Glass in buildings: Design and Application
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Lecture - 11
Structural Control and Design for Energy Efficiency

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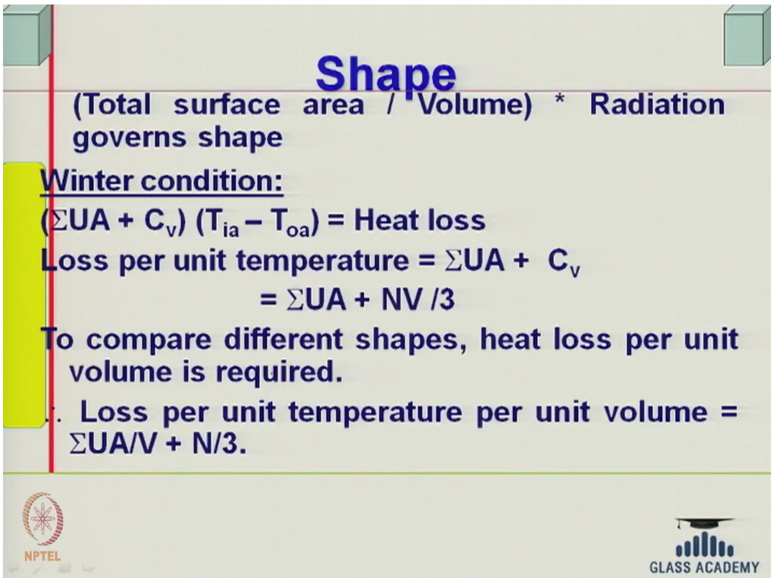

And you actually sum total of summer gain minus inter loss twice summer gain minus inter loss you can minimize. If you want to select the shape, in winter condition of course, you would like to say that minimum heat loss occurs. Now, shape actually talks in terms of surface area to volume ratio right; for a given volume is same. So, surface area larger the surface area, more will be the losses. I am not going into the algebra part of it, but quickly we can see that this you know the amount of heat loss is a function of the outside and inside temperature differences and it is also a function of UA, in case of winter not in Indian scenario actually, but to understand that is better first to understand this.

So, larger the surface area through which actually heat loss occurs, well, it will be less efficient; lesser the surface area through which heat loss occurs, it will be better right, so that is the concept actually I do not think, I am going to the algebra part of it.

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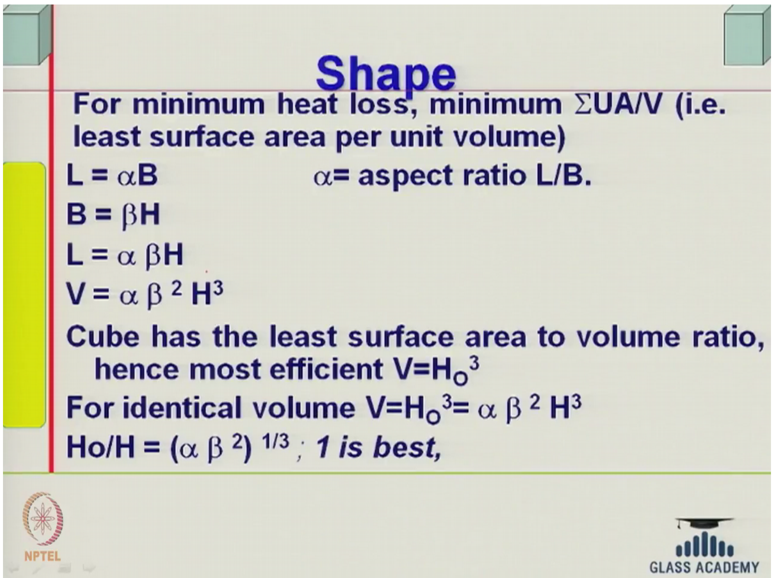

So, minimum UA by V, U A is it is a representative of amount of heat loss occurring per unit volume, that one would like to minimize, in case of winter scenario right. And there are some algebra available this there in a book by this you know this is available in literature actually Markus and Morris, they give you a simple formulation with respect to aspect ratio, how you know simple one hand calculation basically.

So, you can find out which is the best orientation from out of say some 5, 6 orientation which are your choices, you can find out which is the best orientation for heating purposes. I do not think I am again going into the algebra part of it.

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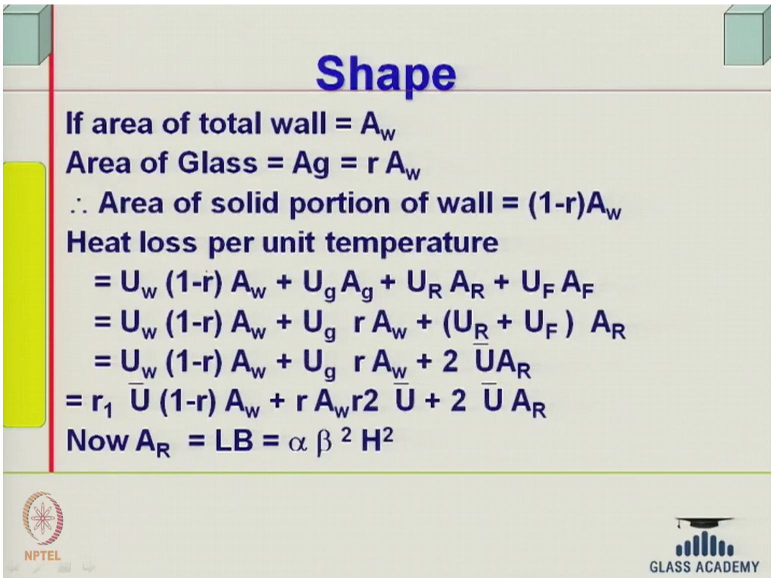

But in case of summer scenario, one got to look into the radiation that would be received and one it possibly you know in case of summer scenario, I am skipping some of those mathematical part of it. If you are interested, you can look into Markus and Morris book that will give you the algebra behind it.

