Glass in building: Design and Application
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Lecture - 10
Structural Control and Design for Energy Efficiency Part III

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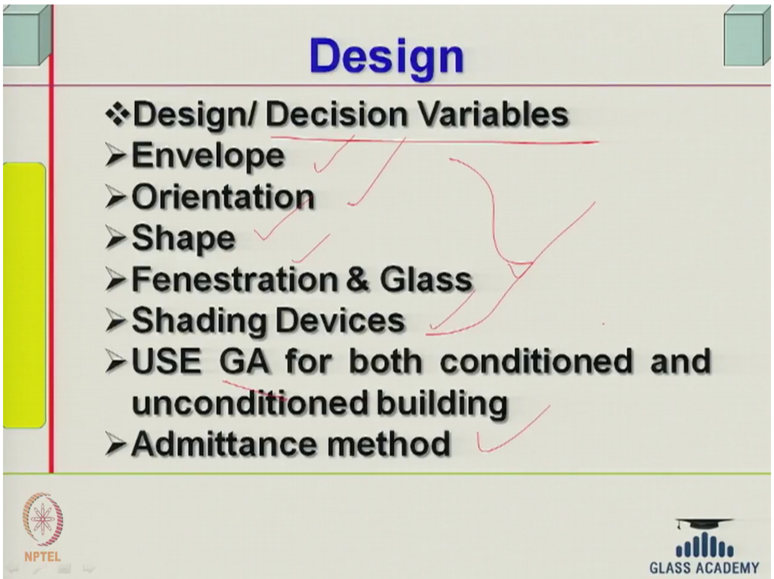

So, this is some aspects; now will look into some aspects, then some more will look into when as in when it comes. Now, in thermal design of building or energy efficient building design of building, the decision variables are envelope parameters which I have discussed so far. Orientation is the other one, shape, type of glass and the fenestration location, shading devices I will discuss some of them; these are the decision variables.

And you want to find out the best combination, you can use some sort of optimization process; for example, evolutionally algorithm of the kind of genetic algorithm etcetera. But then, you must have a method for estimating the quantity quantum of heat coming in; one such method is what we call Admittance method, I am not obviously going to go into the mathematics of it.

There are other methods like there are numerical methods, one can use for calculating the heat transfer, finite element, finite difference and there are some other kind of solutions many software might be using them, like you know time domain solution of heat transfer equation for a periodic wave outside so etcetera etcetera. So, this is you know this the methods. So, one can use them.

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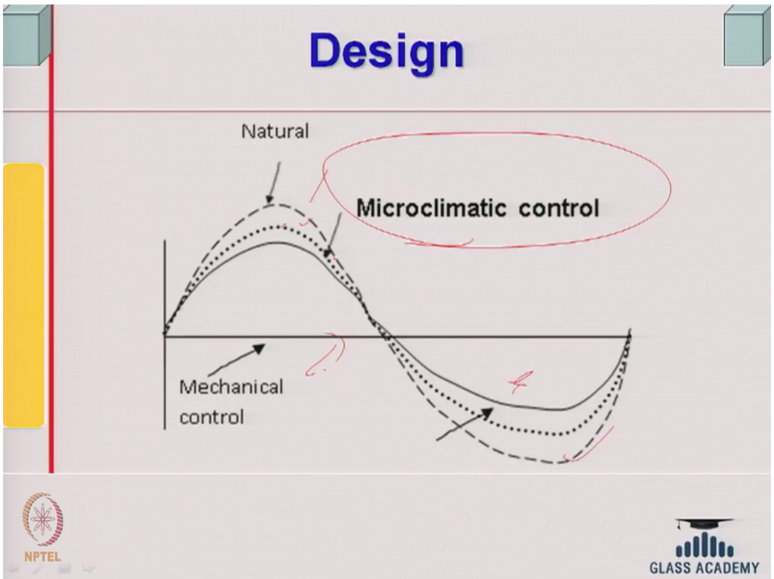

Now, if you look at Design, as I said first is a Natural perturbation which could be the yearly variation or diurnal variation, then I can actually modify my surrounding of the building. For example, plant a lot of trees etcetera right. Have lot of surfaces through which water can percolate and evaporation occurs. So, these are called microclimatic control.

These are called microclimate control. So, I can in the city planning, urban planning in fact all aspects of functional planning or functional design of building starts from urban planning including energy efficient building design. So, to start with you can see there surrounding you know temperature, surrounding temperature and humidity of the environment is modified; somewhat less variation will be there by microclimatic control, then you might use you know passive part or envelope system and overall thermal energy efficient building design of the building passive design of the building. But if you want 100 percent control, then you need mechanical. So, mechanical conditioning air conditioner etcetera etcetera you may need.

