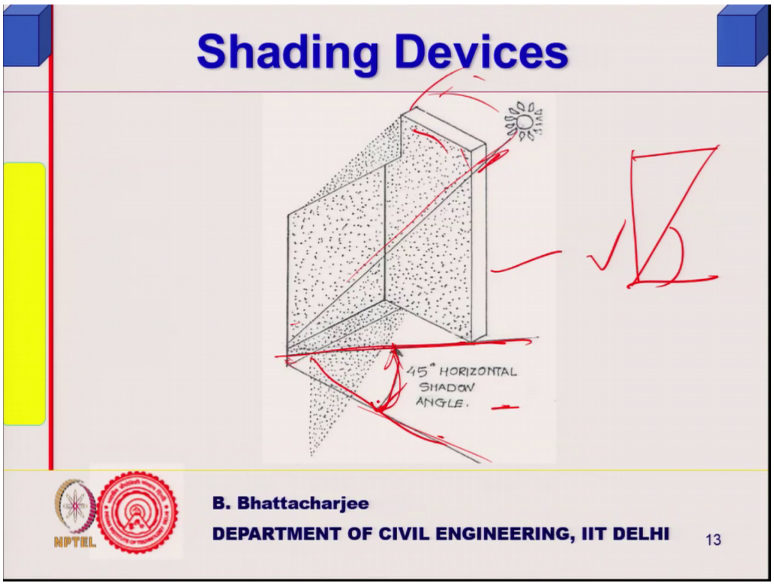
Energy Efficiency, Acoustics & Daylighting in building
Prof. B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture - 24
Thermal Design of Unconditioned Building

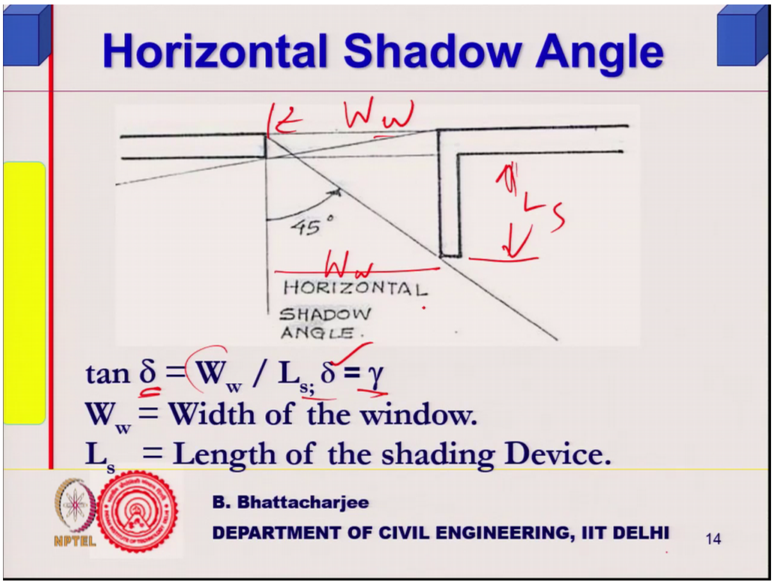
(Refer Slide Time: 00:20)



So, it is a vertical shading device. Now, vertical shading devices has got a horizontal shadow angle, horizontal shading device something like this at a vertical shadow angle. Vertical shading device has got a horizontal shadow angle. What is this shadow angle? See this is a, this is normal to the, this is normal to the window, this normal to the window you know this line and this line is parallel. Sunrise somewhere here its projection will be matching this line this angle we call as horizontal shadow angle right.

So, the angle the tip of, tip of the shading device makes you know x is in horizontal plane touching the window or normal touching the point in the window which it makes with the normal to the window that is ordered. So, this angle is nothing, but, if the sun is right now here then this angle is nothing, but the wall solar azimuth, this is nothing, but the wall solar azimuth.

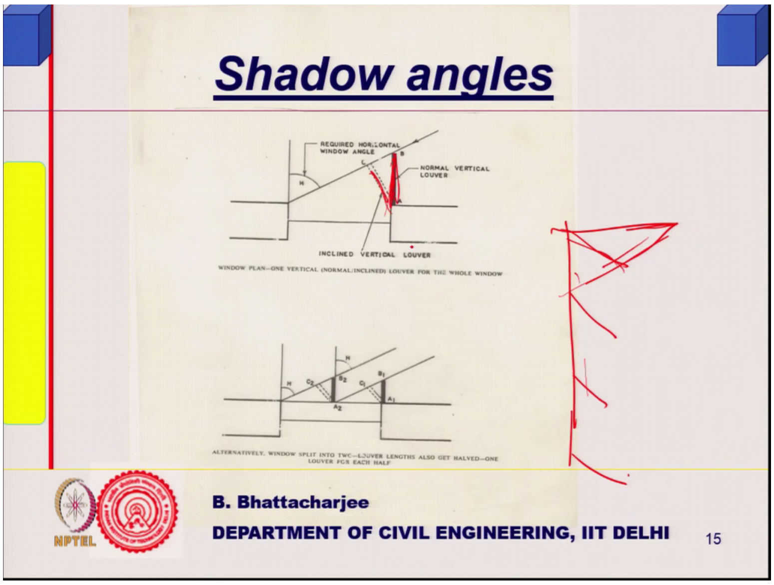
(Refer Slide Time: 01:30)



So, horizontal shadow angle is nothing, but wall solar azimuth. So, horizontal shadow angle is nothing, but wall solar azimuth and you can always write it if this is the length this is the window width earlier it was window height now it is window width W of window width of the window. So, this divided by you know this divided by L s. So, this divided by W, w divided by L S is nothing, but tan delta which is equals to gamma, delta is the horizontal shadow angle.

