Sustainable Materials and Green Buildings
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Lecture 36: Energy Conservation Building Code (ECBC 2007)

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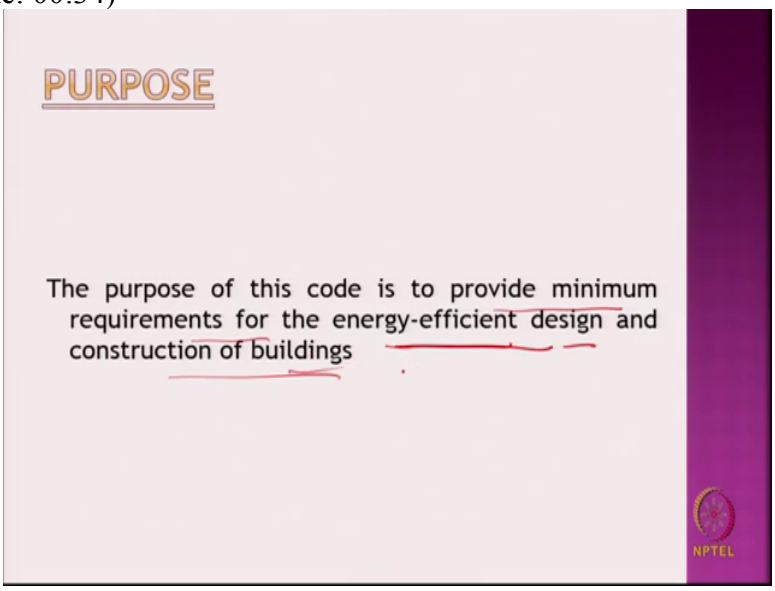

So will look into concepts of energy conservation codes, right, and will look into this one first obviously it has changed now. So, with you know as you will see sometime later on. Many countries have adopted these codes as early as 1980s and 1990s, right, so first we will look in at this Indian code then will look into some some other generally some other code.

So the code is code tends to restrict the consumption of energy in buildings, right, obviously it is in the context of condition building, it is in the context of condition building right. So, basically is to provide is to provide minimum requirement for energy-efficient design and construction of building, but it also takes care of all other aspect, for example, the lighting, all other lighting plus other active systems.

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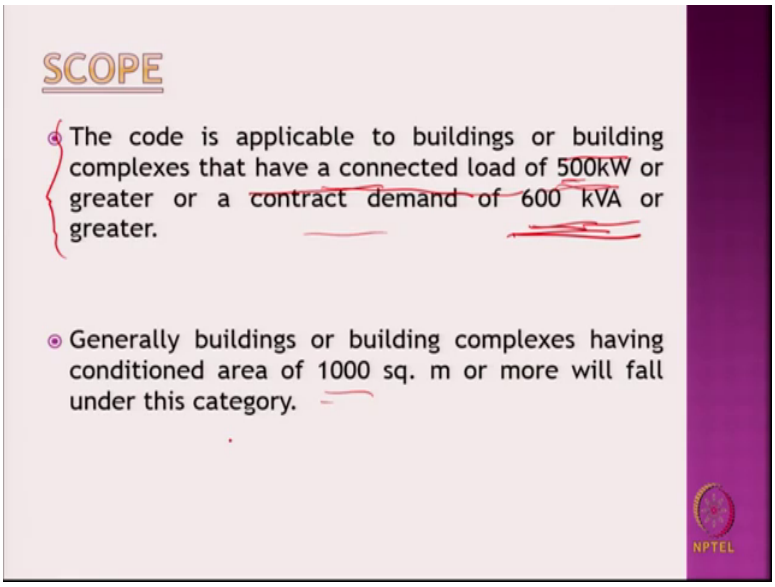

So it gives you a guideline so does this minimized but will largely look into the issue of envelope you know and construction, now scope of such code would be and this is of course to Indian scenario so it is to all buildings and building complexes that are connected to 500 kilo vault or greater, contract demand of 600 kVA or greater or greater right.

So anything ever 500 kilo vault consumption or 600 contract demand that is basically in a consumption is usually less than say your power lines are designed for this much kVA you know this much in terms of kilo vault, this is the consumption actually because this will be multiplied by a power factor in alternating current situation and then you might be using it sometime and may not use sometime some other time although your design is for 600 kVA capacity but this is consumption.

So, generally building or building complexes having conditioned areas 1 square 1000 square meter or more will be there. So anything less than that, of course, you need not look into this but anything more than that you want definitely look into it.

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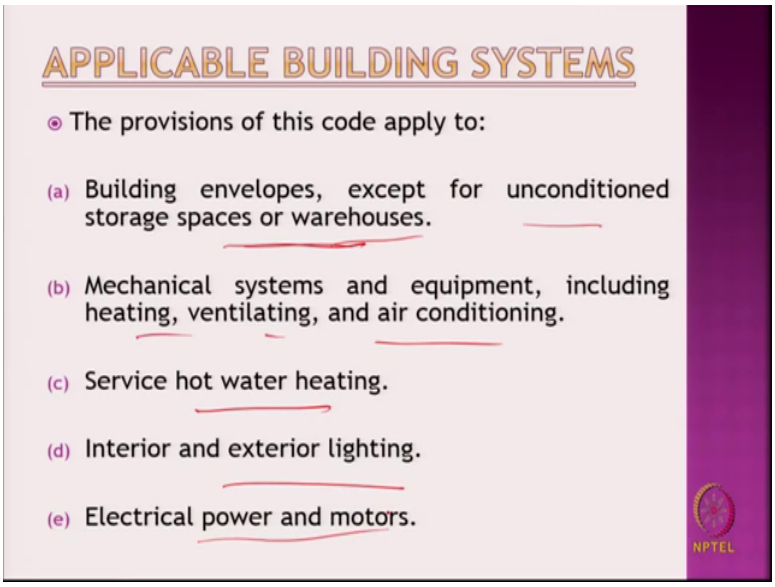

So this applies to as I said it applies to this code, this particular code applies to building envelop of course unconditioned spaces you need not look into or storages, warehouses in the building complexes itself there is some portion storage you need not look into that.

Then mechanical system, equipment that is what I said HVSC system, heating, ventilating and air conditioning system so it applies to this, so you (cause) cause you said guideline related to that as well. Services hot water supply system, Interior and exterior lighting and Electrical power and motors everything.