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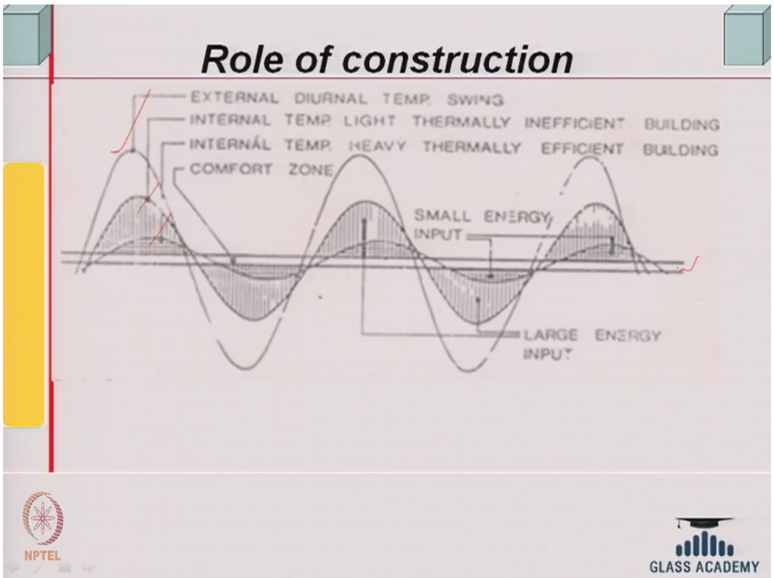

So, that is what I was just talking earlier also, this is the external diurnal variation. This is with some sort of construction, a better construction brings in there, but you want within this small portion, then you have to use active system.

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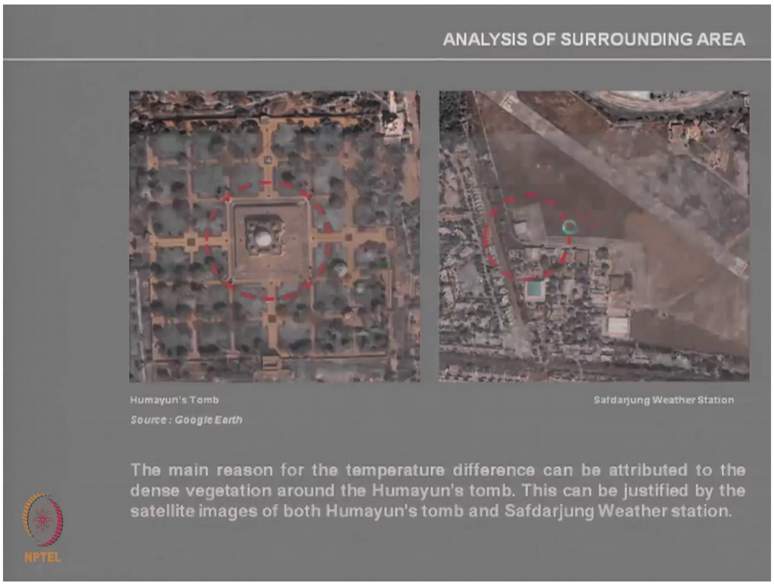

Some aspects of you know microclimatic control, some you can model them. For example, this was a case where we did model, the Humayun's Tomb, you know where there are lot of trees and this is we say we another place another weather station whose data was available to us. This data was measured by us in a project and this was available to us and then, this had got a lot of trees as you can see, lot of trees here, well this did not have right. This is a weather station so that airport in Delhi.

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And this is the case and then, this trees can be thought of as hemispherical bodies green bodies. So, one could calculate and model them and calculate and one would see both by measurement as well as computation that actually temperature in this zone, this place is much lower than the temperature of the measured temperature of the other place that (Refer Time: 05:17) airport or weather station accountable. And, by modeling also one could see that. So, in other words, what I am trying to point out to that you can modify the surroundings environment of the building, bring down the temperature, but remember it increases the relative humidity.

So, it increases the relative humidity; obviously, because a lot of evaporation occurs from the green trees etcetera. But one can modify this that is the first level. So, variation can be controlled somewhat if judiciously done. So, that is the microclimatic aspects. In this case of course, there are a number of trees that are given, but I am not really interested in the modeling part of it.

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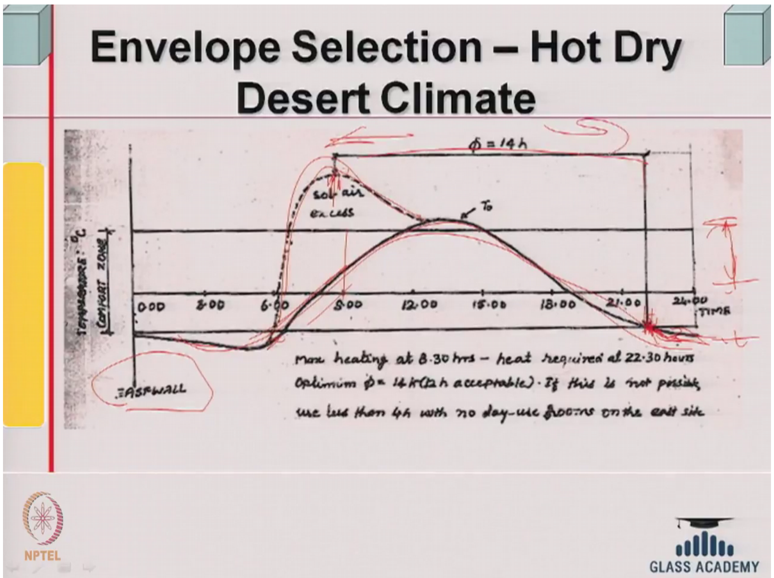

So, let us see now in envelope part, how do we select different types of envelope element? Now, in hot dry desert climate, this is shown for a shown for a you know this is shown for a east wall right; this is shown for a east wall. Now in east, these are the diurnal variation; daily variation of temperature right and east wall receives maximum radiation in the morning.

