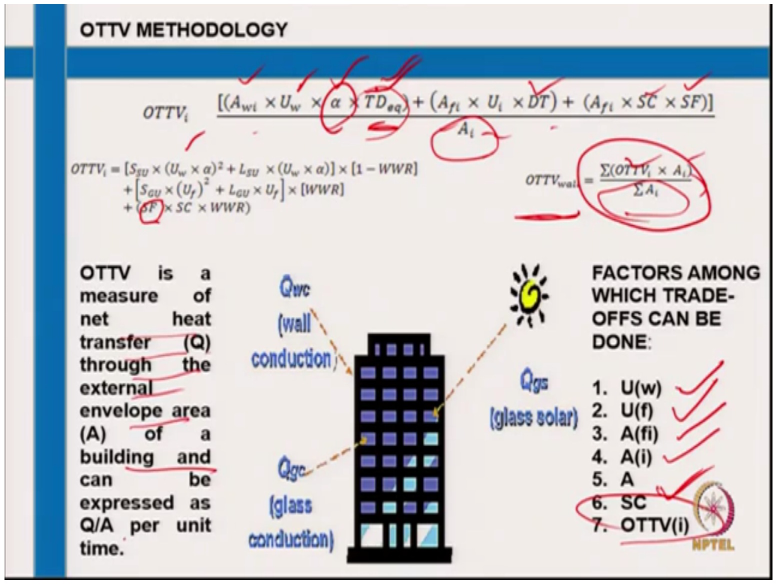


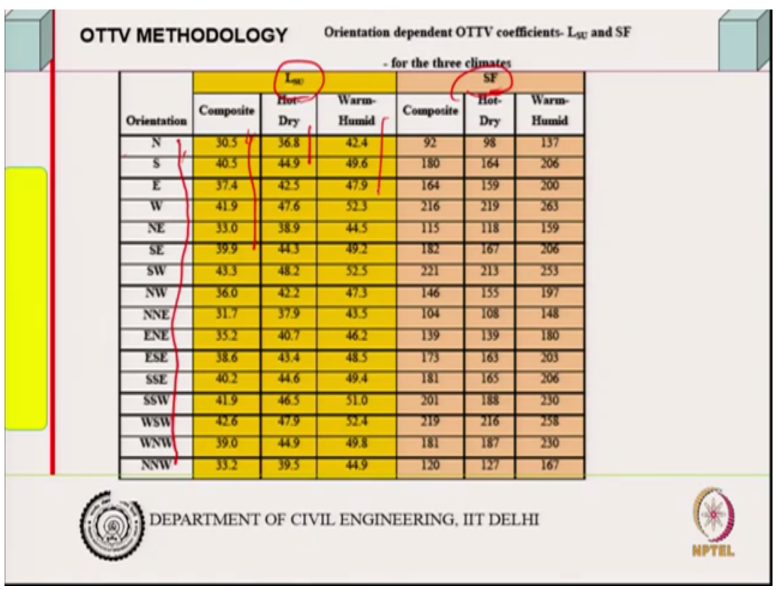


Orientation	L_{SU}			SF		
	Composite	Hot-Dry	Warm-Humid	Composite	Hot-Dry	Warm-Humid
N	30.5	36.8	42.4	92	98	137
S	40.5	44.9	49.6	180	164	206
E	37.4	42.5	47.9	164	159	200
W	41.9	47.6	52.3	216	219	263
NE	33.0	38.9	44.5	115	118	159
SE	39.9	44.3	49.2	182	167	206
SW	43.3	48.2	52.5	221	213	253
NW	36.0	42.2	47.3	146	155	197
NNE	31.7	37.9	43.5	104	108	148
ENE	35.2	40.7	46.2	139	139	180
ESE	38.6	43.4	48.5	173	163	203
SSE	40.2	44.6	49.4	181	165	206
SSW	41.9	46.5	51.0	201	188	230
WSW	42.6	47.9	52.4	219	216	258
WNW	39.0	44.9	49.8	181	187	230
NNW	33.2	39.5	44.9	120	127	167

And this value this value should be below the prescribed value. So, this is for the wall. I will come back to this. I will come to this come back to this again actually. You can see this, this is you know this this for it would vary this td equivalent that will vary for different orientation. Alright I will I will come to this a little bit later on.