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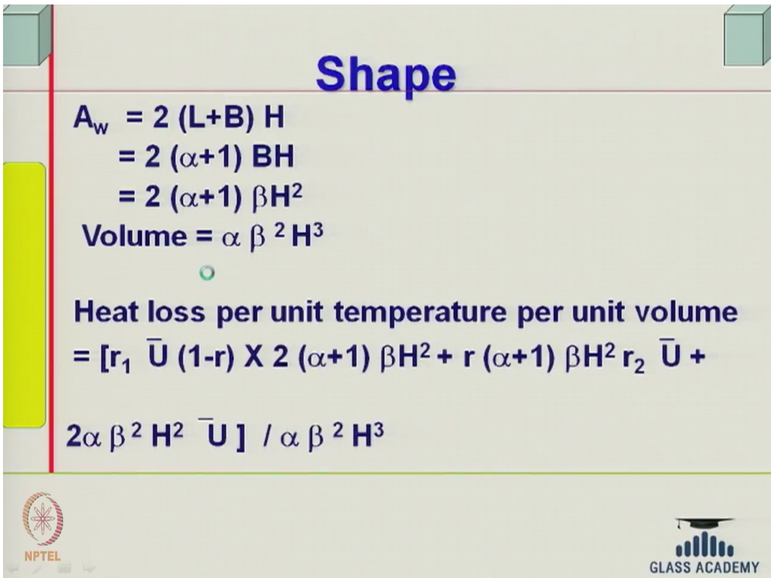

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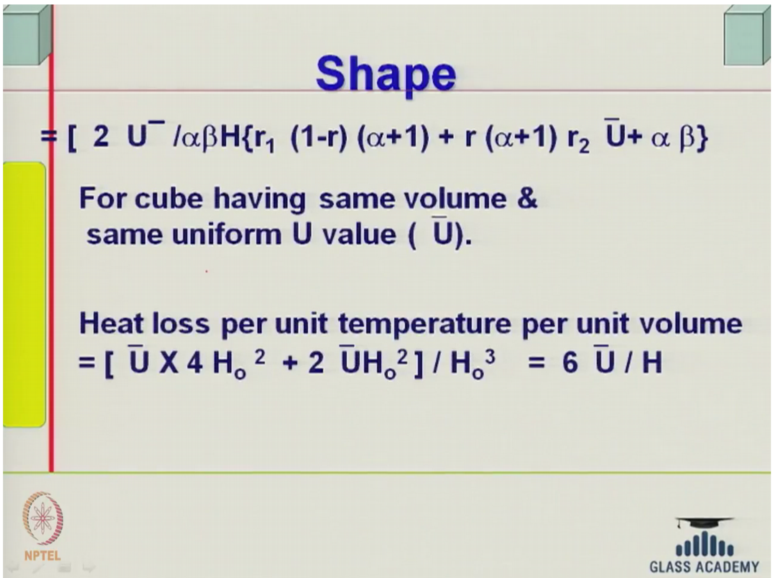

But I think, I will leave that at this stage for here.

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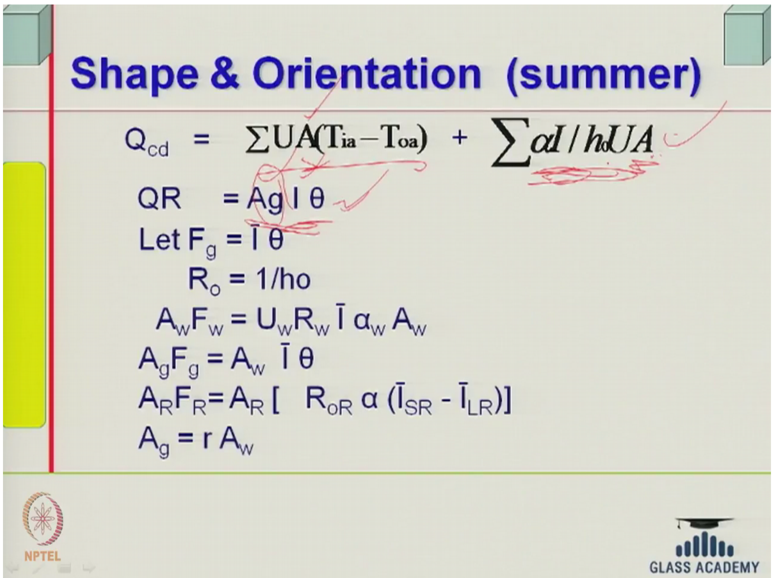

But in summer condition, you would also like to see that you minimize the amount of you know orientation goes together with the shape; shape and orientation will go together, because intensity of radiation received would also depend upon the surface area.

So, if you are external surface area which is radiation that will bring in heat. And also if this area is large, it will bring in heat, because of the temperature difference in outside and inside. Also if there is a glass area, area of the glass and whereas direct solar radiation is being received; it might bring in more heat.

Now, I must introduce this terminology called solar gain factor. Solar gain factor right, is the ratio of amount of solar radiation that comes into the glass or transparent surfaces divided by what is incident upon it right. Obviously, the area is there, so area of the glass also comes into picture; that is intensity of radiation is watt per meter square this is a fraction. So, this gives you the amount of radiation that will come in heat gain that would occur. So, we would like to minimize this as well. So, total radiation heat gained through opaque surface, as well as transference surface plus the heat gain due to temperature differences that one would like to minimize in case of summer.

