Glass in buildings: Design and Application
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Lecture – 12
Structural Control and Design for Energy Efficiency

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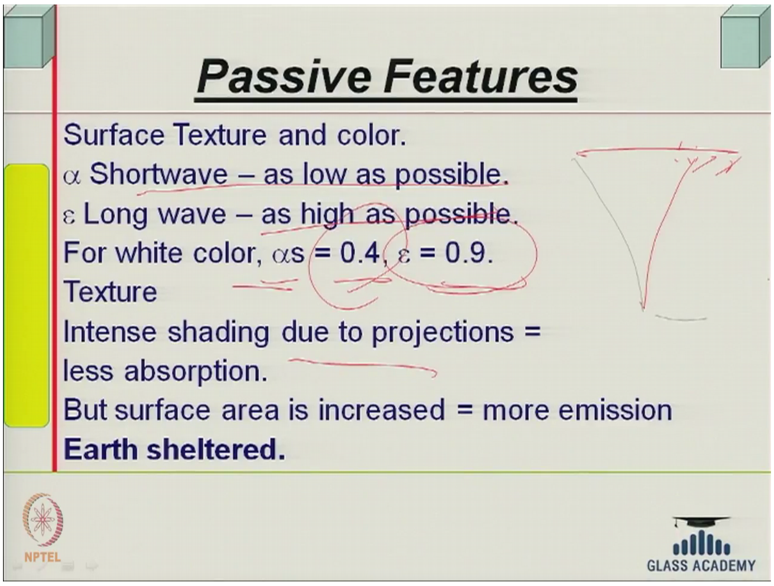

Surface texture and color, they are very important. My shortwave absorptivity should be as low as possible, one should receive you know absorb minimal. But long wave emissivity will should be as high as possible, because night I like it to radiate as much as possible. So, for white surface, alpha is equals 0.4 when short wave absorptivity is 40 percent only is absorbed, but it you know it emits out most of the heat the 0.9 is a radiation you know emissivity for long wave radiation.

Intense shading due to projection is possible that will you know less absorption. We can have even earth sheltered building put a building partly below the earth, earth temperature below the ground does not change so much. While the surface temperature changes, temperature below the ground it is you know in summer here temperature is high, here is low. In winter, temperature is just other way around. Winter surface temperature is low, ground temperature is similar. So, this is about 4 meter or so below you find temperature tends to kind of stabilize out; perturbation is not seen, variation is not much. So, you can use this geothermal energy, and all that. And you know there are various ways of doing the geothermal is of course going far below the ground.

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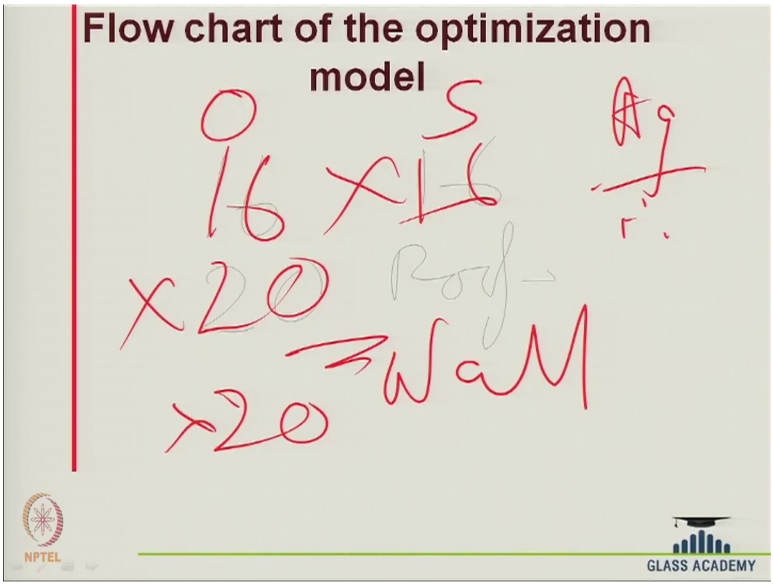

So, one can use an optimization model to do, because I just said simple hand calculation design. But when you have let us say, something like you have possible 16 orientation. So, 16 orientation. Shaped 16, 20 roof construction, 20 wall constructions and several other similar variables area, glass area to wall area ratio and so on. You know that many number of cases you will have, and you got to choose the best.

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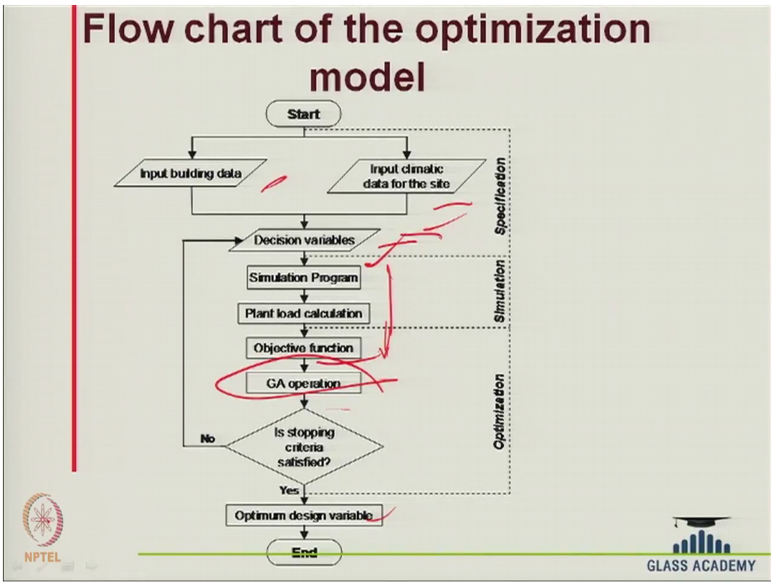

Now, such a thing can best be done to mathematical optimization models, and that one can do using some kind of a optimization method. So, this is this shows a flowchart of a typical optimization problem that will have. In such cases you will have input data building data, input climatic data, because at location where you are doing then your decision variables. And then some sort of a simulation program, plant load calculation, and you want to minimize that plant load calculation that will be some sort of an objective function that we want to minimize. Some optimization tool you might use this shows genetic algorithm as an optimization tool, and then it chooses the best one and that is possible.

So, if you have too many variables in single state, single way you want to design for a complex building also, you can do using some good simulation program which may not be software may not provide this. Because you might do either then software should have an interface with the optimization. Some of the software might provide you today some do provide with some optimization interfacing, so that is already there.

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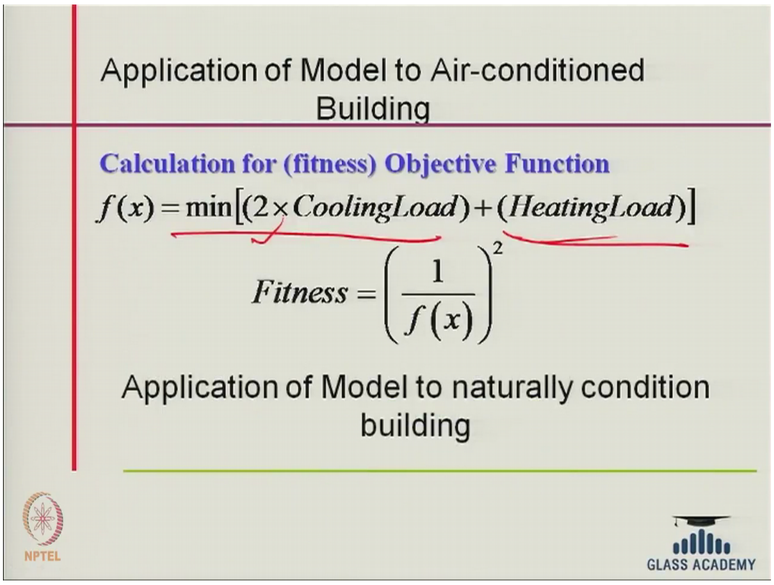

So, something like that minimize the objective function we minimize twice cooling load plus heating load, that is the cooling load you know. Heating load is heating is cheaper than cooling that is why this is 2, which you did earlier also. And you can define fitness function. I am not really interested in this at the moment.

