Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 51
Daylighting (contd.)

So, we will continue with daylighting right.

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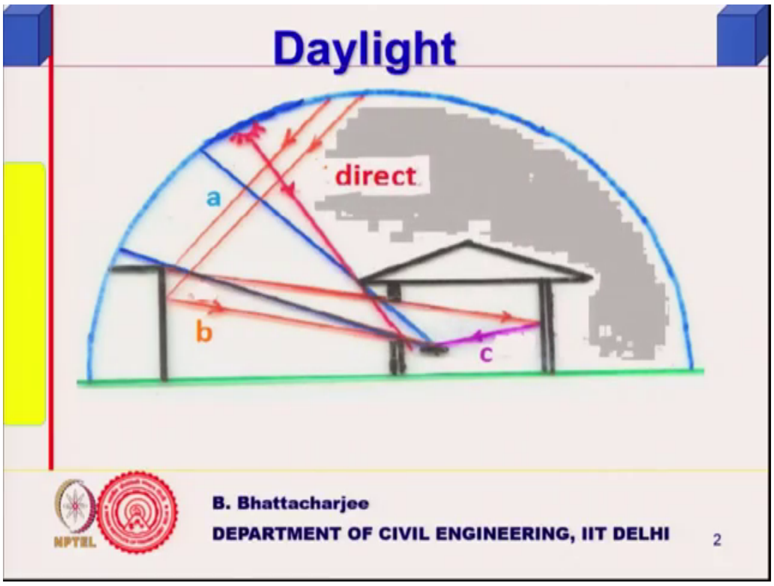

And you recollect that last class we talked about said there are four components of daylight right and one is the sky component.

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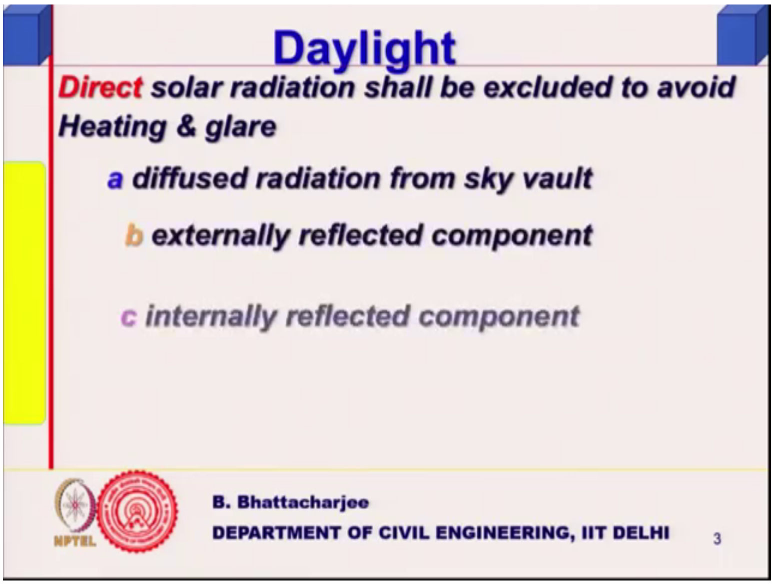

And then we should diffuse externally reflect component.

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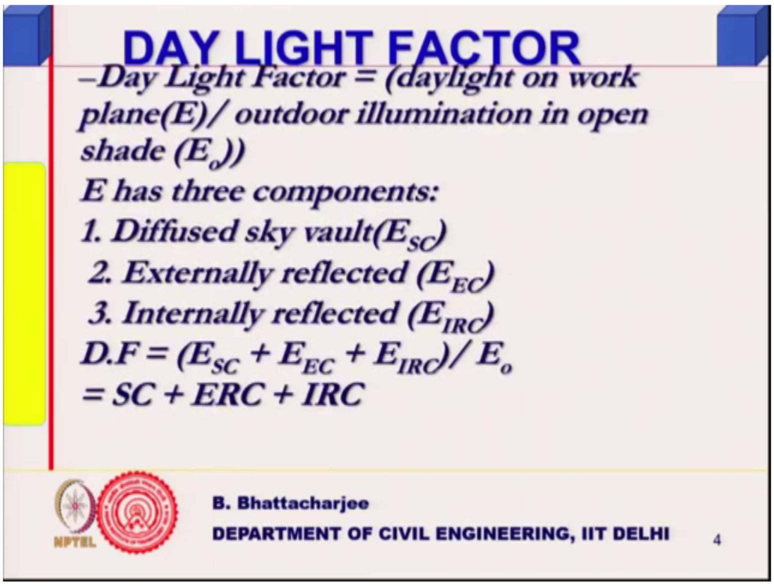

Etcetera etcetera and then we defined also daylight factors.

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Then we talked about the design sky Indian design sky etcetera etcetera.

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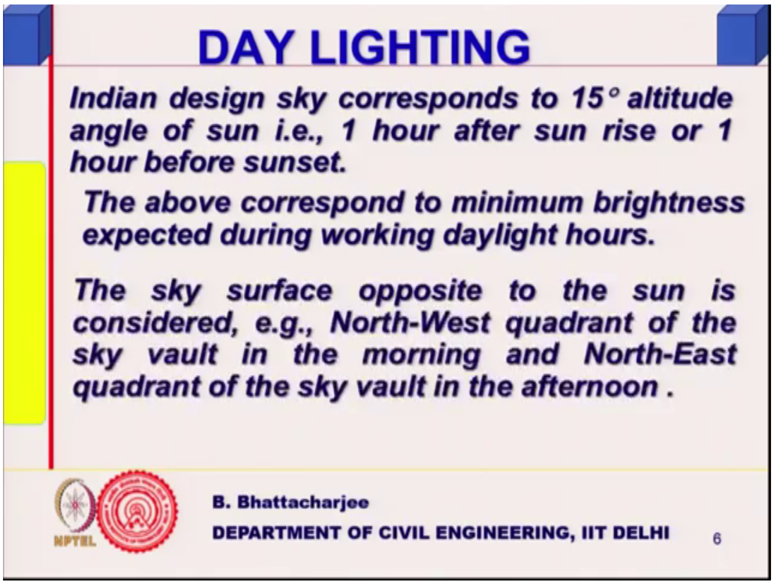

And then we said that design sky.