So, horizontal shadow angle is given by this. So, at any point of time when you want to block it that you depend upon you know this angle will device, this angle will you know control that actually right. So, that is how one can define these angles.

(Refer Slide Time: 02:22)

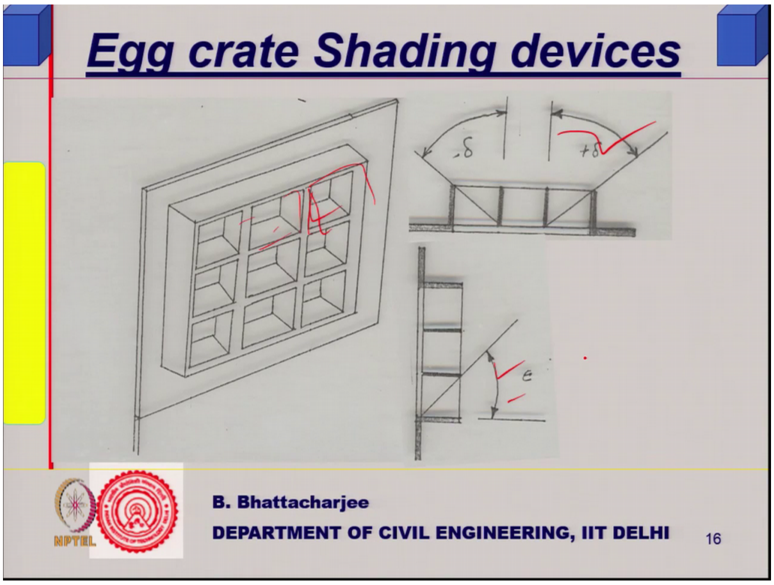


If you have an inclined shadow shading device something like this its effective you can say it is as good as this much smaller length, something like a louver, something like a louver in window vertical louvers in window right instead of something like this you know some places they you can close them also.

But they will also help you in ventilation. They are used to be earlier days you might have seen that there will be a kind of all timber piece connecting all of them. You push it up it becomes horizontal push it down completely closes it. So, it can actually it can make it to move right, but that length would not be very large.

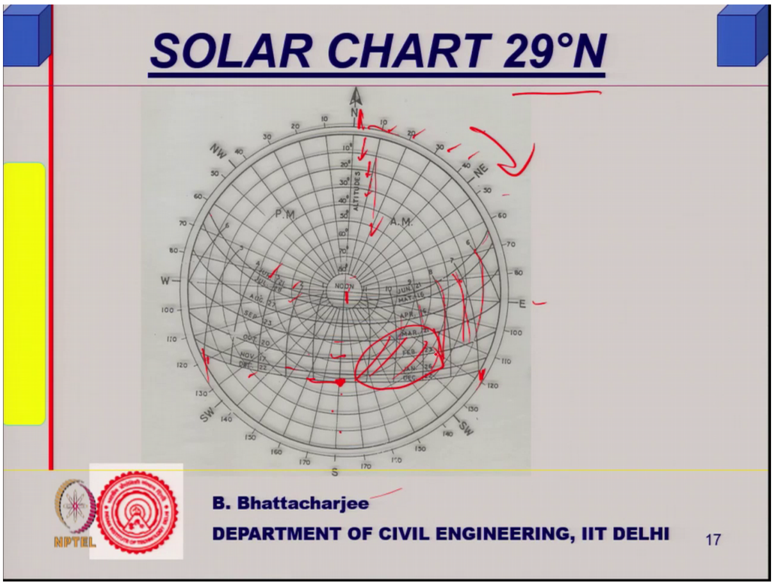
But their effectiveness will be because they will be as good as this much length you know they will because they will block. So, they are as good as this, this much length this much length right this much length this is shown in horizontal plane you know, inclined vertical louver it is shown. So, vertical louvers if they are inclined vertical louvers if they are inclined they actually can block suns, suns position quite a bit.

(Refer Slide Time: 03:36)



Egg crate I have already defined, egg crate so, they will have both vertical shadow angle epsilon and horizontal shadow angle delta. Vertical shadow angle epsilon and horizontal shadow angle delta that is all there.

(Refer Slide Time: 03:52)



Now, good old days people would do what? They would use a solar chart now you need not do that because you can write a small program calculate out any time every time check can do whatever you like. But good old days they would have plotted a solar chart and these are there in Sp 41 or all the books that I have given you in the reference, Canes

Burgers, Marcus and Marcus and Morris every I do find this actually. So, this is for 29 degree north very close to Delhi is very you know Delhi is 29, 29 or 29 point something whatever it is close to it.

So, we can see that what has been done is you are representing the sky volt in a circular diagram I mean you can have it is a polar co-ordinate system in a way. So, what you have made you have made it into plane the hemisphere made into plane and this angles at 10 degree, 20 degree, 30 degree and 90 degree will be some are there, 90 degrees will be some are there. So, they represent altitude angle.