(Refer Slide Time: 19:12)





Orientation	L_{SU}			SF		
	Composite	Hot-Dry	Warm-Humid	Composite	Hot-Dry	Warm-Humid
N	30.5	36.8	42.4	92	98	137
S	40.5	44.9	49.6	180	164	206
E	37.4	42.5	47.9	164	159	200
W	41.9	47.6	52.3	216	219	263
NE	33.0	38.9	44.5	115	118	159
SE	39.9	44.3	49.2	182	167	206
SW	43.3	48.2	52.5	221	213	253
NW	36.0	42.2	47.3	146	155	197
NNE	31.7	37.9	43.5	104	108	148
ENE	35.2	40.7	46.2	139	139	180
ESE	38.6	43.4	48.5	173	163	203
SSE	40.2	44.6	49.4	181	165	206
SSW	41.9	46.5	51.0	201	188	230
WSW	42.6	47.9	52.4	219	216	258
WNW	39.0	44.9	49.8	181	187	230
NNW	33.2	39.5	44.9	120	127	167

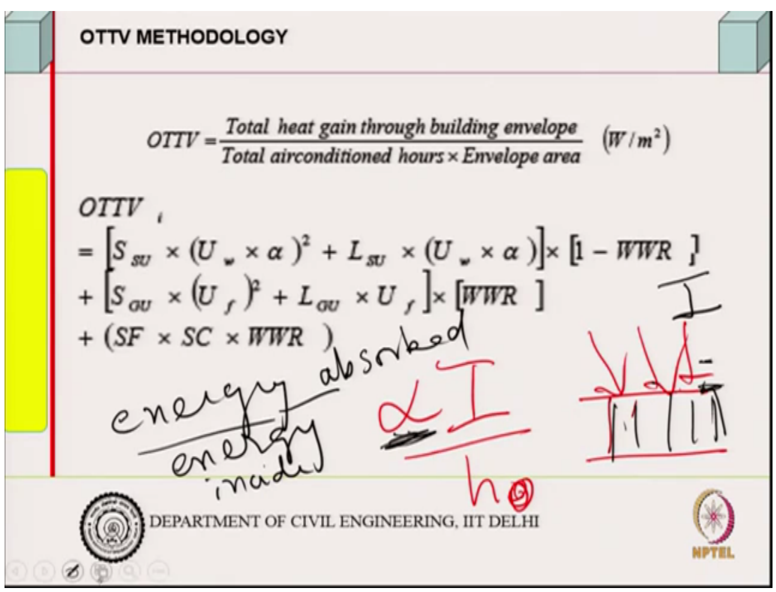
Let me see if I have something you know this (())(19:10). So, these values would vary for different orientation where direct solar gain is involved. Also if I have a shading, if I have you know shading device then the solar factor or shading factor has to be multiplied. So there is some other sf this has to be multiplied. These values are given for different orientation.

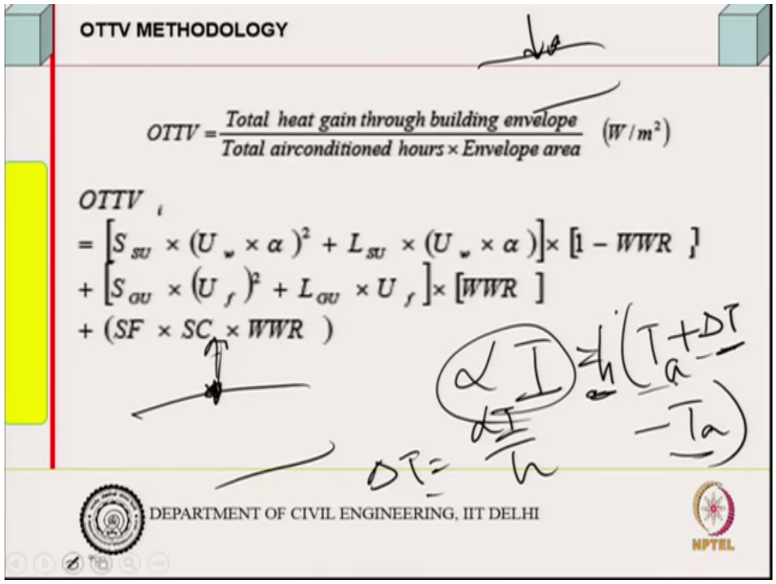
So, a table of this kind would one can generate shading factor and you know for composite monsoon climate hot dry and warm humid climate. So, these values should be actually generated one can generate it in Indian condition. Of course Hong Kong they did not have to do all that because they have only one city, so easily they could give you a guideline for td equivalent dt etc. etc. and that is the end of it. So, basic principle here is you are given a set of values which has been generated for the whole year. And this values are in temperature unit.