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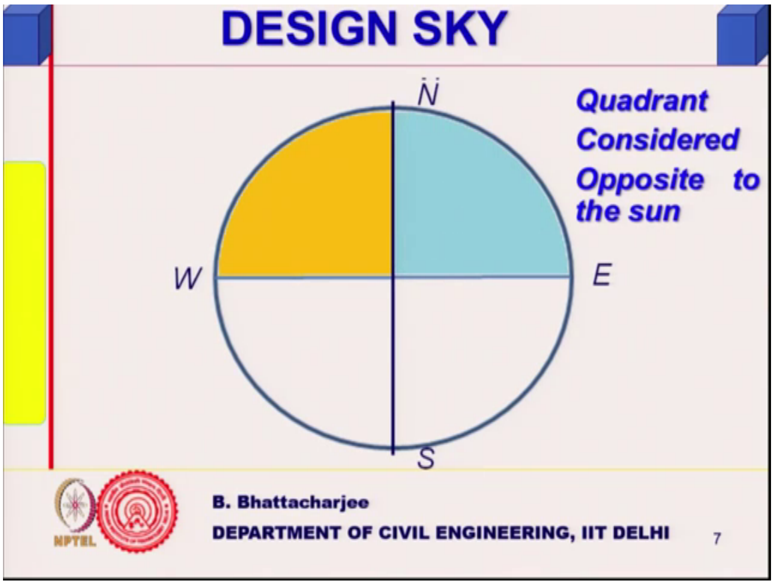

Indian design sky deals with you know this 2 quadrants, morning its in the northwest quadrant etcetera etcetera.

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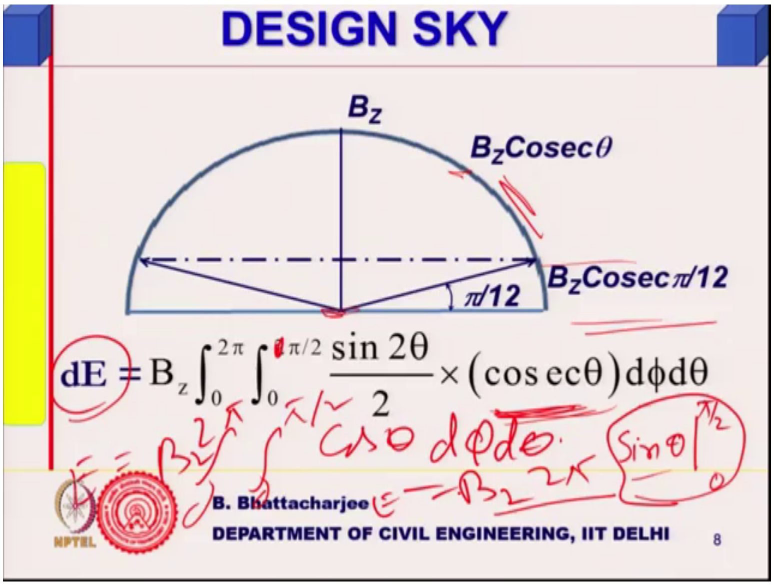

And it is given like this B z cosec theta right given as a B z is a zenithluminance zenith brightness and cosec theta, theta is the elevation angle elevation angle. So, B z up to this point it is up to this point it is B z cosec theta and this. Now this is based on some of their experiments that they did, but you know there was pretty early as I said. Later on of course, new skies came through internationally which I will discuss later on, but let us see what is there right now in the Indian code because they thought that is a best kind of tropical sky description right design sky description and that is what they have taken it.

And as I said this was pi by 12 and the illumination on a small you know its d E on a surface from any point in the sky, any small surface in the sky will be given as B z cosec theta remember we talked about B z, you know it was a this was a brightness multiplied by sin 2 theta by 2 d phi d theta.

So, its cosec theta simply this will be cos theta integral 0 to pi by 2, 0 to this is not there 0 to pi by 2 and 0 to 2 pi and value of B z. So, E will be given at the flat surface unobstructed flat surface will be given as d phi d theta, which will be basically B z 2 pi and cos theta if I integrate, I get sin theta right and sin theta going from pi by 2 to 0. So, therefore, it will be pi by 2 right simply pi by 2, sin pi by 2 is equals to 1.

So, this is one simply this part is 1. So, B z 2 pi is equals to E. So, they measure this illumination and that was taken to be 8000 flux that is taken to be 8000 flux right that is taken to be 8000 flux.

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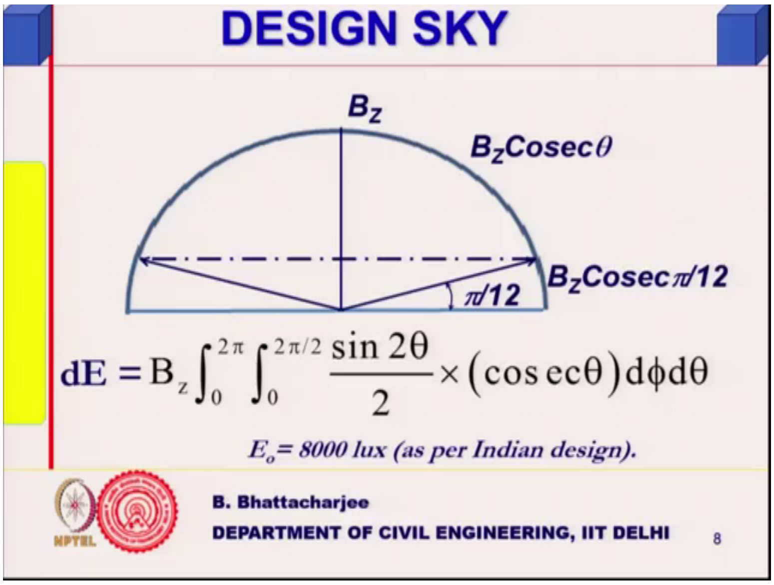

So, 8000 flux that is taken to 8000 lux; In other words you can get an idea about the B z from these 8000 divided by so, they just obtain this and that is, that is what it is right.