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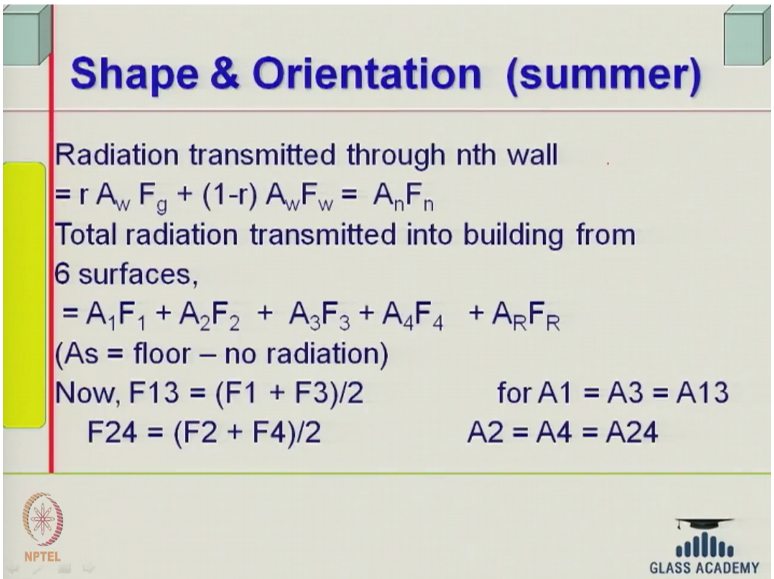

So, choose the best shape and orientation; now that would be governed by area and area of the glass and area of open surfaces all together, the this area corresponds to those area which only receives radiation; this area is the total surface area of external present; where it is you know some surface might receive radiation, some may not receive radiation. So, this per unit volume one would like to minimize, one would like to minimize.

For example, the best tool has been possible is sphere, whose surface area to volume ratio is least, but then spherical buildings are I mean it is generally not the common thing to have a spherical building. So, where surface areas are least that will be good and the mathematical formulation is here.

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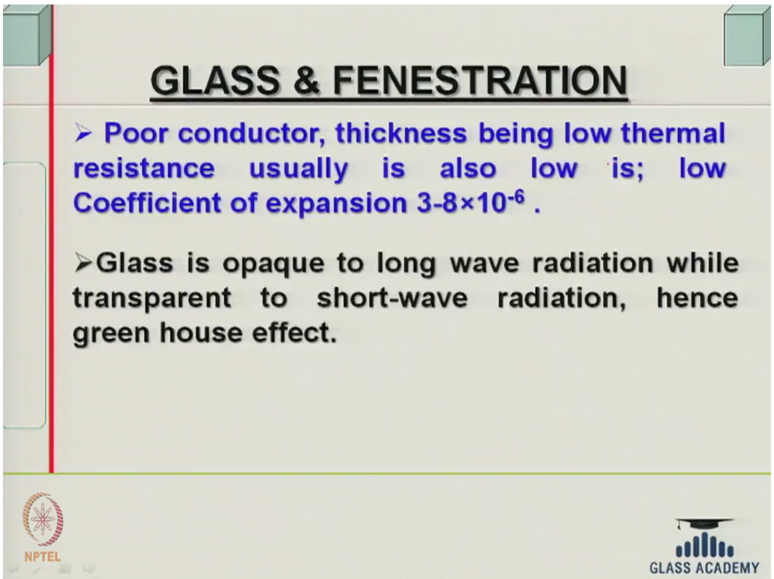

So, surface area receiving radiation or you know surface area receiving radiation and surface area receiving radiation and exposed to outside temperature that per unit volume, multiplied by the intensity of radiation received on each of those surface. The glass area multiplied by the intensity of radiation there, this sum total of all the heat input that can occur through the envelope, divided by per unit volume where whichever is least you know divided by volume because area and volumes are related, whichever is the least that is the best orientation in shape.

So, you might have combinations of orientation and shape. Let us say, I might have combinations of 8 orientation, some 8 shapes, I will have 64 cases from there by even hand calculation or excel spreadsheet calculation; I can choose the best when I know these formulae. So, these are there in Markus and Morris book, the mathematics part of it which I think, I am not going to discuss, because they are relatively you know short duration lecture.

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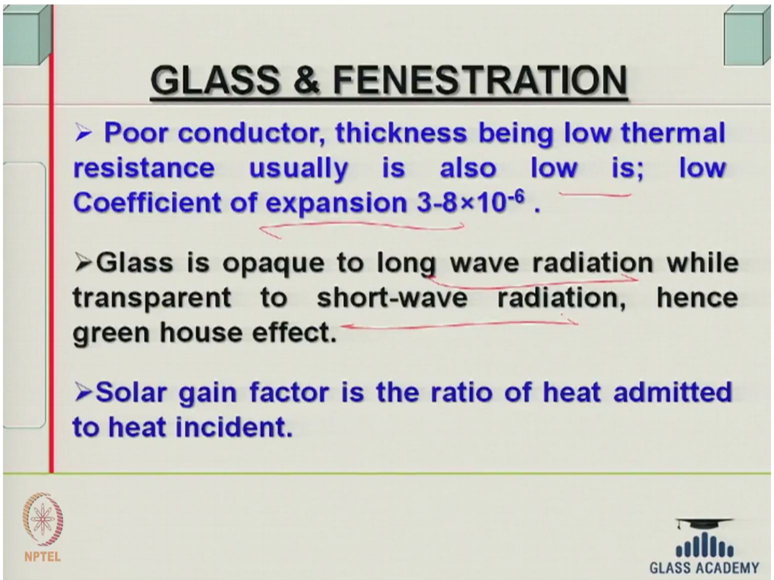

Now, let us come to glass and fenestration. Glass we know is a poor conductor, usually thickness is low, and thermal resistance usually is also, low coefficient expansion of this order; is opaque to long wave radiation that is radiation that is generated from inside. So, does not allow, low temperature radiation to go through it; low energy radiation to go through it, while transparent to short-wave radiation that comes from the sun. And hence in greenhouses in higher altitude locations to preserve the temperature, preserve the plant in winter time, you know they allow radiation to come in and discover by glass.