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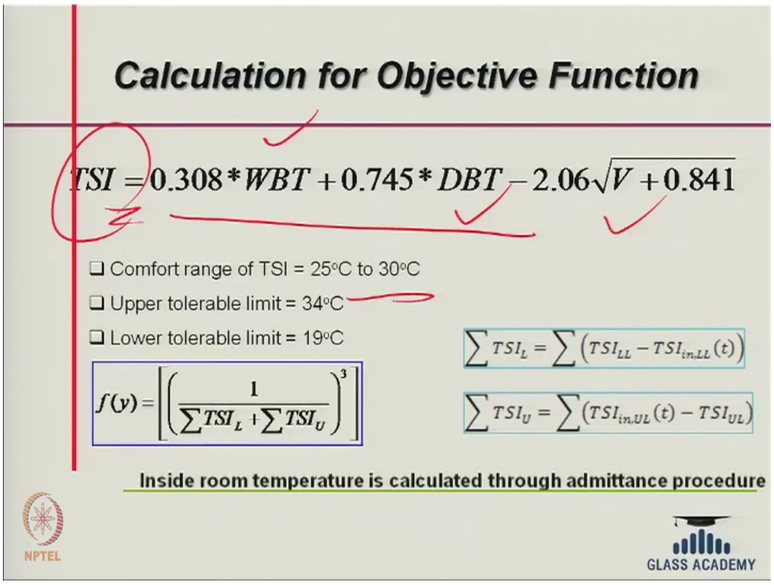

And you can another way is naturally ventilated naturally conditioned building. You might find out something called some sort of comfort indices. Like tropical summer index which is there in sp 41. It is related to wet bulb temperature which is a function of relative humidity, dry bulb temperature, air velocity etcetera.

So, one can actually calculate this out, and see how much deviation of this is occurring from the comfort zone, which is also specified in s p 41. So, you would like to minimize that deviation. So, do an optimization to minimize this for naturally conditioned buildings, so we can use this optimization tool to design even naturally conditioned building. I do not think, I will go I am I am going to go into more details of this.

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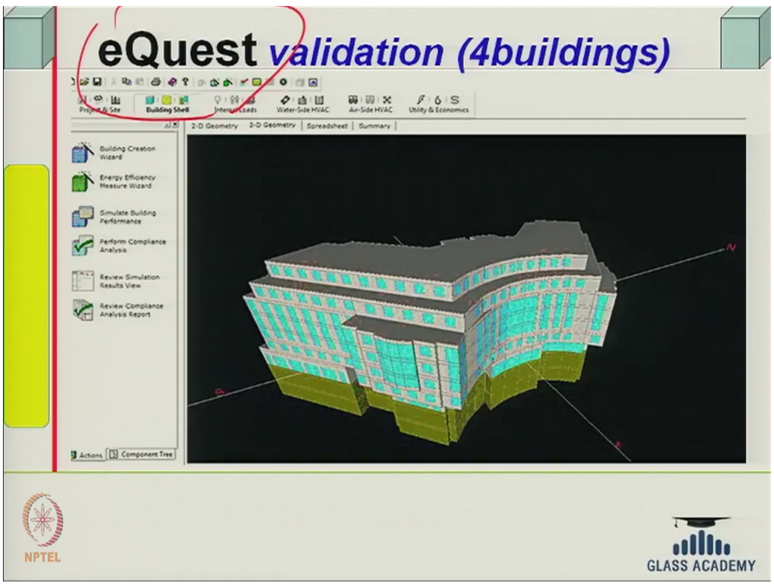

And some of this work we did validated with a software called eQuest right. Such building as a building like this which you can model any eQuest. There are several softwares open source software available this is one of them.

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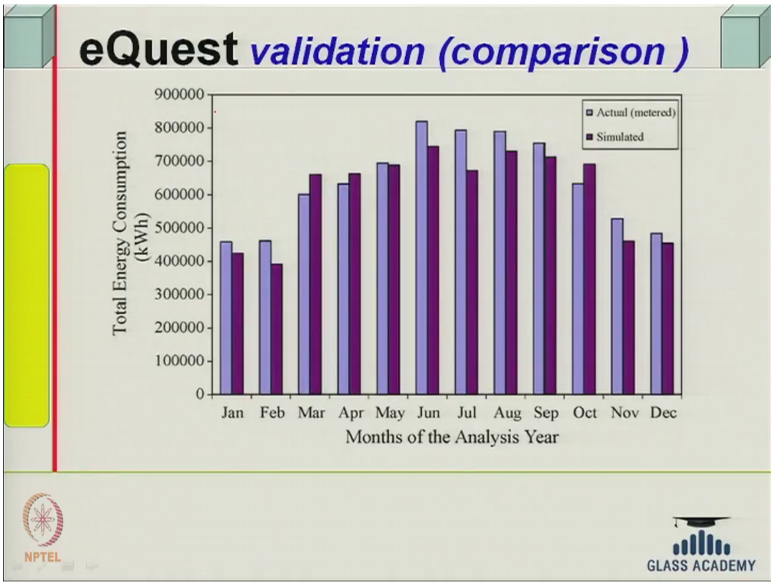

And there of course, and we found that they actually match doing it some kind of our own simulation program right. So that can be done.

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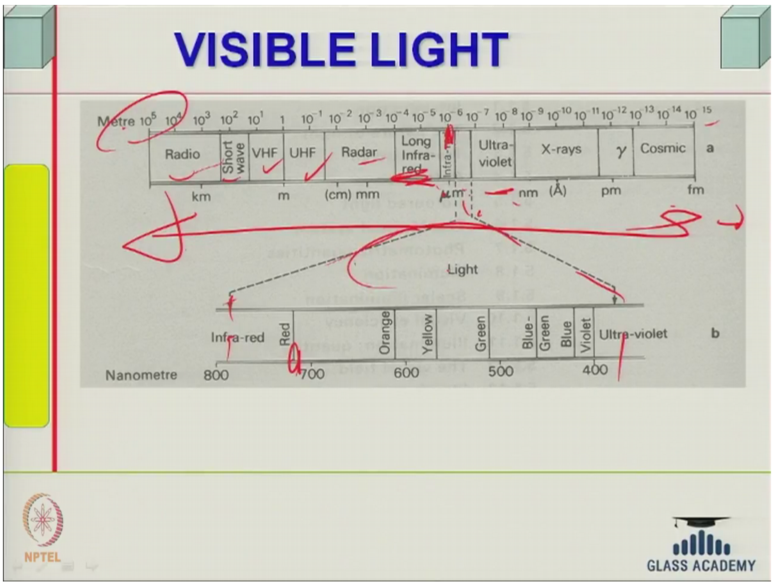

Last part of my discussion our last but one is visible light, because day lighting is very important we are talking about glass. And as I said you know visible light is this is the spectrum of electromagnetic radiation starting from radio frequency, shortwave, very ultra very high frequency, ultrahigh frequency, radar, long wave etcetera, etcetera. And on this side is a cosmic. So, you can see that 10 to the power minus 15 is a wavelength, and here 10 to the power of 5 is a wavelength in terms of meter in meter scale right. So, this is of the similar order because radio frequencies are here I know meter whence and so on we were talking about earlier.

And visible portion is only a small portion. This side is ultraviolet infrared this brings in lot of heat you know. Long infrared this brings in lot of heat that is order to go, but now we are not interested in heat anymore we are looking at light. So, this is the light portion which goes from about 360 nanometers or so to about 700 m, you know this is infrared. So, red finishes here 700, and so whatever the value is not. So this is the visible portion of the light. And we would like that that comes in more.