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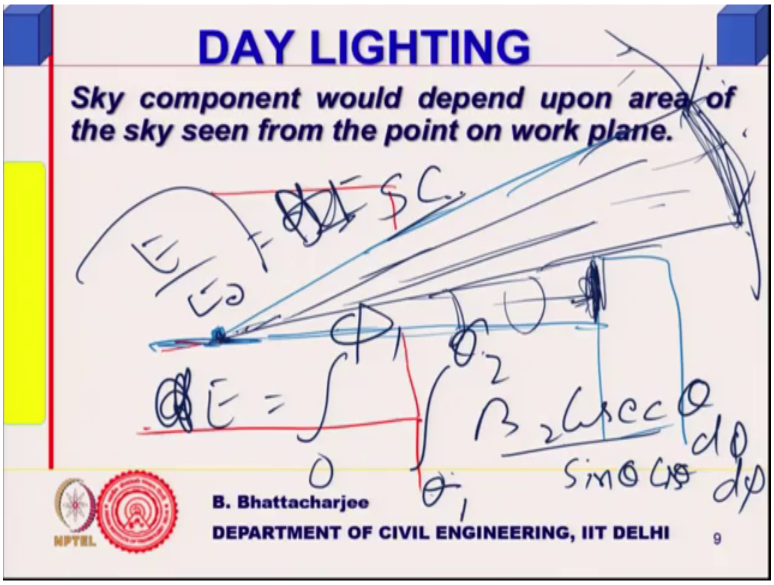

Ok, but then today let us talk of all the tables etcetera that is there in the Indian building code, national building code s p 41, then we will go to other kinds of sky in the next class we look into this. So, sky component would depend upon the area of the sky seen from the point in working plane. For example, I do not think I have the diagram right away I will have the next diagram.

For example, let us consider this is your window is something like this right window is somewhere here and this is your working plane is somewhere there, your this is your working plane this is your working plane right this is your working plane. So and there is no this let us say I was talking about obstructions here building. So, I am interested in this point to find out that illumination level or daylight factor at this point due to sky due to the sunlight basically.

So, what will happen? First of all from this point the light will come from this zone light will come from this zone that is the sky component and this portion will be externally reflected component, this portion will be externally reflected this portion will be contributed by this you know whatever brightness this has this will contribute to this point and this is externally reflected component as we have defined.

But through this I will be able to see some portion of the sky, some area of the sky right some area of the sky and that will contribute to the sky component at this point you know the portion of the sky I am able to see from this point if I place my eye here, whatever portion of the sky I am able to see that will contribute to the sky component here or illumination due to the sky brightness. Because this will act as a source this area will act as a source and light will come to this point from this area only. Beyond this this area it will not contribute because nothing can be seen from at this point nothing can be seen. So, I am dealing with one point.

So, normally one can analyze point by point, one can analyze point by point for example, you can find out in this in a in the room at one point, then the next point and next point and you can analyze point by point. But there are some way of doing gross or averaging we will come to that sometime later on. So, one can calculate out at this point.

Now, only thing now would be area is not the full sky, not the full sky bell vault same formula. So, brightness of this one is known and d E will be simply integral 0 to or 0 or some value of theta, you know some value of theta depending upon what you define 0 to some phi 1 value, and then 0 to or some angle to some you know some angle to some theta 1 angle 2 theta 2, B z cosec theta or whatever the B z is d theta d phi right that is what it is into you know.

So, the area would be sin to sin theta remember sin too sin theta cos theta something like this. So, this would be you know this is this is one can. So, the integration has to be performed now over the full not about the full sky vault, but about the area, for the area for the portion of the sky seen right. So, if you do that then you will find out the illumination. We want to find out the daylight factor. So, this once you integrate you get E, and this E divided by E 0 gives you daylight factor you know it gives you d f. It gives you the sky component of or sky component sorry this gives you the sky component; this gives you the sky component.

Then you can add the externally reflected component and because this is all linear and these are the scalar quantities you can add up you can add up linear scalar quantities you can add up. So, that is the principle that is the principle right. So, this is what a sky component would depend upon area of the sky seen from the point onto the working plane or work plane.

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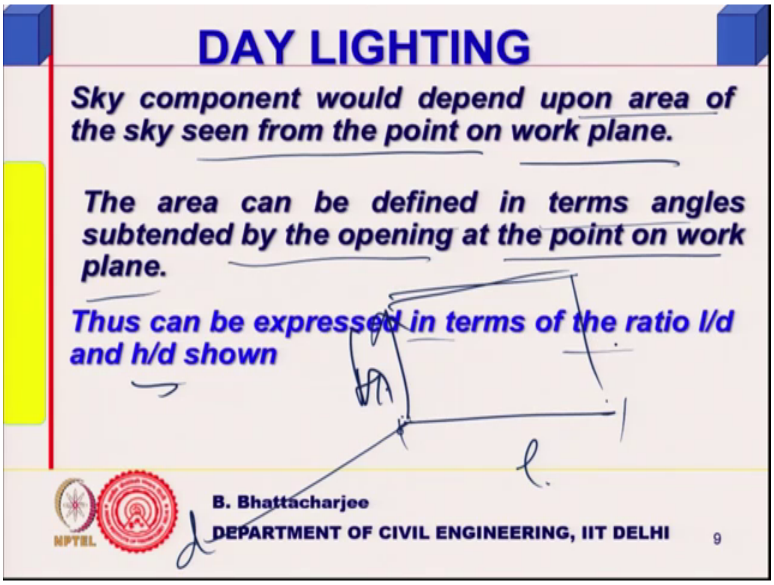

The area can be defined in terms of angle subtended by the opening at the point on or plane. So, it is the angle subtended right angle subtended. Thus can be expressed in terms of some ratio of l by d and h by d I will tell you what is l by d and what is h by d. L by d l is the length of the window, d is a distance of the point, d is the distance of the point from the window at a given one corner and h is the height of the window.