So, you take the projection of the sky vault right and the spacings are same these are called actually equal angle projection, spacing is same equal angle projection right. So, this is vertical angles could be like this horizontal angle this is from north, in horizontal azimuthal plane 10 20 30 40 northeast right and then east 90 is east and so on so forth. So, this angles represents azimuth this angles represents altitude angle, you can have what is called equal angle projection on some cases stereographic projection.

And if you look at this and equal angle projection therefore, suns position in the sky vault is known because it is known through altitude and azimuth angle. So, you can always find it out you know suns position. So, you can plot this is for the month of June, this is for the month of June, this is for November, October, October November December, October and so on so forth. So, each month you can plot. And what about this lines? This lines.

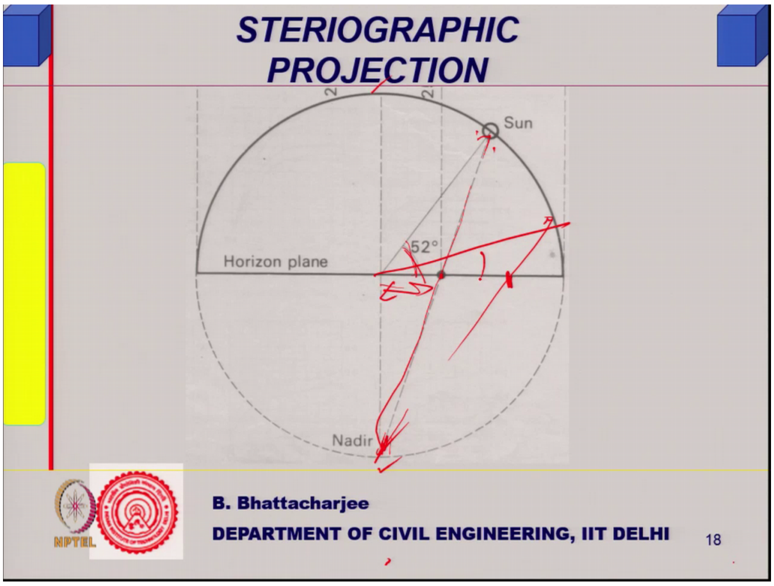
Student: (Refer Time: 06:16).

No, these are the see this is at any point you know. So, suns position azimuth and altitude angle depends upon what, at a given location, I fix the latitude, I fix the latitude. So, latitude is fix it is a function of the declination hour angle declination and hour angle latitude is fixed anyway. And declination will change from day to day of the year; that means, corresponding to a month I can find out corresponding to a month I can find out, corresponding to a month you can find out and hour angle I can find out corresponding to hour angle and month are given to.

So, these are month already have said that this is June, this is October, I am sorry December and so on, and this represents 6 am, 7 am, 8 am, 9 am, 10 am, 12 noon altitude angle of the sun will be at highest point right, but it is in summer month winter months its much less. So, you can see that it is actually 10, 20, 30 can be as good as 40 degree altitude angle or know they also smaller. So, it starts around 7 am to you know this is 5 pm, this is 6 and so on so forth. So, all of the sun path you can plot it on, on a chart like this sun path diagram.

Now, supposing I decide that I want to block the sun for certain period of time then I can just draw it here I am just saying hypothetically. So, I can actually find out what is the, what is the altitude angle of the sun and azimuth angle of the sun which I want to block limiting cases, you know I can find out and correspondingly I can find out the length of the shading devices. Correspondingly I can find out the, this is what were people were using in good old days. So, equal angle this called equal angle projection.

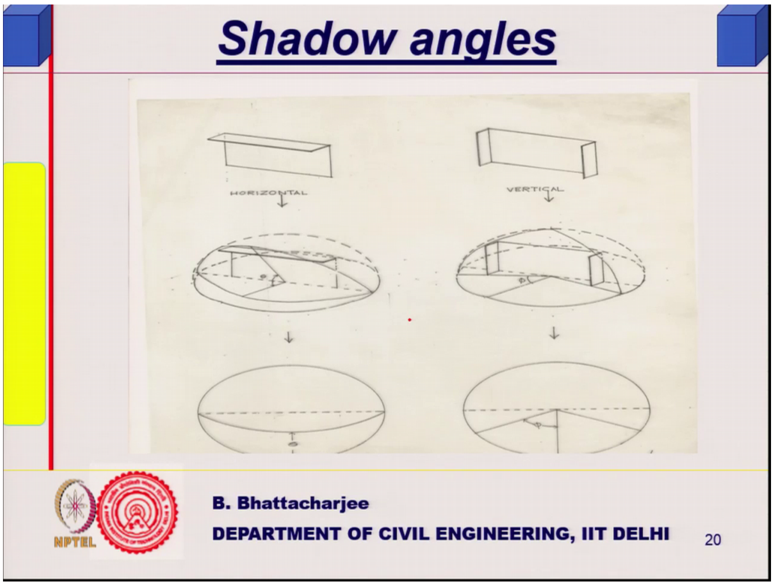
(Refer Slide Time: 08:09)



But you can have another kind of projection called stereographic projection. In that case what is done is this is the nadir, this is the zenith horizontal plane is here suns position is somewhere there then you know the this angle 52 degree altitude angle of the sun is represented by point or circle you know which will have radius, this much thus radius correspondence to the sun joining to the nadir, sun point joining to the nadir.

