# BUILDING ENERGY SYSTEMS AND AUDITING

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**Lecture – 19**

## Lecture 19 : Daylighting Concepts Daylighting Concepts

Welcome to the NPTEL course on Building Energy Systems and Auditing. In module number 4, we are discussing the Energy Conservation Building Code (ECBC). In lecture number 19, the Daylight Concept will be discussed. So, in this particular lecture, the daylight factor, the sky component, external reflected component, and the internal reflected component will be discussed, and we will also see how a daylight factor can be calculated. So, as we all know, the sun is the source of light, and this daylight has been tremendously used in our buildings since ages.

And this particular sunlight has a potential value from all respects. It has value in the sense that it gives a very pleasant indoor atmosphere, and it is also very healthy. So, through windows and some fenestrations in the building, we allow daylight penetration as well. So, the amount of daylight that will penetrate into a building is actually going to save a lot of artificial lighting, of course, during the daytime. So, if you see the daylight, the advantages of the daylight. So, that is one of the biggest advantages; you do not require any kind of energy.

It actually minimizes the artificial lighting cost or lighting load. During the daytime, the total artificial lighting load or cost is almost about 15 to 20, or 40% of the building's electrical cost, or electricity cost. It also lowers the HVAC load because, if there is a lesser number of appliances in service during the daytime, the equipment load is also going to be less. So, it is hygienic, it is disinfectant. It eliminates a lot of bacteria and viruses in the indoor atmosphere.

So, it is always going to be good, and it has a very good impact on mental well-being, productivity, and overall development. So, there are different parameters that are actually going to have a vital role in daylight. Or daylight calculations, or in daylight in a particular indoor atmosphere or indoor environment. So, it depends upon the orientation of the building, and it depends upon the time of the day when I am going to actually measure or I want to have the daylight.

The building shape and orientation go hand in hand because sometimes, you know, the proper orientation you may have placed a building, but the shape of the wall or that may not invite that much amount of daylight, or the shape of the wall, I mean to say, the slope of the wall Maybe it is a very inclined kind of wall, or maybe some other obstructions are there. Maybe it is a mutually shading kind of scenario in that particular orientation. It may not give that much amount of daylight, or in other words, sometimes it is placed in such a way that it invites daylight inside the interior. The size and locations of the opening, we will discuss that one.

Of course, this is one of the very prime factors for daylight consideration. The location of the room again depends upon the room location in the horizontal orientation of the building, or maybe sometimes when you see it vertically, after a certain level, you do not have any kind of obstructions or so, the trees, the other smaller buildings in your periphery. So, that will, of course, give you much, much more amount of the penetration of daylight. The interior color, exterior obstructions, these are also going to help us with the daylight penetration or so, or maybe stabilize the daylight inside the building because of the multiple reflections.

So, next let us discuss the daylight factor, which is very important to know and a very important parameter to understand how much daylight a particular point or a particular working plane, a certain distance from the window or maybe a certain distance from the corner, a particular position, say, can get the amount of light as daylight. So, it is a simple factor, a simple ratio, Ei by Eo or Eo So, Ei is the indoor illuminance at my point of interest, and Eo is the outdoor illuminance in the unobstructed sky hemisphere, and that is multiplied by 100 to give you a percentage kind of scenario. So, these are some of the sky conditions, and depending upon the sky condition, the illuminance is measured and given in lux, which is the unit of illuminance we have seen in the second chapter, second module. So, the brightest sky has a very huge amount of illuminance, and that is received by all the typical surfaces of the building, and then it penetrates, and the daylight will penetrate, and then some part of it, not definitely the whole, some part of it, depending upon the aperture size and all these things, will illuminate the interior.

So, typically, if I just go down, the overcast sky, clear day at sunrise and sunset, it is a little less, almost about 300 to 400 lux, extreme overcast sky with the clouds in the time of monsoon and all, it further goes down. So, normally for our calculation, we always do not take the brightest scenario, and we will not take the overcast and cloudy scenario. So, we take, we assume almost about 6000 to 8000 lux as our calculation purpose for the outdoor atmospheric, the unobstructed sky hemisphere illuminance as Eo. So, that is one of the very important things. So, we should see that.

So, this is one of the very important points that I want to mention. Now, daylight, of course, whatever we are discussing, is a part of your climatology, and probably you have learned that in the second year of architecture. So, but it is required to know because in the next lecture, what we will define is based on this particular daylight factor, as ECBC also stated that. that some of the recommendations. So, we need to understand this particular daylight factor first in a little bit more detail.