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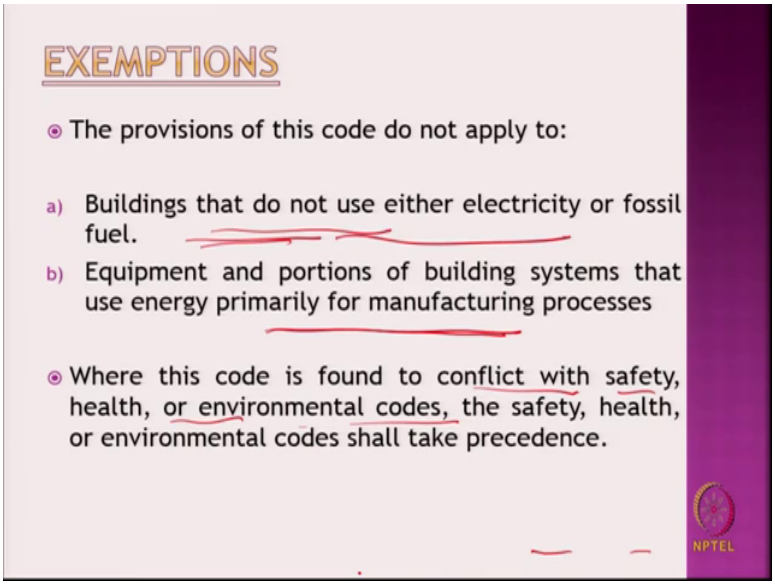

So they gave us guidelines for consumption, minimum consumptions. Well some exceptions are made because they are code. Now generally where do you need codes actually, codes you need once you have to have kind of restrictions or control, some other cases you need code of course where you do not have very objective way of estimating things, for example, in Civil Engineering practices we use codes in design most of them because we do not have very objective way of estimating let us say what should be you know like there are several issues Crack Width or things like that in rain force concrete and so on.

So, some of them are because subjectivity is involved, so their codes bring everybody in same platform, some cases you need standardization, now here is, of course, largely because we want to have a control right, in this this particular type of energy code should be you do not want unnecessarily wasting the energy so that is why you need this.

So, therefore, if a building which does not use fossil fuel at all or electricity you do not have to consider this, if the energy is used for manufacturing process that is in industrial building again this is not, that energy is not to be considered and obviously safety, health and environmental codes shall take precedence, obviously they will dominate. So you the energy code cannot over write structural design code if the structure design requirement is something you cannot over write that through these codes.

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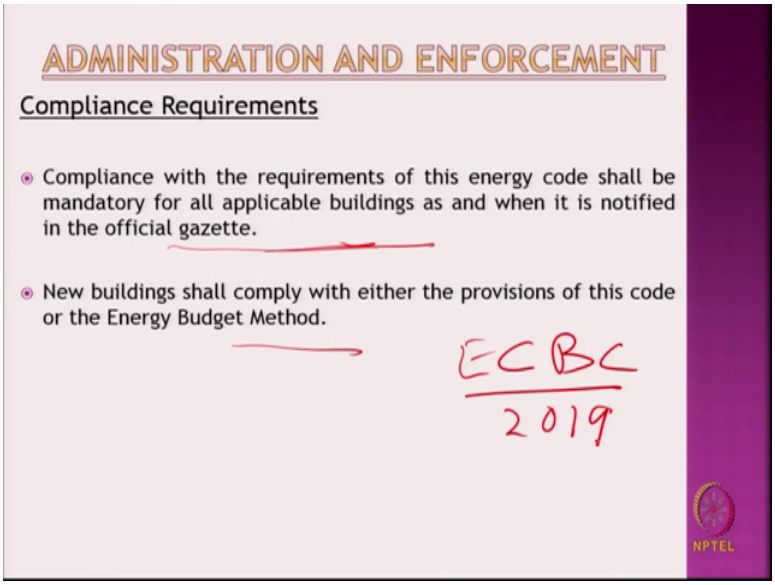

Alright compliance of the requirements of the energy codes shall be mandatory for because in India unlike many other countries codes are you know under central government controlled in

a way and BIS is a government in a way quasi government if not government fully body controlled by the government largely but on the other hand if you see California building code let us say or something of that kind that is not statutory, in US it is not statutory they do not have something like American standard institution. So many countries have many countries do not have, so there are varieties depending up on the country and in India they are trying to make it mandatory by in large through the code.

That will come to Bureau of Indian standard which has recognized this and many aspects of it is actually taken in international building code. The latest code is, of course, 2019 which such you know ECBC code as you call it Energy Conservation Building code. Energy Conservation Building code latest one is 2019 and some aspect of it will helping out later on, right, will look at it sometime later. New buildings shall comply shall comply either with the provisions of this code or some sort of Energy Budget Method it should actually account for right it should take care of.

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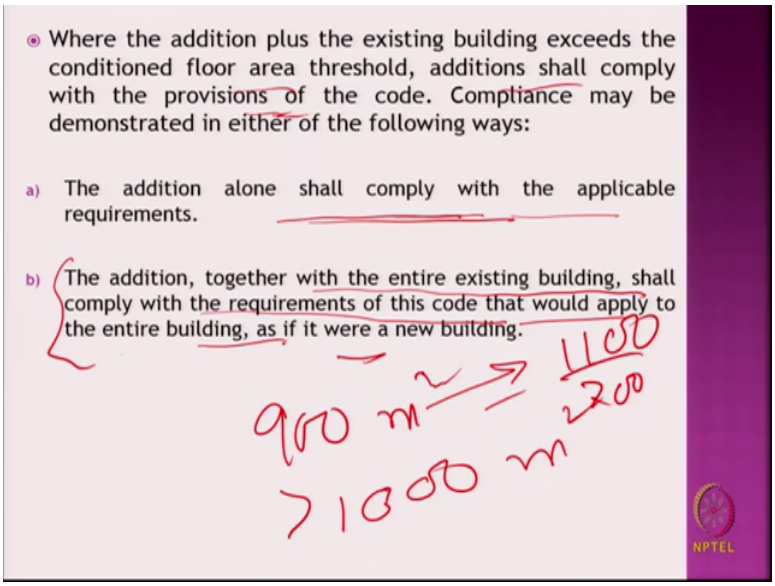

Well addition plus if you are adding something, you know, the existing building exceeds the conditioned floor area of threshold; addition shall comply with the provisions of the code. So, when you are adding something, say ILDR area was less than 900 meter square with the you know consumption whatever it is now you have added something goes beyond 1000, now it goes beyond 1000, it is greater than thousand meter square, then it is because you said minimum is 1000 meter square meter if the building is if area floor area is less than thousand meter square than I may not apply this code.