Today of course, there are other transparent or translucent material which plastics and so on, which can bring in the heat solar radiation it can bring in, but does not allow it to go, and that is why you have all kind of you know greenhouse, greenhouse gas you talk about, because greenhouse gas is supposed to form a layer on top carbon dioxide, methane, water vapor they allow shortwave radiation to come through that; but relatively do not allow so much, long wave radiation which is generated by earth or bodies within building, or human body etcetera to go out, right.

So, glass is one of those kind. Solar gain factor is a ratio of heat admitted to the heat incident, that is what I said denoted by theta, earlier I denoted them. So, poor conductor thickness being low, as I said thermal resistance is high, opaque to long wave radiation etcetera, etcetera.

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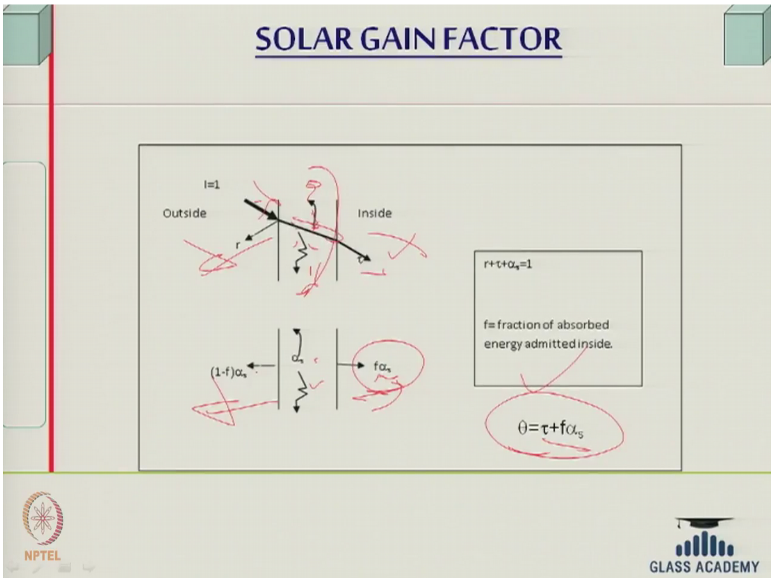

So, this typically something like the solar gain factor would be something that is an important property of glass for our purpose. Outside radiation comes in, part of it gets reflected from the surface from the interface any interface you will have reflection. And then depending upon, you know there will be refraction here, so it bends, because it is depending upon its density and all that. The way a specular ray change their direction, and again it change its direction. So, there is a refraction not relevant for us, but some of the glass heat is absorbed here; some is transmitted. So, you know some is transmitted.

Now, whatever is absorbed here, it is heats up the glass, and later on a fraction of heat is radiated inside; a fraction of it is radiated outside. So, net thing is solar gain factor this we call is the amount of fraction transmitted we call it tau. And the fraction of absorbed one alpha s is the fraction that was absorbed, alpha s is the fraction that was absorbed. So, alpha s a fraction of heat tau plus f alpha s is what is solar gain factor, fraction absorbed and your partial part of it is actually transmitted inside. 1 minus alpha s, 1 minus f into alpha s actually goes out. So, solar gain factor has this affects, you know some are directly transmitted right away; someone absorbed by the glass, and then transmitted nature.

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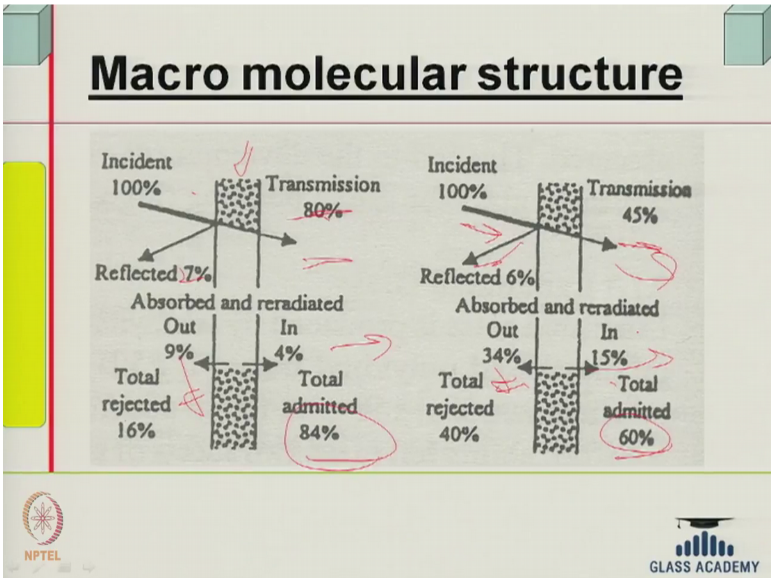

So, some glass high you know there is some glasses for example, 100 percent incident, reflected 7 percent, transmitted 80 percent and absorbed is therefore, 13 percent, because 80 plus 7 is 87, 13 percent is absorbed; out of which 9 percent goes towards outside depending upon of course, outside temperature etcetera, etcetera and 4 percent let us say comes inside, then I will have totally admitted 84 percent. So, solar gain factor is 0.84. This is also a function of incident angle. And you know it is function of incident angle etcetera, etcetera.