So, first of the contributions in this daylight are specifically classified into three major categories. One is the sky component. The sky component is the component which actually comes directly from the sky, the hemispheric sky, or that particular illuminance. So, because of the solar radiation, the whole sky is now like a source of light, and from there, it comes through the windows or so. So, it is directly from the sky. So, these red lines, this one is the sky component.

It comes directly from the sky, and the sky is the source. The second one is the externally reflected component. There will be some kind of obstructions, or there will be some kind of buildings or maybe some surfaces. So, it will not come directly through the window, but it will come via some kind of reflection on the external surfaces, ERC, the externally reflected component, which I have shown in the purple color. It may also come.

The third one is the internally reflected component. The internally reflected component is the component, which is the green one, the IRC, which actually comes to the working plane by virtue of the reflection from the interior ceiling or maybe the interior wall or so. So, this particular internally reflected component will be high. If I have light-colored interior surfaces, the amount of reflection will be much more. Dark-colored surfaces will absorb more amount of daylight. So, the reflective proportion of the reflection will not be so much, so it will be less.

So, that way, internal surfaces, the color of the internal surfaces, and all those sometimes it is the external, a little bit of paving very near to the windows also, and through that, reflections can go to, can strike your ceiling through the window, and then come to the working plane. So, light-colored interiors are one of the So, the solutions are one of the ways that we can improve the internal reflection coefficient or component. We will see how we can compute this particular daylight factor. So, we will, I will go back a little bit, we will actually see this particular fundamental equation is actually based on the sky component.

The sky component is one of the components out of these three components of the daylight factor; the sky component is the major one. One because it is the actual illuminated source of light, the daylight from where directly the daylight is actually penetrating through the windows or fenestration and actually impacting my working plane or falling incidence upon the working plane, and because of that, the working plane surface is illuminated. The other two are definitely going to reinforce the first one, but it is not the primary one. It is going to reinforce a bit or maybe essentially it is going to give you some amount of enhancement, but not the prime one. So, this particular calculation of the daylight factor, this particular equation or this particular formula, is based on the sky component point of view where the Df is categorically equated with some of the parameters which we just now have discussed; the first one, aw, is the

particular opening of the window, the area of the opening of the window. So, for the daylight calculation, So, I want to calculate indoors at some of my points of interest, and that point of interest has a location, that means it has a particular coordinate with respect to the length and the width of the room, and also, of course, with the height of the room. So, there is a three-dimensional point in space. And from that point of my interest point of view, the window, the size of the window which I am going to, I mean, the daylight comes through that particular window, and I want to find out what is the proportion of the daylight factor that comes from the window if there are several windows, not one, two, three, or four, so for each and every window, I have to

Calculate that, and with respect to the window locations by coordinate, the internal point of interest coordinate may change. The Aw is the area of the window, and small t is the visible light transmission of the opening of the window. Now, the character of the window is a translucent kind of material like glass or something, but it has a visible light transmission capacity. So, it may be a little dark in color. So, it will not pass 100%; it may only pass 70% or 60%, or it could be a very clear kind of glass.

So, it may actually allow 95% of the visible light to pass or something like that. So, that also needs to be known as part of the visible light transmission of the opening. Θ is the angle of the visible sky from the midpoint of the window. So, you have to find out that particular angle by virtue of some trigonometric relations, a very simple trigonometric relationship. We will see that in the next slide.

The As is the total surface area of the room. This is important because when the daylight comes, it will spread over, and that particular spreading over There may be some kind of internal reflections that will again reinforce that particular daylight in that particular point. But initially, it will spread over, and then, because of the internal reflections, it will accumulate. R is the average surface reflectance of the room. So, that is what we are talking about: if it is a light color, it is higher or so.

So, 0 to 2% daylight factor is inadequate and it may not be a good condition, and we may require electric light to supplement that daylight factor. 2 to 5 is adequate light, but sometimes it may require electric lighting because it can be dark due to a cloudy day or other reasons. So, that is why it is the middle point, 2% to 5%. If it is more than 5%, so Df more than 5% is good, then it may be well lit. But sometimes it may give some kind of glare or some points on the glossy surfaces may give some kind of glare.

So, this is the visible light transmission, this is t small t, we talked about the spectrum which is 380 to 720 nanometers. We have already discussed that one, the sunlight spectrum which actually transmits the light. The visible component of the light. So, that is going to be how much is penetrating, what percentage of that is penetrating. So, if it is a very light tint color tint glass or so, it is almost 80 to 100%.

