Sustainable Materials and Green Buildings
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Lecture 37
Energy Conservation Building Code (ECBC 2007) Continued.

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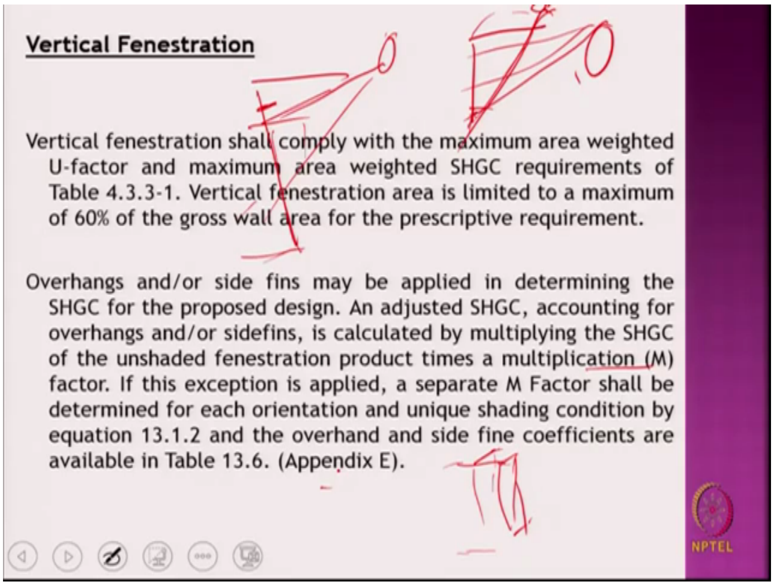

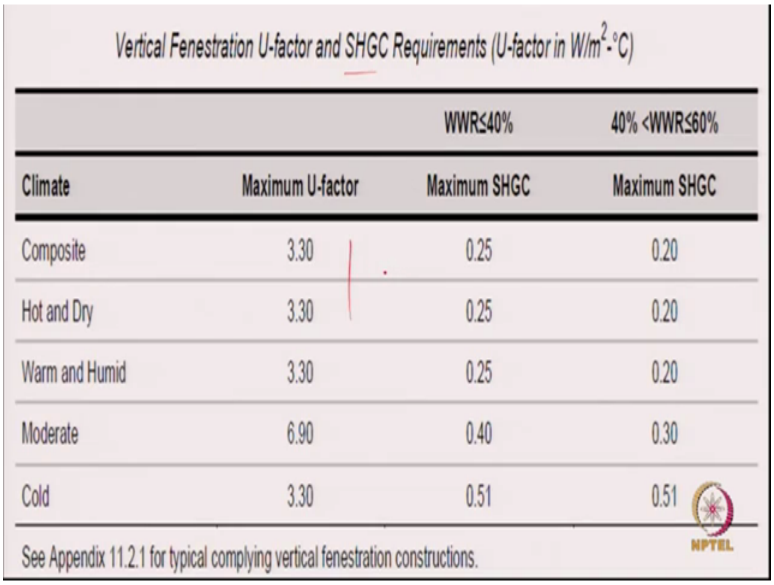

Vertical Fenestration U-factor and SHGC Requirements (U-factor in W/m^2-°C)

		WWR≤40%	40% <WWR≤60%
Climate	Maximum U-factor	Maximum SHGC	Maximum SHGC
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

See Appendix 11.2.1 for typical complying vertical fenestration constructions.

SHGC "M" Factor Adjustments for Overhangs and Fins

Project Location	Orientation	Overhang "M" Factors for 4 Projection Factors				Vertical Fin "M" Factors for 4 Projection Factors				Overhang+Fin "M" Factors for 4 Projection Factors			
		0.25-0.49	0.50-0.74	0.75-0.99	1.00+	0.25-0.49	0.50-0.74	0.75-0.99	1.00+	0.25-0.49	0.50-0.74	0.75-0.99	1.00+
North latitude 15° or greater	N	.88	.80	.76	.73	.74	.67	.58	.52	.64	.51	.39	.31
	E/W	.79	.65	.56	.50	.80	.72	.65	.60	.60	.39	.24	.16
	S	.79	.64	.52	.43	.79	.69	.60	.56	.60	.33	.10	.02
Less than 15° North latitude	N	.83	.74	.69	.66	.73	.65	.57	.50	.59	.44	.32	.23
	E/W	.80	.67	.59	.53	.80	.72	.63	.58	.61	.41	[illegible]	.16
	S	.78	.62	.55	.50	.74	.65	.57	.50	.53	.30	[illegible]	.04

So, that is what we looked into you know and then this is a as I said SHGC factor for glasses and then m factor adjustments for overhangs and fins. So, this are fraction. This is also prescriptive they have given you. How much you should do? But you can calculate and find it out actually.

So, if you have a north facing, latitude greater than 15 degree because this all related to solar radiations. Now, since I have taken care of Indian scenario, India varies from 80 about 32. So, up to 15 they have taken and then 15 and above that is you know that is what and so Latitude Thiruvananthapuram is on the 8 degree, around 8 and Leh, ladakh, Srinagar, etc will be somewhere 31 or something or that kind

So, this and radiation would you know solar radiations there is a thing in, if you go to equator or down below then as I showed you earlier the summer is in the month of December, February, December etc etc. You know that during that period of time and you go to the northern latitudes, the south surface receives quite a bit of radiation in winter but north does not receive anything.