So, we shall see that quickly as much as possible. Some another so heat absorbing glass let us say, which will 100 percent, but transmit 45 percent reflected 6, but it absorbs now 45 plus 6 means 51, 49 percent is absorbed; out of which 34 percent goes outside, 15 percent is inside, so total 60 percent, obviously, this brings in less heat into the room. So, solar gain factor is lower. So, solar gain factor of the glass can vary.

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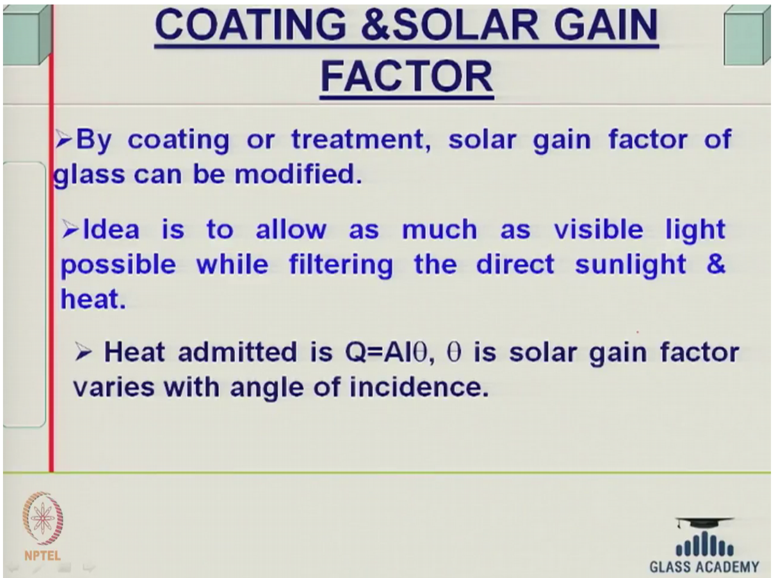

And coating etcetera or treatment of the glass can change the solar gain factor. By coating or treatment solar gain factor of glass can be modified, various kind of treatment there are lot of technologies today available. There are some very intelligent one, like photo chromatic glasses, and there may be all varieties, even the intelligent one like you press the button and you can change the transmission through the glass; like the one used by, you know in the aircraft; Dreamliner. So, you press the button, you know this going 7, I think it is 7 8 7 or whatever it is. You press the button and the transmitivity of the glass changes. So, these are high technology material science that has that allows for all things to be done.

So, various kind of treatment of glass is possible, and you can use them in a positive way. So, idea is to allow as much as visible light as possible, while filtering out the direct sunlight and heat. So, heat admittance admitted is admitted is Q AI theta, theta is the solar gain factor, it varies with the angle of incident.

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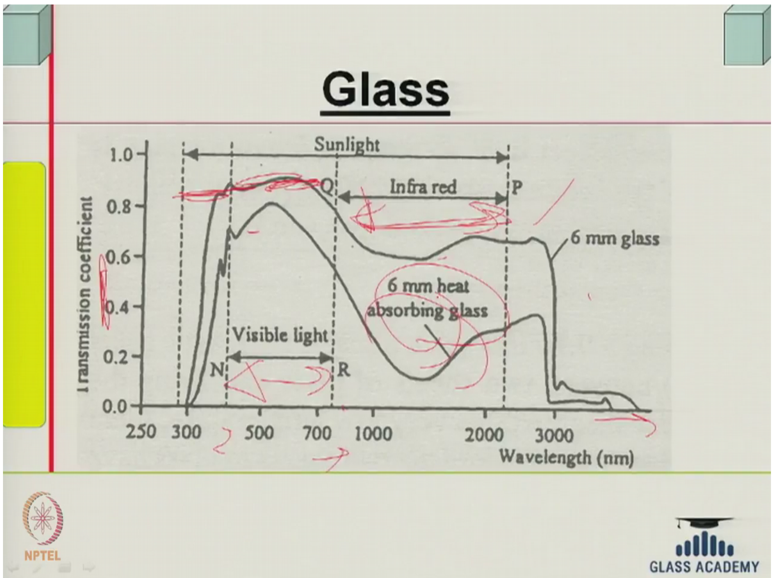

And typically good old days, there are modern glasses, I am sure somebody who talks about I mean if you go through it, you know course on glass technology, they do they would tell you that what are the different types of glass, what is that material science and technology advancement that is occurred, but typically you can see some 6 millimeter glass, this is absorption transmittance if I see, it has got high transmittance in the visible portion, which is around 360 nanometer wavelength to 700 and something, nanometer you know. So, it allows lot of transmission occurs in this space, but it does allow this heat radiation which has infrared radiation, which we do not see them.

For example, if a body is not red hot, but hot; you go close to it, you feel the heat, but you do not see that it is hot actually. You might, it might happen sometimes hot utensils you touch, because you do not realize that it is heat, because there is no light coming out of it. So, infrared radiation is that radiation. So, infrared radiation in the sunlight is also fairly high, I mean and 6 millimeter glass allows lot of it to come, but beyond that it of course, I will be any absorbing.