But if it is now more than that after addition then the addition should shall comply with provisions of the code, whatever you have added maybe 1100, let us say 200 meter square that additional part must comply with the requirements of the code. So the addition shall alone, alone shall comply with the applicable requirements. If it is a new building also both the addition should apply and then overall also it should comply because the addition together with the existing building, shall comply with the requirements of code that would apply to entire building, as if it were a new building.

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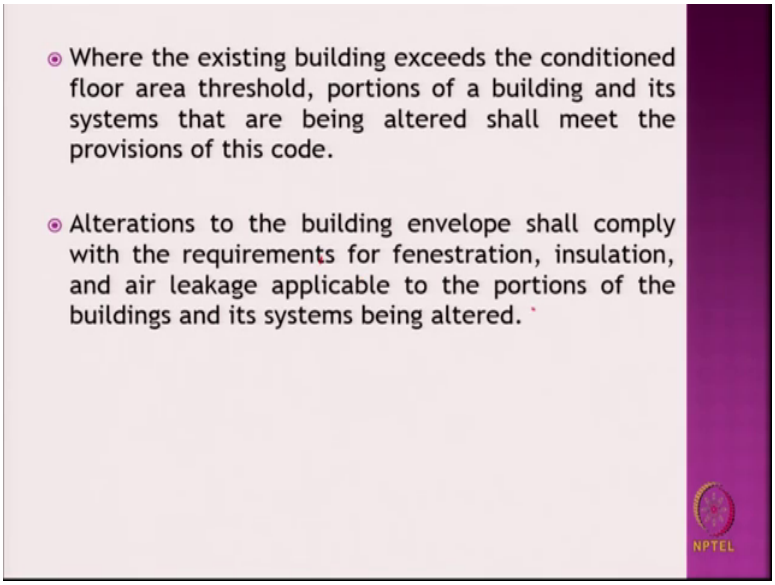

So where the existing building exceeds the conditioned floor area threshold and its system building and its system that are being altered shall meet the provisions of the code. So, if you are doing any alterations and already already existing so you cannot do much about it but any alteration you are doing that should apply. Alteration to the building envelope shall comply with the requirements for fenestration, insulation, air leakages Et cetera the portion of the building system being altered, so whatever you are (alter) Altering obviously it will have huge elaborate.

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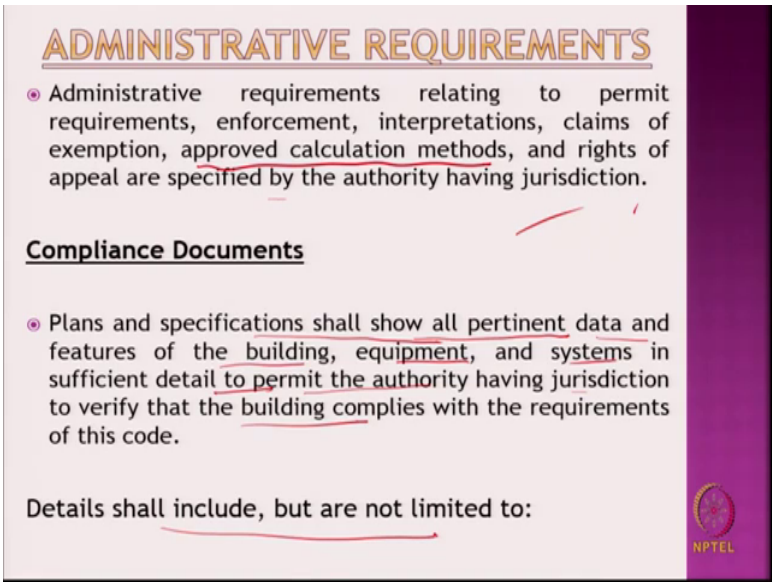

Administrative requirements such as permits you know interpretations, claims, exemption (aprov) calculation methods because after all it has to be estimated, the building does not exist I do not I cannot measure it, and even if it exist you can at best measure for let us say one year or two year consumption but court cannot wait for that, so during the initially phase itself the code will apply therefore, I should have methods of estimating.

What is annual energy consumption in the building? So, these methods are basically approved by there, shall we write and rights of appeal okay that is Et cetera, appeal Et cetera in having jurisdiction and all that will look into this like municipal authorities they should be you know but it has not come to that stage in India.

Plans and specifications show all pertinent data and features of the building, equipment, system in the sufficient to permit the authority having jurisdiction to verify, so therefore verification is require then you need all details to be given right and details shall include but not limited to, of course.

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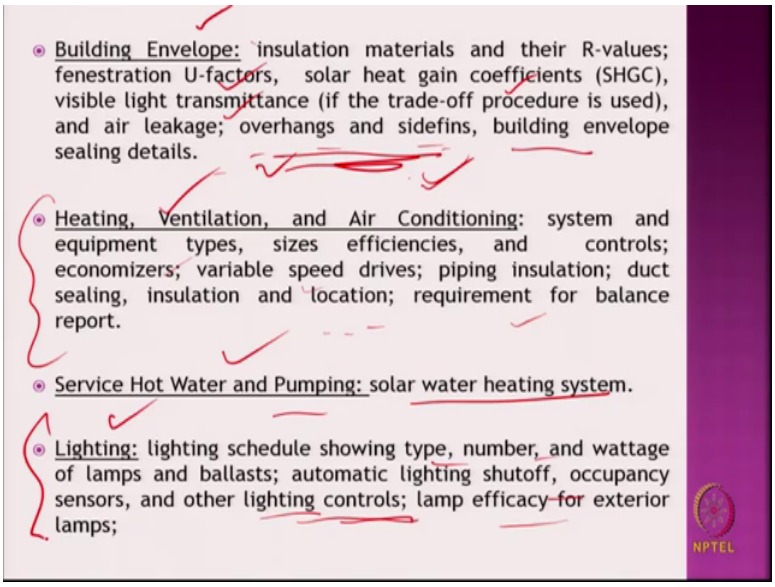

