Energy Efficiency, Acoustics & Daylighting in building
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Lecture - 25
External Shading Multipliers for External Sun Shading

So, we will continue with this shading devices that we did other day right now we talked about efficiencies remember that shading efficiency you know that H o s p and then a g etcetera. So, we define certain shading performance efficiencies, supposing you want calculate out for the whole year how much is the heat is being blocked then one can do with through this external shading multipliers right.

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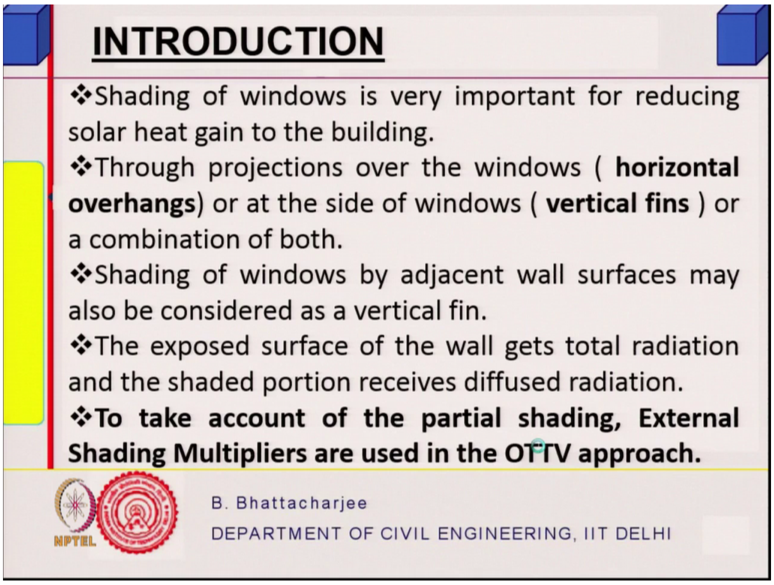

So, what you have seen is that we have already seen that shading is very important this we have already seen as it is stated here. So, you know using horizontal shading or overhangs or the side fins vertical fins or combination we can use and then we can cut down the solar heat gain in summer and also the dimensions can be optimized in order to minimize the summer gain and maximize the winter gain right at the difference between the two weightage factor of half for the winter gain.

So, that is we have to seen earlier right so, this can be you know like for the year if you want to calculate out this you can use this external shading multipliers which are nothing, but a factor now some of the regulatory yardsticks for example, many international codes right or many codes. In fact, many countries code might restrict look the amount of energy you can by design envelop should be designed and the building should be designed in such a manner that maximum cooling load per unit area should not be more than something these are the straight forward yardstick that maximum energy consumption per unit floor area should not be more than something.

But this is relatively difficult people have not done that that way, but there are certain other yardsticks for example, our code e c b c you know energy conservation building code of India that is what that is what it what it does it says it gives you certain prescriptive guidelines say c u value of wall should be this much etcetera right. Also gives you kind of some tradeoff between different you know there other some philosophies there and some performance based design also, but there is one used in Hong Kong, Singapore etcetera they call it o t t v overall thermal transfer value and again they restrict this I am not discuss I am not going to discuss about o t t v in this class, but there this shading multipliers are used external shading multipliers used right.

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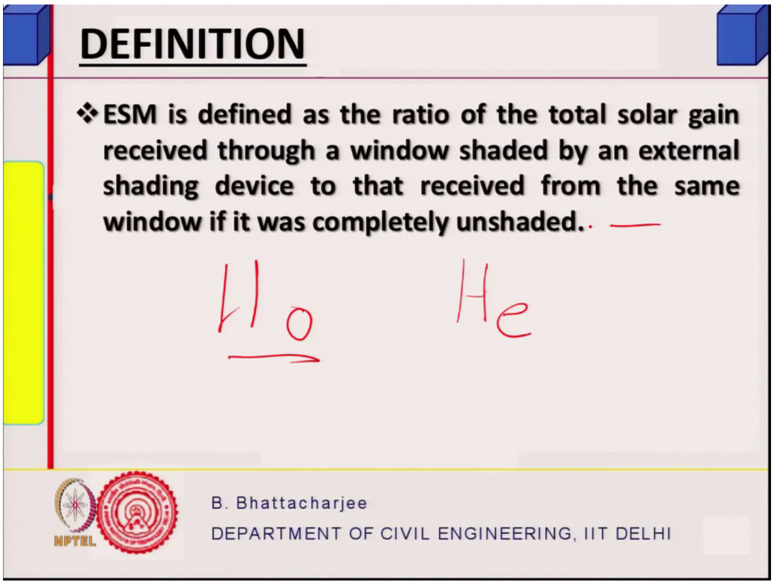

So, external shading multiplier is defined as a ratio of the total solar gain received through a window shaded by an external shading device to that received from the same window if it was completely unshaded. Now, remember H o you must be remembering sometime I talk to about H o right H o was the that is right you know we defined we used something like H o then used H e etcetera. What was H o?

Student: (Refer Time: 03:49).

During the overheated period right divided by then we use total incident upon it. So, if I want to calculate that sort of a thing then this philosophy that or rather the algebra we are talking about this becomes important.