So, this is a sphere celestial sphere right. So, this point if you join. So, will not be equal for example, if the suns position is here, now this corresponds to this angle, so you can see that the spacing will not be same earlier 10 degree, 20 degree, 30 degree etcetera they are same.

(Refer Slide Time: 09:04)



See know this they use this will find that this is 10 degrees more, 20 degrees less and 70 to 80 degrees till lesser. So, they are not, the angles altitude angles are not equal because it is in curve plane. So, they are try you know try to project them on to the horizontal plane. So, this another form of plotting the same thing, plotting the same thing. You can plot the same you know days and hours and all that this called stereographic projection.

But that serves the same purpose you might find in some book they have shown this some other books they might have shown this, with the kind of you know capability computational capability we have the diagrams have lost their values. In fact, nobody uses a graph sheet today, nobody use as forget about semi log or log graph paper you do not use even use ordinary log paper today. So, it is all computational. So, you have the formal issue pretty easy yes.

Student: (Refer Time: 10:02) design that angle will change that particular (Refer Time: 10:05).

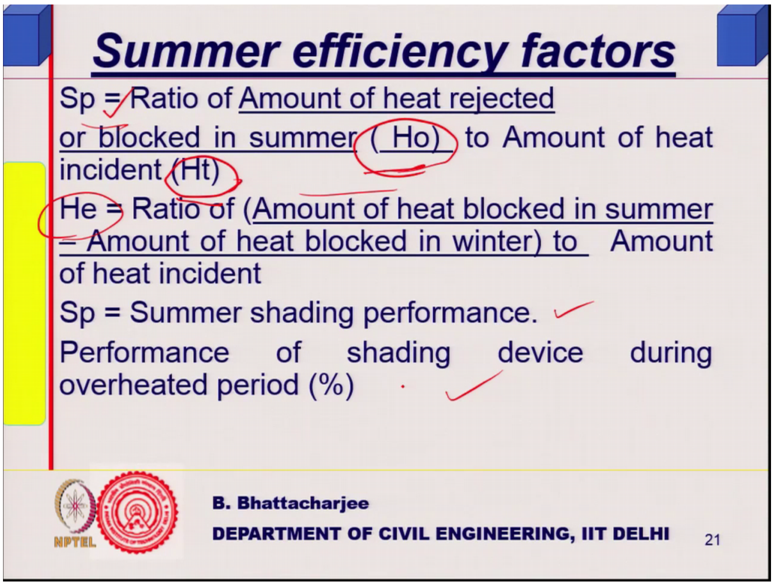
Yeah, but then you take the extremity.

Student: (Refer Time: 10:09).

Because length has to be maximum but feasible, if it comes three meters overhang you may not be able to do it. So, you know there are issues will look at that right now. So, basically you take the extremities, extreme cases.

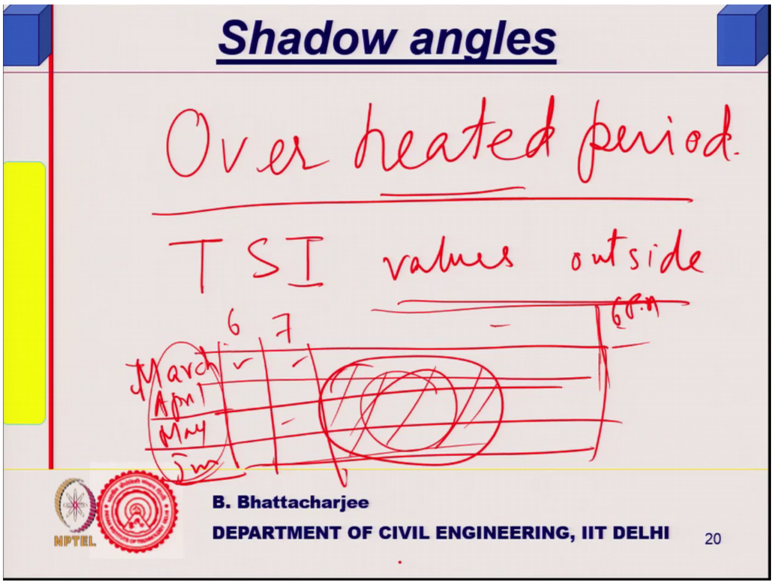
So, see this is this is a shadow angle. In fact, one could plot them; on those graphs as well those should look something like this.

(Refer Slide Time: 10:30)



Now, when you when you want to find out there are various ways of finding out let me see if I have something more to say about this, I will come back to this yeah, I will come back to this I think I will just tell you about this.

(Refer Slide Time: 10:56)



Now, what you can do is there are various ways of finding out what is the extreme point. One of the, one we call it overheated period. For example, I can find out let say tropical summer index value, values outside. I can find out in shade, I can find out tropical summer index values at shade because I know the temperature, I note the relative humidity and do not take the mean radian temperature take the drivel temperature itself in shade as if you know not you are not outside if you are inside and then TSI values you can find out.

Now, for TSI value during the daytime I can find out, during day time I can find out. In other verse I might form make it tabular case like for summer months right say representative days in let say I can start from March, April, May, June etcetera and this is let say 6 am, 7 am to 8 pm you know 6 am etcetera I can find out because up to 6 pm let say or 7 pm, 6 pm because I am trying to block the sun solar radiation. So, during the day time is good enough. And TSI values I can find out for each one of this cases TSI value I can find out and I know the TSI crossing below I mean crossing above 30 or 34 I would like to provide.