So, h is the height of the window l is the length of the window. So, h by you know it can be defined in this term.

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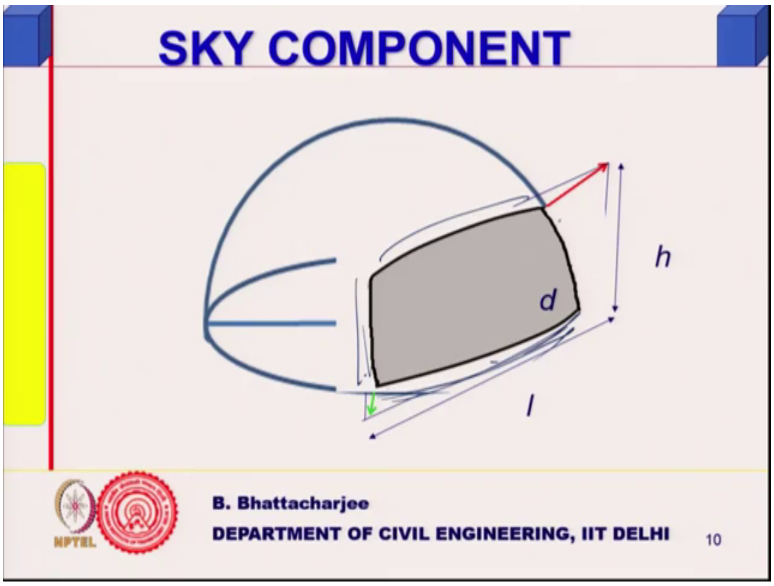

So, let us see what is there further. Now this is my sky vault, this is my window, if I project it to the sky. So, this is the h, this is l, this is a window, this is a window somewhere in the room and this is the point where I am interested in, this is a you know this. So, this is this distance we call it d distance of one of the corner normal to the window or normal to the wall having the window to the point. So, this is for example, if this is the window, you draw a normal to one of the corners and it must touch the work plane.

If it is not so, we know how to handle it will come to that. So, for calculation purpose they use this, because those days it was is not you know hand computation it was all hand composition. So, table generated and which are there in s p 41 or the code they are all actually hand generally hand calculation generator or may be small you know mainframe computer or something of this kind.

So, this is the distance of the d is the distance of the point from the window right one of the corners of the window and it has to be normal distance normal distance from one of the corners of the window the point, but other points you will have we will handle it in some manner this is. So, this is this is this is how you know. So, if I look at this, this is the area projected area I have made it larger actually it is a projected area of the window and in the sky it will take the shape like this because sky is curved sky.

So, if I project this window area beyond the sky vault, I mean an imaginary plane right. So, it would it would actually cover something of this kind and if I project it on to the sky vault, it will be something like this it will be a curved area. So, my integration has to be done over this area.

Now, you see I cannot really variation of phi at this here and variation of phi here are not same. Variation of theta here and theta here may not be same. So, theta can be expressed as a function of phi and then you integrate it both together. So, it this can be done, but they did you know it in the original case they actually did it broken up into several components and did it, today perhaps one can do numerically much easily.

But this is how it was done and the tables are arrived at, tables or paper pot diagram several diagrams which you find on code or s p 41 there is special publication they were arrived at based on this. So, this is our tree.

So, basically conceptually I must be able to integrate over the card area of the sky vault right. Now d E is a small you know force I take a small elemental surface for assuming it to be a point source, find out the illumination over the over the point where it is there, I mean for any point and then integrate over this area.

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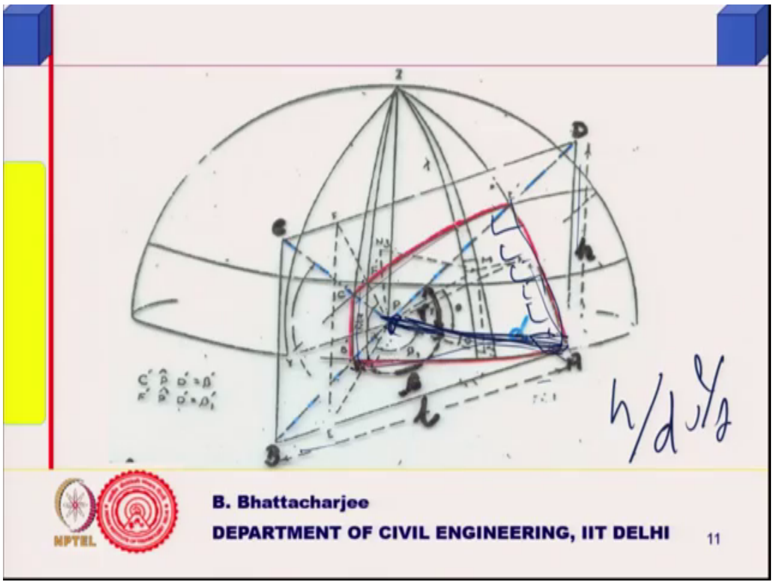

So, that is the idea and this is how it looks like this how it looks like; this will be the kind of area projection of the window, projection of the window this length is d length and for ease of integration what they have done is, they have said that one of the you know there is this what is done in the code, one of the point the working plane normal you know normal to the window must be passing through the work point on working plane and this distance is d, this is h and this is l. So, the angles are functions of d h by d and l by d, this angles are functions of h by d and l by d.