Near equator variation is different, so this covers for near equator situation which I talked to you earlier. In connection with urban heat island issue, I said the radiation distribution summer and winter So, therefore if it is less than north, south also get a little bit of you know south also might get a little bit of radiation if it close to equator but in India, of course, it is 8 degree as I said not 1.

So, in any case that is why the distinction is. So, north actually receives you know basically sun's radiations received in north is very little and you go to feel all northern latitude is still even lower. So, therefore, the multiplier is actually can be you do not get any radiations so putting overhang in north direction does not make any sense because you are not blocking any sun

So, there is no multiplying factor at all. Here, the blockage is very minimal so they have put in this because this will be orientation north in upper latitude. It will receive a little bit of radiation only in summer morning, early morning and summer evening because sunrises day is long you know greater than 15 degrees so day is long.

And you come to this even you know this would be somewhat because then in winter also not close to north you know it gets somewhat you know somewhat more than this. So, multiplying factor is more. But if you come to south this is lower, south-facing because south-facing receives a lot of radiation in winter but you do not know winter radiation you do not mind it coming.

So, it is not very low either, so, only you know this was based on those kind of consideration they would put in some these are prescriptive factors as I said prescription is given but you can actually calculate them out and find it out which is you know how much is a multiplying factor.

East-to west they are put it same and then projection value for projection factors, so m factors for projection you know these are the this is orientation is one thing and this is the amount of length actually related to the length (())(04:20) length of this one divided by the height of the window. So related to the length of overhang to the height of the window so that, how it gives you and these values are therefore prescribed values are given. Vertical fins again these are given so these projection factors are related to the size of the overhang, size of the overhang.

For example, this, this my window height, this is overhang length, so it is related to l by w. So, based on this, these values they have given. Considerations are something like this, higher latitude, day becomes longer in summer and shorter in winter but lower latitudes, the very you know it becomes longer, but not that much comparatively less.

And the south surface gets of lot of radiations in summer I mean winter. In summer it does not get much less. While in the lower latitude you know, the summer comes from sort of sort of moderated, this effect is moderated.

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SHGC "M" Factor Adjustments for Overhangs and Fins

		Overhang "M" Factors for 4 Projection Factors				Vertical Fin "M" Factors for 4 Projection Factors				Overhang+Fin "M" Factors for 4 Projection Factors			
Project Location	Orientation	0.25-0.49	-0.50 - 0.74	0.75 - 0.99	1.00 +	0.25 - 0.49	0.50 - 0.74	0.75 - 0.99	1.00 +	0.25 - 0.49	0.50 - 0.74	0.75 - 0.99	1.00 +
North latitude 15° or greater	N	.88	.80	.76	.73	.74	.67	.58	.52	.64	.51	.39	.31
	E/W	.79	.65	.56	.50	.80	.72	.65	.60	.60	.39	.24	.16
	S	.79	.64	.52	.43	.79	.69	.60	.56	.60	.33	.10	.02
Less than 15° North latitude	N	.83	.74	.69	.66	.73	.65	.57	.50	.59	.44	.32	.23
	E/W	.80	.67	.59	.53	.80	.72	.63	.58	.61	.41	.26	.16
	S	.78	.62	.55	.50	.74	.65	.57	.50	.53	.30	[illegible]	.04

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		WWR≤40%	40% <WWR≤60%
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See Appendix 11.2.1 for typical complying vertical fenestration constructions.

Vertical Fenestration

Vertical fenestration shall comply with the maximum area weighted U-factor and maximum area weighted SHGC requirements of Table 4.3.3-1. Vertical fenestration area is limited to a maximum of 60% of the gross wall area for the prescriptive requirement.

Overhangs and/or side fins may be applied in determining the SHGC for the proposed design. An adjusted SHGC, accounting for overhangs and/or sidefins, is calculated by multiplying the SHGC of the unshaded fenestration product times a multiplication (M) factor. If this exception is applied, a separate M Factor shall be determined for each orientation and unique shading condition by equation 13.1.2 and the overhand and side fine coefficients are available in Table 13.6. (Appendix E).

So, that is why these values are projected and as the overhang length increases this factor becomes smaller because more the overhang length less will be the heat coming in. So, these are multiplying factors, you know this multiplying factor will be multiplied with the value of the this specified values given RDR somewhere I have given those values, SHGC factors so you can multiply you know you can actually multiply by m that is what I am saying, so you can multiply by m, so SHGC of the unshaded fenestration product times a multiplication factor.

So, effective SHGC factor, therefore, would be divided by multiplying factor. You can have you know, so basically this multi the factor the factor that you are actually allowable factor is this much, your factor can be higher multiplied by the multiplying factor which are fraction should be less than this maximum this is given, so it should be less than this for window to wall area ratio 40.

So that is how it is. So, for various projection factor if the projection factor is more than 1, this is for vertical fins, these are for overhangs and both you have provided overhang and fin then this is the ratio. Both you have provided. These are prescriptive you do not have to do calculation just use it. But then this restricts the advantage of designing and optimizing the thing.