Student: Shading.

Shading. Therefore, I can find out the time during which I need the shading right, I can find out the zone in which I knew the shading. So, this is overheated period I can this is one way of finding out one way of finding out you know choosing what kind of shading how much do I want to provide right.

So, the moment outside temperature is increasing I might like to provide this is called summer overheated period. Similarly in winter I would like to begin the you know begin the sun solar radiation as much as possible. So, I might do it for winter months and find out under heated period where I would like to begin the right, detailed exercise can be done, but then today supposing I want to design I will tell you mean the next class may be. If you want to design I mean, I can use my computational capability today rather than just doing by hand and one by one after one variable.

So, far I have been talking about that you have how to get the best shape, best orientation one at a time and we talked about that in case of hot dry desert climate you might vary the thermal capacity you know thermal capacity or time lagging time lag you can find it out because it depends upon royal c. So, you can actually massivity of the wall you can find out.

So, you can actually find you know no, one by one you can do, but the best ways to put them together and design it. Today we have also, rovers computation method through which you can find out right. We will come to that. Coming to simply this, these are overheated period and similarly I can find out what is called under-heated period, under-heated period. Then I must provide shading device length such that it should actually bring in as much as energy possible during winter during the under-heated period, but minimize the gain during.

Student: (Refer Time: 14:56).

Overheated period right other way of determining overheated period is also trying to look at look at the inside temperature, can calculate the inside temperature without assuming any shading device right. Mean and fluctuating temperature if you know all other parameters ventilation, I mean air changes and all that we have gone through those such procedure and then inside TSI you can actually obtain.

Student: Shading devices are fix (Refer Time: 15:26).

Yeah, they will be fix, they are fixed actually, they are passive they are passive that is right.

Student: Then it is better to have the curtains (Refer Time: 15:34).

No, you can have both, but then it can depends upon human being, curtains you know like blinds and such things it would depend upon; they have their I mean one is not alternative to other you can use both of them even together. So, as you know this is, it has got other purpose also shading device shading of horizontal, but horizontal shading or louvers if use you might even direct the wind direction change the nastier ventilation pattern.

So, they have multiple uses, but they are also one of them you cannot just discard them out to one for the other, they are not you know you can use both of the ammunition one or the other decision making is yours they are good things. So, what are what good about them that is what we are trying to discuss. So, they have multiple use, but try to understand what is the use whether to use them or not is a question, but this does not add to extra cost not too much extra cost because the sizes are not large while many other passive system might add to your initial cost high. So, cost benefit has to be same.

So, coming back to this how do we design? So, we have said that overheated. So, then you can define certain efficiency factor if you can find out overheated period and under heated period, overheated period also you can find out by estimating the temperature without any shading device, which you have done earlier put their relative humidity together with it and assume air velocity is 0.

You know anywhere air velocity will only act positively you can find out the temperature within its not finding outside, but then you got to know the building itself it is you know and find out during which time you need shading overheated period and under-heated period right. So, two ways you can do you can look in the out siding shade or if you have already a plan then you can find it out, but then plan you know like we have to first we have a decision of the plan itself then you can find out internal temperature find out overheated period.

Then certain things are defined for examples this is called some there are we can define some efficiency factor because I would like to allow radiation to come in winter under-heated period, but would like to reject the radiation in overheated period. So, let us say Ho is a heat rejected or block during summer and to the amount of heat incident total heat incident yeah. Today there are so much of actually automated system available with the electronics and you know instrumentation coming in varieties of things can be done. So, there was possibility, but these are only passive things.

Some of them can be state way for example, in an intelligent building many things just it will it has it can senses, you have sensors right. So, sensors will sense whether you have come in infrared sensing can be there whether somebody is coming or not light gets own. It also you can have all varieties of sensors possible similarly you can have sensors which would possibly measure temperature in relative humidity inside and instead of two point off on control switch you can have integral control and all that.

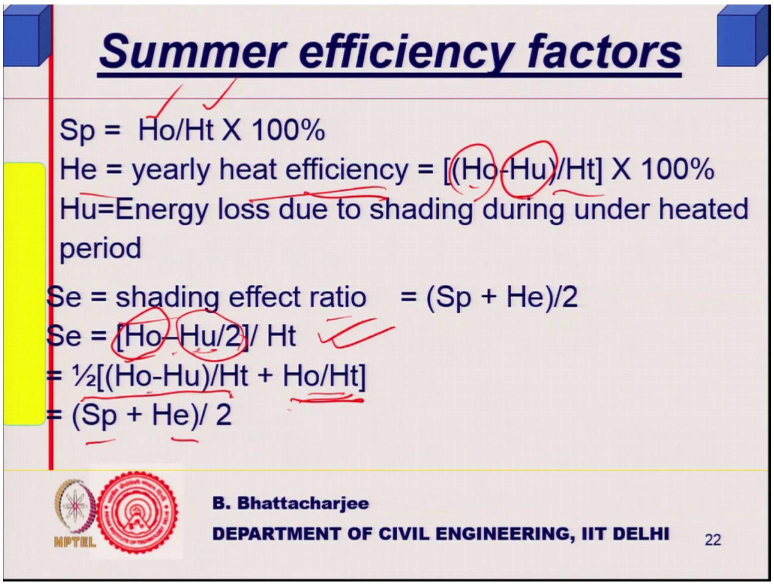
So, that is or such control much much advance control system which will allow the system to operate on its own, but it has to sense even whether it is occupied or not does most important. And its possible it is all possible with varieties of instrumentation available today, today they involve cost they involve maintenance cost in large building it is possible, its large building its possible it is possible to have all that. But first you must understand the physics behind the basic things. So, that is why we have trying to do it in this course.