Now, if you have absorbing glasses like I said, it can absorb lot; actually cuts down this here little bit, but here it cuts down significantly in infrared radiations.

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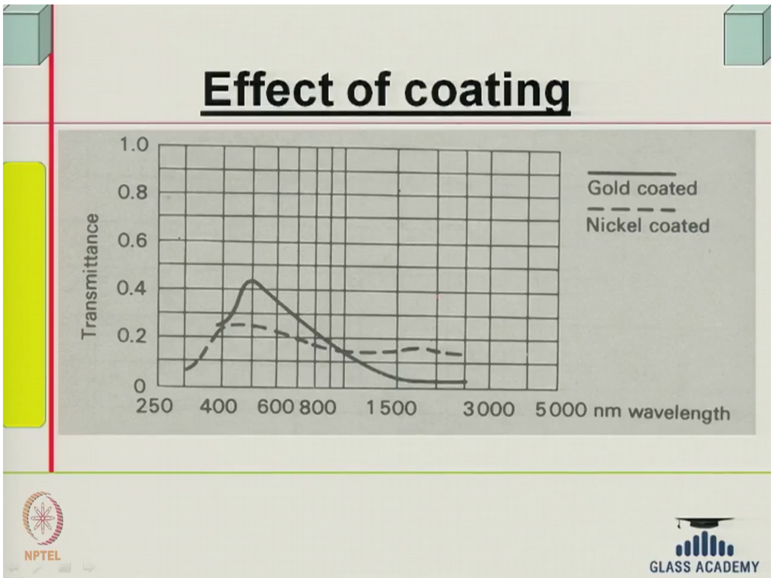

And thereby heat is not brought in much. Some sort of gold coated, nickel coated glasses where this has reduced down somewhat, but significantly reduce down those down also ok.

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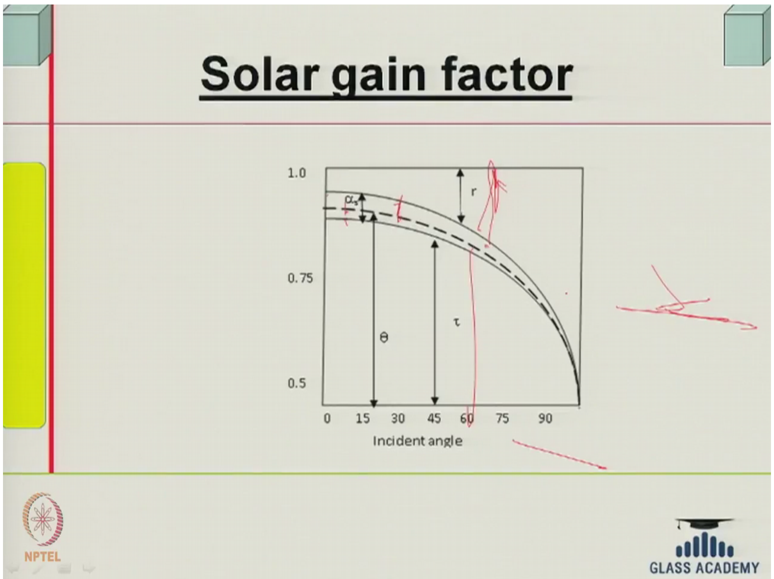

So, solar gain factor varies with the angle of incident, part of it is reflected right. So, when angle of incident is 0, that is angle between the normal to the glass and the radiation that is following almost normally it is high, but when it is nearly 90 degree, that means is passing gauging through the almost you know just passing through the glass surface itself, just going through there is hardly any absorption or transmission, or anything of that kind.

So, it varies with the angle of incident, because the path travelled by the light or heat, or the radiation through the glass will vary depending upon angle of incident; when it is normal least path is trouble, and when angle increases, angle of incidence increases path traveled is more. So, you can say reflected part of it is absorbed, a part of it is actually and part is transmitted, but a part of this absorbed actually also this transmitted inside. So, this alpha s you know and part of it the dotted line, shows the solar wind factor, as we have discussed just a little bit earlier.

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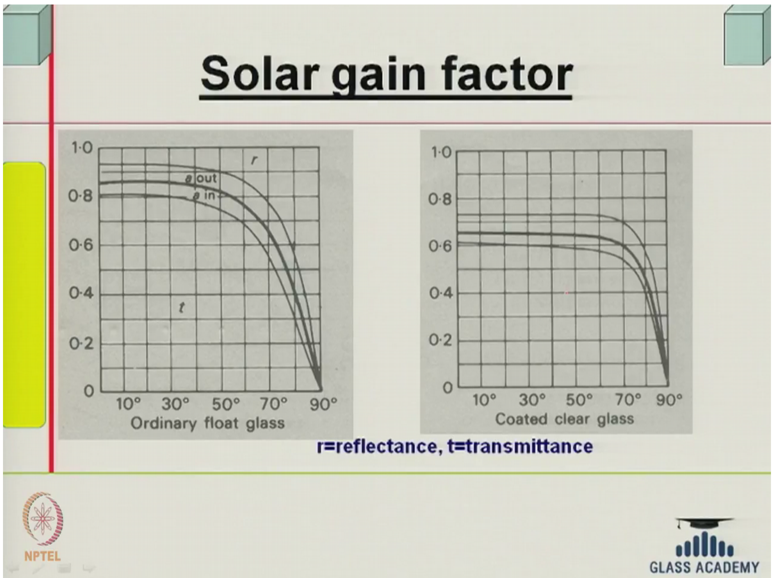

So, typically you can have ordinary float glass, coated glass and so on. So, if you are looking for glass in energy beam building, look for this kind of properties; and depending upon that you know you can choose the best glass that you know right, but that is available to you, all right.