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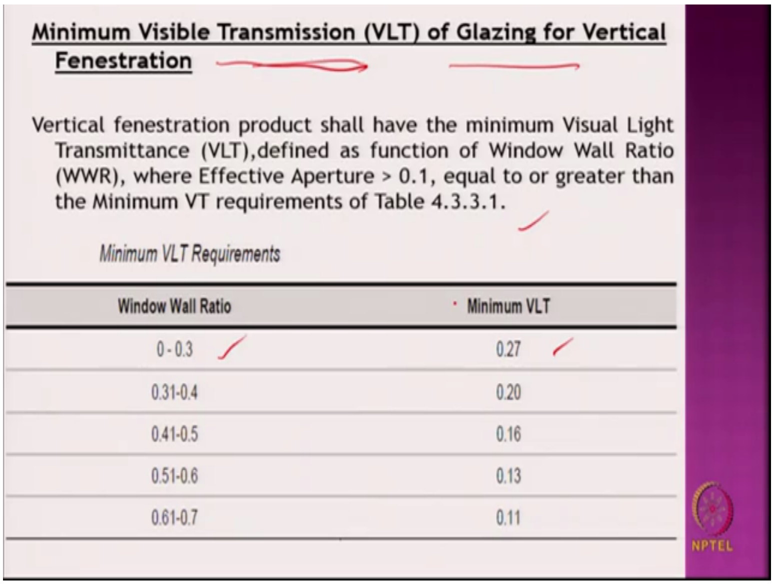

Window Wall Ratio	Minimum VLT
0 - 0.3	0.27
0.31-0.4	0.20
0.41-0.5	0.16
0.51-0.6	0.13
0.61-0.7	0.11

Minimum visible transmission of glazing for vertical fenestration. Now, that this took care of the heat coming in. One is the conduction gain through the opaque bodies the roof U values etc. And direct radiation gain through the glasses, minimizing the infiltration and leakage is should not be there. And then if you are provided overhang this is taking care of this, but then

I must take care of lighting also. So, this is minimum visible transmission of glasses that is prescribed.

That means how much should be the minimum value of the glass for visible light because I can use especial glasses, heat-absorbing glasses even I can go to photo-chromatic glasses. So, minimum value visual light these transmissions are these values are given. So, depending upon window to wall ratios. So, this is what is given. So, this the other control.

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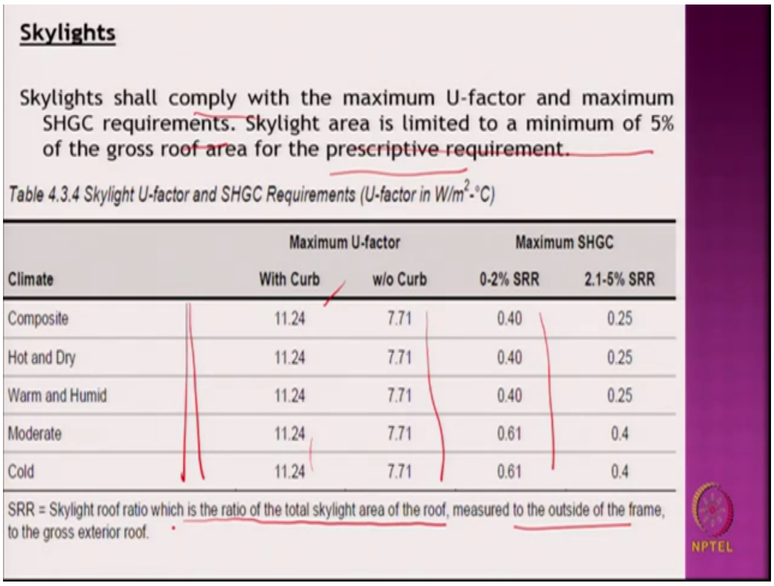

And if you have skylight on the roof, skylight shall comply with maximum U-factor, maximum SHGC requirements and skylight area is limited to minimum of 5 percent of the gross roof area for the prescriptive requirement. So, maximum 5 percent, so industrial building they use also and also one can use and for different climatic condition the skylight you know U-values are given and this is the maximum SHGC values are given. So, skylight roof ratio is the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior area.

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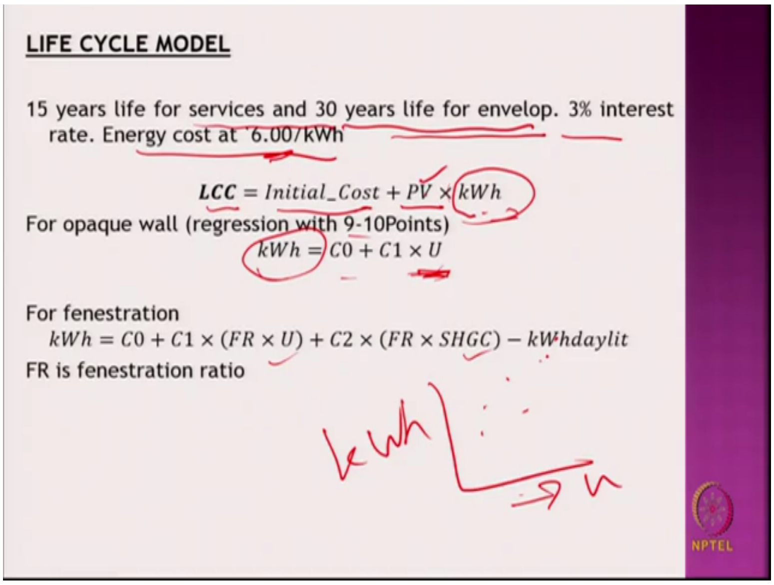