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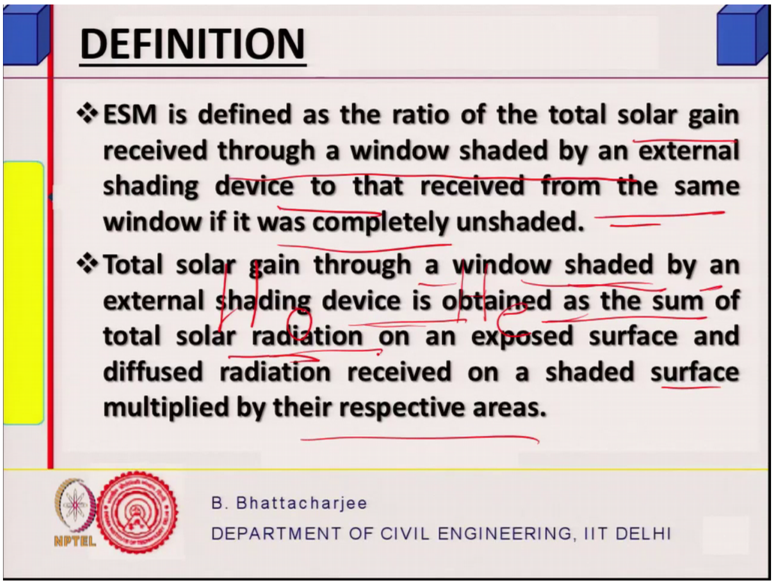

So, you can see the similarity it is the solar gain solar gain received through the window shaded by an external shading device to that received from the same window if it was completely unshaded, right. So, it is the ratio actually.

So, total solar gain through a window shaded by an external shading device is obtained as the sum of total solar radiation on an exposed surface and diffused radiation received on a shaded surface multiplied by their respective areas. So, it is basically intensity of radiation both diffuse and direct multiplied by the area. So, solar gain through the window shaded by an external shading device is obtained as the sum of total radiation; so, let us see; how it is the algebra is not very complex.

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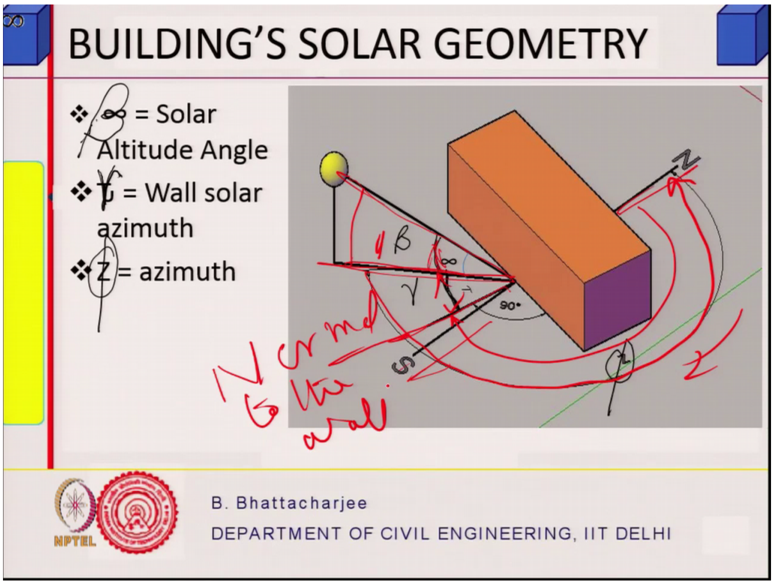

So, you can think in terms of a wall and this is a altitude angle this is a normal to the wall right this normal north due north and due south this is normal to the wall and this is this is the sun ray its projection on to the ground and this is normal to wall this you know normal to normal to wall normal to the wall and this is basically south direction and north direction. So, what is this angle this is phi solar azimuth this is solar azimuth you know going clockwise from this direction solar azimuth and normal to this surface is this.

So, this is nothing, but this complete thing is wall azimuth so, difference between these two this gamma is nothing, but wall solar azimuth right wall solar azimuth. So, gamma is wall solar azimuth this is projection of the sun ray onto the ground so, therefore, this is altitude angle this altitude angle right. So, altitude angle wall solar azimuth and phi of course, is a solar azimuth as you have seen right. So, solar altitude angle wall solar azimuth and just is the azimuth angle.

Since we have used earlier notation beta gamma and phi I would like to concentrate on the same notation even now and that is why I have changed this although my slides say something different.

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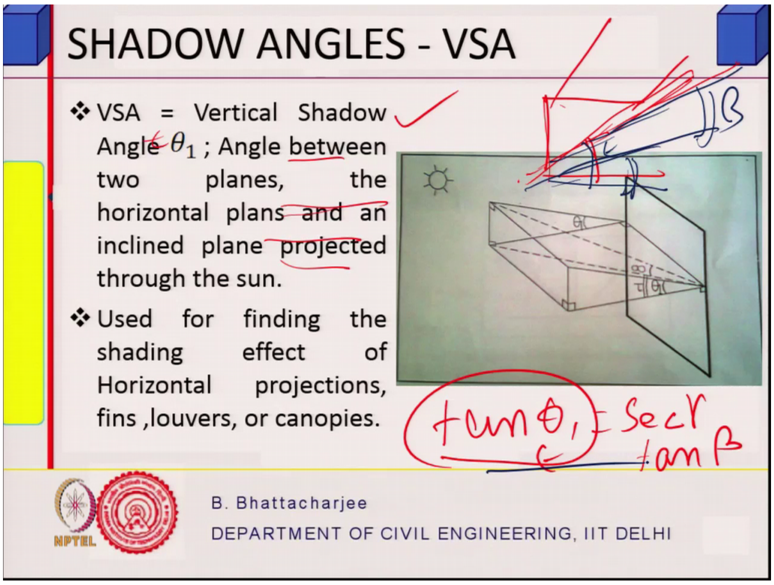