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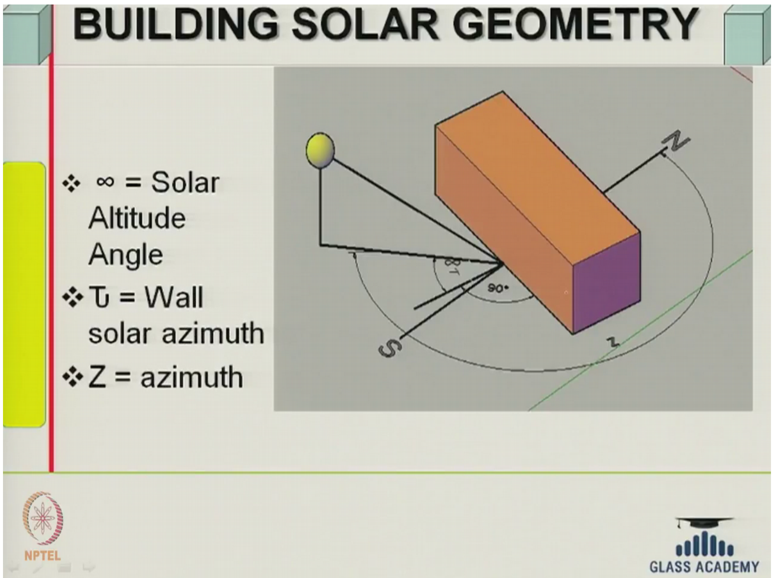

I have already talked about this altitude angle etcetera, etcetera. Now, quickly I will talk about solar gain factor right, this I have already mentioned to you.

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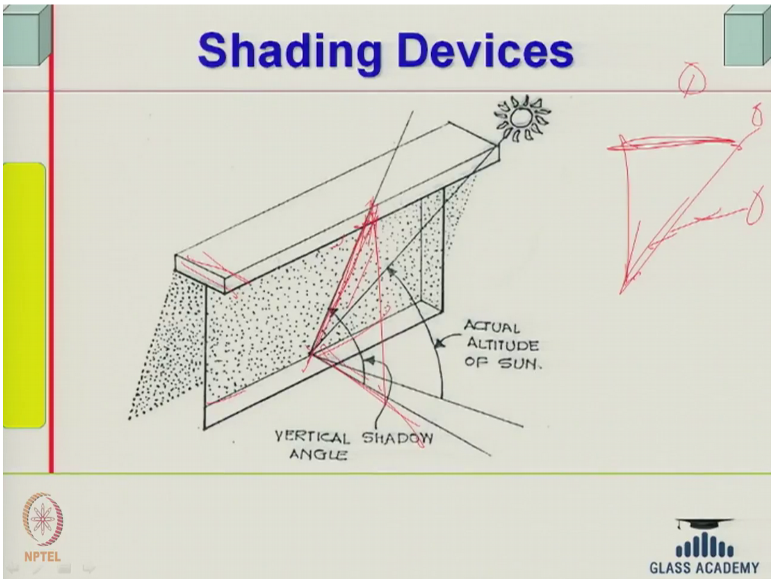

So, we can use shading devices. Now, what does shading device done, see for example, I can have a overhang, over the window right, have a overhang over the window like shown here, such that some if sun is here, nothing comes in; if sun is here, then it just goes up to the you know it completely it does not reach anywhere, but if sun is below that, then radiation comes. So, depending upon altitude angle of the sun, portion of the sunlight is blocked; you know it can completely; I can completely block depending upon orientation of my wall.

For example, in southern wall southern wall southern wall, I can completely block it in someone, because altitude angle of the sun in summer is very high at 12 noon, but in winter, it will allow sun to, sun to come in. So, this is called horizontal shading device, this is called a horizontal shading device. And we define it in terms of what is called vertical shadow angle, which is nothing but this is this plane is normal to this, you know this plane is normal to the this vertical plane actually. And in this vertical plane, angle made at the tip this is this projection right. So, this is what is called vertical shadow angle.

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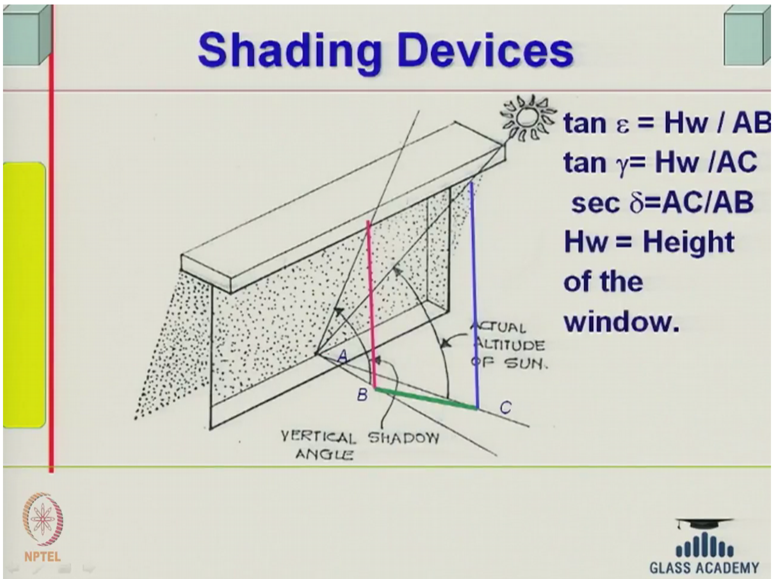

So, horizontal shading device is characterized vertical shadow angle, and similarly I can have vertical shading devices, horizontal shading device yeah this is what the angle, same angle I am showing. And there is an equation, I do not think, I will go into that equation at the moment the algebra part of is being talked about, simply the geometry tan epsilon, epsilon is what is called a vertical shadow angle is you know Hw by AB. So, tan gamma is the wall solar azimuth, it can be related to that sec delta is equals to AC by AB.