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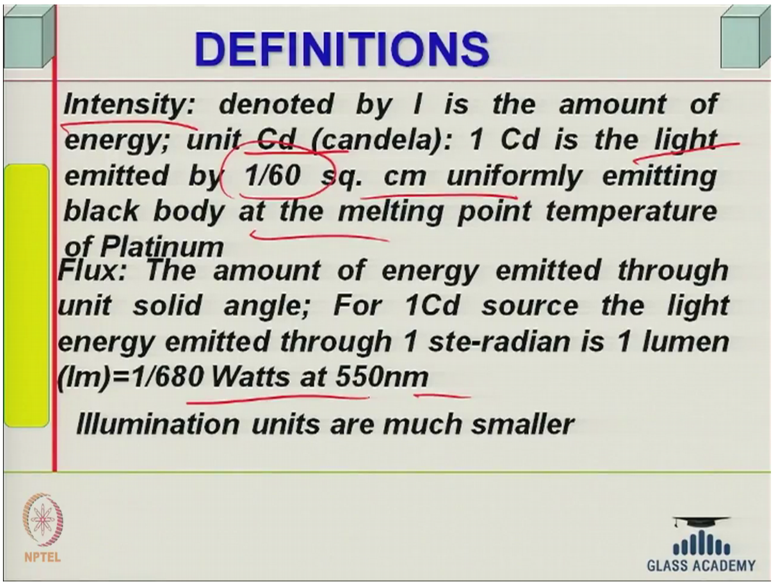

My glass does that job, open window or glass this door. Now, dealing with day lighting or lighting and we have a little bit of problem. The problem is we cannot use the same units, so use different units. I am not going to go into the details of this definition, but I just want to point out fundamental units of lighting is called intensity. And it is generated by candela. And it is standardized at 1 by 60 square centimeter uniformly emitting black body at the melting point of melting point temperature of platinum whatever light it energy light energy it emits that is what is 1 candela intensity. Then flux is the amount of energy emitted through unit solid angle here you deal with solid angle. So, 1 candela source through 1 ste-radian you know, and this is some equivalent with the watts at 550 nanometer wavelength.

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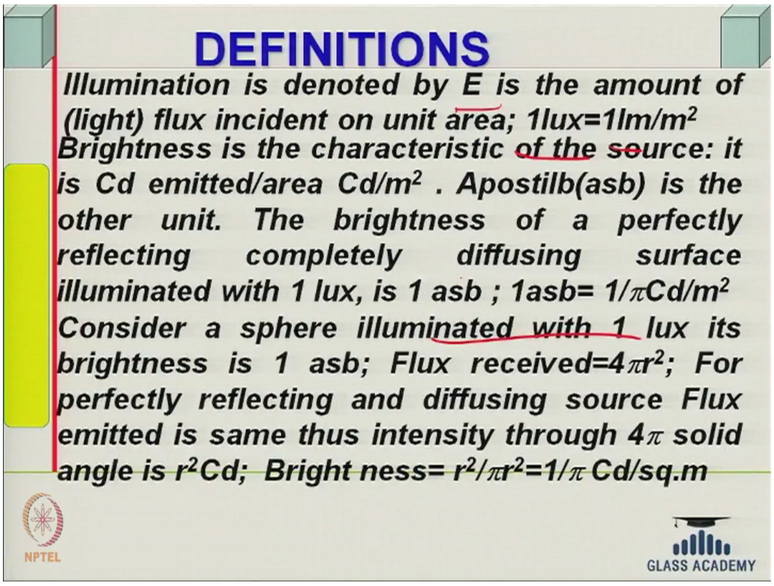

So, units of illuminations are smaller, and we do it quantification when you want to do, we have to do it in deep you know it is a different one. We have something called illumination, which is basically flux per in meter square or it is called 1 lux. So, unit of illumination is lux which is lumen is a unit of flux lumen per meter square. Brightness is the characteristics of a source it is the candela per meter square. I do not think I am going to these details of there are other units, but I do not think, I will go into this. And one can derive various kind of scenario related to this.

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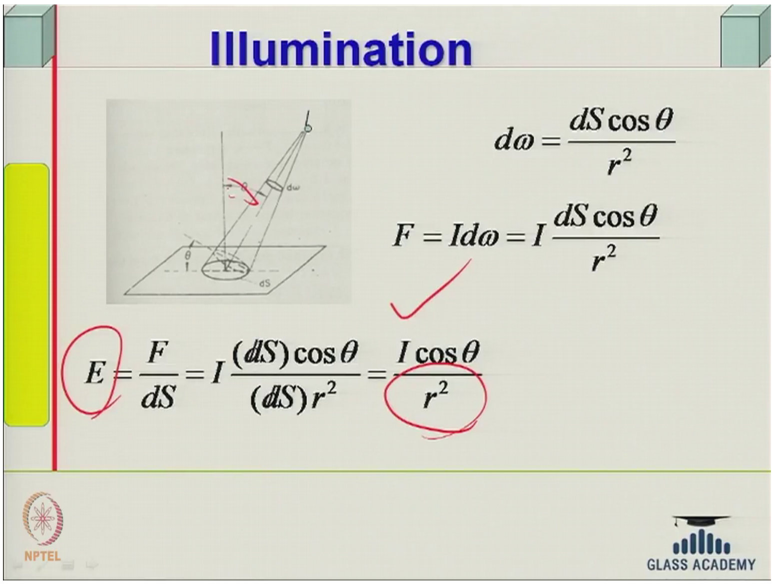

And one important law is inverse square law. I will not again derived this, just simply explain. The illumination depends from a source having intensity I is given by I by r square cos theta, where cos theta is theta is the incident angle; so I cos theta by r square right. So, from a point source the illumination at a distance r is given by this; if its intensity is I, it will be I cos theta by r square.

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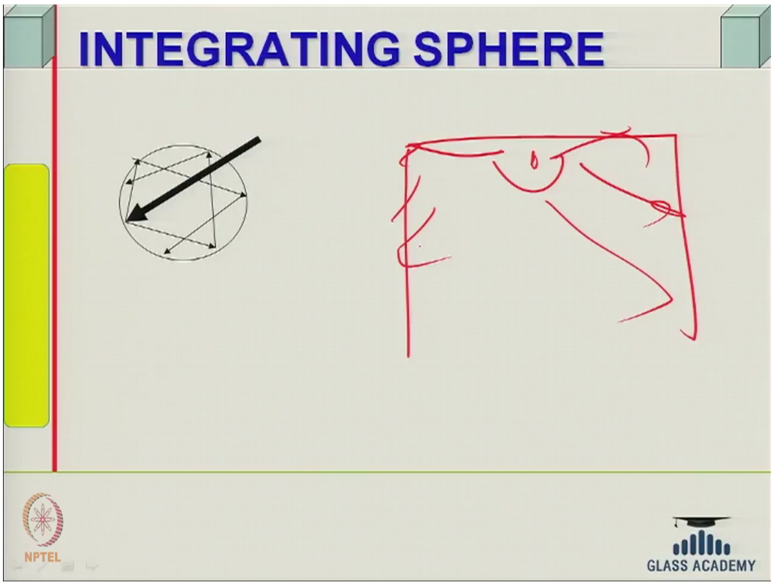

There is another principle which is used in lighting is called principle of integrating sphere. When light comes in from outside in a sphere, it will be internally reflected. For example, you have a building room and you have light facing upward, no direct light coming downward. But still you will find that this is light, it that is because of internal reflection occurring from all these walls in finite reflections. So, that is you know that is model through in principle of integrating sphere the mathematics part of it right.

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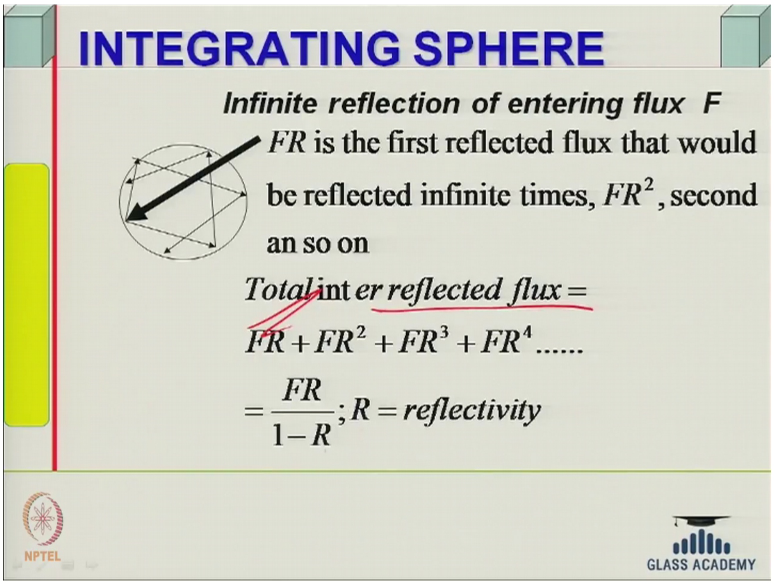

So, infinite reflections, and simple formula comes out to be you know total internally reflected. Flux is given by this, and elimination you can calculate out. I am not interested.