So, these are other guidelines given. Then actually this is they say that this is based on Lifecycle Model, how they found it out, they found it out based on these values they have arrived from Lifecycle calculation, you know that the code arrived at. So, 15 years life for service and 30 years life for envelop that is what have been taken.

So, for envelop 30 years of life with 3 percent interest rate. Well, that is the consciences of the people who actually formulated the code and they calculated the energy cost at that point of time as 6 rupees per kilowatt-hour. So, then the LCC, Life Cycle Cost, the initial cost of the insulation plus present value factor you know by multiplying by present value factor they have actually present value they have multiplied for what which is 6, 6 if you take so this will be 6 multiplying by the discount factor.

So, every year 6 then multiplied by the you know kilowatt-hour, so consumption kilowatt-hour that is all they have found out. That means this much kilowatt-hour multiplied by 6 that is the expenditure every year multiplied by the present value that is what they have found out plus initial cost and then they did some regressions to find out this consumption kilowatt-hour is a function of U-value.

They have taken it as a function of U-value and done some regression for fenestration they have done it in this manner and linear regression they did to arrive at this U-value which are given in the prescription.

Prescriptive value U also been arrived from this. but there is one problem, problem is this some 9 to 10 points regression to come out to care well of U that means what they have done is kilowatt-hour consumption that is plotted as a function of U, some 9 values. So, if you are putting it in a code you know from 8 to 9 values that becomes too small, it tends to be much larger at least more than 30 40 so, this is one of the things and another part of this is some buildings have actually adopted this, but their performance has never been measured so far.

So, you got to check actually whether the energy consumption is coming this much or not, but this is the guideline that the code gives at the moment trying to implement it, trying to see that, there is a kind of you know consciousness or awareness or if it is made mandatory then people have to use this.

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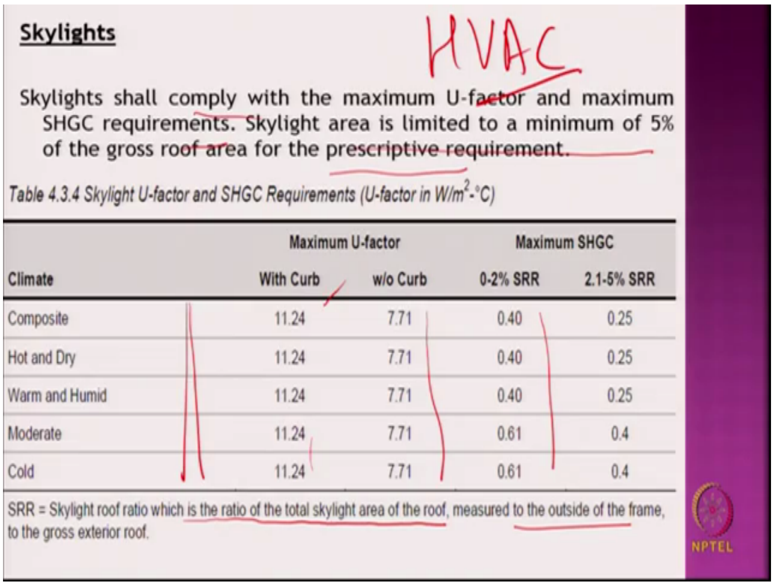

Obviously, this part is you know the building envelop part is one aspect but more important aspect is the other ones those are in terms of commercial issues like the HVAC system, so there if one looks at it actually, the one which consumes more energy are not actually acceptable at the moment, so newer technologies have been favoured by this kind of a code.

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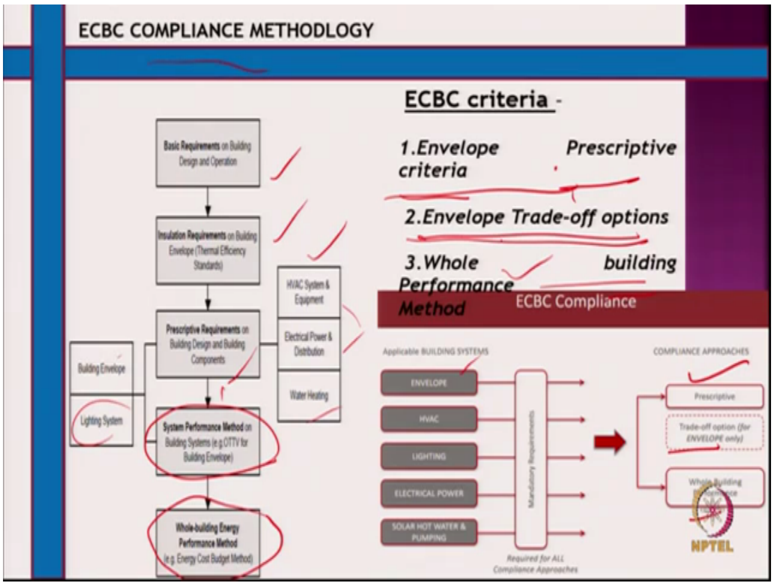

So, this what I was talking to you. So, we are looking at ECBC Compliance Methodology envelop prescriptive this is what so far we have looked into prescriptive criteria. There is a Trade-off Options and there is a Whole Building Performance method, I just mentioned. Now, what is this Prescriptive Criteria what we have looked into now?