Now, then vertical shadow angle actually we have used epsilon earlier as an angle between two planes the horizontal planes plane horizontal plans and an inclined plane projected through the sun. So, what is vertical shadow angle? Vertical shadow angle is you know vertical shadow angle is that angle when sun just sun ray is just blocked remember that is what talked about this is the you know this is the vertical shadow angle vertical shadow angle is this is the I would say end of the wall, but the sun ray might fall just gaze straight and fall somewhere there right and our relationships are well also there. So, tan of we call that epsilon here it is written as theta 1, tan of theta 1 is equals to sec of remember we had the relationship tan beta sec gamma I think that what it was sec gamma and;

Student: Tan.

Tan of altitude angle remember that we derived this earlier tan epsilon is equals to right. So, I am just using different notation so, same concepts you can use here same concepts you can use here, actually same concepts you can use here. So, this you know look like let me use a different color let me use a different color this is for the sun ray sun ray is falling like this. So, projection of the sun ray is somewhere there right this normal to the surface this gamma this is beta right and this is my epsilon.

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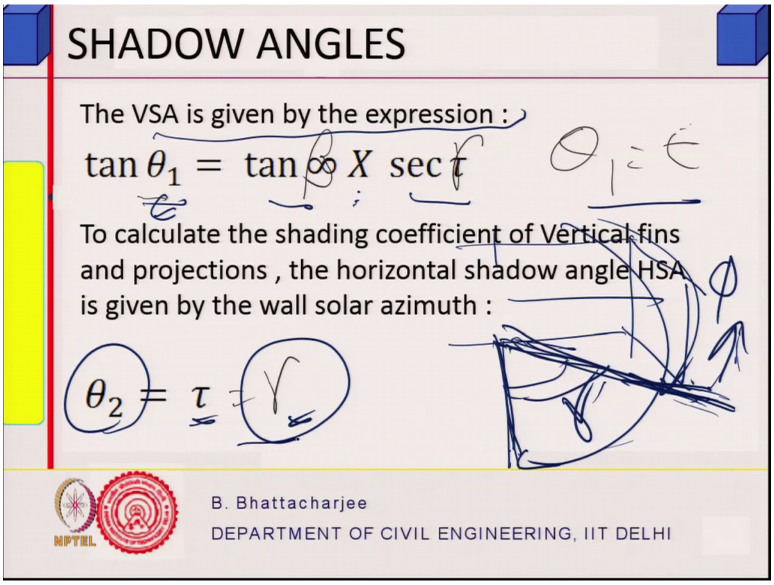

So, we obtain the relationship in the last class I think something like this and we will make use of this here itself so, tan theta one you know. So, that is it is 10 vertical shadow angle given by the expression tan theta 1 we use epsilon actually here we are using theta 1 theta 1 is equals to epsilon that is what I am saying. So, tan beta multiplied by sec of gamma that is what (Refer Time: 08:11).

To calculate the shading coefficient of vertical fins and projection horizontal shadow angle was we are calling it theta 2 right here is equals to simply gamma is you know horizontal shadow angle you remember we talked about that because this was the case of a vertical fins something like this is the window this is the vertical fin of this kind. So, this you know this is normal to the wall this is normal to the wall and this is the suns project suns just at the point when sun just touches beyond that on this side, it will block the sun completely on this side when you know the sun is in this side it will block the sun completely here it will not block. So, it is exactly at that time particular time so, that is what we are calling as you know horizontal I mean yeah horizontal shadow angle.

And this is nothing, but this is the sun rays here on plan this is normal to the wall. So, from north if you come here this will be your phi and this will be your wall solar azimuth difference between them so, this is simply wall solar azimuth wall azimuth difference between wall azimuth and solar azimuth. So, this you know theta 2 is equals to gamma that is horizontal shadow angle is simply is equals to gamma remember that we discussed that in last class earlier. So, this we understand we you will make use of them again alright we will make use of them.