So, coming back to this, this is how we defined this is this is you know this is a ratio of amount of Sp is defined like this and He is the ratio of amount of heat blocked in summer minus amount of heat blocked in winter to amount of heat incident. So, this is the total amount of heat incidence on the surface over the year. This is the amount we reject during summer we have blocking because if you have a shading device it will block and, but at the same time we will block some winter heat coming in also.

So, net if you look at it then we define it is He right, net if you have then we define it as He. So, summer shading performance is a set of the shading device. So, this we all a summer shading performance, Sp is the summer shading performance. So, performance of shading device during overheated period that is what we are doing.

So, it is the ratio of amount of heat rejected during summer divided by total heat that comes in that we call it summer shading performance summer shading performance. And this He is yearly heat efficiency, He is yearly efficiency which is the summer heat coming in minus the winter heat that is did not come in winter good you know required heat that did not come in divided by the total heat came in. So, this we call He is a yearly heat efficiency.

(Refer Slide Time: 21:12)



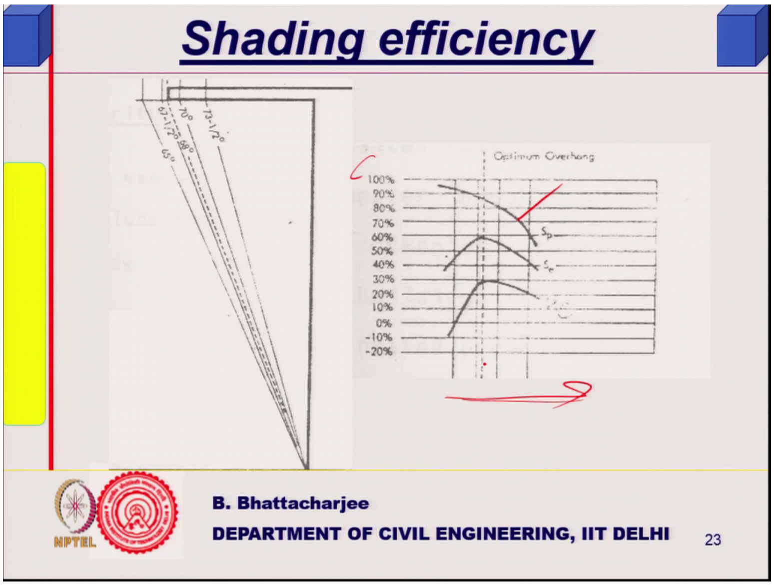
And Hu is the energy loss during shading during under-heated period. So, this is the Hu part. So, Ho minus Hu this is the under heated which is lost. So, divided by Ht thus algebraically it is like this Ho by Ht Ho minus Hu divided by Ht right and then shading effect ratio is defined like this, shading effect ratio is defined like this. What we do is we have Ho the heat summer heat which was coming in minus Hu by 2. Why? Because there is a weight age factor summer cooling is costlier than.

Student: Winter heating.

Winter heating, so that is what we are doing. So, this is the half of you know this is just given a weight age factor of half and that is what we are calling is shading effect ratio you know. So, basically this is the yearly heat efficiency mi[plus the Sp that is summer performance summer shading performance, so Sp plus He by 2. So, this is this half is a weight age factor we are using here you know because we assume that cooling is costlier, cooling is more important for to us losing some heat in winter is half you know.

So, putting a weight age factor and this you can break it up Ho minus Hu by 2. So, Ho minus Ho minus Hu by 2 you must add you know half of this is there. Half of this is there. So, there is a just, just doing the same algebra you can write it as Sp plus He divided by 2 Sp plus He divided by. So, actually you can actually detain in the horizontal shading device length of the horizontal shading device using this kind of concepts.

(Refer Slide Time: 23:13)



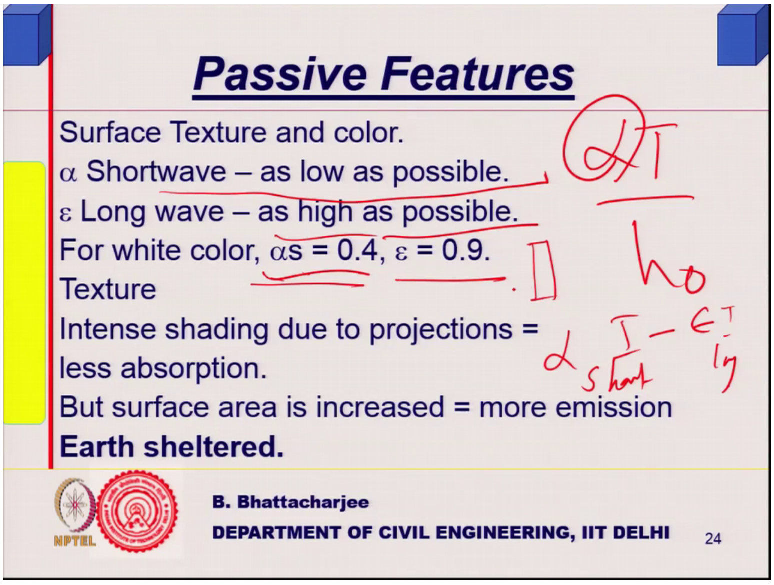
But shading efficiency, if I plot it this is shading efficiency Se is the shading effect ratio if I plot it, shading effect ratio if I plot it you will find that as you go on increasing the length Sp; obviously, you know as you increase the length this is the length actually this is the length and this efficiency as a percentage you know as I mean it is a actually this side as you one side is a length as you change the length Sp is Ho divided by Ht, Sp is Ho divided by overheated period divided by Ht. So, it will go on increasing as I increase the length, as I increase the length along this direction will go on improving right, it will go on improving. What about He? What about He?