So, for given climatic condition, given orientation of the wall, window to Wall area ratio it gives you the prescriptive insulation values or (())(13:03) and SHGC values multiplying factor etc etc. So, this is how envelop is controlled in Prescriptive Method. But in this Trade-Off Methods, you can trade-off, for example, somewhere you want to be comply with Prescriptive Criteria, but somewhere else you have compensated it. So, that guidelines actually allow for such kind of compensation and how this compensation is to be done that is also it suggests.

And Whole Building Performance Method is, look at the whole building and as I said you take as building standard building as suggested in the code itself, with the parameters matching with the, the building that you want to design, certain parameters and then simulate the annual energy consumption in standard building, reference building and your building, your designed building. If it is less than that, it is fine, if it is more than that you have to change the design, either go to Prescriptive or change the design. So that is what it is.

So, basic requirement of the building design and operation, insulation requirement of building envelope that is what we looked into and then Prescriptive requirements that is what it does, so it looks HVAC system, electrical system and water heating that separate but envelope also it looks into it, building envelope is what it looks into and lighting system that is what we just looked into ourselves, this part we are not keeping and then system performance method of building system.

So, these system performance methods are available elsewhere, like OTTV that is a Hong Kong uses, we will look at that later. And Whole Building Performance is the other kind of strategy that is what I just mentioned. So, if you look at these factors envelope, HVAC lighting, electrical power and solar heat water pumping etc etc, these are the factors Prescriptive, Trade-Off and Whole Building Performance Model, these are the 3 approaches. So, you looked into Prescriptive so far. We have looked into Prescriptive so far.

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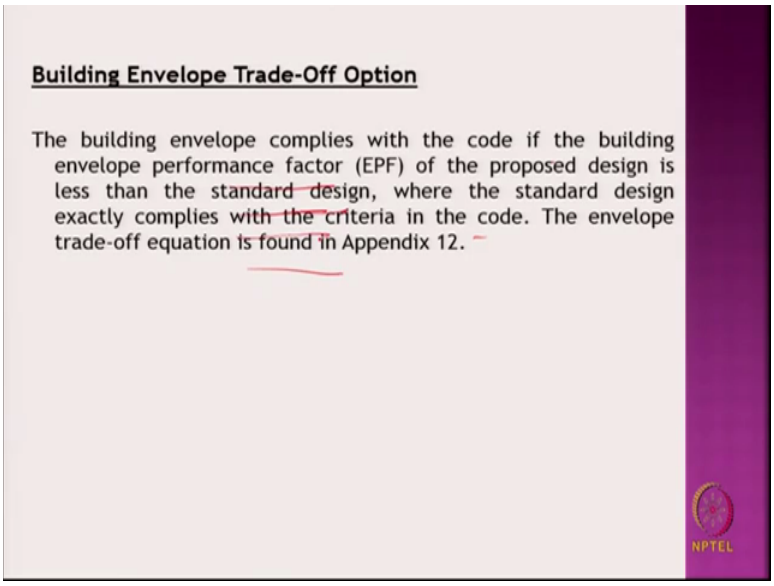

Trade-Off option is something like this. The building envelope complies with the code of the building envelope performance factor of the proposed design is less than the standard design, where the standard design exactly complies with the criteria of the code. The envelope Trade-Off equation is also given. So, what (())(15:37) gives us standard design and if the envelope complies with the standard design, standard design has been you know has taken care of the Prescriptive ideas, the Prescriptive guidelines.

So, if your overall design satisfies the Prescriptive idea is not satisfying individually, that is Trade-Off, that means you have done some Trade-Off somewhere. So, these equations are also given but certain mandatory requirements are there for either Trade-Off or for Whole Building Performance.

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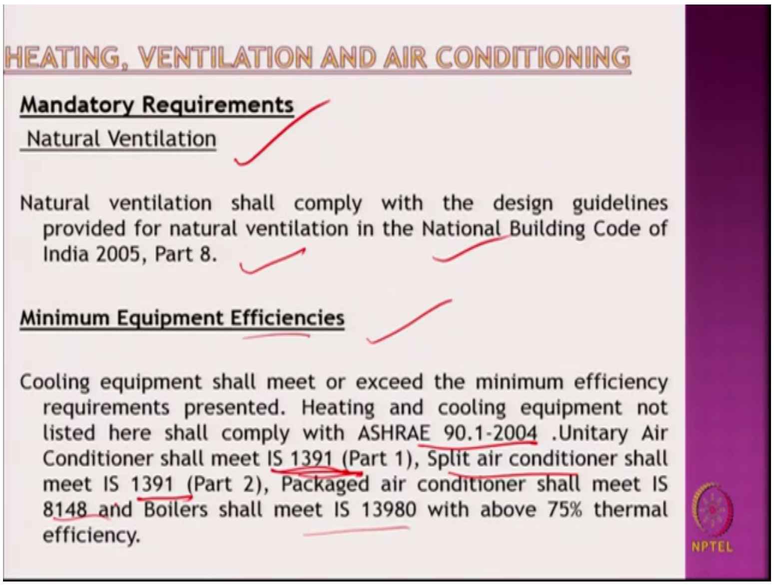