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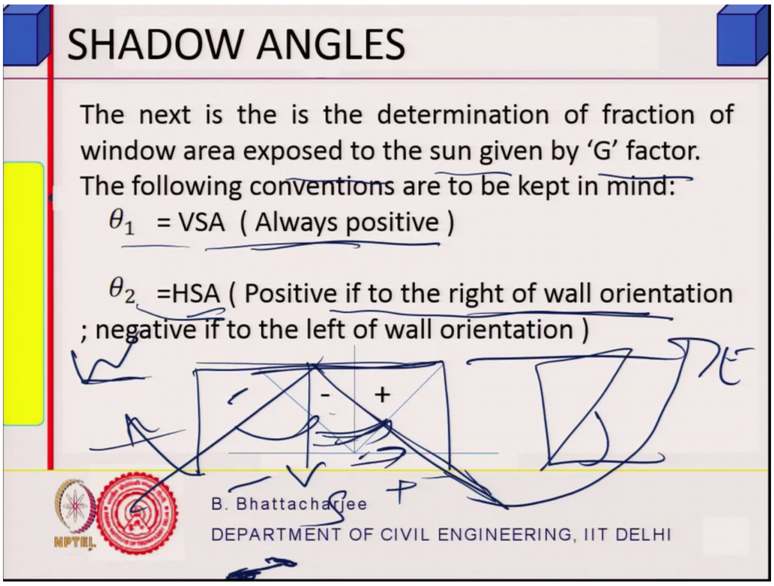

So, the next is the determination of fraction of window area exposed to the sun given by a factor G vertical shadow angle is always positive because it is like that right it. So, it will be always positive vertical shadow, will always positive it cannot be negative because it is from the horizontal ground to vertically upward touching the touching the tip of the shading device, right.

So, this is always positive and vertical shadow you know vertical shadow is always positive and horizontal shadow angle which is for the vertical fins or shading devices it is positive if it is to the right of the wall and it is negative if it is to the you know right of wall orientation negative if the left of wall orientation. What I am mean to say is supposing this is my window right this is south direction this is my window now I have a fin here I have a fin here. So, morning sun will be blocked morning sun starts from here the moment it comes here it will be it will you know it will not block any further right so, this is on the right end what we are saying is positive if it to the right of the wall orientation. So, if it is right of the wall orientation. So, this is positive and in the afternoon the moment sun passes this area because this is west this is east right. So, again it will be blocking the sun's ray, right.

So, this will be another horizontal shadow angle this will be another in general they are sin same because this symmetrical it is facing south they will be same if it not facing south incline then of course, it may be different right. If it is facing due south normal to the south you know normal to the wall towards the south then it will be actually, but it can vary. So, this is negative this portion is this we are calling as negative this one is positive this is negative this is positive all right. So, this is by definition so, that is what it is positive and negative as shown here. So, this is you know positive and negative that is how we are defining it if it is right of the wall then it is positive left of the wall then it is negative.

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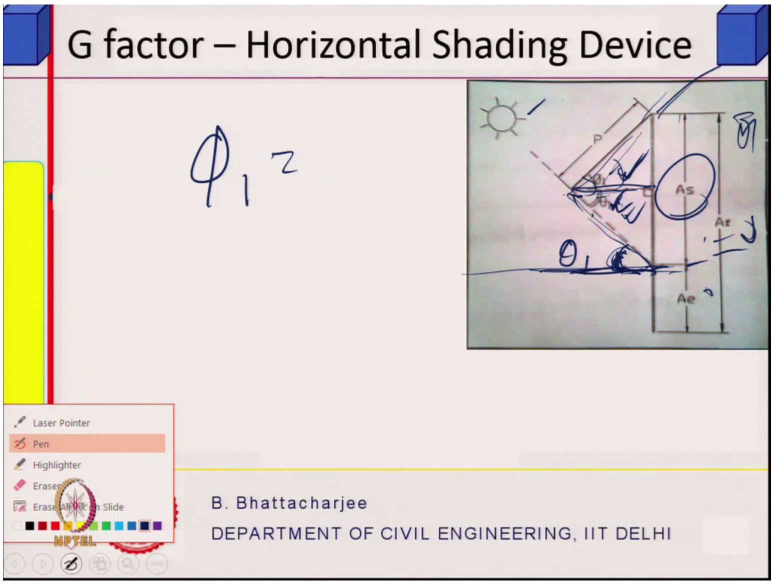

Now, let us make it a little bit general supposing sun is here P is the see all the time it will not be blocking the sun, you design for the extreme condition that is what we said in the last class. We said that we find out the overheated period and then under heated period and then try to find out corresponding to that what would be you know for a given length how much they it will block during the overheated period and how much it will actually block during under heated period half of that we can take and divide it by the total receipt that was the efficiency and we can maximize that so, we will have some length right.

So, it will not block all the time either it is horizontal shading device you know horizontal shading device or vertical shading device whichever it is it will not block the sun all the time it will block only sometime it will block so, how much it blocks that is what we are trying to find out. Now, supposing it is a little bit generalized supposing this is inclined you know shading device is incline I said the shading device can also be incline its effective length becomes actually more, then this portion sun is here this will block A s, will be the one which would be blocked A s is blocked, A s is the area of the window which is blocked I mean we are assuming vertical windows.

So, width will be with multiplied by this length will be what is blocked right or it is the length you know ratio I can find it and this is the portion where solar radiation is received and this is the total right. So, this is the portion where solar radiation is received this is what is blocked and this angle let me this angle is theta you know this angle is theta 1 this I am calling as phi 1. This angle is theta 1 this angle is phi 1 theta 1, why theta 1 it corresponds to you know epsilon and that time epsilon is for you know design purpose we are using epsilon so, theta 1 is same as epsilon at any time any time I am calling theta 1.