So, 90% maybe, and the last one you see very dark tinted glass, very dark tinted glass sometimes we use that glass in our four-wheeler or so. So, those glasses can have 3 to 18% of the transmissions. So, this is some standard. And light reflectance value, that is how much the value, how much percentage of the light is going to reflect because of the different types of color. Interior color and that will reinforce the daylight factor in the particular location that I am going to find out.

So, these are the things. So, if it is black, the last line, the black, it is almost 1 to 4% reflectance. So, almost about 96% to 99% is going to be absorbed by the surface. Whereas, if you go to the top, the white color surface interior surface will reflect almost about 70 to 90% of the light, and almost about 30 to 10% is going to be absorbed by some other means. So, the ivory cream, the light yellow.

So, those are some color lists, and if you see as you go a little downward, the colors are a little bit darker in shade, and your percentage value is decreasing. Gradually. So, the one thing that we have to discuss is $\theta$, that is the visible sky angle. So, it has to be measured from the midpoint of the window. Even if your window is not obstructed, it has to be taken from the midpoint of the window to get the clear sky component of the sky or so.

So, if there is some kind of obstruction, it is going through this particular diagram, which is not very. So, this dotted line should pass through this. So, and this will be the θ then. So, because of the obstruction, this θ value is decreasing. So, θ comes in here.

So, as θ decreases, definitely your Df is going to decrease. If T is increased, that is the transmissibility, the visible transmissions and all light transmissions are still going to increase. If the area of the window is increased, definitely your daylight factor is going to increase; that is obvious. If your r is going to increase, 1 minus r is going to decrease, or r times 1 minus r squared is going to decrease, and then it will definitely increase. If the area of the total surface area of the room increases, it will definitely decrease. So, here we have done that one small.

So, we are finding out that this is the window; 2 meters is the length of the window, and in the sections, I have mentioned that the height of the window is 1.5 meters. So, the room area is 6 meters; you see this is 4 plus 1, sorry, 2 plus 1 plus 1 is 4 meters by 6 meters. So, this is the room area; the room height is assumed to be 3.5 meters, of course, in this particular. In the section drawing, you can see this is 1 meter plus 1 meter, 2 meters, and 1.5 meters. So, 3.5 meters is the room height.

The window dimension is 2 by 1.5, which is also mentioned or shown in that. There is a door also; the door dimension. This is the door. This is the door. This is the door, and the door dimension is 1 meter by 2 meters.

So, my points of interest are A and B, which are 2 meters and 4 meters respectively away from the center point of the window and also 1 meter above the floor. So, above the floor, you can see it from the section drawing, and the horizontal position you can see from the plan drawing. So, point A and point B have some static points, a kind of coordinate, 2 meters and 4 meters from the window and 1 meter above the floor. And I am going to calculate what happens if this particular window and all these things are there and what the daylight factor will be. So, here first I have found out the θ.

So, I know this will be the angle θ. So, I think I have measured the angle θ. So, this is 2 meters for A, 2 meters, and this 0.75, 0.75. So, I have used some kind of trigonometric relationship and found that θ A is equal to 16°. Similarly, I calculated θ B.

Which is now 4 meters. So, see this is instead of the 2 meters, now this will have to be 4 meters. So, geometrically it is from the triangle extended to B. So, now it is 4 meters instead of that, and tan will give me the θ. So, it is 10°. So, I use that one. So, I have measured the surface area. I have measured the window area as three meters squared because it is 2 meters by 1.5 meters or so. The visible light transmission coefficient is 0.8, and I have taken 0.5. This is the surface area, so now I just have to put the

And these are the θ values, and I have to put the right thing in the right place. So, I got 0.8% as the daylight factor at point A, which is closer, and 0.5% at point B. Definitely, it will be lesser because it is not so close to the window. But these two values are not very good values, as we see it should be around 2 to 5% to have a good value. So, anyway, these are our calculations, and that is why we got some values like this. Let us go to the next one. So, the next thing I did was increase the window width by 3 meters.

Instead of 2 meters, if you remember, now I increased it by 3 meters. That is the only change. If that is the change, there will be a little bit of changes. The area of the window now becomes 4.5 meters. The T values and the R value remain unchanged. The surface area of the of the particular room, and please remember, the surface area is the wall surface area of the room, and it is now going to be a little less. So, it is because the window is larger. So, 63.5 meters squared is the area of the surface.