Now, if you can see this is the comfort zone, this is actually my desirable zone actually comfort zone it is. Sorry, this is the comfort zone and early in the morning about 6 am or so or rather late in the night, onwards to early in the morning in a hot dry desert climate, it can be quite cold outside. Because lot of radiation solar radiation you know a lot of long wave radiation would have been there from the surface of the earth to the external sky.

So, temperature comes down, diurnal variation is high. So, this is the typical temperature variation this is the typical temperature variation right and if I superimpose the east surface solar radiation, east surface receives maximum solar radiation in the morning and after 12, you know the sun goes to the south in northern hemisphere.

So, what? This becomes cold after night, in the night it is cold. So, if I can design my wall in such a manner that the peak heat, peak heat you know this one reaches this peak heat is shifted by 14 hours. In other words, at the outside peak temperature is around 8 am, 9 am or 10 am; but inside the maximum with peak of anticipation or heat it intrusion into the space, internal space is somewhere around maybe 12 o'clock in the night or I mean 11 o'clock in the night or something of that kind which means that I would require 14 hours of time lag; 14 hours of time lag.

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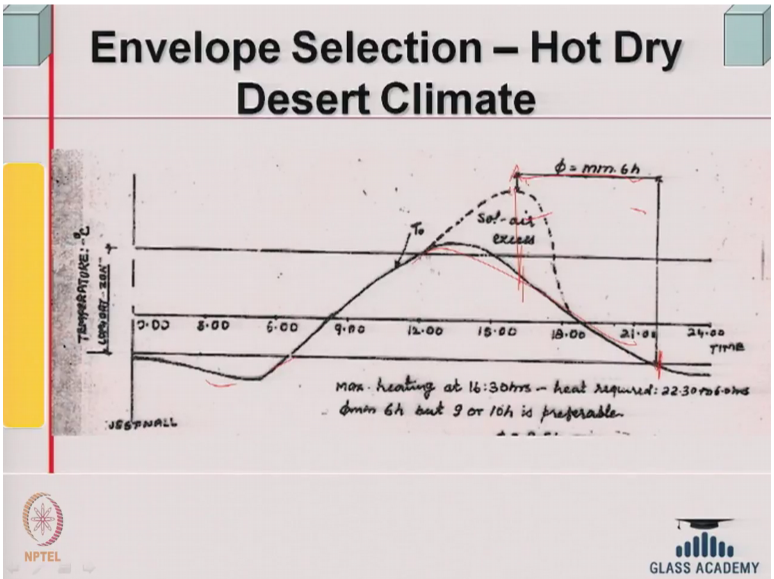

Such examples, I can have some more same hot dry desert climate. This is for a west wall because the west wall same temperature variation is like this, but the radiation received picked radiation would come only in the afternoon.

So, you know, so I need only 6 hours of time lag, because this is the time when I need the heat to come in, to make it comfortable because inside becomes cold by the time. So, I see that the peak should peak heat transfer at the internal surface of the room should take place in the west wall after 6 hours only. So, I provide 6 hours time lag right.

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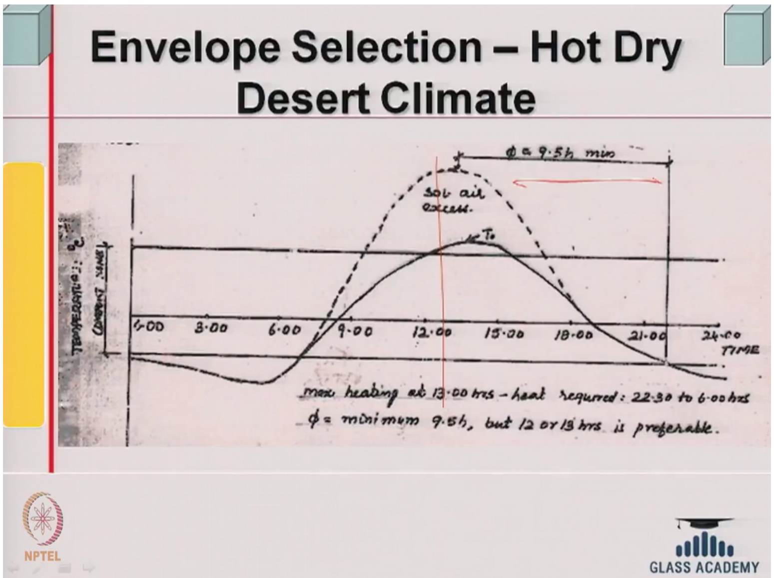

And for roof at 12 noon or near that the peak is there. So, I would need around 9 point half hours or something like this. This is an example how I can choose the wall element. Now to have high time lag on the east wall, I have need heavy wall; density as well as specificity right and also length. So, I can provide you know we can design I am just saying, I mean you cannot design a non uniform wall system, but judiciously one can think about it. Now, this is this is quick understanding of this.