Equivalent temperature units or you know in units of for example in this solar gain coefficient units of solar heat gain coefficient. That means ratio, I mean non dimensional. So, these values are given to you that means average value for the whole year is given to you for a given climatic condition and given location. You got to multiply this with the respective walls and roofs. So, calculation procedure was not very complicated.

But these values depend upon orientation and obviously they will depend upon location also which may be climatic you know condition based. So, combining this two you can actually obtain the overall OTTV value for all the walls and similarly for all the roofs. Multiplied by the roof area and multiplied by the wall area respectively and divide by the total area that will give you the OTVV value for the whole building. And that should be less than the prescribed less than the prescribed value. This should be less than the prescribed value. But when there is one additional factor that will come in when one is looking at it. One is a value related to what we call solar temperature.

(Refer Slide Time: 22:09)





I do not know whether I have introduced this one to you when radiation falls onto a surface, opaque surface, this is what is absorbed and equivalent temperature rises given by ho or whatever I call it. But just for quick reference those who have done course in building science they would have known, supposing radiation is falling onto this surface, this is a solid surface. This is a solid surface. This is a solid surface. This is a solid surface. This is a solid surface.

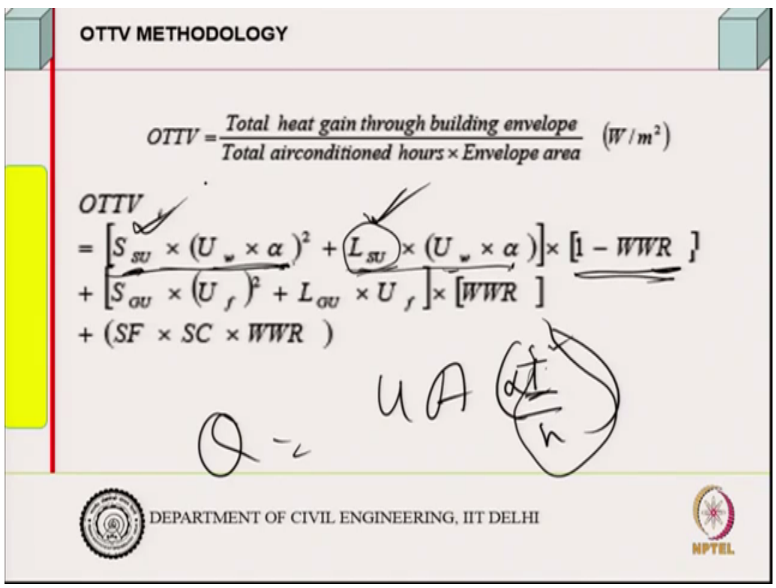
So, this will cause radiation is I intensity of radiation here is I is falling onto this surface. Absorptivity is defined as a amount of energy absorbed divided by amount of energy incident. So, I is this of a ratio energy absorbed because opaque body will absorb divided by energy incident. I think I talked about this RDR energy incident. So, this fraction will be absorbed.

If this fraction is absorbed effective temperature of this one will become higher. Effective temperature of the surface because opaque surface it can absorb or reflect. So, 1 minus alpha is reflected alpha is alpha I is what is absorbed. So, whatever is absorbed that will result in alpha I is absorbed this will result in increase in temperature. Let us say this increase in temperature, effective temperature is air temperature is ta plus some delta t increase in temperature.