So, at this particular time you know what was the angle from the tip to the normal this angle this angle is same as this angle theta 1, right. So, this is the corresponding vertical shadow angle because the by definition, if I draw a line to the tip of the shading device and the angle it makes it horizontal because this is the portion up to which it states let us call it does not shade. So, corresponding to this is angle which is equals to theta 1 which would happen epsilon at some period of time by design purpose we are using epsilon.

So, this is this will be same as because this line and this plane is parallel this is same as theta 1, this is phi 1, I am calling it phi 1 so, phi 1 is the angle of the shading device with the; it makes with the horizontal plane. So, this is the horizontal plane this is this is how it know so, phi 1 is the angle this angle and theta 1 is same as theta you know this angle I want to find out this ratio of this A s by A t at anytime at anytime I will be I like to find out.

Now, altitude angle of the sun will know at anytime azimuth angle of the sun will be known at anytime so, I should able to find out right, is the conceptually is it clear what I am talking about.

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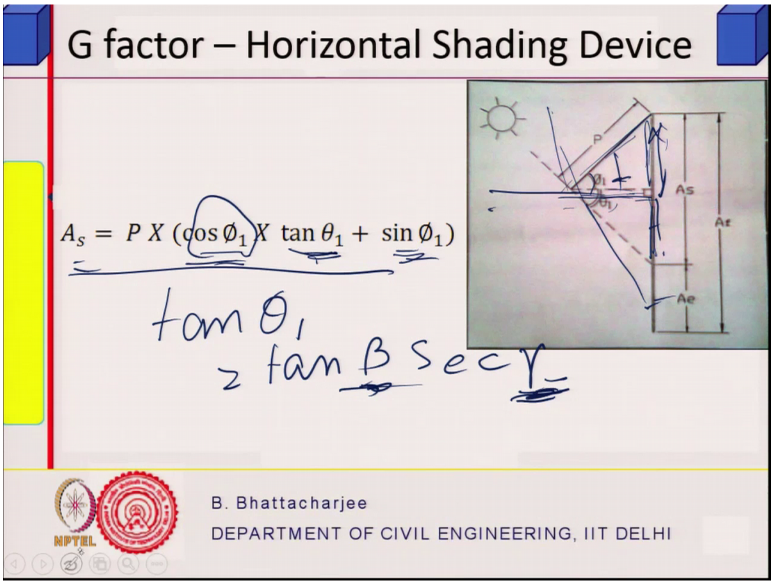

So, A s then is equals to from geometric simply A s is equals to P you know P sin theta right P is this length, length of the inclined shading device is P. So, how much is this one? A s is equal to this plus this plus this right so, this is how much is this one this is P sin theta P sin sorry phi sin phi, phi 1 sin phi 1 because this angle I am calling as phi 1 sin phi 1 and how much is this, this is known to us or P is known to us. So, if P is known this is P cos phi and this angle is theta. So, this by this is equals to tan theta 1 so, P cos phi 1 tan theta 1 right.

So, A s is equals to P cos phi 1 into tan theta 1 and sin phi 1 right now theta 1 I can find out phi 1 is a permanent thing, is a permanent future because inclination is is fixed is a specific feature is fixed, theta 1 will be a function of altitude angle and azimuth angle of the sun you know wall solar azimuth and altitude angle it will depend upon because we already find out that was equals to tan theta 1 is equals to tan beta, right.

So, if that is the case secant gamma this is wall solar azimuth which depends upon altitude angle and azimuth angle right and wall azimuth so, basically we can find out from sorry depends upon azimuth angle and wall azimuth sun solar azimuth and wall at that particular time at it will be the function. So, this will be this A s will be will change with time because some other time the sun will go there. So, sun goes there it blocks this much some other time sun goes there so, it blocks some other it blocks so on and so far.

So, portion of the you can find out the area of the and this is the function of time, hour angle, declination and latitude angle and wall orientation this is again hour angle, latitude and declination. So, therefore function of time of the day in a year on a given day etcetera and a given location so, this we can find out and therefore, A s we can find out as a function of the time so, that is what you can do.

Now, you can tan beta for their whole year every hour; obviously, you will have to use here you know repetitive calculations. So, you have to write a small program on excel sheet whatever you like it you know so, that is right so, this you can sum up.

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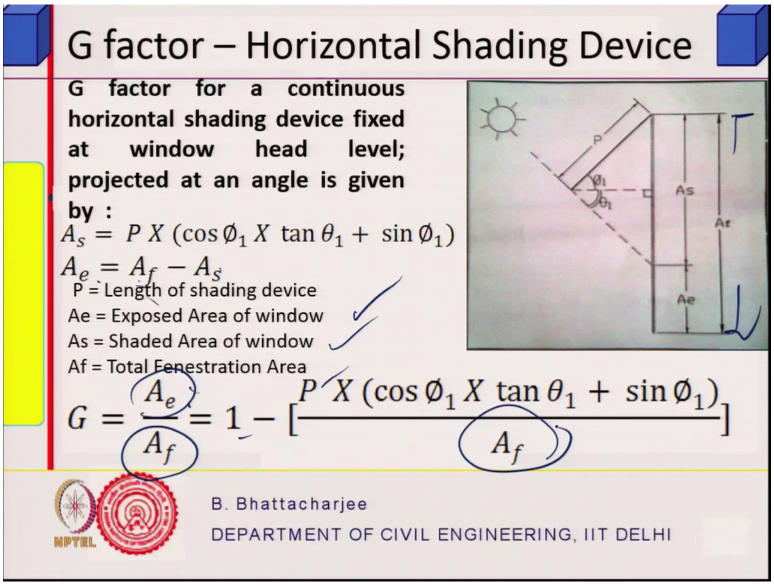

So, G factor is continuous horizontal for a continuous horizontal shading was fixed at window head level projected at an angle is given by this, A e is equals to total is A f total fenestration height or area is A f minus A s is A e is what is receiving the radiation that multiplied by intensity of radiation in that particular time, both are function of time you can sum it up for the whole year. So, P is the length of the shading device, e is exposed area, shaded window, total is this.