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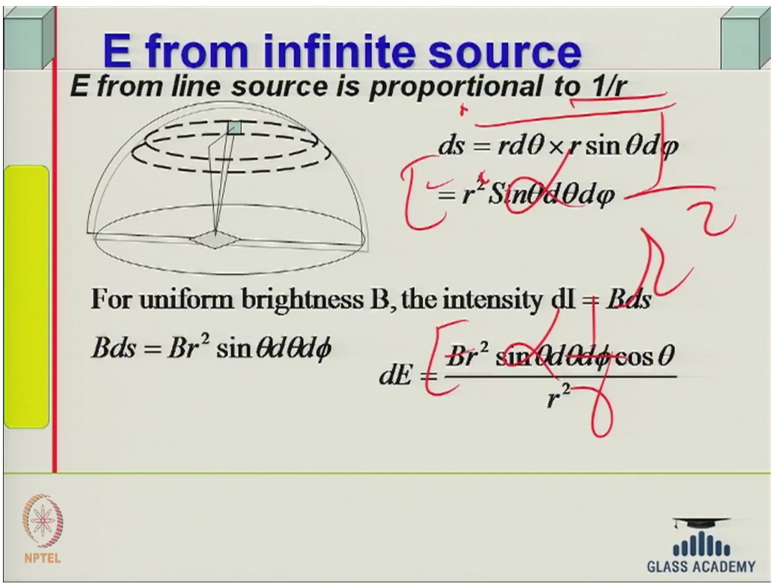

So, it can be shown that E from a line source is proportional to 1 by r. E from a point source E from a point source from a point source is proportional to 1 by r square that is what I just said; from a line source is proportional to 1 by r. From a hemisphere like sky it is independent of r from a point so line source it is E proportional to 1 by r as we are saying. And from an infinite source it is independent mathematically it can be derived. I am not interested in doing that right now.

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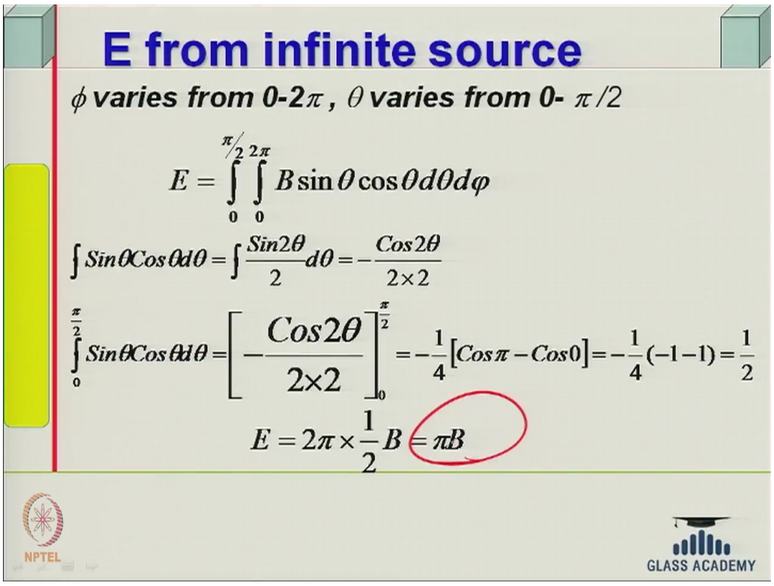

But I just want to say that it is from you know you can derive this it is simply pi into B where B is the brightness of the sky. So, sky brightness is important, uniform brightness I am saying it is not varying with different angle of altitude and all that.

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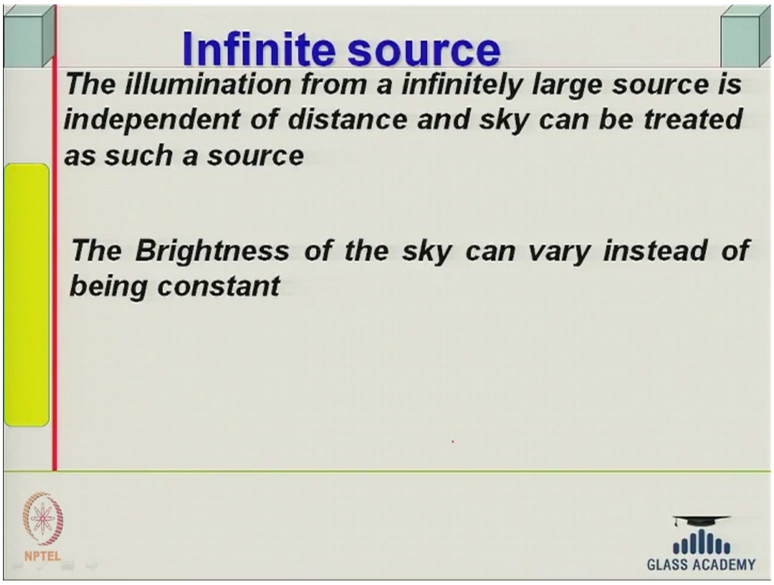

So, illumination from an infinitely large source is independent of distance and sky can be treated as such a source, and the brightness of the sky can vary instead of being constant. It varies, because morning it will vary, evening it will vary Delhi, Chennai, Mumbai, Kolkata, Guwahati all it will vary. So therefore, there is a variation right.

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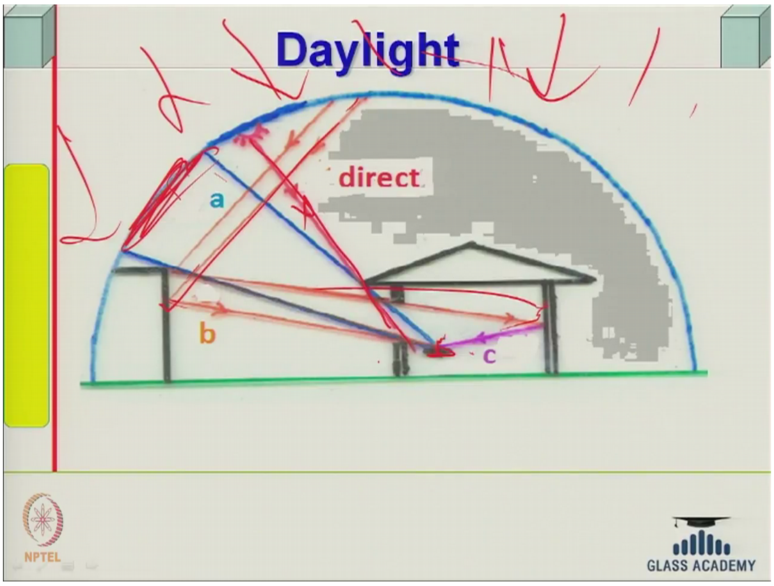

So, some of this you know, so that is why you is something called daylight factor Because, light at a given point can come directly from the sun right, which you would not like we do not like much of it, because it brings in heat direct sunlight we do not want, but it can come. So, this is canceled, this is not there. For lighting purposes, a portion of the sky is visible from this point a. So, light comes from this diffused, light comes from this portion of the sky, because sunlight comes much sun is that far bigger far you know it is some part of distance.

So, whole of the sky vault actually receive sunlight radiation and it diffuses at the atmosphere, and diffused light can come through the sky vault to this point. This is a; b is reflected from another building or tree or anything of that kind; so some light from the sun or the sky coming here, and coming inside. And third whatever comes in they will get internally reflected. It may not come to this point, but some light might come here, and then get internally reflected c.