One is Natural Ventilation, so that should basically go with the National Building code of India, how much is I know that is what I am saying hygienic ventilation requirement minimum or number of air changes. Minimum Equipment Efficiencies that is Prescribed according to certain code or ASHRAE code because they have adopted mostly from American situations, so this much must you know the air conditioner must satisfy IS 1391 part 1 and packaged air conditioner shall meet IS 8148 and etc etc. So, they must meet the guidelines wherever it is available.

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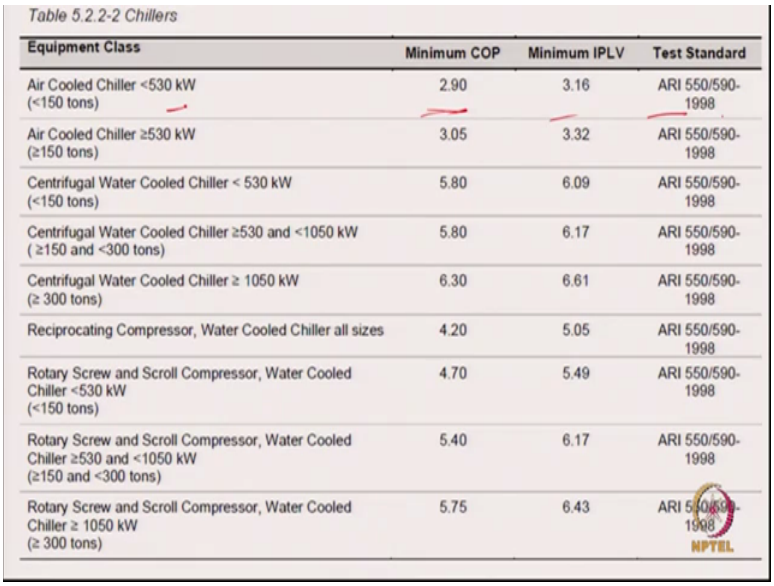

Table 5.2.2-2 Chillers

Equipment Class	Minimum COP	Minimum IPLV	Test Standard
Air Cooled Chiller <530 kW (<150 tons)	2.90	3.16	ARI 550/590-1998
Air Cooled Chiller ≥530 kW (≥150 tons)	3.05	3.32	ARI 550/590-1998
Centrifugal Water Cooled Chiller < 530 kW (<150 tons)	5.80	6.09	ARI 550/590-1998
Centrifugal Water Cooled Chiller ≥530 and <1050 kW (≥150 and <300 tons)	5.80	6.17	ARI 550/590-1998
Centrifugal Water Cooled Chiller ≥ 1050 kW (≥ 300 tons)	6.30	6.61	ARI 550/590-1998
Reciprocating Compressor, Water Cooled Chiller all sizes	4.20	5.05	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller <530 kW (<150 tons)	4.70	5.49	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller ≥530 and <1050 kW (≥150 and <300 tons)	5.40	6.17	ARI 550/590-1998
Rotary Screw and Scroll Compressor, Water Cooled Chiller ≥ 1050 kW (≥ 300 tons)	5.75	6.43	ARI 550/590-1998

You know this is what is given with respect to, these are kind of table which is available with respect to HVAC system. We are not looking into this really but such a table does exist, for example, this is based on kind of standard, test standard ASHRAE standard.

According to this, it should satisfy these values. So, these are equipment part of it. We are not looking into the type of chillers. Also the mechanism mandatory requirements, so mandatory requirements if you are using Trade-Off or you are using Whole Building Performance, both cases this mandatory requirements are there.

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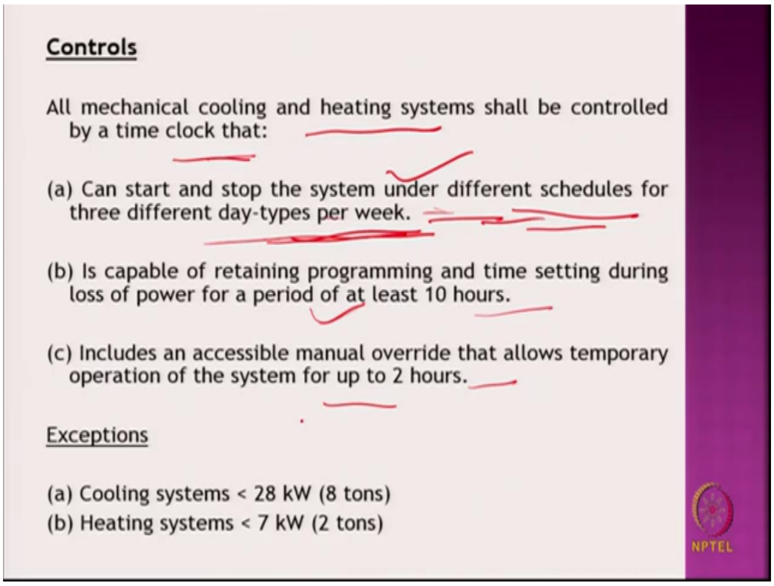

The other one is the control system shall be controlled by a time clock. Can start and stop the system under different schedules for different day-types per week. That means you have to have some kind of control say, without the control this you know these are mandatory requirement you cannot use, for example, if it is an office building you hide, you must have time schedule.