Now, we can find out actually so, G is the ratio of A e by A f and which is 1 minus this we find out 1 minus is because A s was this and A e is you know A e by A f. So, A e is a f if am dividing by this I will get 1 minus A s by A f so, fenestration area is known to me this ratio I can find out right this G multiplied by I, is the radiation received G multiplied by I at given time. So, G is the function of time I is the function of time and we know how to calculate out of for any surface.

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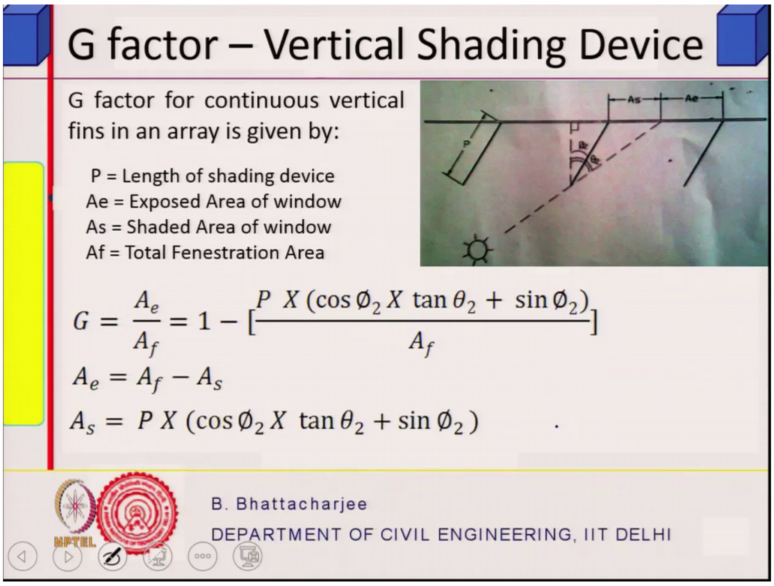

So, I into g sum it for all you can find out I will come back to this again for the horizontal one so, you see this sum up.

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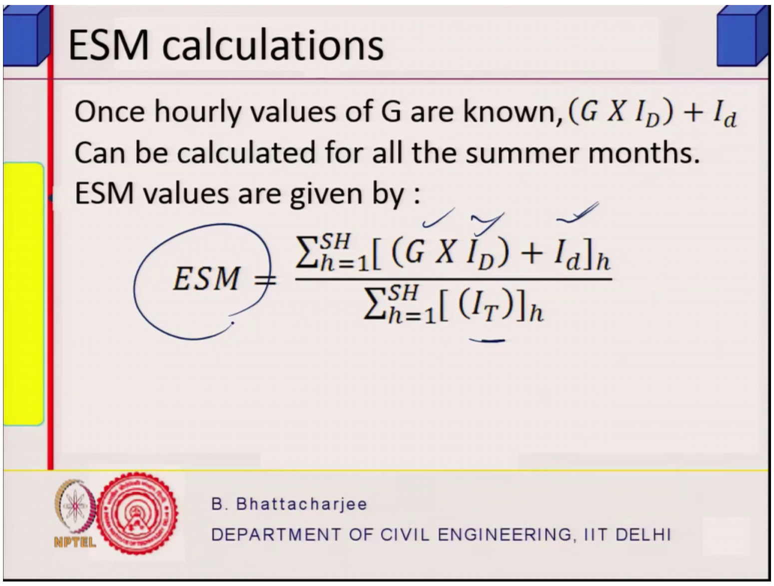

So, external shading multiplied is G and I direct and if we have diffused which will come from half of the hemisphere, diffused to which will come from half of the hemisphere because vertical one it sees does not see the full hemisphere, only one side supposing it is facing south. So, it will see two quadrants south eastern and south west so, total diffuse sky radiation is known half of it can be taken.

So, that will be I diffused this is I direct beam radiation which is global minus diffused we talked about that sometime earlier multi you know so, this we can do it and we can do it from hour 1 to all the hours and sum it up and the total receipt onto the surface if there was no shading there can be find out. So, this is called external shading multipliers and the each are etcetera, other day we looked into you can calculate out using same procedure.

So, this was for horizontal shading device, now if it is a vertical shading device we go here for vertical shading device right, this is what we looked into.