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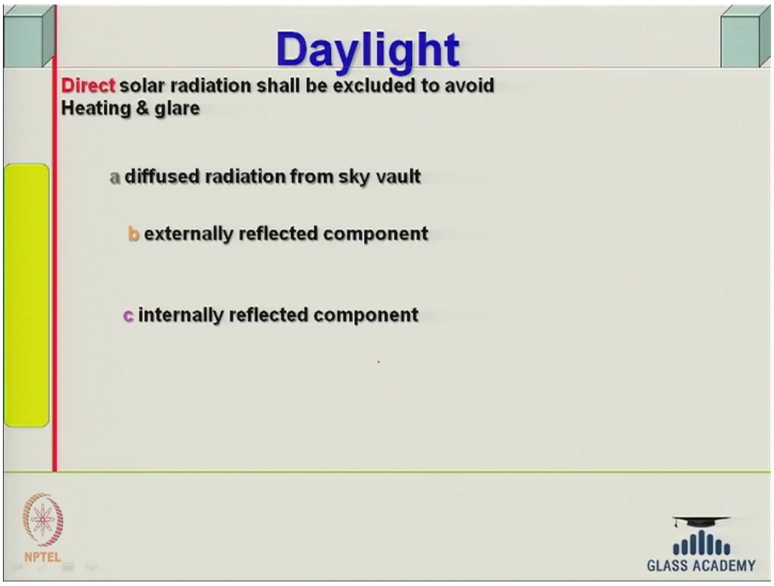

So, there are four components of light, which can come. Direct solar radiation is excluded; a is diffused radiation from the sky vault; b is externally reflected component; c is internally reflected component.

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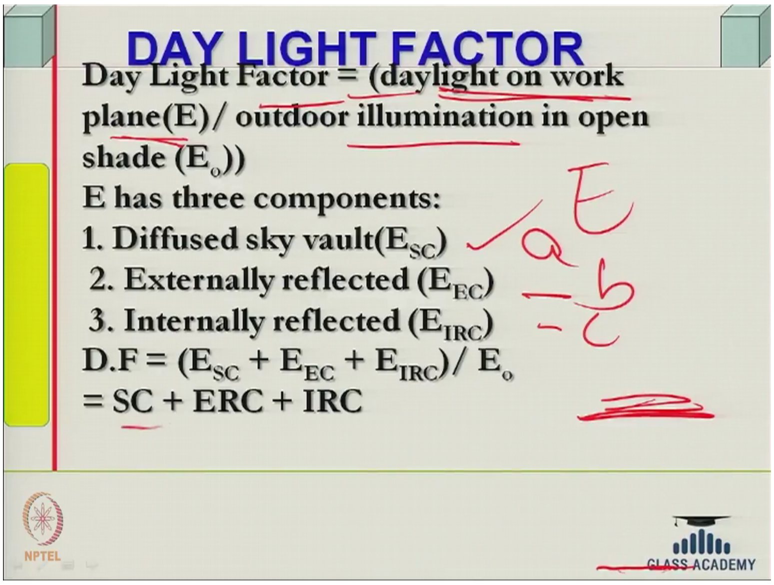

And all these three you know is taken care of in what is called day light calculation. Now, we define something called day light factor. Why do we do it? Sky will change from time to time, even from day to day for a given window or given openings or fenestration. But relative ratio of illumination on horizontal surface unobstructed horizontal surface illumination at a given point relative you know daylight factor work plane is a plane set table, top of table or blackboard or whichever, where you are working where you want to find out how much is the light coming from the sun or sunlight day light which is coming.

So, day light on a work plane E divided by outdoor illumination in open unobstructed sky of course, it should not have directly radiation coming onto it that is we call as daylight factor. This daylight factor has three component, sky component is the one which comes directly from the sky related to a. This is externally reflected component and third one is internally reflected component. So, daylight factor has got three components - sky component, ERC and IRC.

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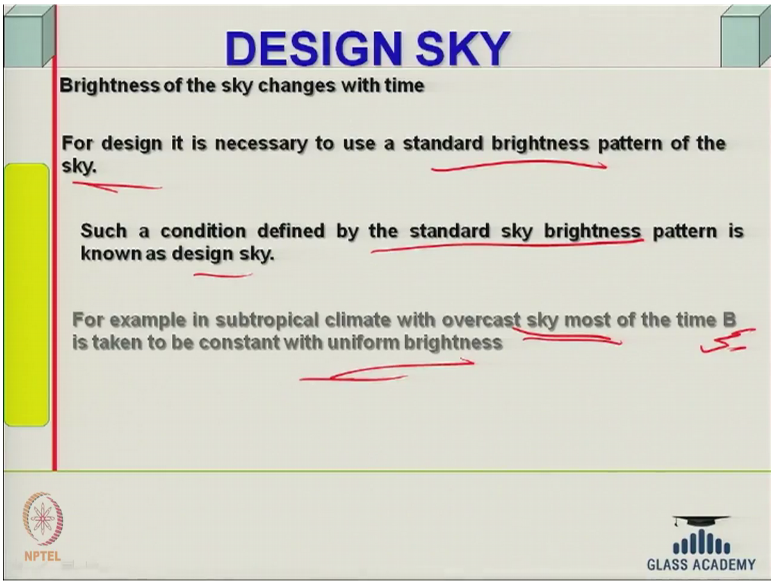

And for to calculate out for design purposes, I need a design sky, because sky changes from time to time, time of the day as well as from location to location right. So, I need a design sky in Indian design sky of course there is one given in sp 41; actually obtained very you know 1970s. Lot of development in the day lighting design has occurred over these years, but of course, our code has still remained same and perhaps it needs some change ok.

So, brightness of sky changes with time for design it is necessary to use a standard brightness pattern of the sky. And such a condition defined by the standard sky pattern is known as design sky. For example, subtropical climate subtropical Northern Europe you know they have a worker sky of the time. Therefore, they use constant brightness or overcast sky. There are some kind of some people earlier they were using uniform brightness same brightness throughout the sky for design purpose. Of course, now you have got there are several standard sky coming from CIE you know the illumination body of illumination society and all that international you know so illumination.

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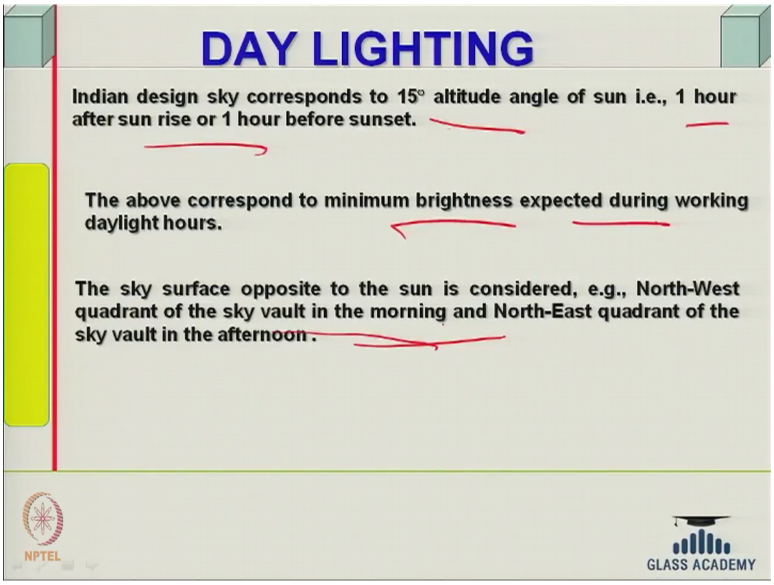

Indian sky of course, corresponds to 15 degree altitude angle of the sun that is 1 hour after sunrise and 1 hour before sunset that they have taken as a design sky. Why1 hour after sunrise, because after that offices etcetera starts not before 1 hour after sunrise; so they have chosen 1 hour, but that actually help them mathematically in some manner.

And 1 hour before the sunset, so the light is daylight is available only during this period of time for functional building you know for functional use using functional building that is not they have chosen that is a design sky. So, minimum brightness, and this also corresponds to minimum brightness expected during working hours; most of your day it will have higher brightness. So, design is usually characteristics value and this is where it corresponds to. Then they also consider sky surface opposite to the sun that is, Northwest Quadrant of the sky vault in the morning and north east quadrant of the sky vault in the afternoon.