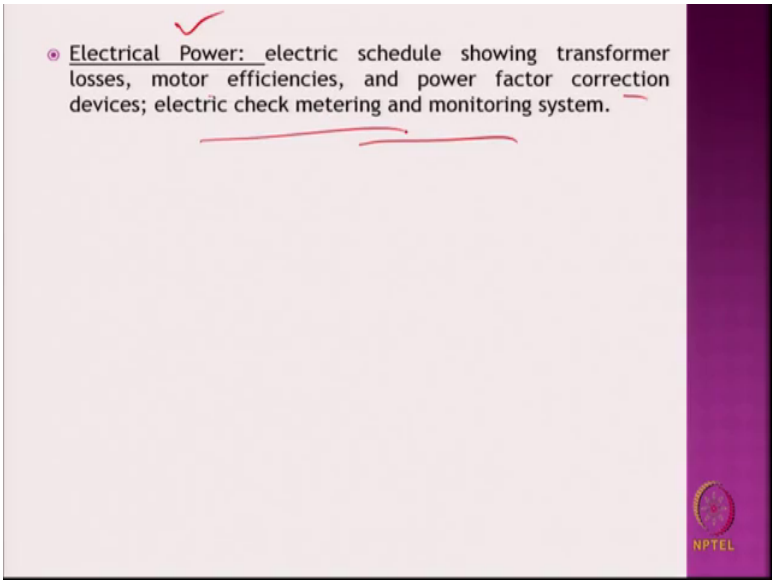

Building envelope so that is the point I am trying to make building envelope, HVAC, services hot water and pumping and lighting and electrical power. So, these are the five components actually and I think now by this time it is (())(10:49) clear to us that this is one of the major thing which concerns failures, right, because envelope their U values, solar heat gain coefficients, light transmittance, air leakages Et cetera and then shading device, any ceiling because you do not want infiltration air infiltration.

So, these are the parts of building envelope that should comply with the (())(11:28). HVAC size system because they are you know improved system now, variable possibly they will get improved further. Efficiencies and controls kind of economizers variables speed drives,

piping insulation Et cetera Et cetera, we will not look into this much but will look into court of provision related to this most of it service hot water and pumping of course solar water heating system we have and lighting schedule I mean you know if there is a lighting schedule that means all the time lights are not on.

If there are lighting schedule showing type, number, wattage lamp Et cetera automatic lighting shutoff, occupancy sensors other lighting controls these are all fallen into this category regular we are not going to look into this so these all related to artificial lighting so will concentrate more on this but will see what is there in the court.

An electrical scheduling showing transformer losses, motor efficiencies everything and power factor correction devices you know correction devices if required because alternating current some amount of energy stored if you have a inductor you know or like like motors where you have magnetic you know in indictors basically alternating energy, current energy stored as magnetic energy and it is stored and released, not consumed only the heating i square r that part i square Royal Stag that i square r is a watt.

So, that is what is utilize, so that is what is energy basically, so therefore, power factors we do to maximize the you know the I think the building have the system you will look at it you will understand that, but I think I am not interested right now in this. So electric check metering and monitoring system all those devices that we use for electric system that also (()) (13:30), but then we are not really interested to this for our purpose we are interested more in envelope.

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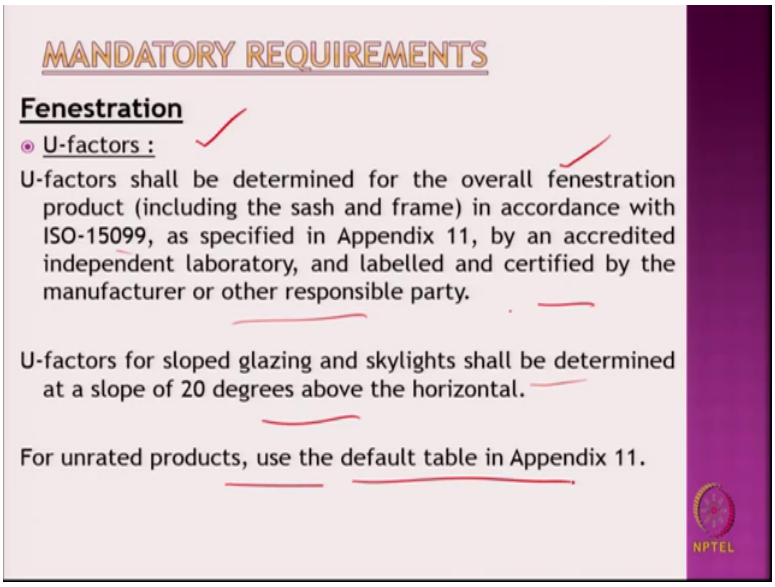

So, this already we have said, you know, U factors already we have mentioned what are this what are e-values right so for glass, for example, fenestration means glass in according to which code and how will you determine that is given right and the values determined should be through some sort of betterments done by approved test houses or laboratories Et cetera Et cetera and certified by the manufacturer or other.

For example, if is a IS standard Indian Standard stamped that kind of thing, so what is the u-value of the fenestration glasses these are important. U-factors for sloped glazing skylights Et cetera Et cetera for unrated product where the rating is not given one can make use of some data. So this information is are available this is given in the code.