This would be the temperature increase minus ta into h is the heat loss. Because when this gets heated up this surface gets heated up this the heat transfer will take place from here to the surrounding by convection and radiation and what I call it equivalent heat transfer coefficient. So, if the temperature rises ta plus delta t minus ta surrounding air temperature is ta then alpha I must be equals to this. In other words, delta t the temperature rise of the surface, I can write it as alpha I divided by h.

Alpha I divided by h. That means I have a surface on which radiation is falling. It causes it to its temperature to rise then it will dissipate the theta out to the surrounding environment. And when it dissipates the heat to the surrounding environment that can only happen when temperature rises occur. So, I want to quantify or found out how much temperature rises occurring. If a steady state situation exists, alpha I is what is absorbed. The amount that would be dissipated will be heat transfer coefficient multiplied by delta t. So, delta t is given by this.

(Refer Slide Time: 25:41)



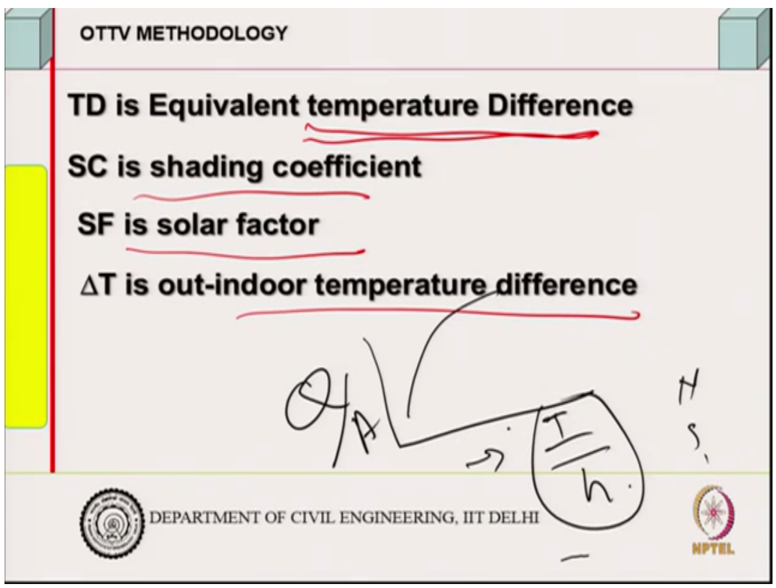
So, when I have, when I have opaque bodies receiving radiation then this equivalent delta t corresponding to this or equivalent you know so my heat transfer will be given by ua you know due to simply this is due to simply this will be I alpha by h naught. I alpha by h naught h.

Now, this I would vary depending upon orientation location etc. etc. And from time to time of the day and over the seasons and so on. So, I must find an equivalent value for this as well. And this is this one. This is this one. Lsu stands for solar gain. You know this is due to the direct solar gain. Whatever the heat transfer conduction heat transfer through this.

So, this is again an equivalent value. So, you know ua alpha multiplied by this is again another component of the heat transfer because the solar radiation falling onto the opaque body. And window to wall area ratio is for unit area if I consider, multiply this by 1 minus window to wall area ratio.

This is one component and actually it has been seen that this is this variation the quantity of heat is not it varies not linearly rather in a parabolic manner. So, this term you know so this this coefficient I mean one can generate this for one equation through regression analysis and ua is proportional to ua alpha square so Lsu so this is the this is actually the quadratic component. This is the linear component. This is the second order component.

(Refer Slide Time: 27:28)



So, this one can generate, so how does one generate for many of the you know for for example you you try to find out the q per unit area for a surface for surface let us say north surface, south surface etc. etc. As a function of I by h which is for the whole year. And if you find that you find that it is not linearly related rather this is quadratic. Some sort of equation of this form. So, this would be q by a is related in this manner.