Now, one can today one can possibly divide this into small small areas and find out for each one of them numerically the contribution coming for each small area, and then sum it up to get it to all you know numerical calculations could be much easier then they did not integrate it in a very complicated manner, starting from you know like relatively complicated. So, some sums broken up into same integration because limits of integrations are broken around to several parts so, that this whole area can be covered. So, by doing that one could obtain the sky component.

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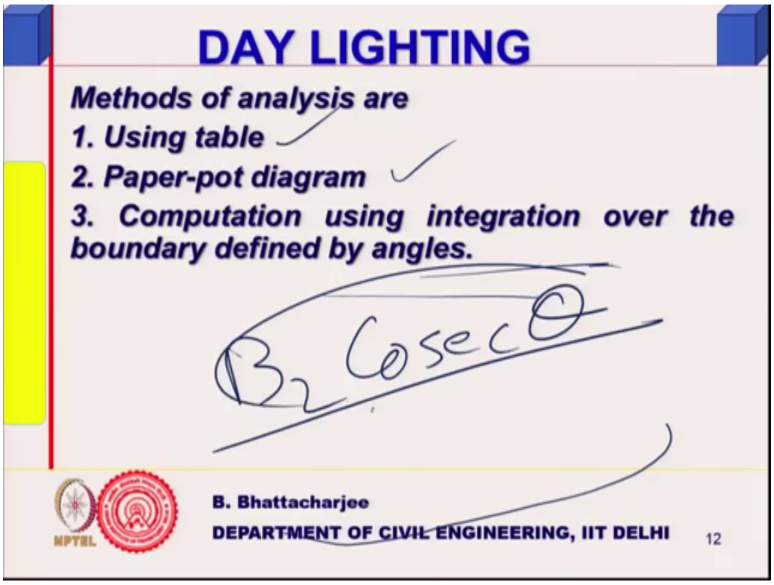

So, there are tables based on this computation paper pot diagram and you can do this today you can do computing using integration over the boundary defined by angles. So, numerical integration even you can do if required, but just numerical integration may not be necessary, only limits are problematic thing limits are not you know the 2 limits are there. So, as distance changes theta as distance changes phi changes, but theta also changes with phi.

So, accordingly you can do the integration right ok. I do not I do not go into details of these integrations at the moment, because this itself is in question the design sky it needs relook some relook has been done. So, integration part is fairly simple, but since it is there already in our design code, I would like to explain this first, then introduce to you the other kind of skies that is possible and possibly way how you can do it if you want to do it that way.

Many software uses those guys, but then you have to be careful to choose the correct sky for Indian condition or you know for given place in India. So, that is that is a lot of given place elsewhere in the world. So, this is self is in question therefore, there is no point spending more time on integration, but whatever is there in the code I would like to cover.

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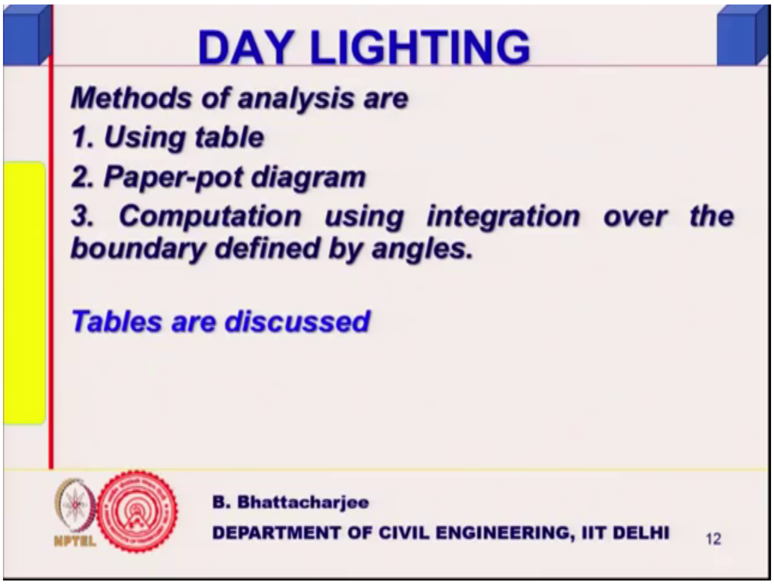

So, tables is tables are what I will be discussing how tables are pretty simple to use. tables are pretty simple to use.

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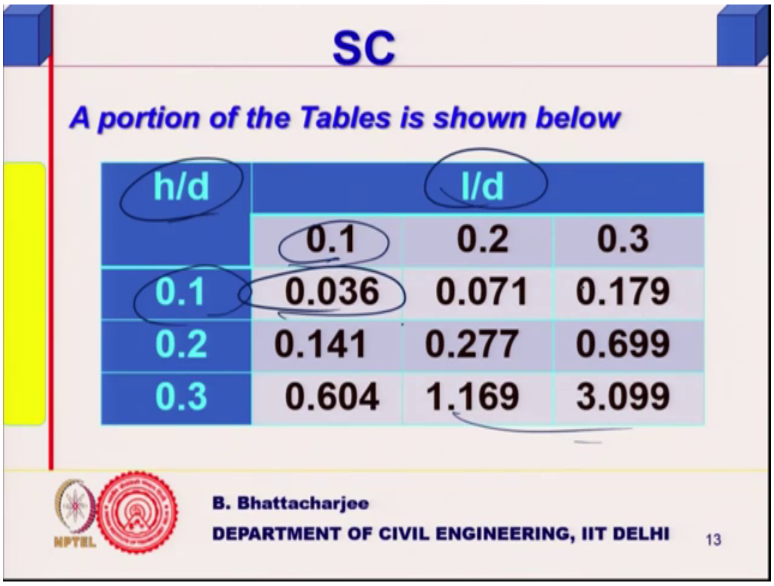

Now, these tables are as I said h by d and l by d. So, for example, h by d 0.1, l by d 0.1, h by d 0.1 the daylight factor in percentage sky component is 0.036. Now how do you find out l by d and h by d let us see. So, this is kind of a table is there large table is there. So, from this table first you find out l by d and h by d.