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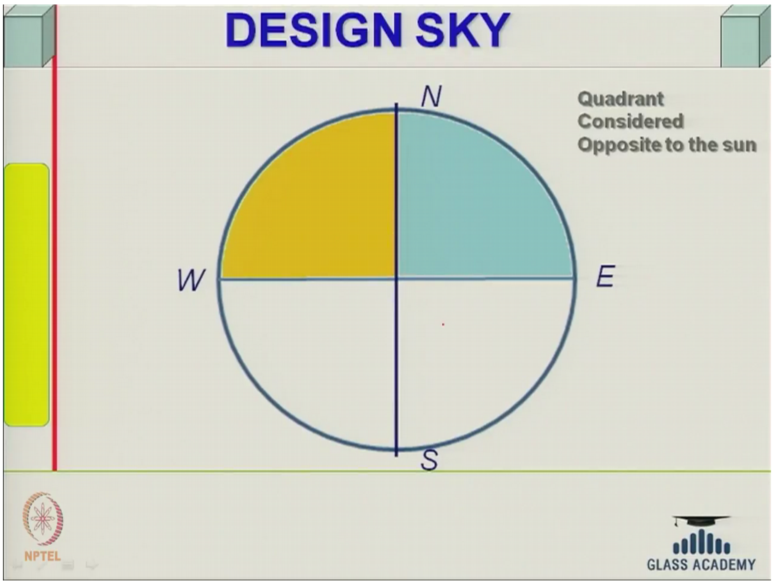

And you know something like this, something like this portion is considered this one in the morning. And this was in the afternoon, this one in the afternoon.

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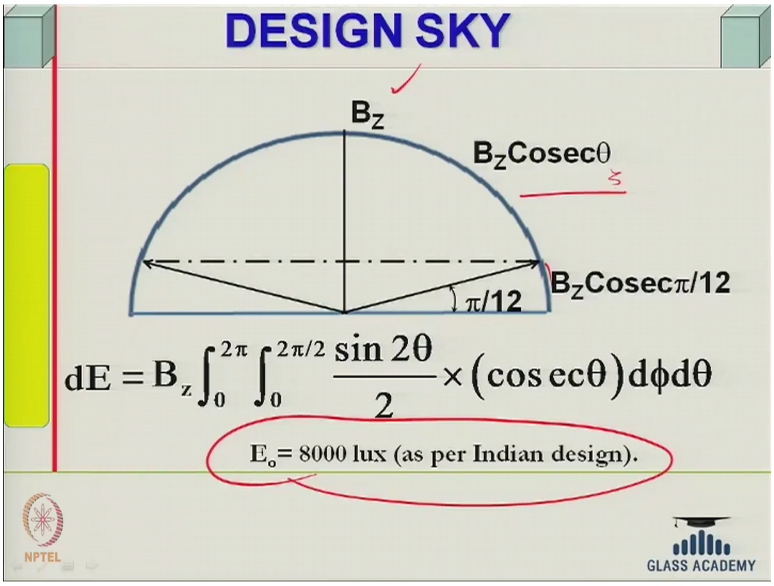

So, they define it by something like cosec function where B z is the brightness of the zenith point. B z cosec theta is the brightness variation that is based on some measurement done in 1970 at CBR at Rookee. And sinc,e cosec function becomes infinity at this point 0, when theta is equals to 0 in this zone it is assumed to be constant. So, pi by 12 one words is constant, so you can actually do calculation tables are available, charts are available for designing or analyzing that daylight on working plane. And based on their this equation, it has been and their measurement E 0 that is illumination at open surface horizontal surface under the design sky has been calculated as 8000 lakhs.

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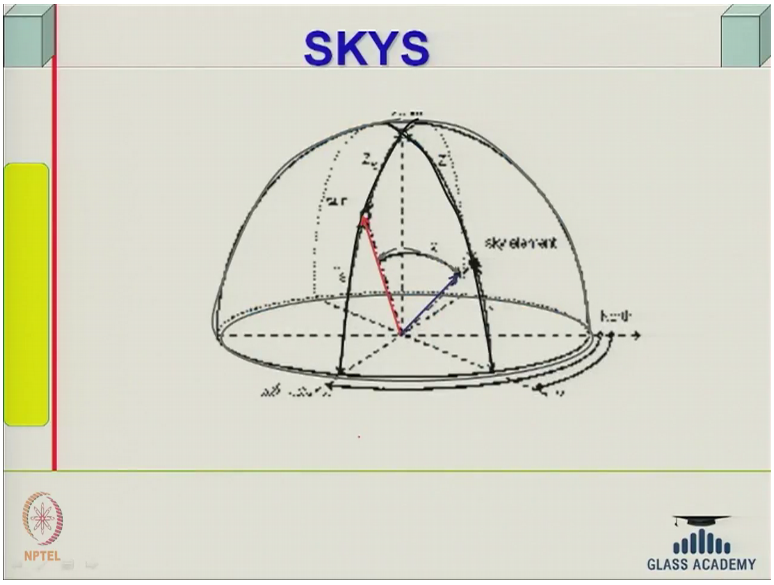

There are other kind of skies as I said, but I do not think I am going to discuss them right now.

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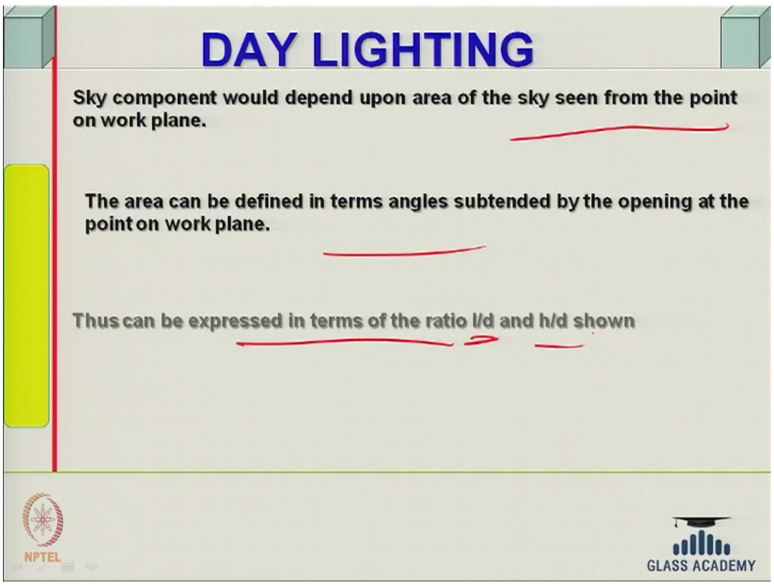

So, sky component would depend upon the area of the sky seen from the point of work plane. There it can be defined in terms of angle subtended by the opening at the work plane. So, we can do the modeling, but I think, I am not going to really look into this. So, there you know one can express daylight factor in terms of l by d, where l is the length of the window, d is the distance of the point from the window in some manner, h is the height of the window etcetera, etcetera.

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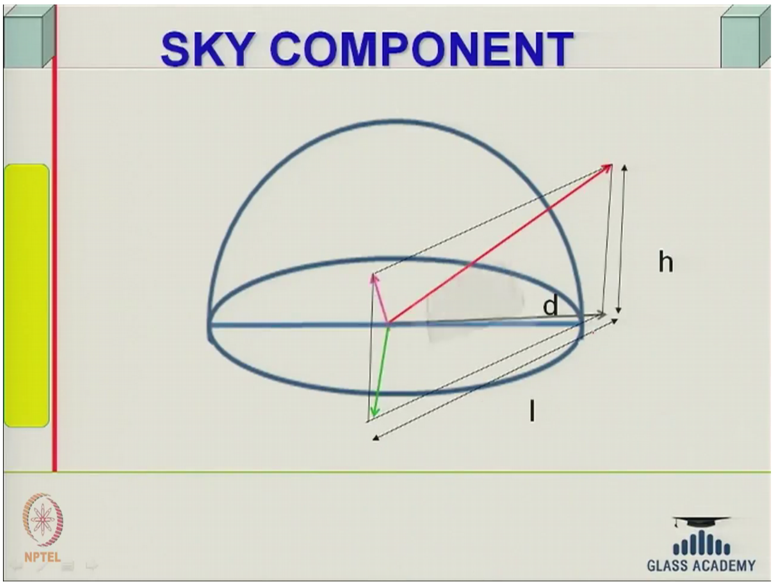

So, there are table available. And this is a kind of modeling they did, I do not think I am going to look at it right now.