So, you might have weekdays, weekend days. So, depending upon, for example, it is a commercial building, office building people will not come during the weekend. So, therefore the schedule would be different, maybe there is hardly any maybe some specific works are there therefore it would be actually operated for shorter period of time.

And maybe Sunday nobody comes and weekdays something like some places there is a half day, Saturday half day some, etc. So, this system and if it is let us say it is a shopping mall or something of that kind, the crowd might be more on Saturday might open remain open for longer period of time.

So, that kind of time schedule must be also given and must be capable of retaining the program time setting during loss of power for a period of at least 10 hours. So, if there is a power failure, this program should still be maintained minimum for 10 hours, this is a mandatory requirement and includes an accessible manual override that allows temporary operation up to 2 hours. So, in case there is a problem there should be a manual override, so I should be able to operate it for 2 hours.

If the cooling system sizes are small, I do not need this. So, these controls are minimum together the sizing of the air chillers etc etc sizing and their standards and also related to the first one that I said was minimum equipment efficiencies these are also prescribed according to some codes.

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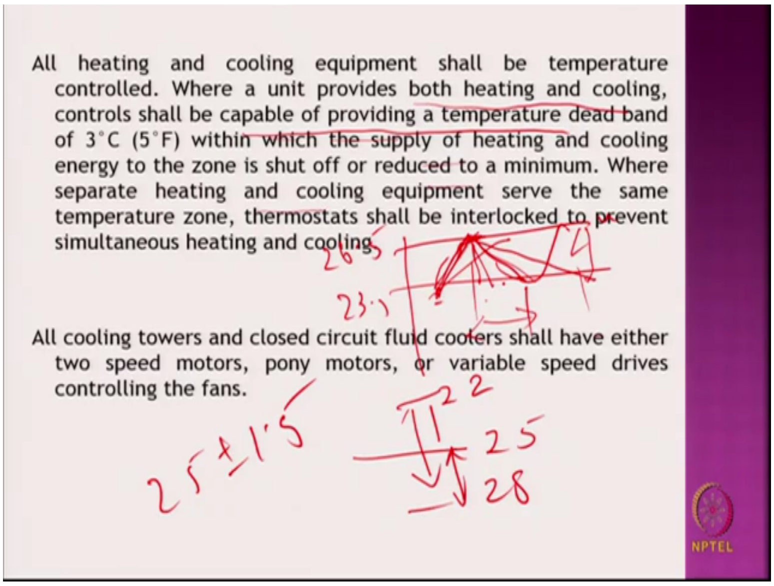

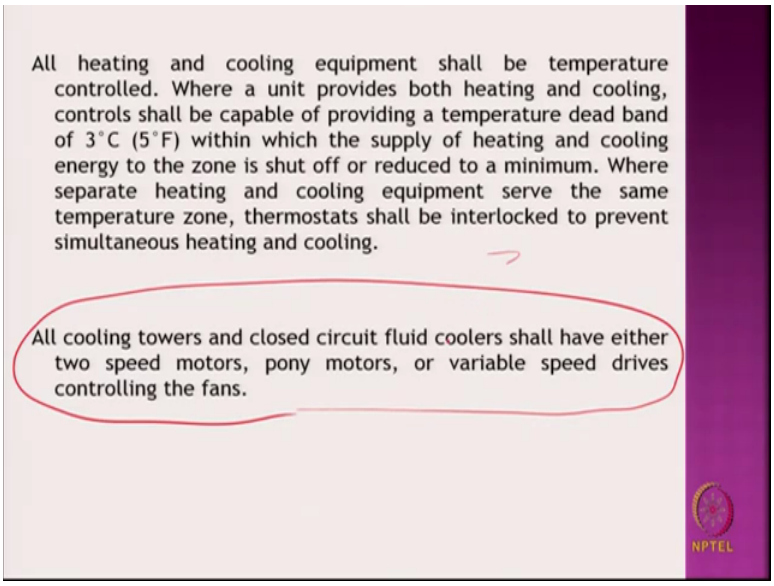

So, all heating and cooling equipment should be temperature controlled that is what I said. Where a unit provides both heating and cooling, controls shall be capable of providing a temperature dead band of 3 degree. You know you have operating differential, supposing this you have fixed it 25 degrees centigrade, it will actually operate to 22 to 28. So, this shall be providing temperature dead band of 3 degree, so this band here it is saying is 25 plus minus 1.5. This one is saying capable of providing temperature dead band but this will depend upon your inertia of the system, the control system and inertia.