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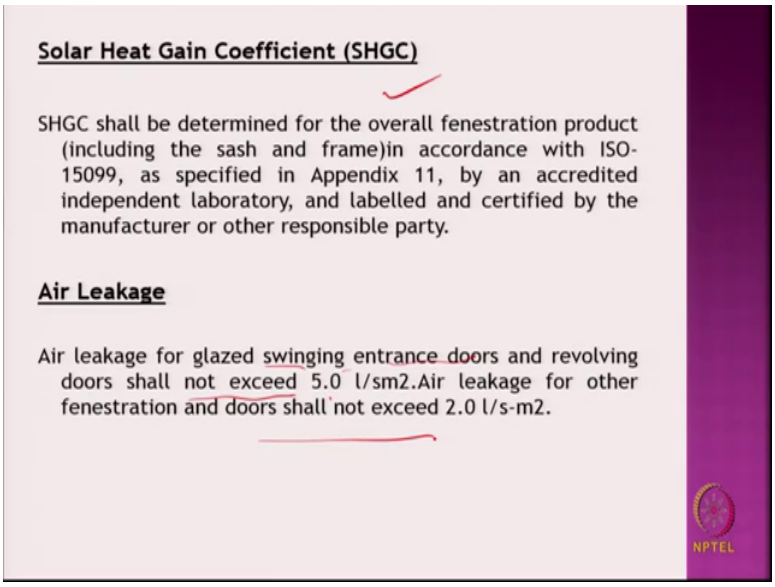

Then the solar heat gain infector of the glass if you recollect we said that the fraction of energy that we enter into the to the glass divided by what is incident that is what we call solar gain solar you know heat gain solar heat gain coefficient. So this also again it code gives you how it should be determined then infiltration is very important and infiltration maximum limit values are again given right.

So air leakages for glazed windows or swinging entrance doors Et cetera and revolving door should not exceed 5 liter per meter square per second so air leakage for other fenestration should not in this. So for you know the ceiling of the windows and Et cetera Et cetera so the infiltration rate is less that is also given in the court.

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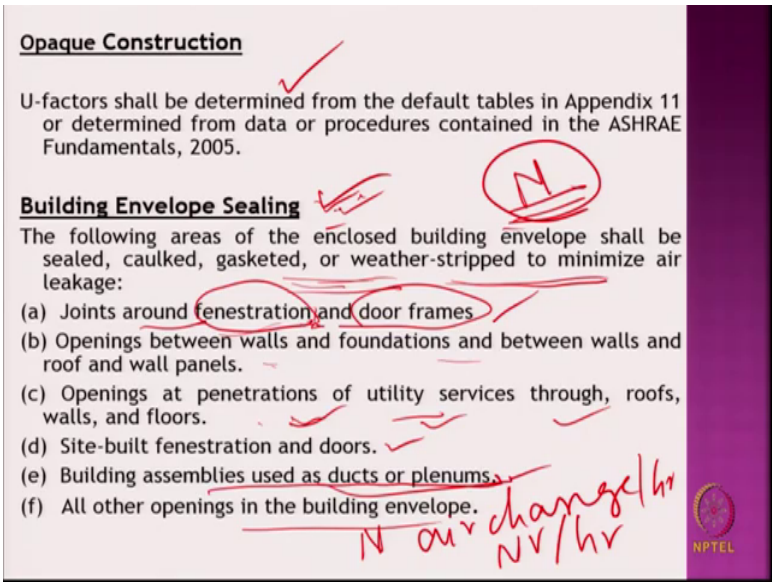

For walls U-values are should be determined and again values are given in appendix or you can determine according to Statin standard codes so this is what it is. Okay so it also says that following areas enclosed building envelope should be sealed, caulked, gasketed, choked, gasketed or weather-stripped to minimize air leakage. So joint around the openings, windows fenestration is basically openings meant for delivered, openings meant for air ventilation or lighting purposes. So, if you have glasses or windows there should be door frames, there should be you know the ceiling applies to these ones.

Opening between walls and foundation and between opening between wall, roof Et cetera Et cetera. Opening at penetration of utility, for example, the pipe duct is coming so the leakages shall be sealed totally this area should be sealed, and utilities services through roofs, wall floor Et cetera so any pipe coming in that area should be sealed and if it is built at Site-built fenestration and doors that is windows and doors, building assemblies used as duct or plenum now this is done (())(17:00), for example, you can have concreate ducts.

So, part of the itself, is the part of the building itself then there you require complete ceiling, all other opening in this, so basically what he is trying to say is openings in the, openings which comes because of poor construction, if everything was done, sizes are all fixed, construction quality is good you will have very little leakage, but even then there would be some and they should be sealed.

So they should be completely sealed therefore, so that your air exchange rate is minimal. Remember I talked about air exchange rates sometimes I might have mentioned what is it air exchanged rate, air changes, number of air changes per hour that is the total air flow in 1 hour n times multiplied with the volume.

Air change n number of, n number of air change means this I think I did talk sometime earlier, n air changes per hour means that n into volume of the room per hour that will be our flow, so you know that is that is basically you do not want this to be high because if it is high, if the flow infiltration rate is high than outside there is warm it will bring in heat together with it right, and if it is cold climate than it will take away the supplied heat into the room to outside.

So, therefore, you do not want this to occur by default, windows ventilation these are by design, when I need it I will use them, but infiltration is by default through leakages Et cetera Et cetera so that has to be controlled and minimized and that is what is done through ceiling.

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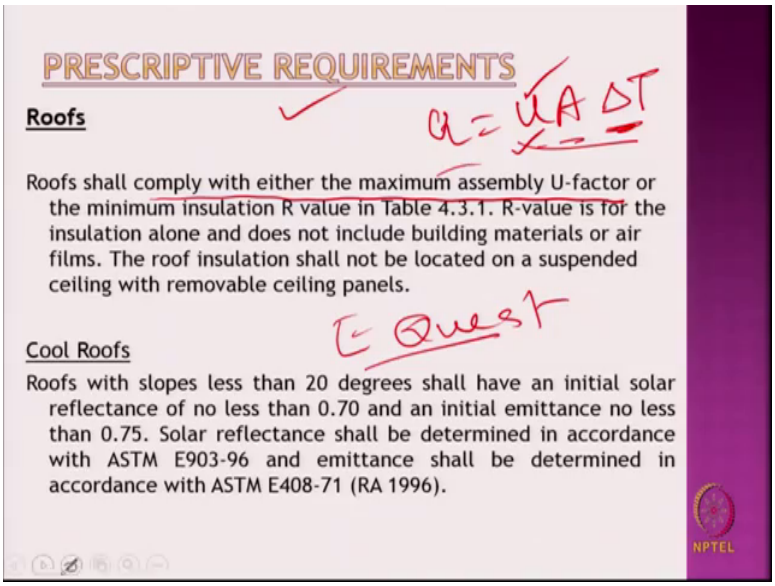