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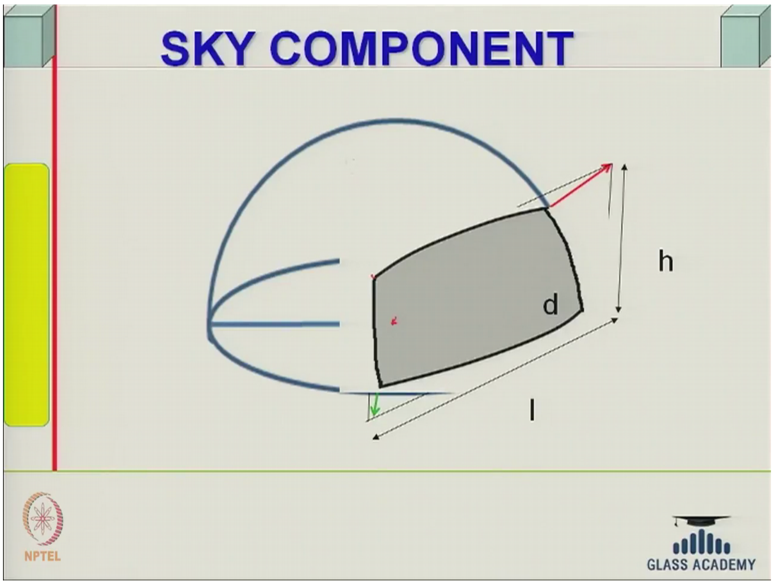

So, this is the portion of the sky which will be visible from a point here. some point here you know this is the point the portion of the sky that will be this is the point. So, this is the point from here. The portion of the sky that would be visible would look something like this sky vault. If I project right; if I project onto the project make a hemisphere on the window itself; on the in the damn along in a distance d at a distance d of the window. The radius d then this will be the part of the sky vault which will be visible. I mean you can project it outward to the sky vault this will be the same. So, from that one can calculate out right.

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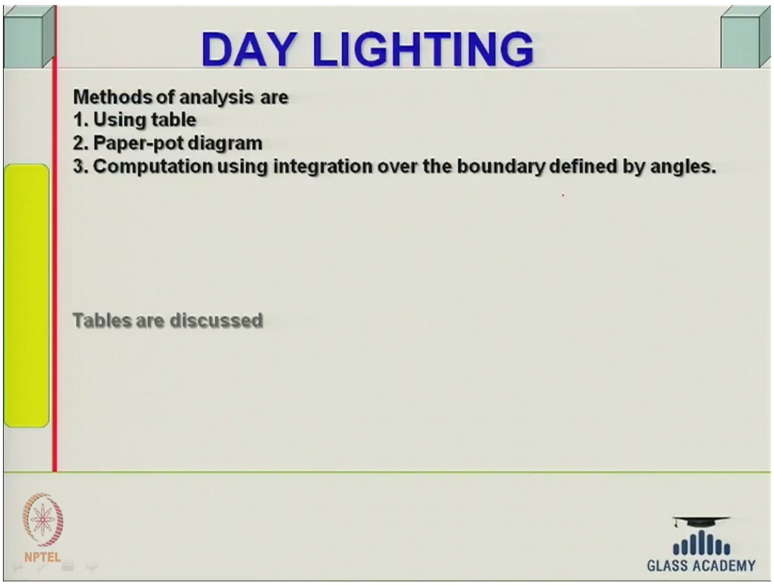

And then one can use day light tables, paper-pot diagram etcetera, etcetera. Today it is possible to make computation, because computational capabilities increases significantly. So, I am not going to discuss anything out of this.

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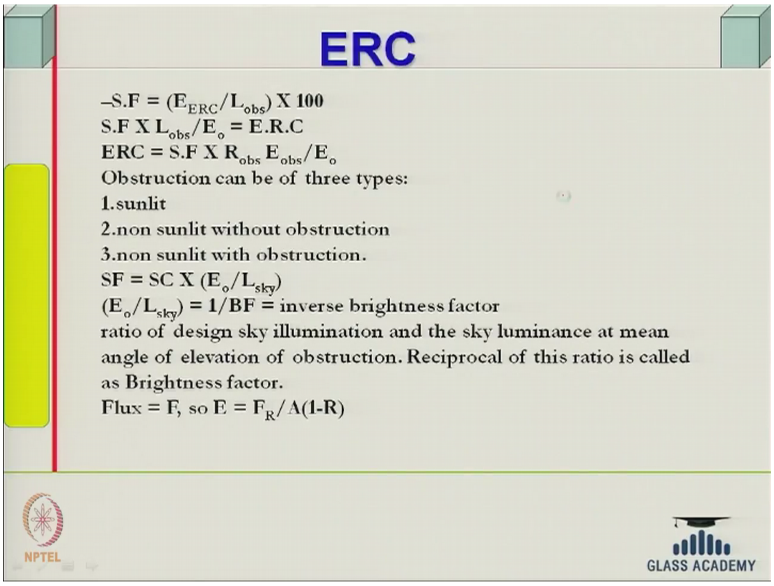

Similarly, ERC formula is available. I am not going to again do the mathematical treatment here, but if you are interested, you can find in sp 41.

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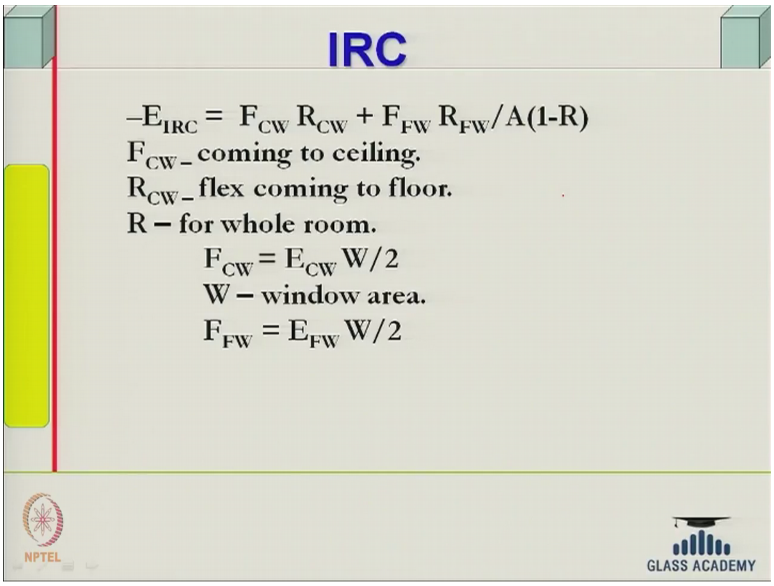

The details are given IRC calculations are also given. The IRC formula is given based on principle of integrating sphere. I do not think I am going to look into this right now.

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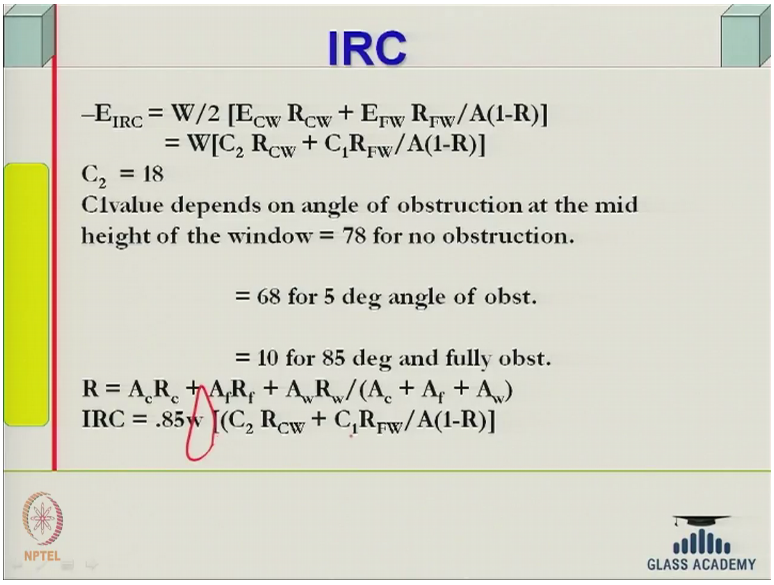

So, IRC formula is available. And it is taken in this formula 15.15 percent 85 percent is taken as a visible light transitivity of glasses. It might change depending upon the type of glass you are using. These are window area ok. These are some coefficients, these are reflectivities, I think, I will not going to the algebra of it.