For example, it might require longer time to cool, supposing I just you know this is the band let us say, so 2 points often control switch supposing you know it has become too cold and therefore system is off. Now, it will go on heating and as soon as the upper value of the band so this was you know 25 minus 1.5 will be 23.5.

So, this is 23.5 this is 26.3 degrees 26.5. So, as soon as temperature reaches here it will stop the cooling system, then temperature will rise like this and as soon as this is 26.5 start cooling. So, heat will come now like this and this will go like this 2 point often control switch, the simplest case operates in this manner.

So therefore, what is happening here, heating and cooling energy zone should separate heating zone ok etc etc. Now that means, this rate at which actually it increases the temperature or rate at which it cool, it depends upon the inertia of the system rate at; so inertia of the system. So, therefore this is where both heating and cooling so it should temperature dead band of 3 degrees the supply heating and cooling energy of this zone is shut off and reduced

So, this band it is suggesting and if I have inertia of the system low, it will take very long time to heat, that means I have to operate for a less period of time. In this case, I actually will be operating for this period of time then I will put it off and again operate but supposing this happens slowly or rather you know this happens faster then I will have, it will depend upon the operating time will depend upon the inertia of the system itself. So, shall I have two speed motors etc etc so this is related to those mechanical systems.

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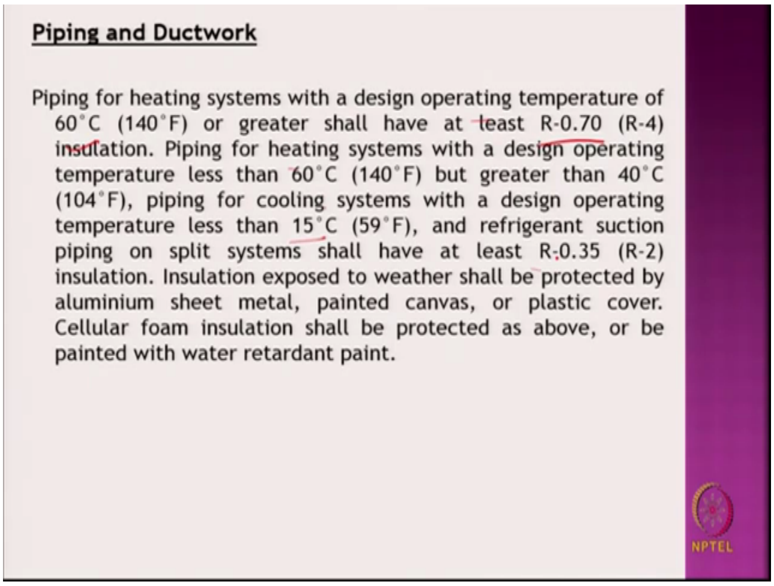

Piping insulation these are also prescribed. So, design operating temperature 60 degree centigrade should have R-value 0.7 for insulation and these guidelines are also given with a design operating temperature less than 15 and refrigerant suction etc, so these values are prescribed for the system as well.

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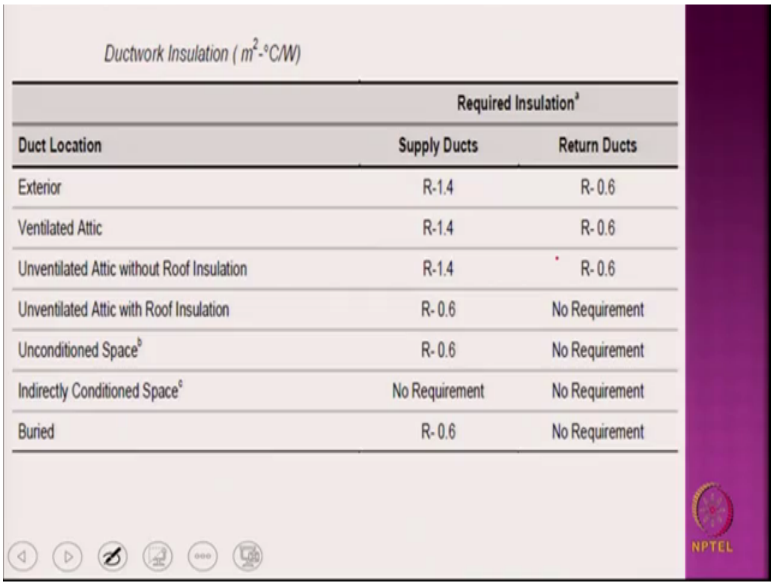

Ductwork Insulation (m^2-°C/W)

	Required Insulation[a]	
Duct Location	Supply Ducts	Return Ducts
Exterior	R-1.4	R- 0.6
Ventilated Attic	R-1.4	R- 0.6
Unventilated Attic without Roof Insulation	R-1.4	R- 0.6
Unventilated Attic with Roof Insulation	R- 0.6	No Requirement
Unconditioned Space[b]	R- 0.6	No Requirement
Indirectly Conditioned Space[c]	No Requirement	No Requirement
Buried	R- 0.6	No Requirement

Similarly, for the Ducts, I think we will look into this in the next class and we will look into the other ones in a system finally then the other part is Whole Building Performance and then look into other types of energy control codes which are they are we will look into that.