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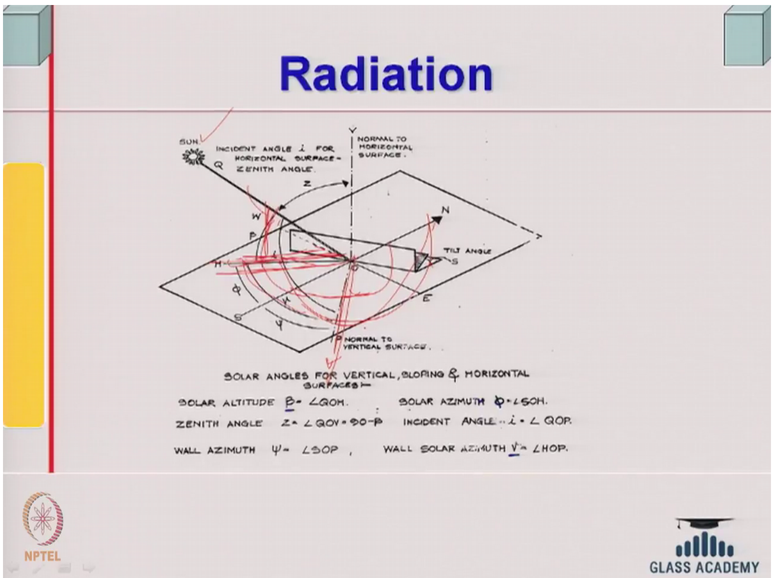

And we got to understand a little bit of solar radiation related issues. There are different angles something called an altitude angle of the sun. So, suns position in the sky is defined by 2 angles. For example, this is my sun. So, this angle we call as Altitude angle; there is something else we call as azimuth angle. So, its position you know it is measured in a kind of a spherical scenario.

So, you have a angle measured let us say from north right, position of the sun or you might measure even from the south depend I mean south depending upon which hemisphere part of the you know like which convention you are using. So, if you use from north, this is what up to the projection of the suns path onto the ground that the angle between north or your reference line reference direction to that line, we call it azimuth and the angle in the vertical plane from its projection onto the ground that we call as altitude angle of the sun.

So, suns position is defined by this 2 angle right and walls position is also defined by 2 angles; one we call a tilt angle depending upon if its inclined or if its vertical, the tilt angle is actually 90 degree right and if I draw a normal to the wall, then its wall azimuth will be the normal; angle between my reference frame and its normal to the wall that is called wall azimuth and we define something called wall solar azimuth which is the angle between normal to the wall and suns projection to the ground. Now, these angles are important, if you are doing some calculation I just thought I have given introduction to this.

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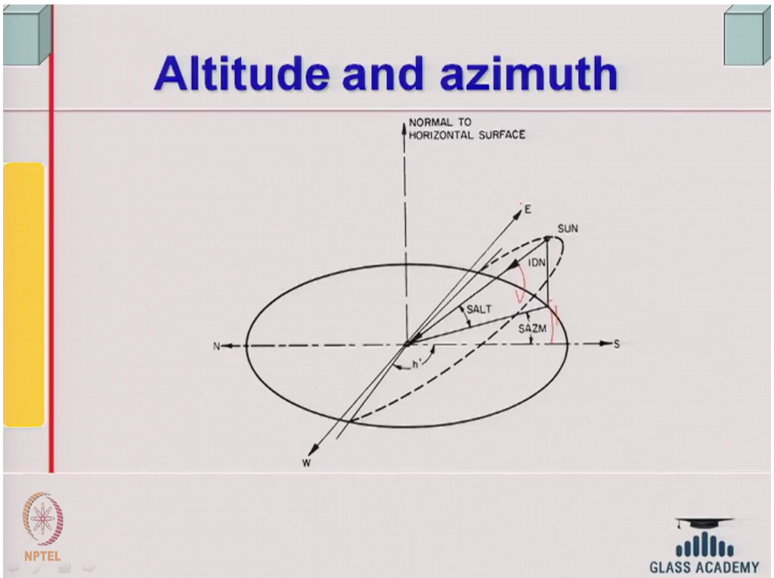

So, azimuth angle of the wall, azimuth angle of the sun you know this is again shown with respect to south here it is showing this is the azimuth angle of the sun and this is the altitudes angle of the sun solar altitude. One may follow from geographical north to geographic angle clockwise geographical north from geographical north to the suns projection of the ground and whatever, but you know that once consistently any convention followed must be consistently followed throughout the, you know analysis that is what is important.