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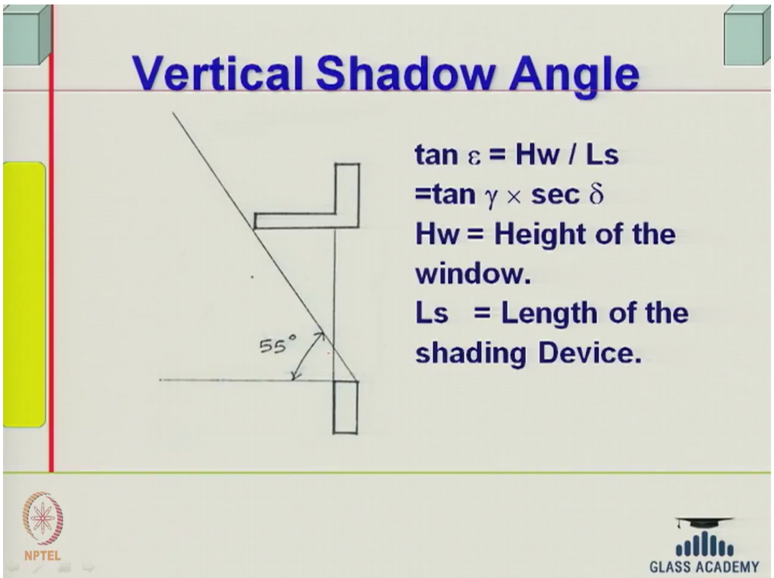

So, one can actually geometrically related. So, this is the horizontal shading device. So, tan epsilon is tan gamma plus sec delta right. I do not think; I will go into this now, algebra part of it.

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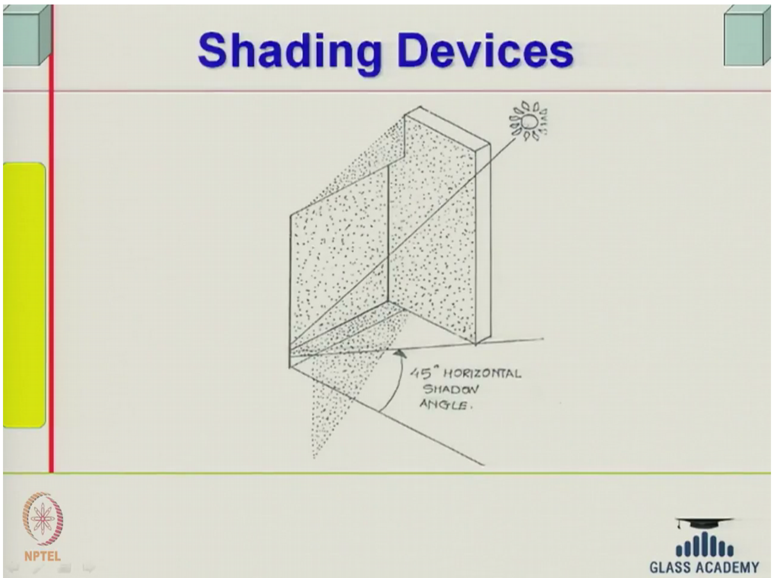

Similarly, I can have vertical shading devices which will block sun, sun on this side can block. For example is facing wall, you know the sun moves so early, early in the morning the sun ray will be falling, but I do not want that sun let us say; so I can block it by vertical shading device. Similarly after noon, I do not want, so, west facing wall; so I can block it, right.

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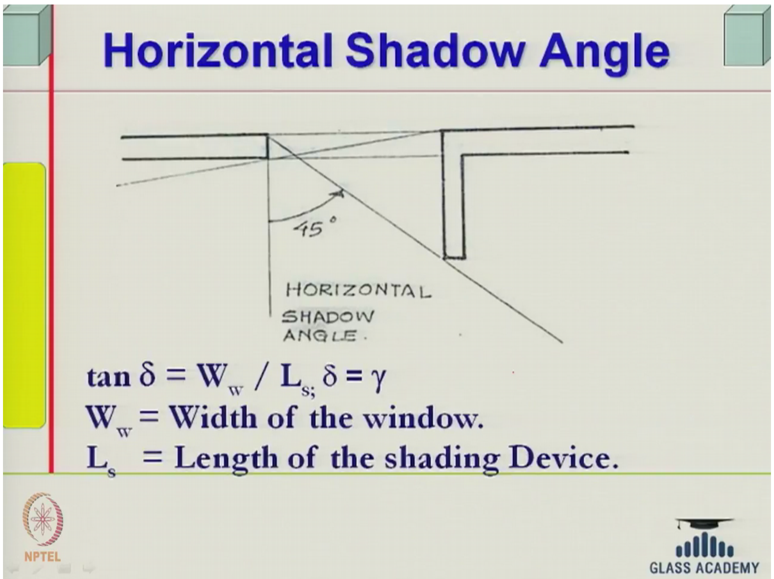

So, vertical shading device have what is called horizontal characterized by horizontal shadow angle. Again this is this same as wall solar azimuth; the geometry from geometry can you define them and find out. So, this is actually same as wall solar azimuth, the derivation of this I think, I am not going to go in this particular lecture, but what going to do this.

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