(Refer Slide Time: 27:58)

OTTV METHODOLOGY

$$OTTV = \frac{\text{Total heat gain through building envelope}}{\text{Total airconditioned hours} \times \text{Envelope area}} \quad (W/m^2)$$

$$OTTV = \left[S_{SU} \times (U_w \times \alpha)^2 + L_{SU} \times (U_w \times \alpha)\right] \times [1 - WWR] + \left[S_{GU} \times (U_f)^2 + L_{GU} \times U_f\right] \times [WWR] + (SF \times SC \times WWR)$$

DEPARTMENT OF CIVIL ENGINEERING, IIT DELHI

NPTEL

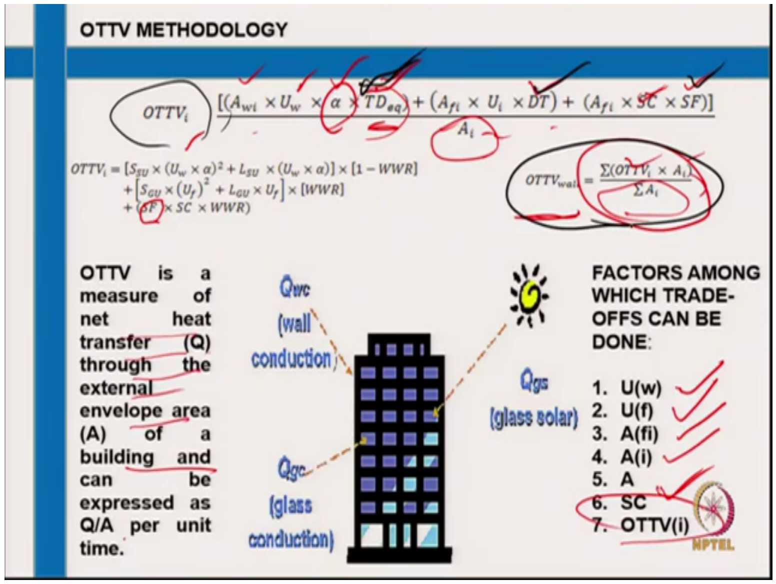
OTTV METHODOLOGY

Orientation dependent OTTV coefficients- L_{SU} and SF - for the three climates

Orientation	L_{SU} Composite	L_{SU} Hot-Dry	L_{SU} Warm-Humid	SF Composite	SF Hot-Dry	SF Warm-Humid
N	30.5	36.8	42.4	92	98	137
S	40.5	44.9	49.6	180	164	206
E	37.4	42.5	47.9	164	159	200
W	41.9	47.6	52.3	216	219	263
NE	33.0	38.9	44.5	115	118	159
SE	39.9	44.3	49.2	182	167	206
SW	43.3	48.2	52.5	221	213	253
NW	36.0	42.2	47.3	146	155	197
NNE	31.7	37.9	43.5	104	108	148
ENE	35.2	40.7	46.2	139	139	180
ESE	38.6	43.4	48.5	173	163	203
SSE	40.2	44.6	49.4	181	165	206
SSW	41.9	46.5	51.0	201	188	230
WSW	42.6	47.9	52.4	219	216	258
WNW	39.0	44.9	49.8	181	187	230
NNW	33.2	39.5	44.9	120	127	167

DEPARTMENT OF CIVIL ENGINEERING, IIT DELHI

NPTEL

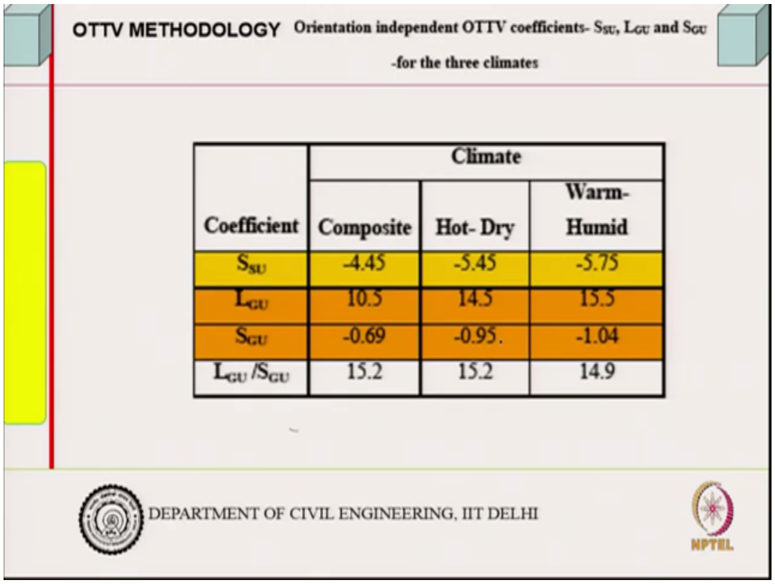


As you can see here this is the coefficient, this coefficient is given in the code. This coefficient can be given in the code. The linear coefficient can be given in the code and 1 minus window to wall area ratio. And similarly for glass. Again it has been seen that it is can be quadratically related.