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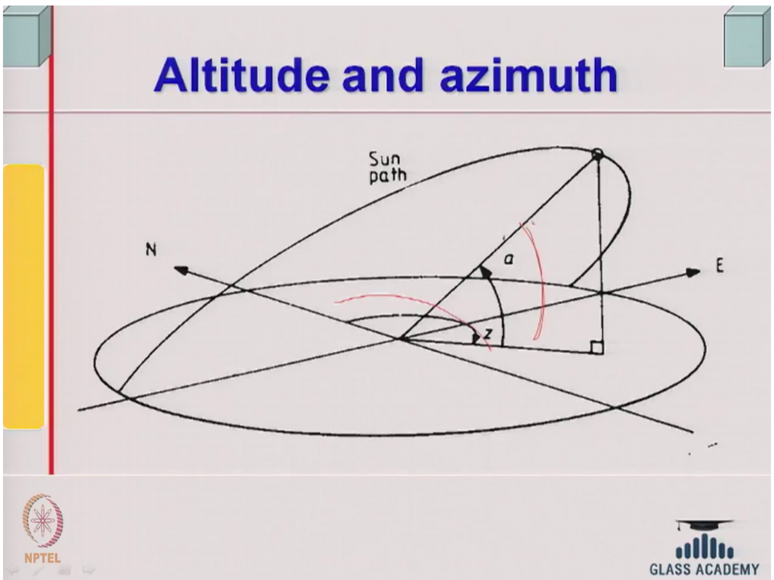

So, both this sort of thing is done for example; here it is clockwise from the north. This is your azimuth angle Z and this is called altitude angle is this one is the altitudes. So, this gives you an understanding of what these angles are, they are important.

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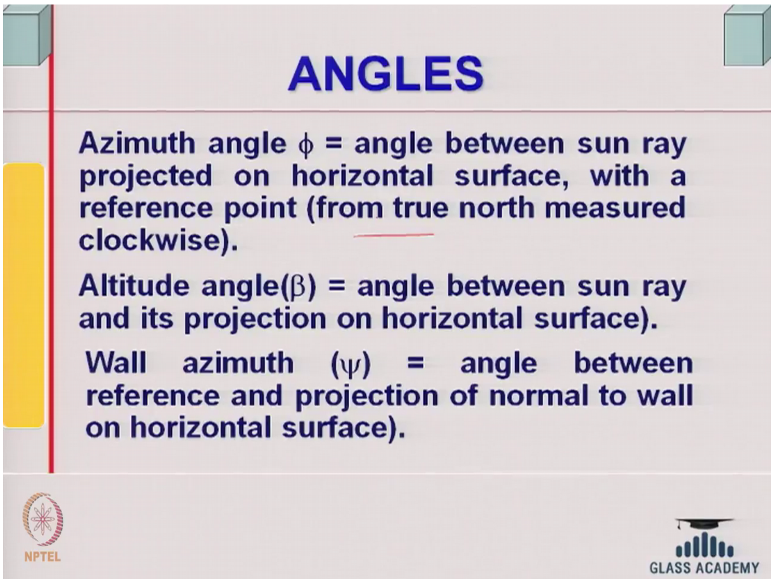

I think, I you know, so azimuth angle is angle between the suns ray projected on horizontal surface with a reference line; reference line from true north measured clockwise maybe one of the convention in northern hemisphere people would prefer to do that.

Altitude angle is the angle between sun ray and its projection onto the horizontal surface and Wall azimuth is an angle between reference and projection reference and projection of normal to wall on horizontal surface right.

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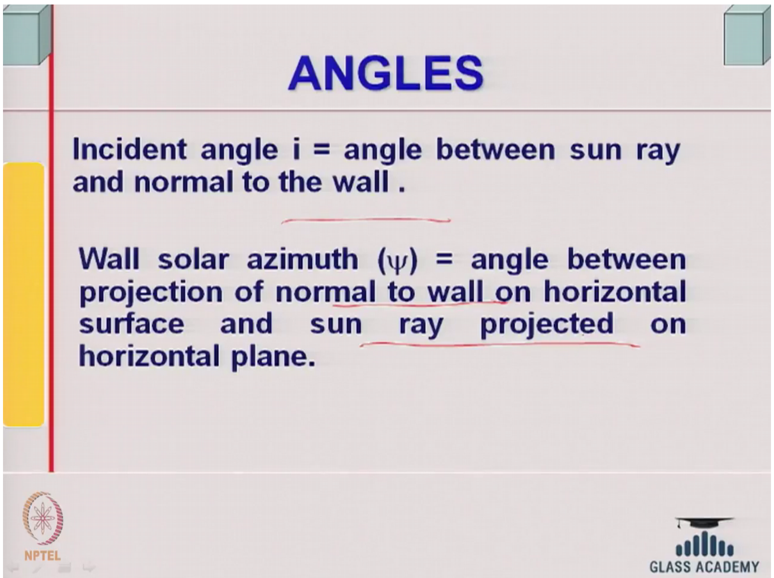

So, the studies and incident angle is an angle between sunray and normal to the wall that is called Incident angle right. Wall solar azimuth is the angle between projection to normal to the wall on horizontal surface and suns ray projected on horizontal plane; which I just mentioned a few minutes before and again I write is coming in written form right, is coming in written form.