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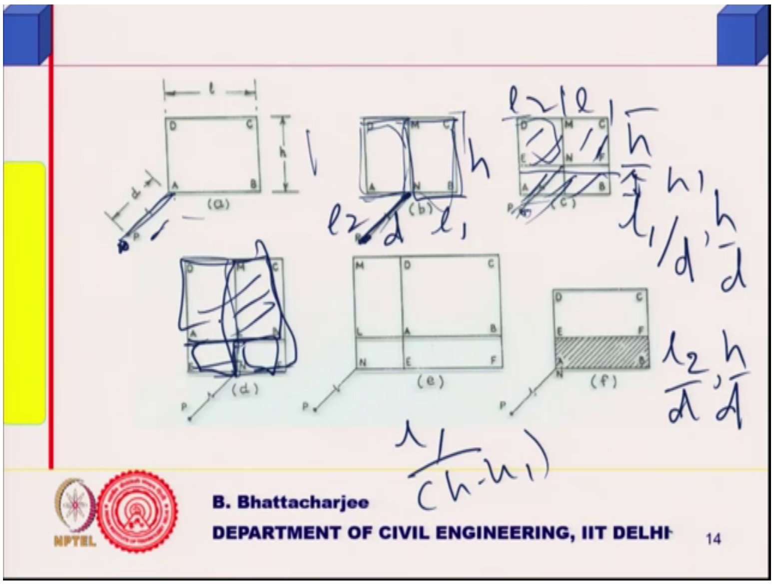

In order to do that, the one assumption is made that the working plane point p and normal to the window from one of the corner must pass through p. So, this is your l this is your h and this d. So, l by if you are working plane is such that it passes through this, then there is no problem straightforward you can use, but supposing your point is somewhere here the window is something like this.

So, according to this assumption, the normal from you know from this point if I draw a normal to the wall or the window, it touches the window at this point. So, I divide this into 2 parts. So, l 1 is this l 2 is this h is common and d is this distance. So, what I do? I find out the sky component for l 1 by d and h by d, and also I find out sky component for l 2 by d and h by d then sum it up.

So, then I am not violating this principle that normal to the normal passing through the work plane or the point in concern, touching one of the corners of the window. Here it is touching the corner of this window and here it is touching the corner of this window. So, you can use the l by d and h by d table and sum it up. If your point is somewhere here and window is a b c d, in all this diagram window is a b c d. If window is a b c d then this will not contribute anything to the sky component why? Because you know window your point what plane is above.

So, it only comes from the top from the bottom the ground does not contribute here. So, what you do is, you again find out for this portion of the window and this portion of the window and sum it up. So, what it would be? Say this is l 1, this is l 2 and this total is h and this is let us say h 1. So, you will find out for l 1 by h minus h 1 and l 2 by h minus h 1 and sum it up and that is how the tables are used that is how tables are used the only thing is you must ensure that the point of concern. Normal grounded through the point of concern must pass through one of the corners to the window it could be right corner or left corner does not matter.

So, more general case is let us say something like this, now this is your window this is your window a b c d, it is somewhat below. So, now, you what to do? You consider this l by d for this one and l by d for this one, sum it up and subtract the l by d for this portion and l by d you know l by d and h by d for this portion let me just write it write it rather in a more clear manner so that it becomes clear.

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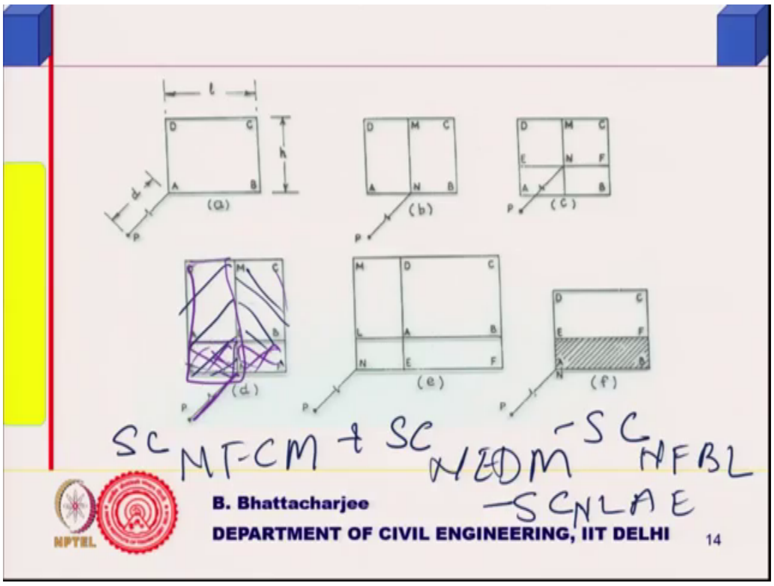

So, for example, for this case I first find out the sky component for MFCM plus sky component for NEDM 18.41 minus sky component for n f b l minus sky component for n l n l a e first I find out for this portion full and also find out for this portion full amount full quantity then I find out for find out for find out for this portion which I subtract and then this portion I subtract. So, then that would contribute to the sum total of this one because I am not violating the principle for this one I am not violating the principle that one of the corner of the window.

So, hypothetically I can assume the windows of the larger size then subtract for this portion which is again I am not violating that one of the you know normal drawn at the window one of the corner of the window passes through that work plane. So, this is how we can find out now this is still more general I suppose this must be there here not really no its not there. So, let us take at this still more general a b c d is my window right this is my window and my work plane is point time interest point of interest is here.