So, one can make this OTTV a little bit more complicated than usual by these values are actually obtained through regression analysis or large number of walls and roofs for each climatic condition. And prescribed values in the table they actually come from the there. For example, Lsu values and the shading factor and so on, so linear coefficients for composite climate for different orientation. These values are given.

So, these values are can be adopted you know some of them in case of Hong Kong code they have linear variation they have given. But supposing one looks at the regression analysis one might find something of this kind. The all point that I would like to make here is that these values are obtained for yearly average for a given orientation and given shape. I mean given orientation and given location. And OTTV can be easily calculated for each wall and roof. And sum it up for all the surfaces that gives you overall thermal transmission. Maximum values are prescribed in the code. Maximum values are prescribed in the code.

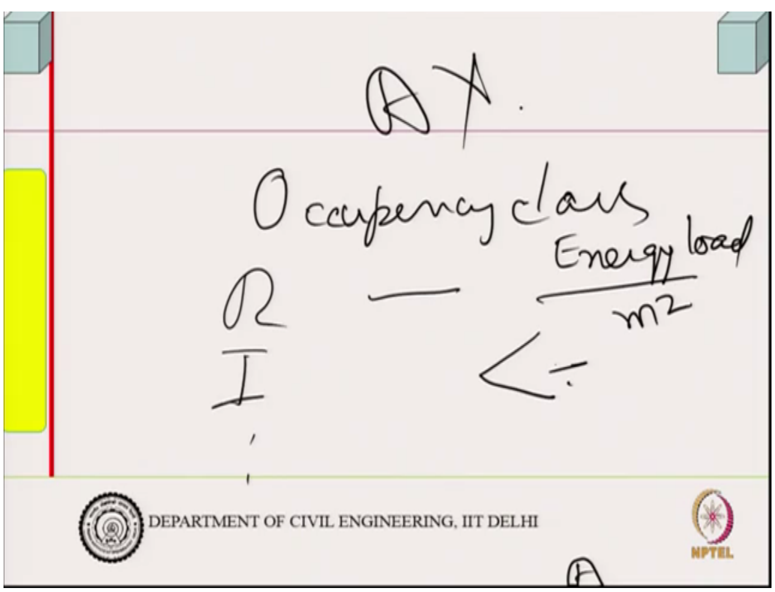
(Refer Slide Time: 29:27)



Coefficient	Climate		
	Composite	Hot- Dry	Warm-Humid
S_{SU}	-4.45	-5.45	-5.75
L_{GU}	10.5	14.5	15.5
S_{GU}	-0.69	-0.95.	-1.04
L_{GU}/S_{GU}	15.2	15.2	14.9

And maximum values are prescribed in the code. So, depending upon various climate this is this is what are given. So, one can calculate out the OTTV value and that should be less than the prescribed value. But best would be still a better and for a future approach to such course would be you have occupancy class.

(Refer Slide Time: 29:46)



Occupancy class, let us say residential then institutional etc. etc. now for each of these class you specify that the energy load, yearly energy load per unit area should not exceed a value so much.

That is the best control of the code. But it has to be demonstrated because policing is not possible. You cannot see there but then it should be demonstrated in design.

So, demonstrated in design that the total area, so if you know your area of the building, area of the building is known that multiplied by this value, the energy consumption by design each accepted design should show that that value is less. Then but at the moment they are at difficulties. Because the changes are too much the equipment changes and so on and so forth, everything put together.

So, codes you know the codes have come in order to control this and this is the code some introduction to the code or more on information of the type of codes you can have. I think that finishes our discussion on this one. Familiarizing you with the possible codes that could be there and this you know on many most of the countries they have this now. Okay.