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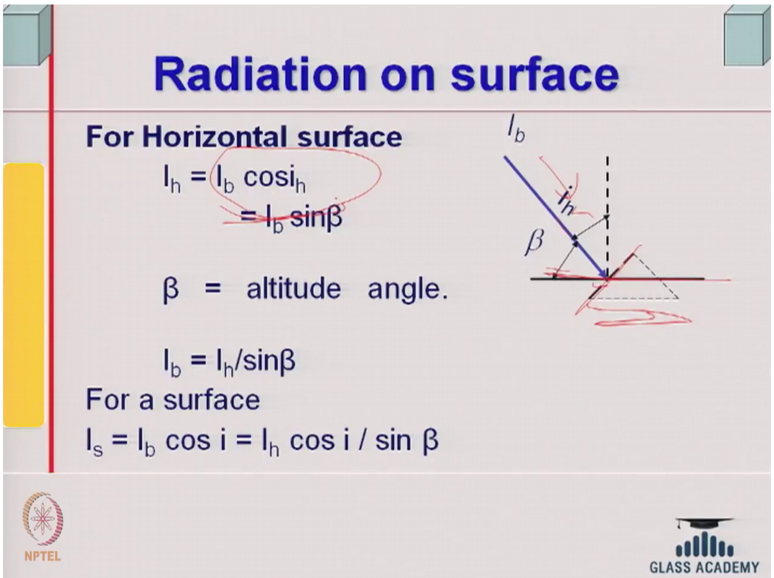

So, for horizontal surface, one can find out the radiation; what we call beam radiation is the normal to the beam direction. The sun's rays, say this is my sun ray and the beam radiation is normal to a surface which is normal to the beam direction and you can find out if I have incident angle which is the angle between normal to this surface and the suns radiation this called incident angle.

Then, you know this is; obviously, the altitude angle this is I h is the incident angle for the horizontal surface. So, one can find out the radiation received here is I b cos I less you know because normal surface radiation density would be more. What per meter square would be higher, but on this surface, it will be less; the same energy gets distributed more. So, it is because I h, where I h is the incident angle which is nothing but sine beta; which is nothing but sine beta altitude angle for horizontal surface.

Vertical surface is vertical surface one can calculate out, but I do not think I will go into details of this too much. So, measurement is usually done on horizontal surface. Therefore, beam radiation can be calculated backward from knowing knowledge of radiation received on horizontal surface, for any other surface actually can find out with cos I, you know and i h cos i by i sine beta.

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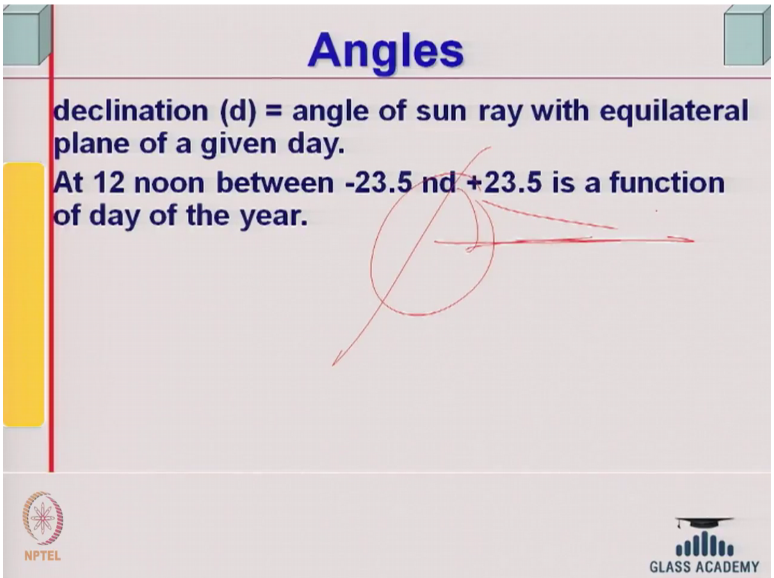

So, that is what it is ok. The suns position is defined by 2 angles I said, but suns position actually changes from day to day because you know earth has got a banking of 66 point whatever degree 723.5 and 66.5. So, earth is inclined, it moves like that it makes an angle with a plane of its revolution about the sun. And therefore, the normal suns radiation in summer falls on tropic of cancer, it is normally an in winter it is tropic of Capricorn.

I mean I would not say summer and winter for northern hemisphere, I am saying summer and winter or if I may put it that way it is around December 25th around that you know around that time, suns radiation winter solstice during on which suns radiation falls normal on to the tropics tropic of capricorn. While in June, it falls on you know tropic of cancer so and in between it falls on equatorial plane right equinoxes which you call it equinox.

So, I do not think I will go too much into this. So, you can see that suns angle of the suns radiation falling on a given position is not same right. It may be normal on equator; actually suns radiation falls normal between minus 23.5 to plus 23.5 and it is angle with the equatorial plane, where is suns radiation directly radiation varies and we call this angle as declination. I do not think I will go into details of this, it will take longer time to explain. So, if I take a look at any point on this surface of the earth, the suns at 12 noon, suns you know altitude angle at 12 noon, it would vary depending upon the day of the year. Now declination is angle between equatorial plane and suns direction of suns radiation; maybe I have a better diagram to explain.