So, what I do I draw normal passing from the point touching the wall which is which you know touching the wall is this then I extend this to at the up to the window end extend this up to the window height and this is my l 1 this is my h 1 let us say for this I can find out the for this I can find out the sky component right then what you do then what you do then what you do find out the sky component for this portion and then find out the sky component for this portion

So, what we will do first you have found out for the total first you have found out for the total first you have found out for the total everything now you have found out from this found out for this. So, subtract this. So, what I am trying in the process I have subtracted this one twice end it up end it up. So, sky component for a b c d would be s c for a b c d in this case would be s c for you know n f c m n f c m I just extend this n f it is you know plus minus.

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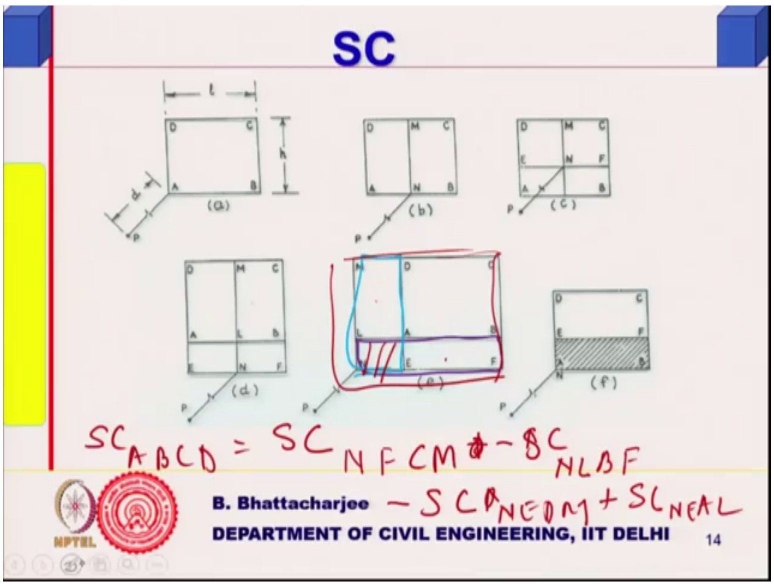

Minus n l s c for n l b f minus s c for NEDM s c for NEDM right and then I got to add because I have subtracted this twice s c for n e a l that will give me the sky component for this. So, for corresponding l by d h by d you can find out and then find out from the table and then. So, this is a one can use the table these is a one can use the table right these is a one can use the table similarly for this also you can find out. So, this is more general most general.

So, all you do is some fine extend the you know as if hypothetical window size to match that condition that normal drawn at one of the corner of the window must pass through that must pass through the point of my concern. So, every point you can calculate this out every part you can calculate out; that means, in or in other words you can analyze you can analyze the you can analyze the sky component values everywhere right.

So, that is that is what current code as it exists does current code as it exists us. So, that is what I was saying to find for this you have to first find for this first find out for this find out for this subtract and this will end add again this is we dd again. So, that is how it is done right. So, that is how we can use the table.

Similarly, there are some other diagrams have provided , but I think it is not worthwhile anymore because tables are good enough if you want to use this same table, but today you can yourself do some you know simple integration if you understand the basics then you can yourself write a program and do the integration, but the sky itself is in question similarly for projections outside.

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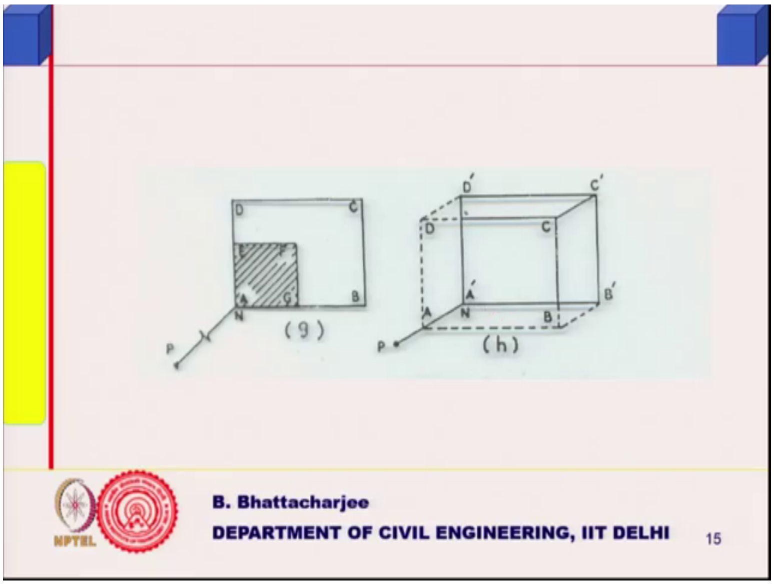

You have to find out the shaded portion if there is a projection for example, you have a a crate shading device. So, that would actually block some portion of the sky. So, all the visible sky portion you would take and accordingly you can find out right. So, this is what our code does let us look at externally reflected component now externally reflected component what would change the brightness would now change.

So, brightness will be the brightness of the external obstruction either the tree or the building or whatever it is right.

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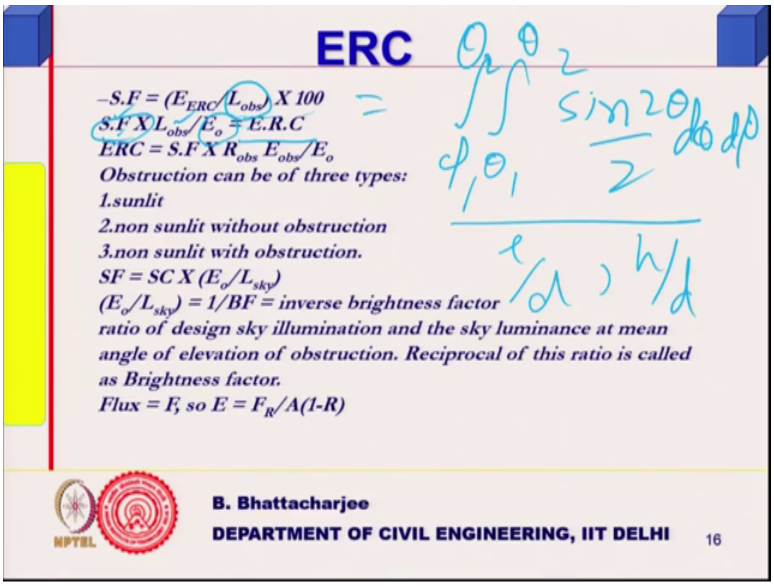

So, we define something called sky factor sky factor; now what is sky factor you know sky factor basically sky factor is defined as illumination due to externally reflected components divided by brightness illumination due to externally reflected component at that point by sky brightness sky brightness in other words what it is

First thing we do is we assume that brightness of the obstruction is constant brightness of the obstruction is constant. So, we assume brightness.