Student: (Refer Time: 24:07).

He is this line, as I go on increasing you know this will tend to reduce it down because I will block the winter, up to this point winter sun does not get touched at all beyond that is it will start blocking and then combination would be somewhere in between. So, basically there is an optimal length you can find out which will be govern by this equation actually you know best, so optimal length you can find out it will be a function of length, Sp and He will be all function of length. So, you can find out a length where this is maximum this is maximum you can find out a length where it is maximum. So, that is what you can do. Find out a length where half Sp plus a g is maximum. So, that is the (Refer Time: 25:00). So, this is how we can do.

Now, we can look into another feature surface texture and color. So, far we looked into shading, we looked into orientation, we looked into shape, we looked into you know construction u values and we talked about time lag etcetera. Another feature is surface texture and color alpha. Now, alpha is to shortwave should be as low as possible we have seen because its al I alpha divided by?

(Refer Slide Time: 25:29)



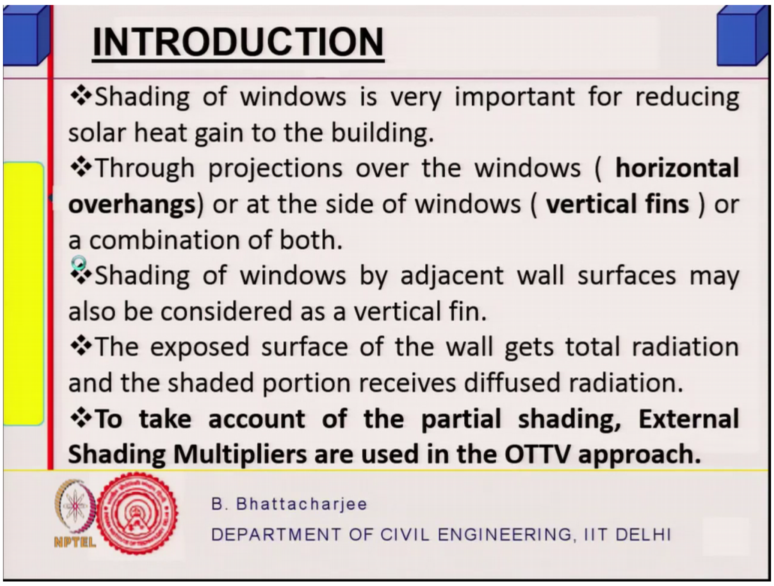
Student: Ho (Refer Time: 25:35).

So, I do not want this to be too high right, but also when we try to found out the solar temperature remembered we said that alpha shortwave I minus epsilon long wave right, but this I is not very large actually. So, this should be long wave should be as high as possible.

For white color alpha shortwave is 0.4 and epsilon is 0.9 therefore, it is very good right. So, this is important. Surface text color is important, its alpha should be as low as possible epsilon to long wave should be as high as possible and (Refer Time: 26:25) does a very good job, (Refer Time: 26:27) does a very good job to that extent because it has got alpha shortwave is around 0.4, epsilon is 0.9. While red brick color would be alpha is high, epsilon is similar alpha is pretty high, alpha is relatively higher and if it is black end surface that would be pretty bad in fact, you know it will have large higher alpha also. So, one can select them, choose them.

Then texture is important, supposing you do rough texture you know some sort of texturing stone protruding out, say surface area through which heat can be rejected is higher, but mutually some protrudent; texturing would block the radiation being received on some other parts of the surface. So, intense you know intense shading due to projections that is less absorption, but surface area is increased more ambition. So, will see if I have some diagram related to that then earth sheltered I will come later on. So, before we look into the texture for some time you know you look into something called external shading multiplier.