The θ A and θ B remain the same because the height of the window remains the same: 2 meters and 4 meters. I am sorry, that is your 1.5 meters remains the same. So, there is no change in that. So, that is not going to be changed: 16° and 10°. So, I recalculated with the new values. So, now it is 1.2 and 0.75. It is improving because I have increased the window size from 2 meters to 3 meters.

The width and the window area are also increased. So, that definitely means the daylight factor is improving, and it is now 1.2%, which was around 0.8% or so in A. Now, what I did is that I again came back to the first case: the width of the window is 2 meters, but the height of the window, instead of 1.5 meters, I increased it to 2 meters. So, the height of the window is increased to 2 meters. So, again, there are some changes: the changes in the total window area, there is a change in the total surface area, but these two values remain unchanged, but here.

You see the tan values also have to be changed. So, all the changes in the values where there is a change I have mentioned in red color. So, 2, 1, 2, 1 those are in red. So, here, the size or the height of the window is 2 meters, not 1.5 meters. So, first, I have to take 2, and the second part of the tan inverse I have to take half of that 2, which is 1.

So, now your aperture angle, which was 16° and some other 10°, now it has become 18° and 12.5°; the aperture is increased. So, the θ angle between the midpoint of the window and the top portion of the window, where the aperture has been increased because of the increment of the height, and I have to again put the corresponding value of that in this equation. So, the 4 is the AS, which is 4, and the 64 is the surface area, and all other things, 18 and 12.5, are the angles of the aperture angle. I got 1.2% of Df.

For point A and point B, it is 0.83%. So, point B has improved. Point B has improved. Point B has improved from point, I think, uh, is this? Yes, this was 0.75, and from 0.75, it improved to 0.83 because of the height change. The improvement or the increase in the height, the B was in the back, so more daylight comes to the back side, but in the front side, it remains the same, point one two. So, I have a chart. See, in the base case, what we have kept in the base case, the width is 2 meters, and the height is 1.5 meters. The window area is 3 meters square, and Df for A is 8.8%, and Df for B is 0.5%. I am actually using 6000 lakhs as a LO, so from that point of view, I calculated the

EA and EB. I think this is my calculation, the equations. So, Ei I have calculated. I put this value as 6000; this is the average value, and Df is your 0.8% or whatever I have I have to actually give because it is by 100. So, 48 lakhs and 30 lakhs, 72 and 45, 72 and 50. So, those values are very small values, I understand, but a window for one window, maybe there are two such windows.

This is a very small window. So, two such windows may improve this value; we have to see. So, that one has to be calculated. Case 2 and case 1 are devised from the base case. So, in case 1, you see, we have increased the width from 2 meters to 3 meters, and there is a considerable change I have seen in the Df.

Of course, there is a window area that is also going to be changed, but you see in case 2, the window area decreases from 0.45 to 0.4. This is very important. So, this is a decrease in the window area, a decrease in the window area, but your This remains the same, the illumination or the daylight factor at A, but the illumination or daylight factor at B, the higher depth, is increased even though it is a five-block. It doesn't matter, but it is increased, so theoretically speaking, So, it is better to increase the depth of the window instead of increasing the width. It will illuminate the higher, deeper part of the room. So, that is all for this particular lecture, but yes, this is another particular graph, I think no.

Two or three things also we have to discuss over here. One is this: this is the distance when, if the distance increases from the window, the Df is going to decrease, which we understand from our other calculations also. And there are some other ratios like uniformity ratio and all. So, what is the Df minimum and what is the Df mean of all points of some of the strategic locations of the robot.

So, then we can find out the ratio between the Df minimum and the Df maximum, Df minimum and the Df min. So, that will give me some uniformity ratio. So, we can also use some kind of a thumb rule. This is another thumb rule: the gross area if you want to find out from the Df. So, you can use this equation: the area of the gross area of the glazing or in the window. So, Df, how much Df you want, 2% or whatever.

Af is the area of the floor 0.2, and Tg is the visible light transmission. So, suppose I have a room size of 4 meters by 6 meters, and VLT is 0.45. The daylight factor is 1 to 2. So, how much area of the window can I provide? So, the area of window glazing comes out to be calculated by this formula. It is a thumb rule.

It is a thumb rule formula: 5.33. Because 24 is the area of the floor, and 0.45 is the VLT. 0.2 is this particular constant value, and 0.02 is the daylight factor. This is the daylight factor. So, I can actually go for 5.3 square meters or so. So, that concludes this particular lecture. So, we mostly discussed the daylight factor in this lecture, and we saw the impact of the window size, mostly the window width, and the change of window depth, and how it determines the daylight factor.

Thank you very much.