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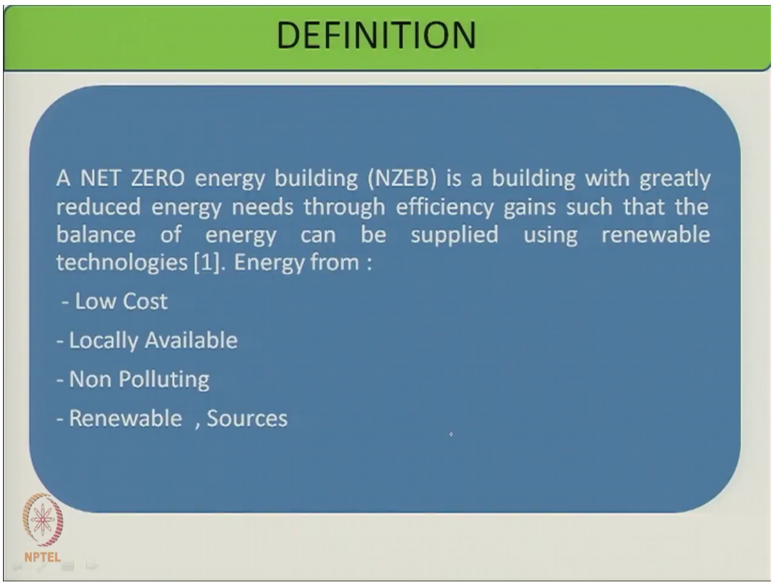

Now, extension of this one could be a net 0 building, where you use actually building integrated photovoltaics or something or some windmill etcetera, etcetera. And energy you can design the system for minimal energy consumption or maybe for, no energy maybe some is might supply to the grid as well if you have building integrated photonics.

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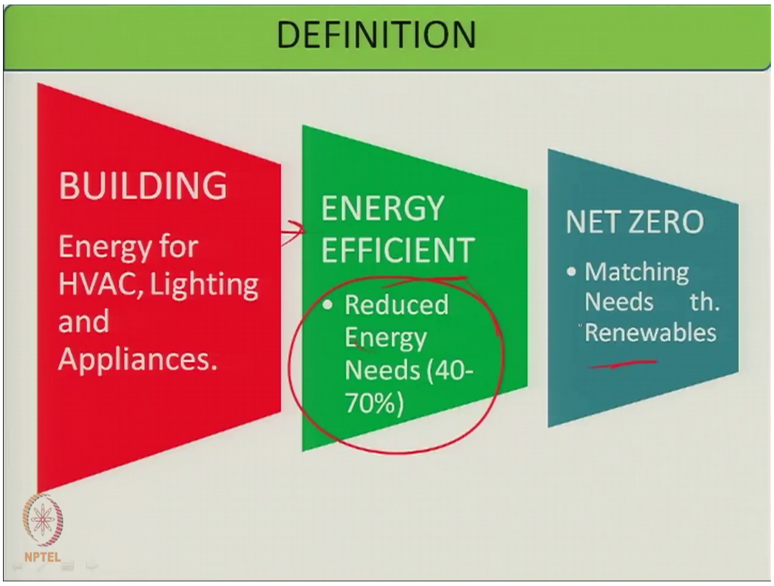

So, zero energy building net zero building or net positive building this is a concept which are coming. So, energy for building so energy for HVAC, lighting and appliances;, energy efficient, if it is next step, if you make it, you will need reduce their energy need by 40 to 70 percent, by doing a good energy efficient design. And then, matching need from renewable energy like building integrated photovoltaics you can do that can make a building net zero.

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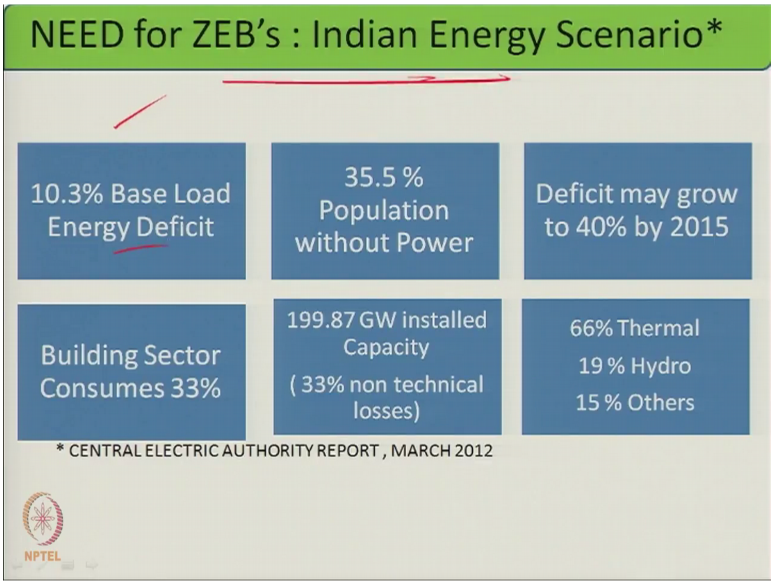

I think that would finish more or less our discussion. So, need for there is a need for looking at this 13, base you know energy deficiency etcetera, etcetera some statistics, I am not interested.

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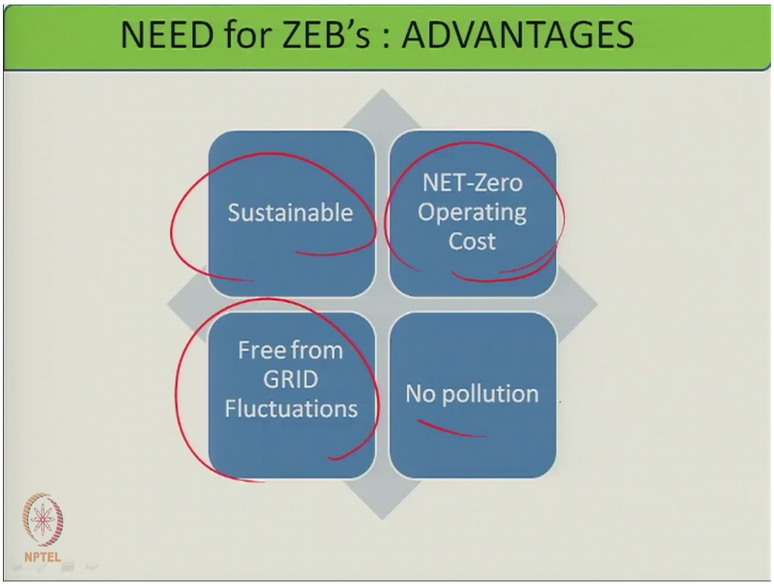

So, this is net zero kind of building will have very little operating cost, sustainable free from grid fluctuation, obviously, nonpolluting if you can use the solar energy most of the thing right. So, what we have discussed quickly summarize I define an envelope of the building, defined some of the features. I mean decision variables related to energy efficiency some of the features of climates, talked about embodied energy, and the operational energy. And we have seen the operational energy is much higher and operational energy is controlled by envelope elements, their time lag, decrement factor you know there will thermal capacity, and u value.

And then we talked about shape, orientation, the glasses right. And then we looked into also we looked into day lighting part of it because it is related to glass we are talking about glass and similar sort of thing, and envelope. And lastly I just said that you know one advancement towards that would be by using everything optimally designing it optimally, we can actually going to natural building.

So, thank you very much. Thank you; we are closing this lecture at this point of time.

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