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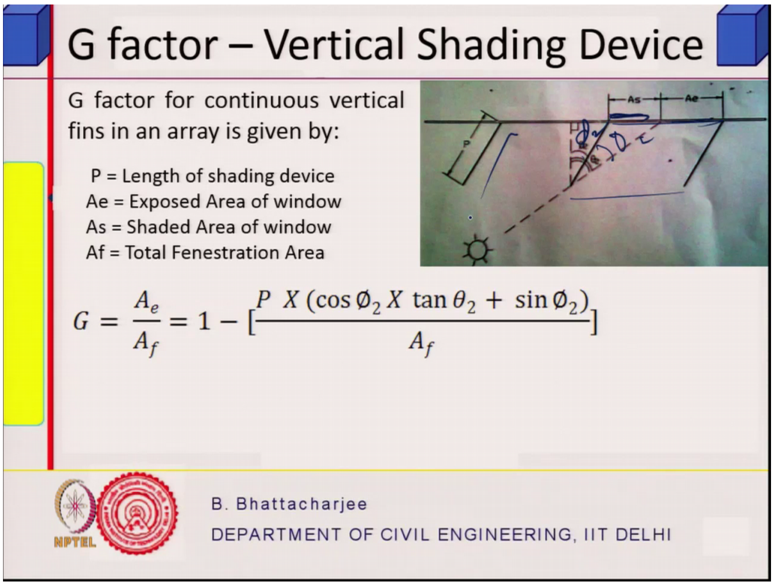

So, for vertical shading device now again I take an inclined case which is more general and what is this is theta 2 and this I am calling as phi 2 which is a permanent feature? phi 2 is a permanent feature, this angle is a permanent feature because inclination is concept specific feature. So, this is phi 2 this is you know what we are calling is theta 2 which will be equals to gamma at particular time this is exposed area, this is the shaded area and total is of course, this area total is this area P is the length exactly in the same manner that we have done. Earlier, exactly in the same manner that we have done earlier notations are same G factor we can find out, you know same as you defined. Now, I will not I will I will first come to so, this is my P length I want to find out this.

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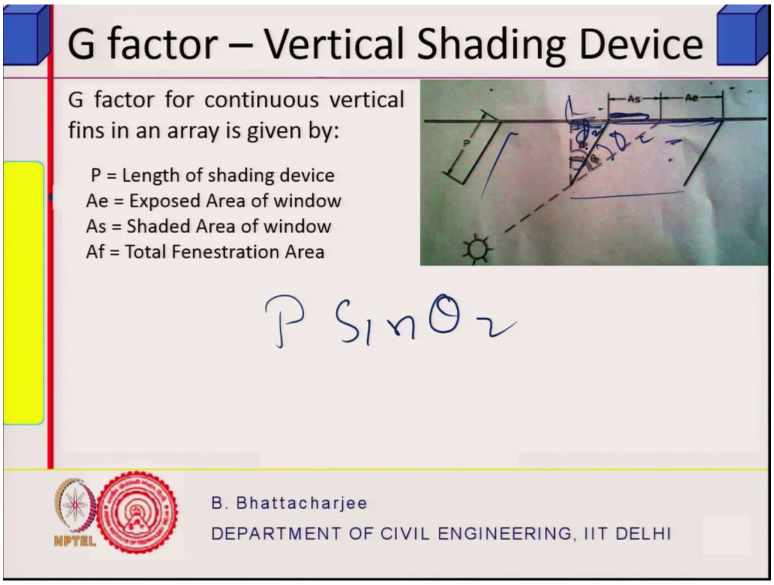

So, how much is this actually this first I should be able to find out a total you know A, total this is this is P, I want to find out this angle is known to me. So, this is theta 2 plus theta 1 theta 1 plus theta 1 actually this is 90 degree so, if I want to find out I am interested in finding out these two sum this I can find out very easily.

This is P this is basically theta 2 so, this is P sin theta 2 right P sin theta 2 is this one, sin theta 2 is this portion and I want to find out this portion then what I have to do is this is theta 1 theta 2 or first is this one this is my phi 2 right because it is a permanent feature this inclination is constant. So, P phi 2 P sin phi 2 is this much P cos phi 2 is this p cos phi 2 tan theta 1 theta 2 plus phi 2 will be this length. So, let us see what we have done; theta 2 should be this whole angle.

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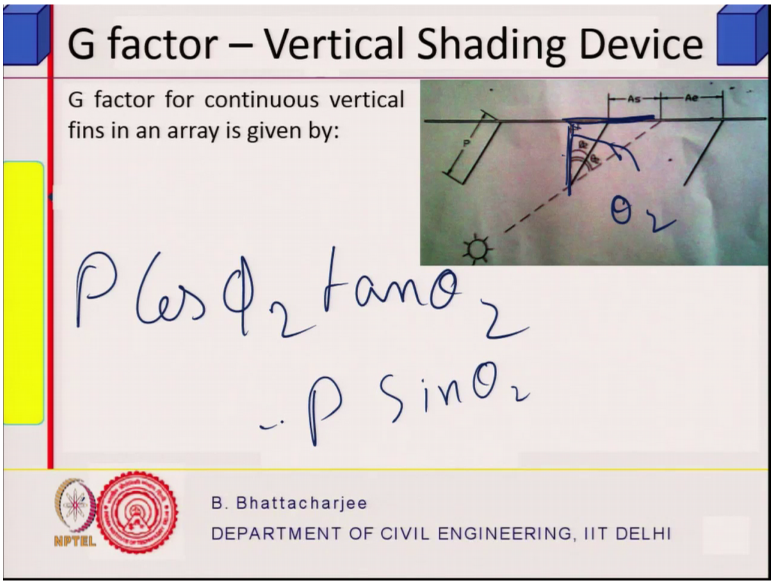

So, this one if I want to find out tan of theta 2 will give you that tan of theta 2 will give you that and how much is this is cos of phi 2 so, P cos phi 2 tan theta 2 would be this full end and this will be simply P this will be you know.