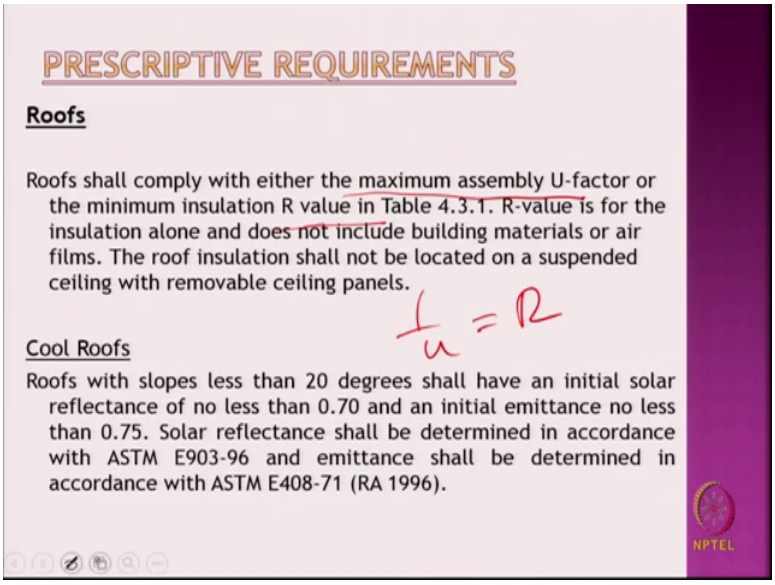

So that is one thing right, so code this code this scenarios actually it gives, you know, it tries to look into three approaches actually it has one what we call Prescriptive requirement so it says that you know it simple gives you the value prescribes, this should be the insolation value of the wall or roof.

The other one is you can calculate this out and satisfy your requirement of your envelope all properties and that should be good enough. Roofs shall comply with the maximum assembly U-factor, so these u values are prescriptive values are given, the values are is for (())(19:42). So if you are looking into your building and you want to see that whether it is a ECBC compliance one way is to look at the prescriptive requirements which is not the very best thing because it leaves very little to the designer for you know choose from because it is already prescript.

So there can be a tradeoff possible that means I have high, you value somewhere there will be low u value elsewhere because you know that amount of heat that will come in is equal to U into delta T, U into area into delta T that is what we talk about for apex bodies and delta T is a temperature difference between outside and inside at a given instant instantaneously flow be like this.

So, overall if I have to find out in other more, of course, complexed but then this property is the one which governs so it is this code tends, one ways it prescribes simply the value so of U otherwise it allows for a kind of tradeoff and third one is what we call hold by building performance which you estimate through some software.

So the softwares which are actually also kind of software or the software or methodology in a way it is actually prescribed some sort of some guidelines they have given which kind of software or what software can be used some ideas are given and it has to approved by the appropriate authority. So using those software you can actually estimate the annual energy consumption. For example, I has eventually E quest one of them energy plus, there are several softwares which they have actually given.

So using those one you will find out whole building performance and this whole building performance compared with us given type of standard building for the same floor area Et cetera Et cetera you try to you know define the standard building and measure calculate the whole building energy consumption, annual energy consumption for the standard building and your design that should you know it should be less than the standard design that they have suggested for the given floor area, given occupancy Et cetera Et cetera whatever they have suggested.

So, first is the let us look at prescriptive one there is maximum u value factor is given in the code table or minimum insulation, because 1 over u is r resistance, so this is given. This is given for the insulation alone, does not include structural element right building material or if there are air films and things like that shall not be located on a suspended ceiling, so therefore what minimum insolation you should use that is the guidelines gives you.

Similarly if you are using something called cool roofs, right roof slopes, less than 20 degree shall have an initial solar reflectance, so these are the kind of prescription that is given initial emittance is not less than point 75, so these are the kind of guide lines given so the approach is I mean values of course you can you can look in the court and find out. The reason for this is prescriptive so they have given you the insulation, minimum insulation should be the thing and you know minimum these properties those are should be one should be using.

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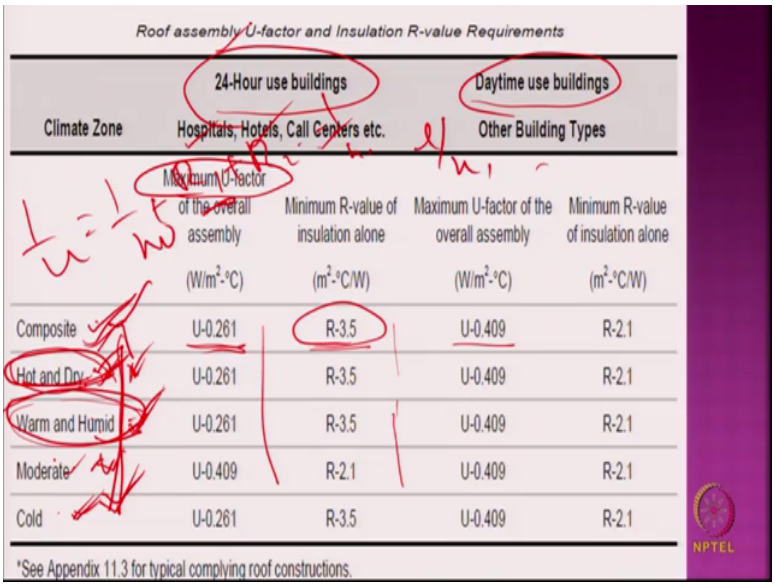

For example this is what it is two types of buildings are given 24-Hours application and Daytime use buildings only, so if you use 24 hours buildings like hospital, hospital are typical 24 hours building, hotels, things like call center and so on, and residential building or office building let us say it will be only daytime use. So, maximum u values for different climatic conditions are given. For example, for composite monsoon climate this point 261 and minimum value of insulation alone is also given, minimum values of insulation is also given in terms of 1 by u, so maximum value is u i give overall and this is for the insulation alone.

So, first you check the u value of whatever is existing and then you provide minimum 1 over this r is u, you know u is 1 over r, so, therefore, you can calculate out because you remember we said one over u is equal to 1 by h u plus r1 plus r2, r3 Et cetera Et cetera which was l1 by ki plus 1 by h dot so minimum value of insulation required that one can check and for you know for maximum value of u for only daytime used building these are the values given. So this is given for different climatic condition of India and I think I might have mention that India is divided into these five climatic zones.