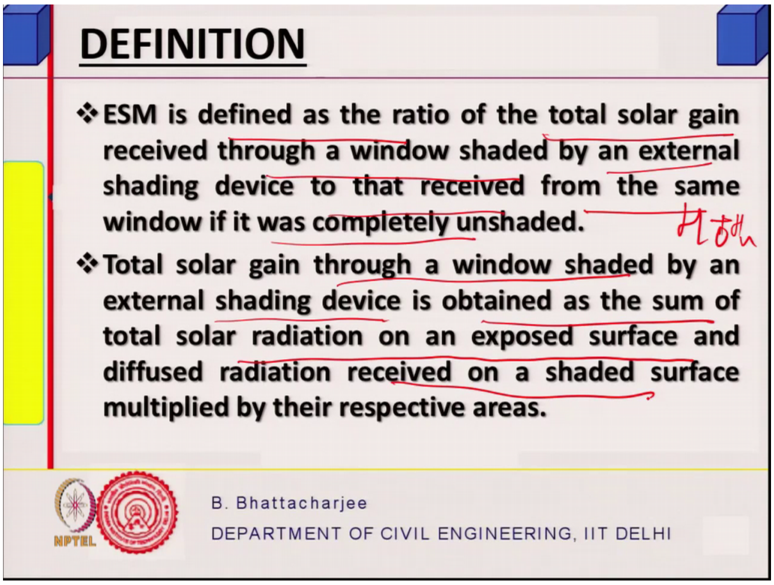
(Refer Slide Time: 27:39)



So, basically this we have looked into the shading of the windows very important, through projection over the windows we can actually control the both you know reduce down the summer heat gain and allow winter heat gain etcetera, and vertical fins also can do the same. So, we define something called external shading multipliers to take care of this what is happening all during, throughout the year, you know throughout the year. We looked into some of those efficiencies. We will come back to texture again after this.

So, we define something called external shading multipliers right, external shading multipliers, we define something called external shading multiplier.

(Refer Slide Time: 28:26)

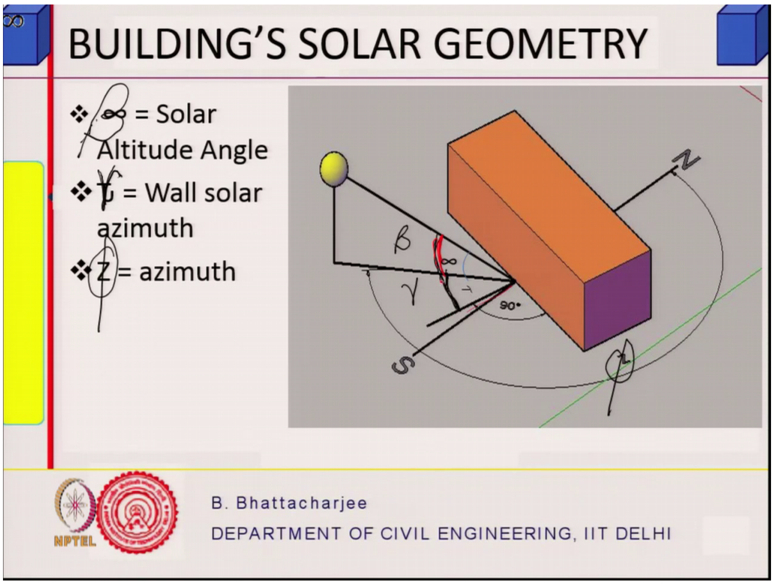


It is a ratio of total solar gain received through the window shaded by external shading device to that received from the same window if it was completely unshaded that is what, that is what we looked into earlier Ho, we call it something like Ho in case of summer and if I take the total Ho plus H.

Student: u.

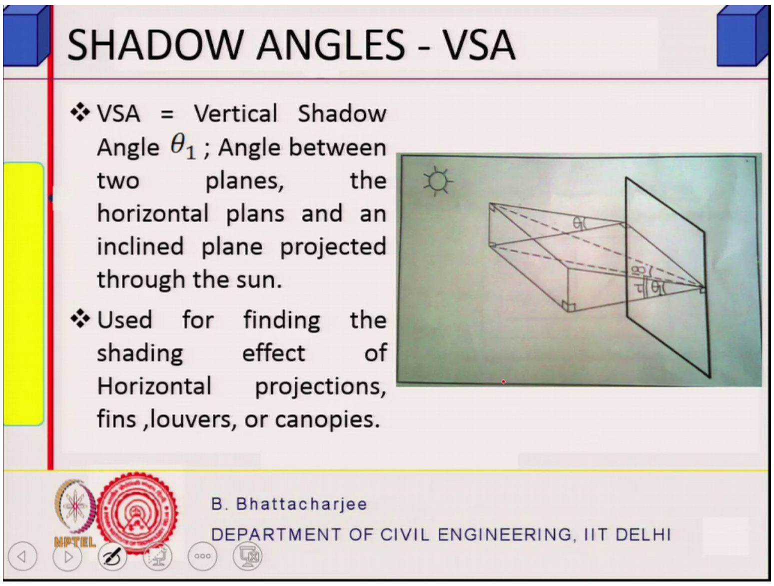
u under heated period that is what it is will be this. So, how do we calculate this out? This is what we like to look into. So, total solar gain through the window shaded by an external shading devices obtained as the sum of, total solar radiation on an exposed surface and also diffused radiation received on shaded surface multiplied by their respective areas. So, total energy gain we would like to look into.

(Refer Slide Time: 29:17)



So, this beta is solar altitude angle, wall solar azimuth as we have used, and instead of you know we trying to use our own notation, this is solar altitude angle, normal to the surface this is wall solar azimuth and from the north I am defining the azimuth you know phi or gamma this is gamma and this is phi.

(Refer Slide Time: 29:44)



So, based we look into this vertical shadow angle already we have calculated. We will make use of some of this and then find out the how to calculate out this Ho and H s that sort we will find. Then we look into some of those specific features including some issues related to texture and many other features in the next class. I think that is what we will do.