Student: (Refer Time: 23:52).

Sin phi 2 P sin phi 2 So, P cos phi 2.

Student: Sir but this has to be subtracted.

Yes, this is to subtracted, but this will get subtracted depending upon the direction of because you said it is positive and negative. So, it will automatically get subtracted accordingly right so, this is fine this alright so, general form of this equation still stand as a same one, cos phi this is 1 minus exposed area and this has to be subtracted.

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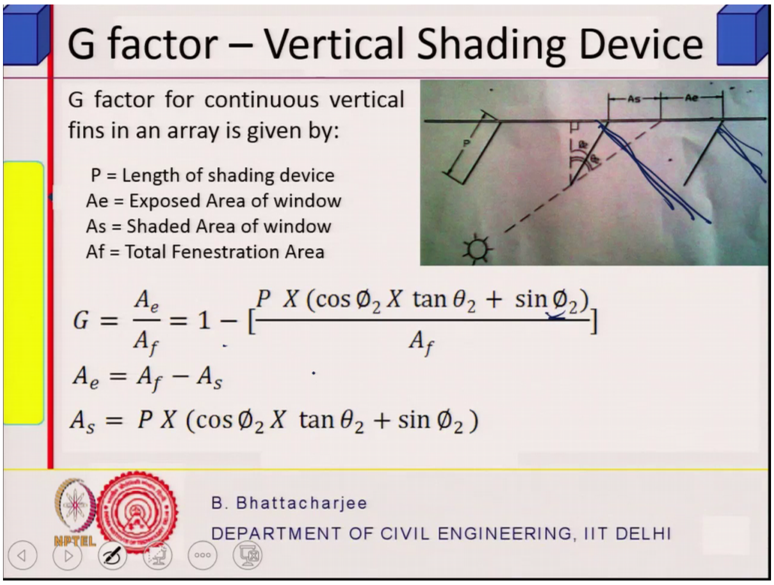

Student: (Refer Time: 24:30).

Right, depending upon whether the shading is on the left of the you know; like we defined this earlier. So, it will automatically get actually subtracted depending upon left or right supposing it is on the right the my shading is something like this right it will depend upon that depending upon that actually sin phi and theta as taken according to the sin convention of you take it. Either it will be plus or it will be minus depending upon where the shading is actually corresponding to the window, where is shading corresponding to the window that is how we defined actually.

If you recollect this is how we define, angles are defined this is define positive or negative if we get if you feel you are confused then you take the you know absolute value, but you have to do the addition or subtraction you have do it accordingly yourself you will have to do. Otherwise, this sin is positive or negative depending upon angle for theta be theta to be positive or negative it will depend upon sin you know this being positive or negative alright.

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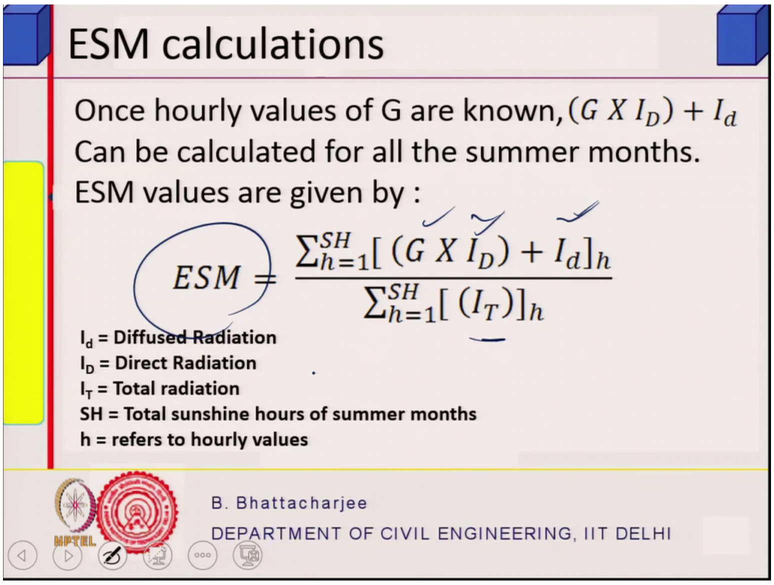

So, that is how you can calculate out and if we find out G yeah, then if we find out g the same thing so, for whole of the year you can repeat this process and you can find out what is called external shading multiplier which is the ratio right or else you know you can also use them for designing the shading device because this wall call response to you are taking the total radiations that is being blocked.

So, yearly heat efficiency remember we talked of yearly heat efficiency that was the ratio of the energy block divided by total falling on to it, actually this is something similar to early heat efficiency, but supposing you only want to find out for summer months you can do that as well, you want to find out for winter months you can do. So, this is a generalized formula that gives you so, how to calculate out.