I am not sure whether I have mentioned here in this class but let me just tell you then what they are right. So, there are there are five climatic classifications in the country did I mention I am not very sure but let me repeat it. Central you know if you look at it there is a western, north western side north western side around the desert third desert Rajasthan these areas are you will have almost desert, desert climates which are characterized by high variations of day and night temperatures, day temperature is very high, night it is very low well little

precipitation rainfall is low relativity is generally low while if you come to costal area and north east those areas.

Rainfall is very high, diurnal variation is day and night variations are not so much but relativity is high throughout the year right throughout the year it is higher at least six months it will be follow into a given kind of category of this where the relative immunities is above starting value mean temperature is above started value Et cetera Et cetera. So those are we call as warm humid climate right.

So warm humid climate and desert climate hot dry, you know, so desert climate there is given so they are calling it hot and dry that is the desert climate, and warm and humid is this one. Now moderates are some modification of this climate so or you know largely this and once in a while this also because of altitude. For example, Over the Deccan plateau the temperature variations is relatively less, is almost comfortable condition that is what you call maybe you know around 25 and relative humidity around 50, 60 percent so thus more or less.

So moderate climate is somewhere there, now where 6 months belong to this or 6 months or more belong or 6 months or more belong to this, they fall into this categories, where 6 months falls into this they fall into this category, cold is what where temperature is very low like Himalayan areas, some on the hill top so those areas temperature is much lower relative humidity maybe high but temperature is much lower so they follow into cold climate for example Ladakh, J and K they will be all cold climate and well none of these category is more than 6 months that is composite.

That means in that one part of the here you will have this climate, part of here you will have this climate and maybe sometime you may have it somewhat cold climate as you all, so that is like central Indian condition it falls into those. So its May you know May June before monsoon this is the nearly this is the climate you find, and during monsoon period and just beyond you find lot of humidity, lot of rainfall so rainfall Et cetera Et cetera.

This will be Mumbai, Chennai Et cetera Et cetera alone this is Delhi, Nagpur and so on, this is Jodhpur, Jaisalmer those area Jaipur of course belongs to this and cold climate will be something like its Leh, Shillong Et cetera Et cetera those kind of Shimla and so on. This is Bangalore would be moderate climate so this is how it is, so therefore, for various climatic condition this r values have specified and u values they have maximum value if you just check yours and if satisfies fine this is for you know roof assembly and if it does not satisfied.

So therefore, the you know the actual compliances very simple and on drawing board it is not on table it is pretty simple but then this does not allow you to you know designers choice become very minimal, because it is already prescribing, supposing designer tries to optimize orientation, shape Et cetera Et cetera and try to reduce the energy, then this is not talking in terms of wheel orientation Et cetera Et cetera only building type it is used will only gross kind prescriptive one. So one can look into that and the choice, then you do not have much choice available.

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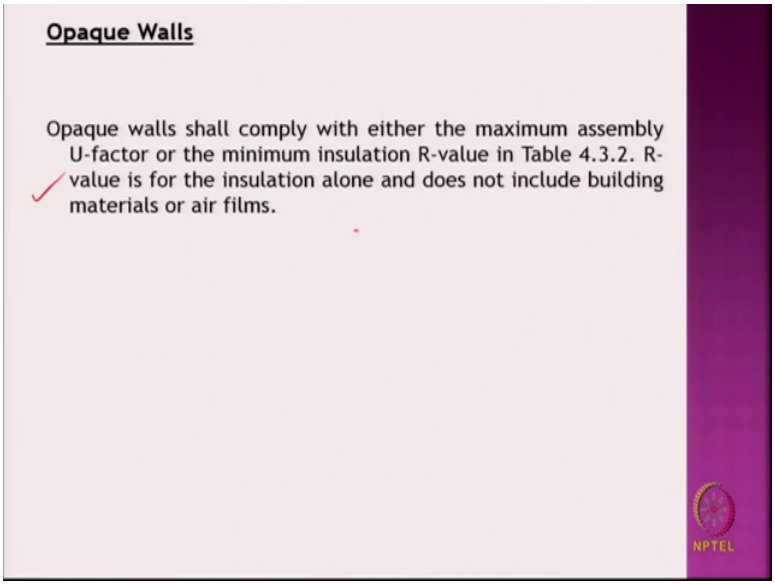

So walls opaque walls like brick wall brick wall or you know block machinery Et cetera wall this walls has complied with maximum assembly that is given r value and in the similar manner so this is for wall assembly.

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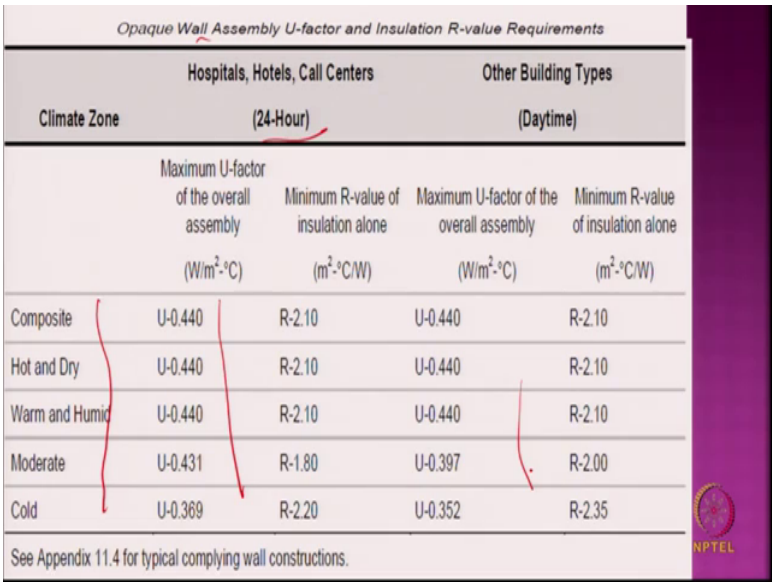

Opaque Wall Assembly U-factor and Insulation R-value Requirements

Climate Zone	Hospitals, Hotels, Call Centers (24-Hour)		Other Building Types (Daytime)	
	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)	Maximum U-factor of the overall assembly (W/m^2-°C)	Minimum R-value of insulation alone (m^2-°C/W)
Composite	U-0.440	R-2.10	U-0.440	R-2.10
Hot and Dry	U-0.440	R-2.10	U-0.440	R-2.10
Warm and Humid	U-0.440	R-2.10	U-0.440	R-2.10
Moderate	U-0.431	R-1.80	U-0.397	R-2.00
Cold	U-0.369	R-2.20	U-0.352	R-2.35

See Appendix 11.4 for typical complying wall constructions.