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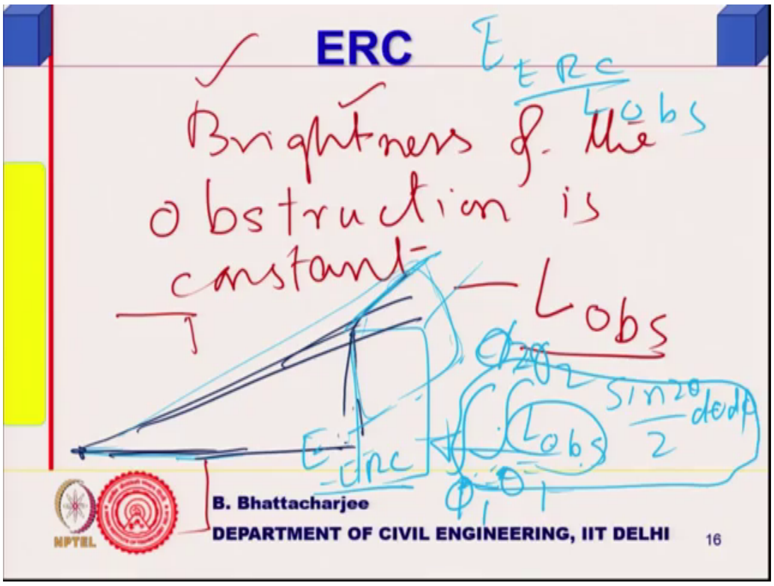

Of the obstruction or building is constant and you we had in a code writes it in L and Lobs; Lobs actually we have been using b, but since the in the code it has also used the notation used is l I have kept it same as code. So, that you refer to s p 41 you will find that it writes Lobs. So, this is what is assumed then supposing now I obstruction is you know, I know the obstruction area for example, I was just telling you earlier that this is my room the window is somewhere here right and the building is the building is somewhere there you know building is somewhere there this is my working plane this is my working plane this is my working plane this is my working plane and this is my point.

So, this portion will contribute to externally reflected component right and therefore, again this has got a this has got a you know this has got a this got it this has got a there is something like this. So, that there is an area there is an area involved there is an area involved this is obstruction area because the window width is also there. So, accordingly there is an area involved which has got a constant brightness

So, how do I find out the illumination due to this it will be simply the brightness l o b s multiplied by sin 2 theta by 2 d theta d theta d phi and the integration will this integration limits of integration will depend upon the size of the obstruction it will depend upon the projection of the obstruction onto the window it will depend upon the projection of the now you see l o b s is constant.

So, I can take it out. So, this you know. So, this will be what this will be if I integrate from appropriate you know angles appropriate limits phi one to phi 2 and theta one to theta 2 if I integrate it this gives me simply e r c illumination due to e r c isn't it illumination due to e r c illumination due to e r c because integrated from theta one to theta 2 phi one to phi 2 this will give me the illumination due to the externally reflected component right.

Now, therefore, this since Lobs is constant I take it out. So, e e r c divided by Lobs that is nothing, but that integration part you know integration sin 2 theta which is actually again I can write it in terms of l by d n h by d in the same principle. So, this is called sky factor. So, sky factor is nothing, but e a e r c divided by l o b s which is nothing, but you know just let me let me raise this out and just. So, what I am saying is sky factor is e r c by l o b s because this was expressed in percentage.

So, e r c by Lobs if it is expressed in percentage it will like this is nothing, but this is actually integration theta one to theta 2 phi one to phi 2 sin 2 theta by 2 d theta d phi right am I right this is right because this is what we saw for a small element in the sky to I sin theta cos you know sin theta cos theta d theta d phi was there. So, I have just written it in this manner. So, this is nothing, but multiplied by hundred anyway if I leave it hundred because l o b s if you take

Now, this I can find out for various l by d n h by d like earlier I did the integration with B z cosec theta, but now I will not do B z cosec theta I will do it for just no B z nothing just this part. So, this is what is sky factor this is what is sky factor similarly sky factor tables are given in the code sky factor tables are given in the code.

So, sky factor if you find out and it is the same principle one of the corner must pass through the pass through the you know one of the window one of the corners of the window must pass through the normal to the point same principle as I just discussed earlier now there is no problem with this is absolutely fine because this has nothing to do with the sky only thing here you need is l o b obstruction of the external ones which are taken for different surfaces if it is reflect you know direct sunlit surface or diffused sunlit surface you know facing the sun or not facing the sun building etcetera etcetera bright whitewashed and so, on.

So, it will depend upon those kind of scenario and we assume it to be constant. So, sky factor tables are not it is not you know it is not dependent on the sky type it is not. So, these are usable even today and exactly in the same manner we use them in the same manner as I just mentioned earlier.

So, e r c can be then obtained because sky factor you can determine from table multiplied by l o b s which is given again in a table I just tell you something related to this table and e 0 is 8000 lux is given e 0 I told you already 8000 lux for the kind design skies are there. So, externally reflected component of the daylight factor you can actually find it out

So, this is a principle actually this is a principle. So, will break and again start from there right. So, whatever we will discuss about the types of obstruction right. So, we will just break if you have some questions I will answer in