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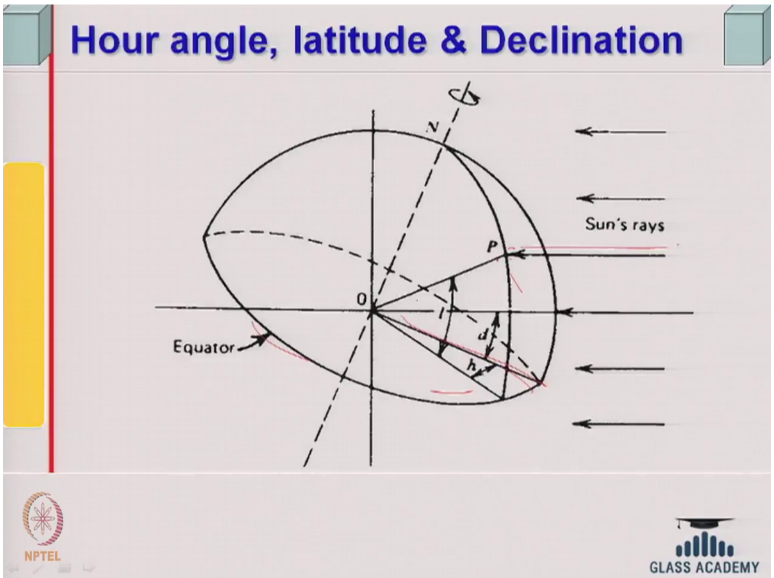

This suns radiation and this is the you know this is the sun’s rays right and this is the equatorial plane; this is the equatorial plane. The angle made between these two, we call it declination angle made between these 2 point is called declination right. This is the north direction on which the earth rotates; it is always permanently inclined as I said to the plane of its revolution and this might be my point ok. So, this is related to Declination is that angle.

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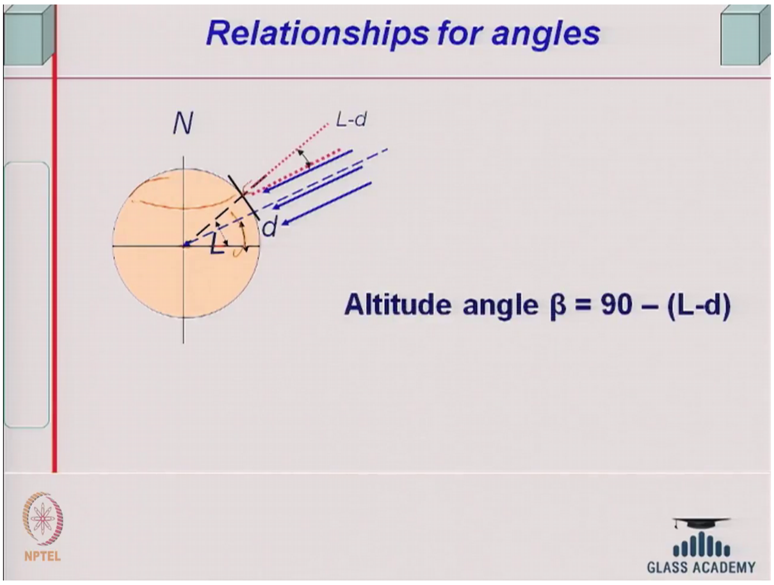

So, altitude and azimuth angle of the sun will depend upon declination. It will also depend upon time of the day right and also latitude of the place. So, if this is the arc, if this is the direction of the sun; I think this is a simpler diagram to explain for a short period of time. This is the equatorial plane, this angle we call it declination angle and if I have a point somewhere there, this is the point right, this is the latitude; this is the point I am into the point of my interest, this is the latitude; latitude the angle made at any you know called circle right. The angle this angle this angle we will call it. So, at equator latitude is 0 and as you go up, North Pole it will be plus 90; South Pole it will be minus 90 or you can call 90 degree north or 90 degrees south.

So in India, actually it is 8 degree north to about 32 degree north latitude. You know Thiruvananthapuram is 8 degree or somewhere close to that places and Ladakh or Lay would be somewhere around 32 or close to that. So, we belong to northern hemisphere with this kind of latitude. Now, one can actually find out the angles and calculations and formally which I am not real interested at the moment right.

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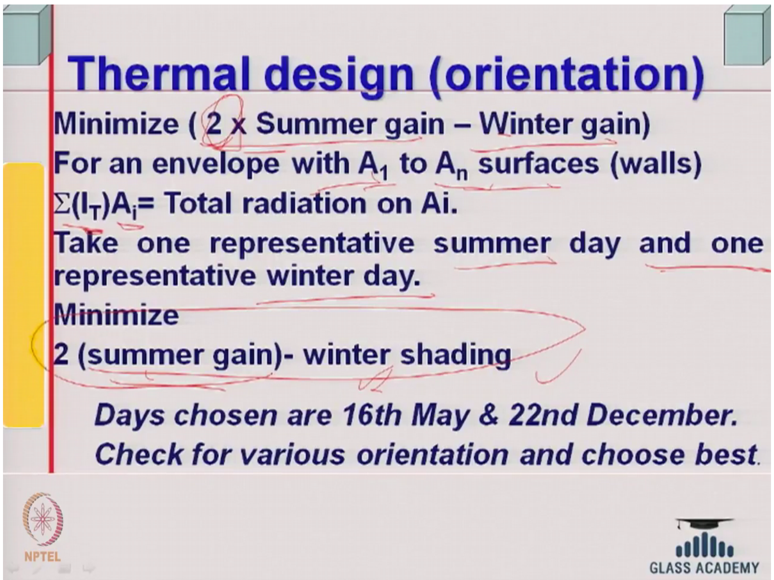