Same for this climate and these are the values for 24 hour and these are the values for daytime applications only. So this is how the prescripted guidelines are given.

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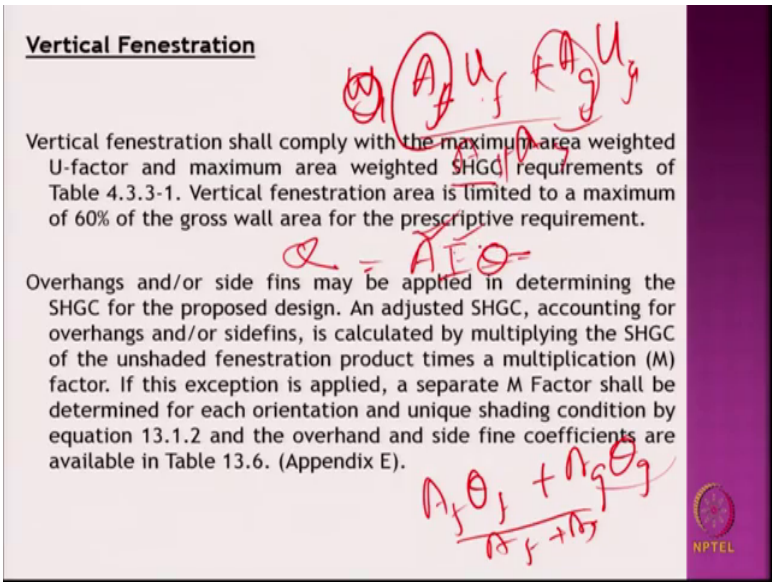
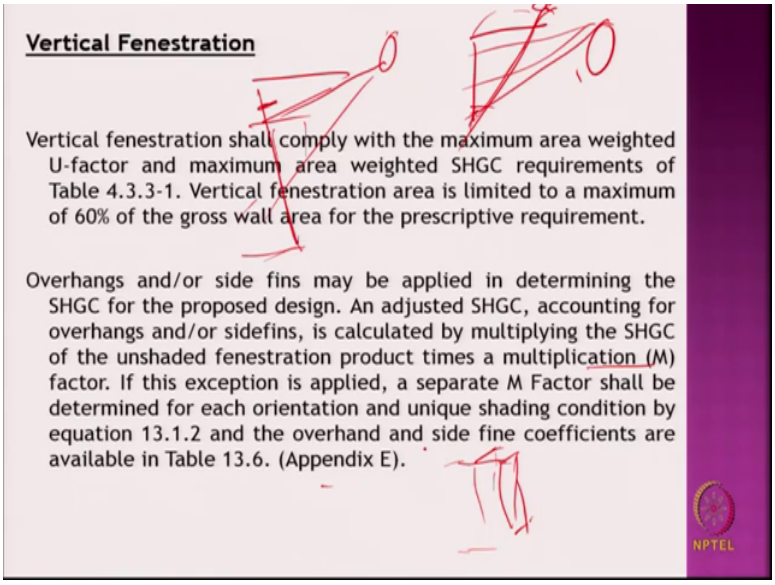


Vertical Fenestration

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).



Then it gives you maximum area weighted u factor for glasses now glass will have frame, window left frame also right so some glazed area the frame portion also, so take weighted average for example w1 area which will area or let me put it like this area one of the frame. Area of the frame u frame plus area of the glass u of the glass right this divided by total area af plus will be area weighted average value of the u, af plus ag, af plus ag would be the area weighted.

So fraction of the area of the frame multiplied by the u of the frame fraction of the area of the frame multiplied by the u of the frame fraction of the area of the glass multiplied by the area of the glass thus the area weighted u factor and also SHGC recommend that is your solar gain factor because I said that ai theta is the amount of weight it will come in where this theta is a solar gain heat because there fraction is a proportion of heat that will come in divided by the incident radiation so ai theta i is the incident radiation area and this theta so the theta values maximum area weighted sg requirements also given.

In that case the this fraction will have no sg this will be 0 because it will be af theta f lets say plus ag theta g divided by af plus ag now this will be 0 so only that fraction or window you should be taking as area which will bring in the solution, now if you are using different types of glazing by chance which in that case for in the building there will be different glass, doors they might have different so then we have use this together.

So then you have what is called overhand, overhand sunshades and verticals fins, you know vertical fins because you have vertical setting devices I mean fins, you know this is this is your lets say this is your wall, this is the wall and then there can be vertical fins so this side

fins applied for determining you know that also you should be actually you can apply because some proportion of the solar radiation will not enter.

If I have a overhand this will block the sun radiation, sun radiation up to this point so till the sun is here and when sun comes here this will come in, this will not block so therefore that proportion I can take into account that is what it is saying right, overhand side fins is calculated multiplying the SHGC of the unshaded portion product times multiplication factors.

So this is called Solar Shading Multiplier you know that one can calculate this out I am not sure whether I have included it in this part of the course but will see but essentially you can find out how much area for example this is my overhand the sun is here, so this portion will be shaded this portion through which the sun rays will come through this so area available is only this portion of the window.

One can calculate this out, one can estimate this at every hour and then sum total for the whole day year you can do in fact or you know so that will give you the overall shading this values multiplication factor right and m factors will one determined for each orientation you can determine and for unique shading condition okay Et cetera Et cetera and then you can add that actually that is what it is saying.

(Refer Slide Time: 34:29)

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

		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 2.1 for typical complying vertical fenestration constructions.

So for the glass these values are given again prescribed values are given maximum you value for the glass for different climate this is given and it allows maximum window to wall area

ratio is not more than 60 percent so window area should be minimized, if you want to reduce heat gain to a minimum right minimum.

So window area should be minimized, so this is what maximum window area permissible is 60 percent in fact it should be less than 40 percent. So if it is less than 40 percent maximum SHGC is also prescribed for different climate and this is prescribed for if the window area is something like this. So I think that is what it is over in fact I will just look into after we break and take few.