So, when you do thermal design; therefore, this radiation calculations becomes important and one can do that. Now, in order to find out the best orientation a simple method has been given in SP 41; I find out because the if I orient this in the in northern hemisphere, sun goes from east and then if the suns radiation is received on the onto the south surface and then, goes to the west right. West surface will also receive some radiation in the afternoon and the altitude angle of the sun in summer is very high; while, in winter it is much less. Winter it is much less right.

So, therefore, if you have something facing north, it do not receive any radiation and if you want to find out depending upon the oriental. So, large surface you know supposing depending this is my surface, this is the plan of the plan of the building let us say. This is my not direction; this is my south direction. Now you change, I change the plan to this one; I changed the plan to this one, long axis parallel to east you know north and south; here it is parallel to east and west.

So, the orientation change is occurring. In that case this would not receive any radiation; larger surface is not receive any radiation. This will receive radiation in winter, but summer, it will receive much less radiation. This receives radiation in the morning; this receives radiation in the afternoon. So, orientation has got a role to play. Shape has got also a role to play because aspect ratio if it is square, it do not matter, the orientation do not matter.

One simple way of finding out the best orientation is given in SP 41 the standard publication, you know the special publication of bureau of Indian standard related to energy efficient you know the functional design of building other than what is called industrial building. What it says is minimize twice summer gain minus winter gain; I mean it does not say that, but I am saying the philosophy would be minimized twice summer gain minus winter gain. Why twice? Because cooling is always costlier; it could be 3 to 4 times costlier than heating right.

So, if I choose a plan which will have high winter gain that is actually good for me. So, I would like to you know minimize this function, but summer gain I would like to reduce. So, minimize summer gain minus winter gain that would be a good orientation, good design, but then I put a weightage factor at least 2 here because if more I minimize the summer gain, more I reduce the summer gain I will say gain to the cost. So, energy efficiency this is a good idea.

So, for an envelope A 1 to A n surfaces let us say walls, roof own matter as far as orientation is concerned as long as my floor coverage is same. So, A 1 to A n surfaces you find out the radiation intensity on that surface vertical wall surface multiplied by the corresponding area that will give you total radiation; it will give you the total radiation. Take 1 representative summer day and 1 representative winter day, the code SP 41 takes 16th May and 22nd December. These are winter day; these are summer day right and it says it says you know you find out the sum total of heat gain minus the winter shading and all the coat this is not from the coat.

But I am saying it would a good way to possibly find out calculate out the solar radiation received onto the whole building; that is I into A for the whole building on 16th May and also on 22nd December and find out this quantity; whichever orientation gives you minimum that is the best. So, if you are manually quickly doing it, you can do it right. Manually you can quickly do it in this manner; it in fact, SP 41 gives you tables of radiation on different surfaces for certain latitudes, but you can calculate out in the formula I did not give you those formula of course in this, this lecture.

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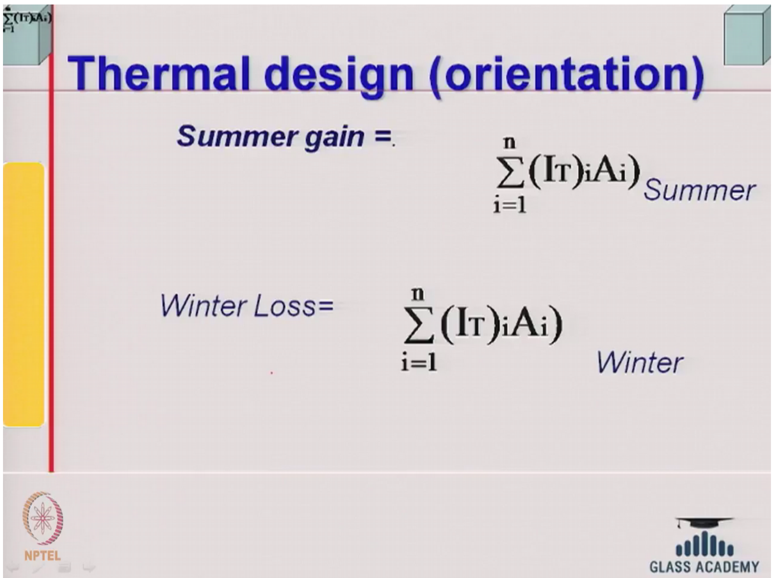

So, basic formula is something like this, if there are n walls summer gain will be I T you know summer gain and winter loss and you actually you know sum total of summer gain minus winter loss twice sum summer gain minus winter loss you can minimize.